Retrofitting ESP Equipped MWCs to Meet the 1995 Emission Guidelines Using Sensible Heat Exchanger Cooling and Dry Reagent Injection

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PEER-REVIEWED

INTRODUCTION

Many municipal waste combustion (MWC) facilities are equipped with electrostatic precipitators (ESPs) and have no acid gas controls. Latent heat of vaporization (water spray) temperature control combined with Trona (sodium based acid gas control reagent) and powdered activated carbon (PAC) injection[1] met EPA's December 19, 1995 Emissions Guidelines for small plants[2]. A follow-up study to demonstrate similar performance using sensible heat removal (heat exchangers) for enhanced energy recovery along with powdered hydrated lime and activated carbon injection at an ESP equipped MWC was conducted to provide maximum flexibility to facilities needing to come into compliance with these regulations.

In 1995, the authors performed a proof-of-concept testing program at the Davis County Energy Recovery Facility in Layton, Utah under a subcontract from the National Renewable Energy Laboratory (NREL), a U. S. Department of Energy national laboratory to the American Society of Mechanical Engineers. That testing demonstrated that small MWCs equipped with ESPs could meet the EPA's small facility MWC emissions guidelines if the ESP inlet temperature was controlled and dry acid gas reagents and powdered activated carbon were added to the gas stream. Temperature control at the Davis County facility was accomplished by injecting water into the gas stream ahead of the ESP. This method of temperature control produced some operational problems, including particulate deposition in the gas ducts. Another test was conducted in 1996 in which temperature control was accomplished in a facility using extra heat exchangers to reduce the ESP inlet temperature to nearly 300°F from the 425°F traditionally found at MWCs. This testing was accomplished under an extension of the original arrangement with NREL.

Demonstration testing was conducted from December 1-11, 1996 at the 2x120 TPD, ESP equipped MWC at Energy Answers Corporation's Resource Recovery Facility in Pittsfield, MA (EAC/Pittsfield). The test plan was expanded to obtain duplicate metals (Cd, Pb and Hg), particulates, dioxin and acid gas runs at each condition.

Nine distinct emissions control conditions (two ESP operating temperatures, three levels of activated carbon addition and three levels of powdered hydrated lime acid gas control reagent) were planned to be tested during normal plant operations. The no acid gas reagent, no activated carbon (baseline) condition was replicated to provide a measure of reproducibility and experimental error.

During testing, selected plant operations, furnace conditions and Continuous Emissions Monitoring System (CEMS) data were continuously recorded by a digital data acquisition system. CEMS emissions data included NO_x, SO_2, CO, and O_2 both at the stack downstream of a tail-end wet scrubber and immediately after the electrostatic precipitator (ESP) as well as Continuous Opacity Monitoring System (COMS) data at the ESP outlet. The data covers periods of operation before, after testing and during each test run. It was used to demonstrate that the facility was operating normally during the proof-of-concept demonstration testing.

The operating conditions for each test day were established during the previous evening after all testing was completed. Testing activities commenced at dawn each day with sampling starting 3 to 4 hours later. The following emissions were measured at the ESP outlet:

- Front-half particulate matter, metals & mercury — Method 29
- Acid gas (HCl) — Method 26

- Dioxins and Furans (PCDD/F — 2,3,7,8 substituted isomers (congeners) plus homologue totals — Method 23
- Other combustion gases (CO, NO_x, and SO_2) — Methods 6c, 7 and 10 (CEMS)

To obtain replicates in the small rectangular duct leaving the ESP each day, a dual- or quad-probe sampling system had to be used. Duplicate Method 23 and 29 samples were obtained. The average of the duplicate results is used to characterize emissions for each test series. Method 26 used another port as did the Method 7 (CEMS) extractive probe.

For about six hours prior to and throughout sampling, the tested incinerator was run at its rated capacity of 30,000 lb/hr of 500 psig, 515°F steam. The specified ESP temperature (nominally 325 or 350°F) and targeted acid gas reagent (0, 12, 160 and 180 lb/hr of powdered hydrated lime —equivalent to stoichiometric ratios of 0:1, 2:1, 2.5:1 and 3:1) and activated carbon feed rates (0, 4 and 8 lb/hr — equivalent to 0, 100 mg/dsm^3 and 200 mg/dsm^3 were also maintained.

SITE SELECTION CRITERIA

While there is considerable evidence that reducing ESP operating temperature and adding reasonable amounts of acid gas sorbent and activated carbon to incinerator flue gas can theoretically allow existing ESP equipped MWCs to economically meet proposed guidelines; field experience has shown that it is difficult to reliably reduce ESP temperatures using evaporative (water spray) cooling techniques. Phase I testing under this program at Davis County, Utah Energy Recovery Facility demonstrated that dry acid gas sorbent and powdered activated carbon injection resulted in satisfactory performance of existing APCS. It was also demonstrated that the air or steam atomization system had to be carefully designed, located and operated to achieve reliable operation. The question remained, however, if similar emissions control performance could be achieved while recovering additional heat using heat exchangers without water sprays.

HOST FACILITY DESCRIPTION

Although built with three pre-engineered, refractory wall, excess air furnaces of the Enercon design, rated at 120 tons/day each, EAC/Pittsfield is only permitted to run with two of the furnaces on-line. Each furnace includes controlled overfire and underfire airflow, a large loading ram and water cooling of steel components. Dual fuel burners, gas or oil, located in the primary chambers provide initial ignition of refuse and at the exit of the trim economizer preheats the air pollution control system (APCS). These burners are turned off after the MSW fire is established. Primary chamber outlet and waste heat boiler (WHB) inlet temperatures are normally controlled using recirculated flue gas (RFG).

The manifold or tertiary chamber transports the hot gases from the furnaces to the WHBs. The normal gas flow is from both on-line furnaces to both Bigelow WHBs. Each WHB is rated at 30,000 lb/hr at 250 psi and 515°F. Flue gas temperature entering the boiler is maintained in the tertiary chamber with recirculated flue gas to 1,500°F. Boiling and trim economizers serve to heat boiler feed water before it enters the boilers, while reducing flue gas temperature to 350°F at the ESP inlet. Downstream of the ESP, a condensing heat exchanger is used to preheat the 100% boiler make-up and reduce the flue gas temperature below the acid gas saturation point before final flue gas cleaning in a packed bed scrubber.

The facility is equipped with a 4-field ESP designed to achieve particulate levels of 0.015 gr/dsft^3 @ 12% CO_2. Acid gas control is provided by a wet scrubber using a sodium carbonate scrubbing solution located downstream of the ESP and condensing heat exchanger (also called a "raining economizer"). Sampling access exists between the ESP outlet and raining economizer inlet. This is where most of the testing was conducted. Limited simultaneous sampling was conducted in the stack, after the wet scrubber, to provide an indication of the benefits of using a tail-end scrubber.

Figure 1 is a process flowchart of the facility. Table 1 is a heat balance for an individual combustion unit when the facility is burning 4,500 Btu/lb MSW at maximum continuous rating (MCR) conditions, or 120 TPD of MSW burned. The stoichiometric powdered hydrated lime addition rate (based on the plant's historical uncontrolled HCl and SO_2 concentrations) is 64 lb/hr.

Dry hydrated lime (Graybec Calc Inc.) and Powdered Activated Carbon (PAC) (Norit's FGD grade) were delivered to the site in nominal 1,000 kg supersacks. They were out-loaded using calibrated metering screws to a common eductor. The original temporary installation used compressed ambient air and a small commercial eductor. The system plugged rapidly when lime was added even though it was more than satisfactory for PAC-only injection. Air dryers were added and plant air was used on the system, but operating time only increased from 1 to 2 hours. The eductor was replaced by an entrainment device fabricated out of a 2", Schedule 40 cross connection (reagent falls into the top, pipe plug in the bottom to facilitate cleaning, ½" pipe nozzle in one side supplying nominal 10 psig dry air and a 2" pipe connected for exhaust flow from the other side of the entrainment box). This very inexpensive eductor substitute performed without difficulty throughout the balance of the test program.

PROGRAM OBJECTIVE

The objective of this program was to determine the emissions performance level achievable by a combination of ESP inlet temperature control, acid gas reagent injection and activated carbon addition. The target was to meet the emissions guideline requirements for small facilities and to determine if large facility guidelines can be met for particulates, dioxins, SO_2, HCl and mercury using dry sorbent injection technology in conjunction with sensible heat removal temperature control. The emitted concentrations and removal efficiencies are the numeric objectives shown in Table 2.

EXPERIMENTAL DESIGN

To accomplish the program objectives, a fractional 2x3x3 factorial test plan with one replicated test condition was developed. The order of testing was randomized using a 2x2x3 test matrix, but the no acid gas reagent condition was excluded from the overall randomization. To minimize the chance of lime carry-over effects from controlled test conditions to baseline, the baseline runs were scheduled to be conducted the day after a PAC-only run. Due to field exigencies, baseline testing was conducted at the beginning of the test program between the PAC-only and lime plus PAC test conditions to both maximize the applicability of baseline testing to other tests and to accommodate start-up difficulties with the dry powdered hydrated lime handling system.

The unbalanced experimental design provided in Table 3 makes maximum use of the available test runs. Data reduction is slightly complicated by this experimental design since traditional fractional factorial designs do not include partial replicates and utilize a different pattern. Mathematical tools do exist to interpret this data. The selected pattern enabled the fitting of a theoretically based predictive equation for dioxin and mercury control to the data so that interpolation (and limited extrapolation) to other conditions can be performed and the expected performance of a retrofit application determined.

RESULTS

The test matrix is provided in Table 3. The majority of the baseline runs were done under normal operating conditions where the flue gas temperature entering the ESP is less than 330°F. One high temperature run was performed with 4 lb/hr of PAC addition. Acid gas reagent (powdered hydrated lime obtained from Graybec Calc, Inc., Marbleton, Canada) was tested at three nominal temperatures in combination with two different PAC addition rates. A zero PAC, acid gas reagent test was not conducted because this condition provides neither baseline information nor was likely to produce operating conditions in compliance with EPA's December 19, 1995 Emission Guidelines for Existing Facilities.

The first question addressed was how much PAC and lime can be injected before the ESP and still maintain current emissions control performance.

Table 4 is a summary of the particulate and trace metal emissions test results. The particulate concentrations measured at the ESP outlet, the emissions likely to be seen by a MWC equipped with only this emissions control device, are unchanged regardless of the amount of lime or PAC injected. This is not particularly unusual given the comparatively large size of the dry sorbents being injected. Particles larger than 44 μm, those that pass a 325 mesh sieve are visually very fine, but are actually very coarse as far as an ESP designed to control sub-micron particles is concerned. Unfortunately, due to their large size and relative abundance compared to normal particulate loadings from the furnace, the residue take-away conveyors under the first hopper overfilled and plugged. Design modifications to overcome this problem are needed for a successful commercial installation.

As with the particulate results, lead and cadmium are unaffected by the dry injection of lime or PAC. This is the expected behavior since these pollutants are associated with the front-half particulates. Mercury was substantially reduced by the addition of PAC. Lime injection had a negligible effect on mercury emissions. Inspection of the data provides a strong indication that there is a temperature effect with lower temperatures enhancing mercury removal. The nominal 4 lb/h PAC injection rate is equivalent to 100 mg/dsm^3 7% O_2. Three-run average mercury emissions below 50 $\mu g/dsm^3$ @ 7% O_2 can be expected with this injection rate over the temperature range tested. This is as predicted by the extrapolated Davis County[3] results.

Dioxin concentrations shown in Table 5 are comparatively low at the ESP outlet due to the low flue gas temperature. With PAC addition, a factor of four reduction in dioxin emissions was observed. It is important to realize that the dioxin concentrations leaving the ESP were already in compliance with EPA's December 19, 1995 Emissions Guidelines for existing ESP equipped facilities. Simple inspection of the table indicates that the reduction is larger with lime injection. This could be real or simply a data artifact since the emitted concentrations are less than the Reference Method Practical Quantification Limit for Total and International Toxic Equivalent (ITEQ) dioxins established by the supplemental simultaneous results performed during this effort.

Other combustion condition related pollutant emissions (CO and NO_x) were unaffected by the addition of PAC.

Dry hydrated lime injection is expected to reduce sulfur dioxide and hydrogen chloride emissions. Reductions were observed in the data displayed in Table 6. Comparison of the results with and without lime injected indicates that using the calculation procedures in Method 19, better than the 50 percent HCl and SO_x removal needed to meet the 1995 Emissions Guidelines for Small Facilities was achieved.

The data in Table 7 include the results of three HCl tests conducted between the boiler and boiling economizer on the last day of testing (e.g. 301-3). This location is upstream of the lime/PAC injection point and represents uncontrolled emissions. Comparing these values to those obtained at the ESP outlet during conditions when no lime was being added to the system suggests that there is either a problem with Method 26 or relatively significant removal, on the order of 30 percent, is occurring across the economizer and ESP as a result of native alkalinity in the fly ash.

CONCLUSIONS

This performance demonstration test was successful. Dry acid gas and mercury reagent injection combined with ESP inlet temperature control are capable of bringing existing ESP equipped MWCs into compliance with EPA's December 19, 1995 Emissions Guidelines for small facilities. Large facility guidelines can be met for all pollutants except acid gases (SO_2 and HCl). Given the amount of acid gas reagent injected during some tests (almost a stoichiometric ratio of 3:1) and the results obtained, it is questionable if sufficient reagent could be injected to achieve the 95 percent HCl removal required by the large plant guidelines without causing particulate emissions exceedances.

Most importantly, ESP performance, while unchanged by dry injection, was not improved. This indicates that the addition of heat exchangers to reduce flue gas temperature while recovering more energy; hence, cover some of the costs of additional pollution control is prudent. However, using water sprays to accomplish part of the temperature reduction also improved ESP performance sufficiently that this effect might justify dealing with the difficulties described in the Davis County report.

Injection of either dry hydrated lime or Trona in combination with powdered activated carbon is capable of meeting the 1995 Small Plant Emissions Guidelines and all but the acid gas reduction requirements for large plants. Dry reagent injection in combination with temperature control is a viable method of extending the life of existing facilities at reasonable cost and seriously considered for plants that must be modified to comply with small plant standards.

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Site modifications, routine operations and acquisition of facility data were performed by EAC/Pittsfield personnel under the direction of Dr. Lew Clark, Special Consultant and Dave Consalvo, Plant Manager. Emissions sampling was done by Bovar Environmental, Toronto, under the direction of David Law, and analytic laboratory support was provided by Zenon Laboratories, Burlington, Ontario, under the direction of Dr. Ron McCleod. TCLP analyses were performed by Inchscape Laboratories. The contribution of each organization and individuals involved contributed to the successful conclusion of this demonstration program. The efforts of everyone involved are gratefully acknowledged.

REFERENCES

1. H.G. Rigo and A.J. Chandler, "Retrofit of Waste-to-Energy Facilities Equipped with Electrostatic Precipitators," (Davis County), an ASME Research Report, CRTD-Vol. 39, April 1996.
2. USEPA, Proposed Standards of Performance for Municipal Waste Combustors and Emission Guidelines for Existing Sources, 60 Fed. Reg. 65,387, December 19, 1995.
3. Op. Cit. Ref. 1, Figure 3.3.

Table 1. Boiler heat balance for EAC/Pittsfield (4,500 Btu/lb reference fuel).

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Pittsfield Conditons -- Individual Unit Balance

FUEL CHARACTERISTICS	
C, % by weight	24.89
H2, % by weight	3.22
N2, % by weight	0.34
S, % by weight	0.13
O2, % by weight	19.38
Cl2, % by weight	0.24
H2O, % by weight	31.80
ASH, % by weight	20.00
HHV, Btu/lb	4,500
Fd, DSCF/MBtu	9,113
Fc, DSCF of CO2/MBtu	1,775
Fo, F ratio	1.08

SYSTEM CHARACTERISTICS	
Main Steam Flow, lb/hr	30,000
S.H. outlet press.. psig	230
S.H. outlet temp.. deg F	525
S.H.outlet enthalpy, Btu/lb	1,278.0
Feedwater press.. psig	325
Feedwater temp.. deg F	240
F.W.inlet enthalpy, Btu/lb	208.3
Drum press.. psig	275
Drum temp.(sat.) deg F	414
Drum sat vapor enth.,Btu/lb	1,202.6
Drum sat liq. enth., Btu/lb	390.5
Blow Down	1.0%
Misc. Steam Leaks & Losses	1.5%
Fraction of Ash to Boiler	10%
Grate ash discharge temp, F	250
UBC in Fly ash	4%
UBC in Bottom Ash	5%
Residue, lb-residue/lb-fuel	21.0%
Avg temperature of residue, F	241
Unburned Comb. loss, %	2.2
UBC in residue, %	4.9
Gas temp lvg econimizer, F	160
Gas temp lvg air heater, F	160
U.F.A. Steam Heater Rise, F	0
Radiation loss, %	7.0
Sensible heat in residue, %	0.2
Unaccounted for loss, %	1.0
Reference Temperature, F	60
Ambient Air Temperture, F	60
Total Excess Air	80%
Fraction air under grate	70%
Excess Air Supplied by Fans, %	61.5
weight flue gas recirculation	40%
General Air leakage-% of Theo.	18.5%
deNOx Carrier air--% of Theo.	0.0%

MOLES/100 lbs FUEL actually burned
adjustment for UBC as proportion of
heat lost to unburned combustibles

C =	2.027
H2 =	1.563
S =	0.004
O2 =	0.592
N2 =	0.012
H2O =	1.765
Cl =	0.007

THERO. O2 REQ'D, MOL/100 LBS FUEL	
For: C + O2 = CO2	2.027
For: 2H2 + O2= H2O	0.781
For: S + O2 = SO2	0.004
For: available O2 & Cl	-0.599
Theo. mols O2 to be supplied	2.213
Wet Theo. Air, lb air/lb fuel	3.082
Mols dry air./ mols O2	4.764
Moles Dry air /lb fuel	0.190
Lb. dry air req'd/lb fuel	5.476
Lb. H2O in air/lb fuel	0.071
Lb. Std. Air req'd/lb fuel	5.547

FLUE GAS ANALYSIS	
Moles HCl/ lb fuel	0.00007
Moles CO2/ lb fuel	0.02027
Moles H2O/ lb fuel	0.03716
Moles SO2/ lb fuel	0.00004
Moles N2 / lb fuel	0.15008
Moles O2 / lb fuel	0.01771
Tot. Mols Flue gas/lb fuel	0.22533

FLUE GAS CHARACTERISTICS	
Partial Pressures	
P(CO2)	1.322
P(H2O)	2.424
P(SO2)	0.003
Percent by Volume (Orsat)	
% CO2	10.8
% O2	9.4
PPM SO2	211
PPM HCl	352
Gas weights, lb gas/lb fuel	
Lb. HCl/lb fuel	0.002
Lb. CO2/lb fuel	0.892
Lb. H2O/lb fuel	0.669
Lb. SO2/lb fuel	0.003
Lb. N2/lb fuel	4.204
Lb. O2/lb fueL	0.567
Lb. Dry flu gas/lb fuel burnd	5.668
Lb. Wet flu gas/lb fuel burnd	6.337
Flue gas molecular weight	28.126
H2O in gas, % by weight	10.564

MOLECULAR WEIGHTS	
Hydrochloric Acid (HCl)	36.46
Carbon (C)	12.01
Hydrogen (H2)	2.02
Sulfur (S)	32.06
Oxygen (O2)	32.00
Nitrogen (N2)	28.01
Water (H2O)	18.02
Chlorine (CL2)	70.91
Carbon Dioxide (CO2)	44.01
Sulfur Dioxide (SO2)	64.06
Carbon Monoxide (CO)	28.01

STANDARD AIR COMPOSITION	
O2, % by volume	20.99
N2, % by volume	79.01
H2O, % by weight	1.30
Molecular weight dry air	28.85

ADJUSTMENTS TO HHV FOR DIFFERING CONDITIONS		
Sensible Heat in Fuel	Btu/lb	0.0
Sensible Heat in Air	Btu/lb	0.0
Compression Heat	Btu/lb	6.4
Steam Air Heater Input	Btu/lb	0.0
Effective HHV	Btu/lb	4,506

BOILER EFFICIENCY -- ACTUAL	71.6
-- ADJUSTED TO AS-FIRED HHV	71.7%

HEAT LOSS ANALYSIS	
Dry gas loss, %	3.0
Water from fuel loss, %	15.0
Moist. in air loss, %	0.1
Total losses, %	28.4

BOILER OUTPUTS	
Feed Water Flow	30,303
Blowdown flow, lb/hr	303
High press. h/out-h/in, Btu/lb	1,070
Blowdown : h/out-h/in, Btu/lb	182
High press. duty, Btu/hour	32,089,050
Blowdown duty, Btu/hour	55,188
Total Boiler Output, Btu/hour	32,144,238
Lb-steam/Lb-fuel	3.01
Fraction of Combustibles Burned	97.86%

BOILER FUEL, AIR, & FLUE GAS FLOW RATES	
Fuel flow rate--tons per day	120
Fuel heat input, Btu/hr	44,905,027
Fuel flow rate. lb/hr	9,965
Total air to boilers, lb/hr	55,273
Flue gas leaving boiler system, lb/hr	63,150
Air leakage, lb/hr	5,671
Thermal DeNox Carrier Air,lb/hr	0
undergrate air flow, lb/hr	34,722
overfire air flow, lb/hr	14,881
Flue gas recirculation, lb/hr	25,260
Flue gas leaving economizer, lb/hr	88,410
Total residue generation rate, lb/hr	2,096

Table 2. Target emissions control objectives for ESP equipped MWCs.

	Small Plant Guideline	Large Plant Guideline
Dioxins	125 ng/dsm^3	60 ng/dsm^3
Particulates	0.030 gr/dsft^3	0.012 gr/dsft^3
Mercury	80 mg/dsm^3 or 85% removal	80 mg/dsm^3 or 85% removal
SO_x	80 ppm or 50% removal	31 ppm or 75% removal
HCl	250 ppm or 50% removal	31 ppm or 95% removal

All emitted concentrations at 7% O_2, dry, standard conditions (68°F, 760 mm_{Hg}).

Table 3. Overall test matrix -- allocation runs conducted.

ALLOCATION OF TEST RUN CONDITIONS				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	T07 T08 T09 T10		
0	4	T01		T02
0	8	T03 T04 T05 T06		
120	4	T11	T17	
120	8		T18	T16
160	4		T12	T13
160	8			T14 T15
180	8	T19		

Table 4. Particulate, lead, and cadmium test results.

PARTICULATE CONCENTRATION gr/dsft^3 @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	0.032 0.021 0.016 0.025		
0	4	0.030		0.024
0	8	0.017 0.025 0.015 0.011		
120	4	0.038	0.053	
120	8		0.031	0.032
160	4		0.018	0.024
160	8			0.021 0.033
180	8	0.027		

LEAD CONCENTRATION µg/dsm^3 @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	1,591 1,718 1,161 2,108		
0	4	2,490		2,346
0	8	1,697 2,034 1,244 1,202		
120	4	2,515	2,456	
120	8		1,430	1,351
160	4		946	1,461
160	8			1,438 1,805
180	8	703		

CADMIUM CONCENTRATION µg/dsm^3 @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	70 86 51 64		
0	4	73		60
0	8	50 54 48 58		
120	4	86	74	
120	8		51	40
160	4		28	42
160	8			37 59
180	8	32		

Table 5. Mercury test results and estimated removal efficiency.

MERCURY CONCENTRATION µg/dsm^3 @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	13 239 240 151		
0	4	93		13
0	8	16 6 7 11		
120	4	45	26	
120	8		21	17
160	4		31	89
160	8			22 25
180	8	15		

MERCURY REMOVAL EFFICIENCY				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0			
0	4	65%		95%
0	8	94% 98% 97% 96%		
120	4	83%	90%	
120	8		92%	93%
160	4		88%	66%
160	8			92% 91%
180	8	94%		

Table 6. Dioxin, oxides of nitrogen and carbon monoxide test results.

TOTAL DIOXIN CONCENTRATION ng/dsm^3 @ 7% O_2

REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	20.9 36.6 22.2 17.6		
0	4	10.3		~~4.1~~
0	8	6.0 3.6 5.2 ~~4.8~~		
120	4	~~12.0~~	3.3	
120	8		1.5	1.9
160	4		2.5	2.7
160	8			1.6 2.0
180	8	1.2		

TOTAL DIOXIN REMOVAL EFFICIENCY

REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0			
0	4	68%		~~87%~~
0	8	81% 89% 84% ~~94%~~		
120	4	~~62%~~	90%	
120	8		95%	94%
160	4		92%	92%
160	8			95% 94%
180	8	96%		

OXIDES OF NITROGEN CONCENTRATION ppm$_{dv}$ @ 7% O_2

REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	98 165		
0	4	152		100
0	8	162 90 99 86		
120	4	90	98	
120	8		91	93
160	4		89	86
160	8			94 98
180	8	157		

CARBON MONOXIDE CONCENTRATION ppm$_{dv}$ @ 7% O_2

REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	9.7 7.1		
0	4			8.9
0	8	5.2 3.1 7.5 2.2		
120	4	4.9	3.8	
120	8		7.6	6.9
160	4		3.2	6.9
160	8			5.3 4.0
180	8	6.4		

Table 7. Sulfur dioxide and hydrogen chloride test results.

SULFUR DIOXIDE CONCENTRATION ppm$_{dv}$ @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	101 121		
0	4	237		154
0	8	201 122 67 100		
120	4	101	57	
120	8		83	97
160	4		80	99
160	8			75 76
180	8	84		

SULFUR DIOXIDE REMOVAL EFFICIENCY				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0			
0	4			
0	8			
120	4	48%	70%	
120	8		57%	50%
160	4		59%	49%
160	8			61% 61%
180	8	56%		

HYDROGEN CHLORIDE CONCENTRATION ppm$_{dv}$ @ 7% O_2				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0	448 580 636 485		
0	4	402		463
0	8	285 398 420 457		
120	4	333	403	
120	8		259	502
160	4		118	165
160	8			124 151
180	8	237		

HYDROGEN CHLORIDE REMOVAL EFFICIENCY				
REAGENT FLOW		ELECTROSTATIC PRECIPITATOR TEMPERATURE		
LIME lb/hr	PAC lb/hr	<330°F	330-340°F	>340°F
0	0			
0	4			
0	8			
120	4	39%	26%	
120	8		53%	8%
160	4		78%	70%
160	8			77% 72%
180	8	57%		

Table 8. Test results data tabulation.

Test Date YYMMDD	Run Identification	lb/h LIME	lb/h PAC	mg/dsm³ LIME	mg/dsm³ PAC	°F Stack Temp.	Flue Gas dsft³/m Flow	Flue Gas % Moisture	Flue Gas % Oxygen	% Opacity	ppm Carbon Monoxide	ppm Sulfur Dioxide	ppm Oxides of Nitrogen	ppm Hydrogen Chloride	-- @7% O2 -- gr/dsft³ Front-Half Particulates	ug/dsm³ Lead	ug/dsm³ Cadmium	ug/dsm³ Mercury	ng/dsm³ Total Dioxin
961201	T01	0	4	0	94	328	18,685	12.1	12.4	3.5		~~237~~	152	402	0.030	2,490	72.7	~~93.0~~	10.3
961201	T02	0	4	0	91	345	17,803	12.1	11.7	3.6	8.9	154	100	463	0.024	2,346	59.7	~~42.5~~	~~4.1~~
961202	T03	0	8	0	205	318	18,598	11.3	13.1	2.6	5.2	~~201~~	162	285	0.017	1,697	49.9	16.5	6.0
961202	T04	0	8	0	199	326	18,532	12.8	12.8	3.1	3.1	122	90	398	0.025	2,034	54.2	~~5.7~~	3.6
961203	T05	0	8	0	175	326	18,870	12.9	11.9	3.7	7.5	67	99	420	0.015	1,244	48.1	6.8	5.2
961203	T06	0	8	0	195	327	19,601	10.8	13.1	4.5	2.2	100	86	457	0.011	1,202	57.8	11.5	1.8
961204	T07	0	0	0	0	324	18,922	11.9	12.0	4.0	9.7	101	98	448	0.032	1,591	70.3	~~13.0~~	20.9
961204	T08	0	0	0	0	328	18,999	11.7	13.0	5.1	7.1	121	165	580	0.021	1,718	85.9	238.7	36.6
961205	T09	0	0	0	0	314	20,028	12.0	14.7	3.8				636	0.016	1,161	51.5	239.6	22.2
961205	T10	0	0	0	0	328	19,626	10.8	13.9	5.8				485	0.025	2,108	64.3	151.3	17.6
961206	T11	120	4	3,358	112	323	19,073	10.5	13.9	1.1	4.9	101	90	333	0.038	2,515	85.6	44.8	~~12.0~~
961207	T12	160	4	3,298	82	339	19,571	12.2	11.7	1.2	3.2	80	89	118	0.018	~~946~~	27.8	30.6	2.5
961207	T13	160	4	3,772	94	348	18,465	11.1	12.4	1.6	6.9	99	86	165	0.024	1,461	42.5	~~88.9~~	2.7
961208	T14	160	8	3,765	188	353	18,607	11.8	12.4	2.8	5.3	75	94	124	0.021	1,438	36.8	21.9	1.6
961208	T15	160	8	3,850	192	351	19,394	10.5	12.9	2.5	4.0	76	98	151	0.033	1,805	59.4	24.8	2.0
961209	T16	120	8	2,913	194	351	18,529	11.8	12.7	4.2	6.9	97	93	502	0.032	1,351	39.8	17.2	1.9
961209	T17	120	4	2,996	100	340	18,994	11.5	13.1	3.5	3.8	57	98	403	0.053	2,456	73.9	26.2	3.3
961210	T18	120	8	2,859	191	335	19,288	11.4	12.8	3.0	7.6	83	91	259	0.031	1,430	50.6	20.5	1.5
961210	T19	180	8	4,252	189	327	19,215	12.5	12.7	2.9	6.4	84	157	237	0.027	~~703~~	32.3	15.0	1.2
961211	BO1	180	12	5,190	346		18,989	13.4	14.1					705					
961211	BO2	180	12	4,383	292		18,989	11.0	12.9					821					
961211	BO3	240	25	6,469	674		18,989	12.1	13.7					638					

Note: Lined through data points are statistical outliers; outlying individual data points are excluded from displayed pair averages displayed.

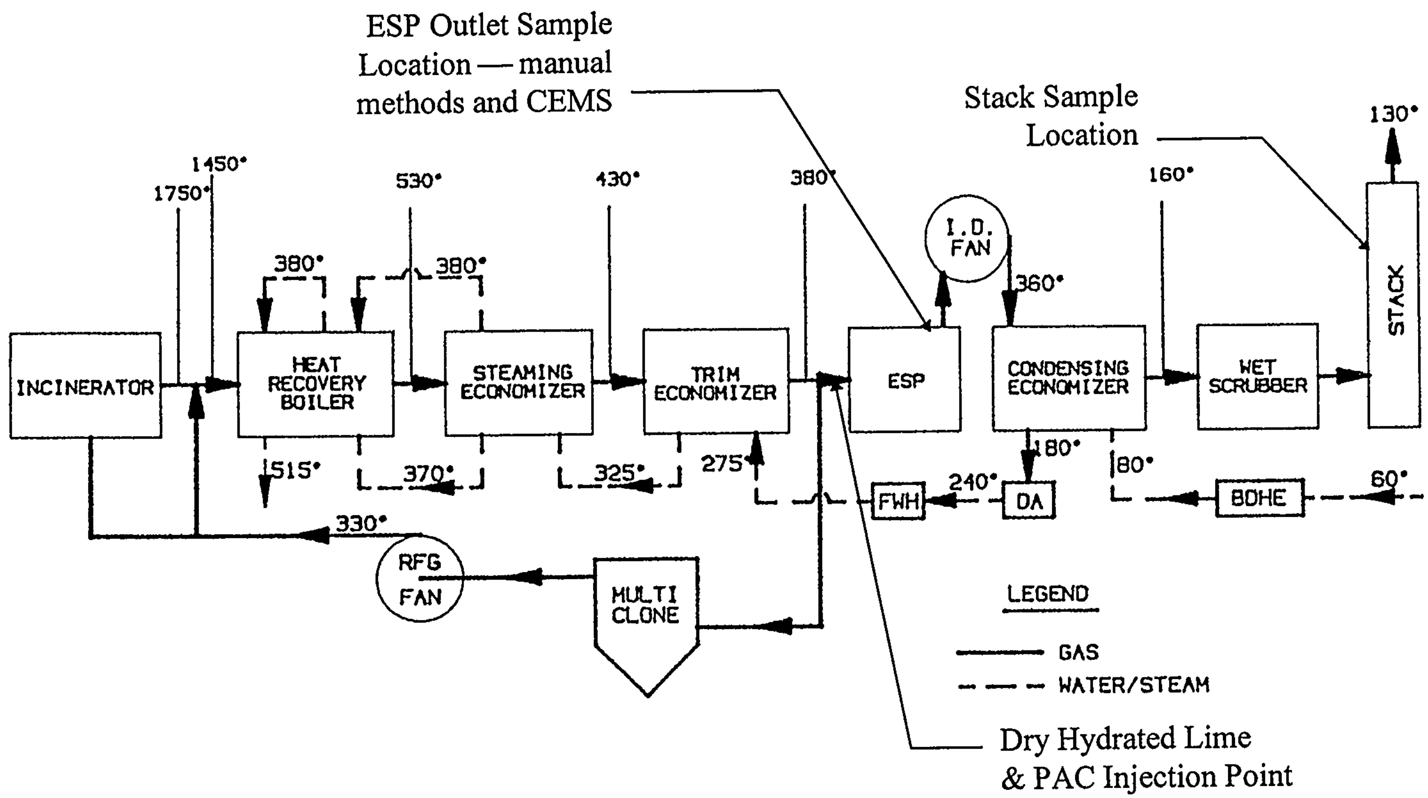

Figure 1. Process flow chart for EAC/Pittsfield.

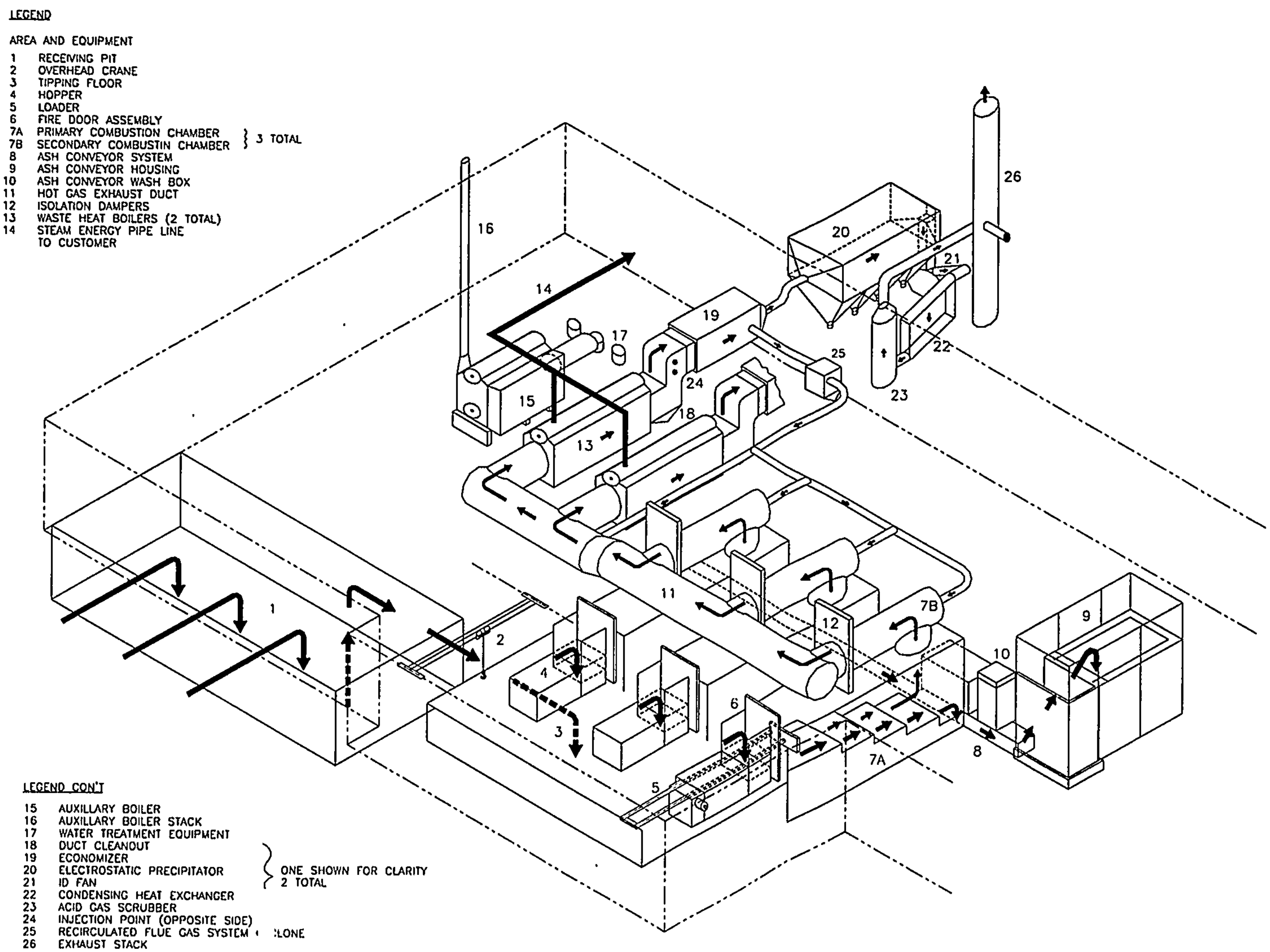

Figure 2. General isometric arrangement drawing of EAC/Pittsfield facility.

Complete Refurbishment Of An Existing Hazardous Waste Incinerator In Eastern Germany On a Turn-Key Contract Basis

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INTRODUCTION

The area around Leipzig and Halle in eastern Germany attracted the chemical industry already in the 1920's. The abundance of lignite that could be easily mined in open pits served as an ideal source of inexpensive energy and raw materials supply.

Before the second world war the area hosted some of the largest chemical production facilities in the world. In 1990, shortly after the reunification of Germany, most of that pre-war structure was still in operation and largely unchanged.

During privatization, a large complex was formed to become the Buna-SOW-Leuna-Olefin Verbund (BSL) which is being taken over by Dow Chemical. Part of the BSL-structure is the Saxonian olefin production facility in Böhlen near Leipzig. The site originally covered 5.8 square kilometers including a 4 x 200 MW lignite fired power plant. Due to the fact that each chemical production facility generates various environmentally harmful residues, a combustion plant was built in 1974 and commissioned in 1977. The Rückstandsverbrennungsanlage RVA Böhlen (= residue combustion plant Böhlen) was nestled in the center of the chemical complex. Today after major restructuring of the complex, it is located directly adjacent to the new 2 x 930 MW_{el} lignite fired power plant Lippendorf, which is currently under construction.

The RVA Böhlen, as commissioned in 1977, was finally shut down at the end of March 1997. Figure 1 shows the old facility. It consisted of various storage tanks for aqueous and halogenic liquid wastes, an open pit bunker for solid hazardous wastes, a counter current fired rotary kiln, a horizontal secondary combustion chamber (SCC), a low pressure steam waste heat boiler, a multi cyclone fly ash separator, an I.D. fan, and a 90 m brick stack.

Due to insufficient throughput capacity, totally outdated technology and wear and tear of 20 years of operation, it was decided that everything except the bunker and the stack has to be replaced. The new plant, as shown in Figure 2, consists of the existing but refurbished open pit bunker, a refurbished crane for solid hazardous waste, the new feed system, a new cocurrent fired rotary kiln, a new vertical SCC, a new waste heat boiler, a new 7-stage APC-train, a new tank storage facility and various other new balance of plant (BOP) equipment such as weighing station, container storage, and I + C system etc.

In 1992, when the RVA Böhlen was privatized, the grace period given by the Reunification Contract was 4 years and ended on December 1st, 1996. On that day, the old facility was destined to be shut down unless it would fulfill the requirements of the German 17th BImSchV[1] in all respects. A complex planning and bidding process for a total overhaul of the plant was started. Various concepts were developed and scraped again.

Finally in April 1995, way too late to meet the December 1996 deadline, the turn-key contract for the complete refurbishment of the existing hazardous waste incinerator was awarded to the L. & C. Steinmüller GmbH (LCS), Gummersbach. In the meantime some minor but badly needed improvements were made.

The new storage tank B7 for high calorific liquid hazardous waste was installed, the office building was refurbished completely and some infrastructure repairs were carried out. The permitting procedure for the new facility had also been started. After contract award in April 1995, the first priority was to obtain a permit for the construction of the new facility as quickly as possible. These efforts came to an abrupt halt when the owner decided to abandon all plans and sell the plant. In October 1995 the plant was purchased by its current owner, the Broerius Abfallwirtschaft Sachsen GmbH (BAS).

SCHEDULING

In October 1995, after takeover of the plant by its new owner, time was the biggest problem in three ways:

1. The plant had been shut down by the local permitting agency, the RP Leipzig, because it was evident that the plant could not be brought into compliance with the requirements of the 17. BImSchV by the imposed deadline of December 1st, 1996.

2. The downtime of the plant was the most critical economical factor for the new owner due to the fact that each day out of operation generated cost but no revenue.

3. With the market for hazardous waste to be incinerated being highly competitive, each day away from the market due to downtime of the plant meant that customers would find alternative ways of disposing of their hazardous waste.

Fortunately intense political interest in keeping the only hazardous waste incinerator in the state of Saxony in operation led to a deal between the new owner and the permitting agency, which accommodated the interests of both parties to the most possible extent.

The terms[2] agreed upon in late 1995 can be summarized as:

1. The plant can go back on line immediately after it is upgraded with an ESP, thus reducing the emissions of particulate matter to below 30 mg/Nm^3.

2. The plant will be operated only with a restricted input menu (no halogenated waste, no heavy metals in the waste)

3. The plant will be ultimately shut down by March 31st, 1997

4. The plant will be upgraded with state-of-the-art equipment by September 30th, 1997, leading to emission limits fixed in the permit[3] in the range of 5 to 10 times below the values required in the 17th BImSchV for acid gases and heavy metals. Table 1 summarizes the emission limits imposed through the permit.

4. The owner will demonstrate the seriousness of the plan to complete refurbishment of the plant by submitting the permitting documents by December 31st, 1995 and by starting construction on site by mid 1996.

Based on that, a new contract was negotiated between BAS and LCS. The milestones of that contract in terms of keeping the tight schedule imposed by the permitting agency were:

December 4, 1995:	- submittal of the permitting documents for the ESP-retrofit
December 9, 1995:	- start of construction for the ESP-retrofit (based on a special interim permit)
December 31, 1995:	- submittal of the main permitting documents for the complete refurbishment of the plant
March 15, 1996:	- start-up and commissioning of the old plant with the new ESP - submittal of the remaining documents to accompany the permitting process
March 31, 1996:	- start of commercial operation of the old plant upgraded with the new ESP
June 1, 1996:	- start of construction of the new APC-plant
August 1, 1996:	- start of erection of the new APC-plant
October 15, 1996:	- start of construction of the new SCC, waste heat boiler, and tank storage facility
December 15, 1996:	- start of erection of the new SCC, waste heat boiler, and tank storage facility
March 31, 1997:	- decommissioning and clean up of the old plant
April 14, 1997:	- start of demolition of the old plant and start of construction of the new rotary kiln and remaining BOP-equipment (new feed system, feed water storage tank, etc.)
May 13, 1997:	- start of erection of the new rotary kiln and remaining BOP-equipment
July 1, 1997:	- start-up and commissioning of the new APC-plant
July 14, 1997:	- start-up and commissioning of the new rotary kiln, SCC, waste heat boiler, tank storage facility, and remaining BOP-equipment

October 1, 1997: - burning of the first hazardous waste

November 11, 1997: - start of the trial run

December 19, 1997: - preliminary acceptance and take over the plant by BAS

This extremely tight schedule, allowing only 3 months between the end of operations of the old plant and start-up of the new plant, required thorough planning of each individual step in order to identify the critical path.

GENERAL AND INFRASTRUCTURAL CONSIDERATIONS

Whereas the APC-plant and the tank storage facility could be erected adjacent to the old plant on an open site, the major part of the BOP-equipment, the SCC, the waste heat boiler and especially critical, the rotary kiln had to be placed into the existing plant.

The new plant, as can be seen in Figure 3, has a layout similar to the old one. This was mandatory due to the fact that the open pit bunker with the crane feeding solid hazardous waste could not be relocated. Another fix point besides that building was the existing steel structure to support the pipe connections to the existing infrastructure of the adjacent industrial /power generating complex. This pipe support structure Q2 is the umbilical cord of the entire hazardous waste incinerator. Since the plant itself does not generate electricity, but exports steam, the pipe support structure is crucial to the plant's concept. The following media are supplied to and exported from the hazardous waste incinerator via Q2:

- Low pressure steam (4.8 bar, 250°C) is exported into the low pressure steam district heating system of the BSL (after 2001 the low pressure steam will be used in the newly erected lignite fired power plant for the primary air heaters).
- Boiler feed water is imported from the BSL net (later from the power plant)
- Pressurized air is imported from the BSL net
- Nitrogen gas is imported from the BSL net
- Water is supplied through the BSL net
- Sewage is discharged into the BSL sewage treatment plant

The technological and economical concept of the plant is based on utilizing the existing infrastructure of the surrounding industry. Thus the plant can not be viewed as an independent operation.

The most important connection is the feed water import / steam export loop. The new steam generator is designed to supply approximately 15 t/h of steam @ 25 bar, 270°C (363 psi, 518°F). Since the plant does not generate any electricity, the entire electrical consumption must be purchased through the public grid at a cost of about 0.23 DM/Kwh (15 cents/Kwh). Therefore it is mandatory to reduce electric power consumption to the absolute minimum. In the new plant, the I.D. fan as one of the main consumers will not be driven by an electric motor, but by a steam turbine.

The turbine will be fed with high pressure steam directly from the boiler (25 bar, 270°C) and will discharge low pressure steam (4.8 bar, 250°C) into the BSL net. Various other consumers of high and low pressure steam within the plant are also connected as shown in Figure 4.

PHASE I - THE NEW ESP

In October 1995, the most important task was to bring the old plant back online as soon as possible. Under the settlement with the permitting agency, operation could be resumed only after the retrofit of an ESP.

However, the ESP had to be erected in such a way that:

- It must be easily incorporated into the layout of the entire refurbishment
- It must not interfere with erection of the new APC-plant or the new SCC and waste heat boiler
- it must directly connect to the new waste heat boiler on one side and to the APC plant on the other side without extensive duct work.

In order to balance these criteria, the general arrangement of the new plant had to be laid out. Figure 5 shows how the new ESP was fitted to the old plant. Several changes had to be made to accommodate the new ESP without violating the criteria outlined above. First the flue gas inlet at the old brick stack had to be rotated 90° clockwise to the south. This was necessary for two reasons. First, the original flue gas duct and inlet at the stack was in the way of the new waste heat boiler. Second, the final flue gas duct had to be installed in order to accommodate the continuous emission monitoring system (CEMS) required during operation. Therefore, the new ESP was located bridging the roadway between the existing old plant and the location for the new APC-plant. The new waste heat boiler had to be tailored into the remaining space between the stack, the new ESP, and the existing old I.D. fan. To allow for maximum possible space the old I.D. fan was rotated 180° and the interims duct work from the old boiler / multi-cyclone outlet was detoured in a wide angle to the inlet of the new ESP. As can be seen on Figure 5 the inlet duct to as well as the outlet from the new ESP, and the inlet to the new flue gas duct to the stack past the CEMS were kept clear for the connection of the new waste heat boiler and the new APC plant respectively. On the side connecting to the new APC plant this was realized by utilizing what was meant to become the bypass duct of the APC plant after the complete refurbishment.

The extremely short period of time between beginning of construction on December 9th, 1995 and beginning of start-up and commissioning on March 15th, 1996 could only be realized taking into account the fact that the chosen ESP size and design was already in operation elsewhere, so that the engineering time could be reduced to an absolute minimum.

PHASE II - THE NEW APC-PLANT

The design of the APC-plant was governed mainly by the extremely low emission limits imposed on the plant by the permitting agency combined with the legal requirements of a waste water free zero discharge plant and the necessity to recycle the maximum possible amount of residues. Considering these factors a state-of-the art 7-stage APC-train was planned.

It consists of the ESP followed by Steinmüller's patented Sodium Tetrasulfide injection system for the removal of mercury, especially elemental mercury. As detailed in Figure 6, the next stage is a spray dryer and a baghouse to collect the dried neutral salts from the first scrubber. After the baghouse, a two stage wet scrubber for the removal of HCl and HF is installed. The effluent from this first scrubber is neutralized externally with slaked quick lime followed by a flocculation and precipitation process to complex the heavy metals. The generated liquor consists mostly of Calcium Chloride ($CaCl_2$), Calcium Fluoride (CaF) and complexed heavy metals. The dissolved salts and the complexed heavy metals are dried in the spray dryer and removed from the flue gas stream in the baghouse. The residual mixture is combined with the fly ash from the ESP and disposed of in an underground landfill. These underground landfills commonly represent former salt mines, where the formed caverns need to be refilled for structural support. This way of disposal is currently considered recycling in some cases, such as this one.

The next stage is a second wet scrubber for the removal of SO_2. Slaked quick lime is used as a scrubbing liquor in order to form marketable gypsum. The flue gas polishing is done by the Steinmüller patented activated carbon reactor (ACR) followed by a low temperature SCR-DeNO$_x$-reactor (LTSCR).

In order to enter the ACR, the flue gas leaving the scrubber must be reheated from its saturation temperature of approximately 65°C (150°F) to about 130°C (265°F). This is achieved in the first stage by a steam reheater for the primary drying of the flue gas followed by a cross-flow heat exchanger.

After the ACR, NH_3 is injected into the flue gas for the LTSCR-process[4]. The temperature of the LTSCR is set at 170°C (340°F). Heating the flue gas from the ACR-temperature of 130°C (265°F) to 170°C (340°F) is done in a first step by the I.D. fan. It supplies about 10 - 13 K to the flue gas due to the pressure drop of approximately 130 mbar (1.88 psi) across the entire flue gas path. The second step is overcome by another steam reheater for the final adjustment of the flue gas to the LTSCR temperature.

The flue gas leaving the LTSCR is discharged through the cross-flow heat exchanger prior to the ACR and then past the CEMS into the stack. As shown in Figure 7, the APC-plant is set up in a very compact open steel structure. Only the spray dryer, the baghouse and the ACR have a penthouse for the weather protection of their critical components.

Adjacent to the APC-train is the pump building, housing all the pumps and vessels handling the two different scrubbing liquors. The main circulation pumps for the wet scrubbers as well as most of the vessels are located on the ground floor. The first floor is occupied by the lime slakers, the gypsum centrifuges, and the neutralization, flocculation and precipitation system for the effluent of the HCl-scrubber. The second floor accommodates the entire low voltage switch gear and electrical equipment for the APC-plant. The storage facility is located on the west side of the APC-plant. Due to the green field advantage, construction and erection of the APC-plant is not further detailed.

PHASE III - THE NEW INCINERATOR

November 15th, 1996 marked the start of Phase III of the project. This must be considered the beginning of the critical path and, therefore, the most important phase within the entire project.

Comparing Figure 5 and Figure 8 gives a rough idea about what it means to start construction and erection of major pieces of equipment such as the SCC or the steam generator literally inside the operating hazardous waste incinerator.

In Phase III, the renewal of the following pieces of equipment are summarized:

1. The bunker crane for feeding solid hazardous waste
2. The feeding system for solid hazardous waste including the feed hopper, the belt conveyor, the drum feeder etc.
3. The primary and secondary air system, including fans etc.
4. The rotary kiln, including burners, cooling systems etc.
5. The SCC, including burners, ash extractors etc.
6. The waste heat boiler including the feed water system, the ash extractors, the steam system etc.
7. Parts of the electrical power supply for the entire plant.

Technologically, none of those components deviate from the well known, well proven, state-of-the-art hazardous waste incineration technology based on the rotary kiln technique. Therefore, the equipment is not further detailed from a technological point view.

The first problem was to clear the space for the steam generator and the SCC. Unfortunately the main power supply lines, as well as some controls, the natural gas lines to the burner of the existing rotary kiln and various other critical media supply pipes had to be cleared before construction could begin. The only time available for that was a scheduled 8 day maintenance outage of the old plant in October 1996. After that hurdle was successfully overcome construction of the large foundation for the boiler and the SCC resumed.

The most critical difficulty for this foundation was first, the slight overlap of it onto the existing foundation of the stack, and second the interference with the existing foundation of the front end of the old rotary kiln. The first difficulty posed a problem because it was absolutely mandatory to avoid inducing any weight onto the foundation of the existing stack in order not to interfere with its statics. The second one forced a gap in the new foundation for the SCC and the boiler, which had to be filled after the existing plant was demolished. After months of detailed planning, endless calculations and numerous different ideas and suggestions on how to solve the two problems, the foundation was finally poured into place touching the existing foundation on all four sides. In early December 1996, the new foundation was in place and by about December 10th the erection of the steel structure supporting the SCC and the waste heat boiler was started and completed before Christmas.

Due to the large weight of the SCC after being refractory lined, its supporting frame had to be adjusted about 10 - 12 cm (4 -5 inches) above the support frame of the boiler. Here the much higher compression of the steel structure had to be compensated for, so that after completion, the inlet of the steam generator and the outlet of the SCC would be leveled.

Just before Christmas the steam generator could have been erected. Due to the Christmas holiday season and a very harsh winter, it was chosen to preassemble the pressure part of the waste heat boiler to a maximum possible extent in our shop in Gummersbach and deliver it in 3 preassembled sections to the site by the end of January 1997. The size of the preassembled sections was determined by the maximum permissible dimensions for the road transport. The pressure part of the boiler was erected in about 5 days on site with a minimum of welding. It was completed with the drum and the connecting pressure pipes by the end of February 1997. The pressure test was delayed until the end of March due to weather conditions and the fact that the supports for the insulation had to be mounted first to avoid any possible leakage by improper mounting.

In early January 1997 the old plant had another scheduled maintenance outage of 10 days. This outage was used to refurbish the existing bunker crane. After a week of 16 hour work days, operation of the old plant was resumed with a refurbished crane.

The next critical milestone was the erection of the SCC, weighing about 42 tons. Due to its size, it was shipped in eight sections from the Steinmüller workshop in Poland and preassembled to three pieces on site. One piece represented the quarter spherical head piece connecting the cylindrical part of the SCC to the waste heat boiler. The second piece was the above mentioned cylindrical part with the third piece being the bottom of the SCC with the inlet housing for the end of the rotary kiln. Since the steel frame supporting the SCC was above the front end of the operating old rotary kiln, this third piece would only be lifted to the inside of the steel structure and rested on the concrete bottom underneath. The remaining two pieces were erected on February 4th, 1997.

Great care had to be taken since the steel structure of the SCC touched the platform on the front end of the operating rotary kiln at various points, and the distance between the new SCC and the burner of the operating rotary kiln underneath is merely 3 feet.

After the erection of the SCC and completion of the steam generator, the time in February and March was mostly spent completing these components, building the new road ways on site and preparing for the decommissioning and the demolition of the old plant. During that time most of the APC-plant was completed, construction of the tank storage facility was finished and the new I + C system was partly installed. On March 17th, 1997 the first life line of the old plant was cut. Due to the facts that the throughput of the refurbished plant is about 60 % higher than of the old plant and there wasn't any kind of APC-equipment before, the electrical consumption of the new plant exceeds by far the capacity of the transformers of the existing plant.

One of the two redundant 6 KV-transformers, each with a capacity of 1.200 Kwh/h was replaced by the first one of the new used 1.600 Kwh/h transformers. This left the plant and the construction site running on only one transformer for about 6 weeks.

In the same week, the new foundations for the new rotary kiln were poured elsewhere on site. These prefabricated concrete blocks were lifted into place about a month later. Pouring the concrete foundations externally at a different location than they ultimately rest saved about 4 weeks in time. The tight schedule after shut down of the plant did not allow for conventional construction by excavating the foundation pit, casting the mold, introducing the steel reinforcement pouring the concrete and letting it harden and dry. In early May, after the old rotary kiln was demolished and the new foundation pits excavated, the precasted new foundation blocks were lifted in place without interrupting the erection process for the new plant.

The old plant was decommissioned and handed over for demolition starting April 14th. Only two days were available to completely dismantle the front end platform of the rotary kiln, remove the burner and the rest of the combustion equipment and take off the front end plate of the rotary kiln. At the same time the refractory lining of the old rotary kiln and the old SCC was broken out. Immediately after that the rotary kiln was disassembled into three sections.

These were lifted out by a large crane. By early May the demolition process of the old plant was almost completed and the new foundations for the new rotary kiln were in place. What had been in operation for 20 years vanished in less than 3 weeks!

The steel structure of the old SCC and the old waste heat boiler was saved to be reused in the new plant. The new 80 m^3 boiler feed water storage tank was rested on the steel frame of the old boiler. The old SCC steel structure serves well in supporting numerous pipelines, the primary air duct, cables, platforms and the new feed belt conveyor.

Parallel to dismantling the old rotary kiln the inlet duct to the ESP had to be removed quickly. It blocked the critical path from the ESP via the existing boiler feed water degasifier to the main building. Since the main building not only contains the control room but also holds the low voltage switch gear and electrical equipment room for the entire plant (except the APC plant) it was very time critical to clear that path as quickly as possible.

Two weeks were available for demolition of the old equipment and erection of pipe and cable support ways between the ESP and the main building. At the beginning of May, the start for laying cables and pipes was made. By early June the plant was fully hooked up electrically and the first function checks were performed.

At the other end of the busy site, the beginning of June marked a very critical time. At the second of June the new rotary kiln was delivered on site and lifted in place by a large caterpillar crane. At this point in time the 250 tons of refractory lining in the new SCC were completely installed. One week later, the new rotary kiln was assembled to the point for the refractory lining to be started. Lining the kiln would take about four weeks until almost the middle of July 1997.

With the rotary kiln, as the last major component in place, the most critical part of the erection of the new plant was completed.

BOP-EQUIPMENT AND COMMISSIONING

Besides the major components mentioned above, numerous other things had to be installed. Fortunately none of them were conflicting with the time critical path.

Among the numerous BOP-equipment was:

- A new entrance gate
- A new weighing station
- New I & C equipment and a new digital control system (DCS)
- A new container storage building
- A refrigerated storage container for medical waste
- A new drum feeder
- A new tank storage facility including 3 unloading stations for tank trucks
- New roadways including lighting and run off collection
- A new control room
- A complete new fire protection system for the entire plant
- A safety platform for securing leaking tank trucks etc.
- Landscaping of sites where old equipment was removed
- Other details and odds and ends which are needed to make the refurbished hazardous waste incinerator fully operational.

In the first half of July 1997, the refurbished plant will be started up and commissioned. Loop checks, function tests and cold test runs will occupy most of July and August. During September 1997, the hot commissioning will start by firing the burners on natural gas, thus drying out the refractory lining, cooking the boiler, and for the first time, producing flue gas.

The first hazardous waste feed is scheduled for early October. After balancing the plant and adjusting all controls to ensure normal operation, a trial run period of six weeks is anticipated from November 7th, 1997 to December 19th, 1997. On that day, the preliminary acceptance and hand over of the new plant to the owner is planned.

CONCLUSION

From starting the project in late October 1995 to hand over in late December 1997, a time of only 26 months will have expired. A 20-year old hazardous waste incinerator will have been completely demolished and rebuilt with a downtime of only 3 months between decommissioning the old plant and commissioning the new plant. Only 6 months from stopping to resuming the incineration of hazardous waste mark a true accomplishment, especially due to the fact that this retrofit is a very complicated one. Constructing and erecting an almost entirely new plant around an existing old one during full operation as in Phase I and II is already a task in itself. But constructing and erecting a new steam generator, SCC, rotary kiln, feed system etc. within an existing hazardous waste incineration plant not only requires exact planning, scheduling and precise execution of the job, but also a lot of enthusiasm, personal motivation and engagement of the engineers in the offices and the erection crew on site. The greatest quest for project management, in order to accomplish that task, is to keep the spirit alive and ensure that the team stays on track. And most important of all, only if the vendor and the customer pursue the same goal together as a team can the goal be reached successfully.

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4. H.-U. Hartenstein, A. Licata, "The Application of a Low Temperture Selective Catalytic Reduction System for Municipal and Hazardous Waste Combustors", in Proceedings of the 17th Biennal Waste Processing Conference & Fourth Annual North American Waste to Energy Conference, Altlantic City, N. Y., 1996

Table 1. Emission limits imposed by the permit in comparison to the German 17th BImSchV.

Emissions Controlled by a Continuous Emissions Monitorius System (CEMS)

Pollutant	24 Hour Mean		30 min. Mean		Unit
	RVA Böhlen	17. BImSchV	RVA Böhlen	17. BImSchV	
PM	5	10	10	30	mg/m^3
NO_x	70	200	200	400	mg/m^3
HCl	2	10	10	60	mg/m^3
SO_x	5	50	20	200	mg/m^3
HF	0.25	1	1	4	mg/m^3
C_{org}	5	10	10	20	mg/m^3
CO	50	50	100[1]	100[1]	mg/m^3

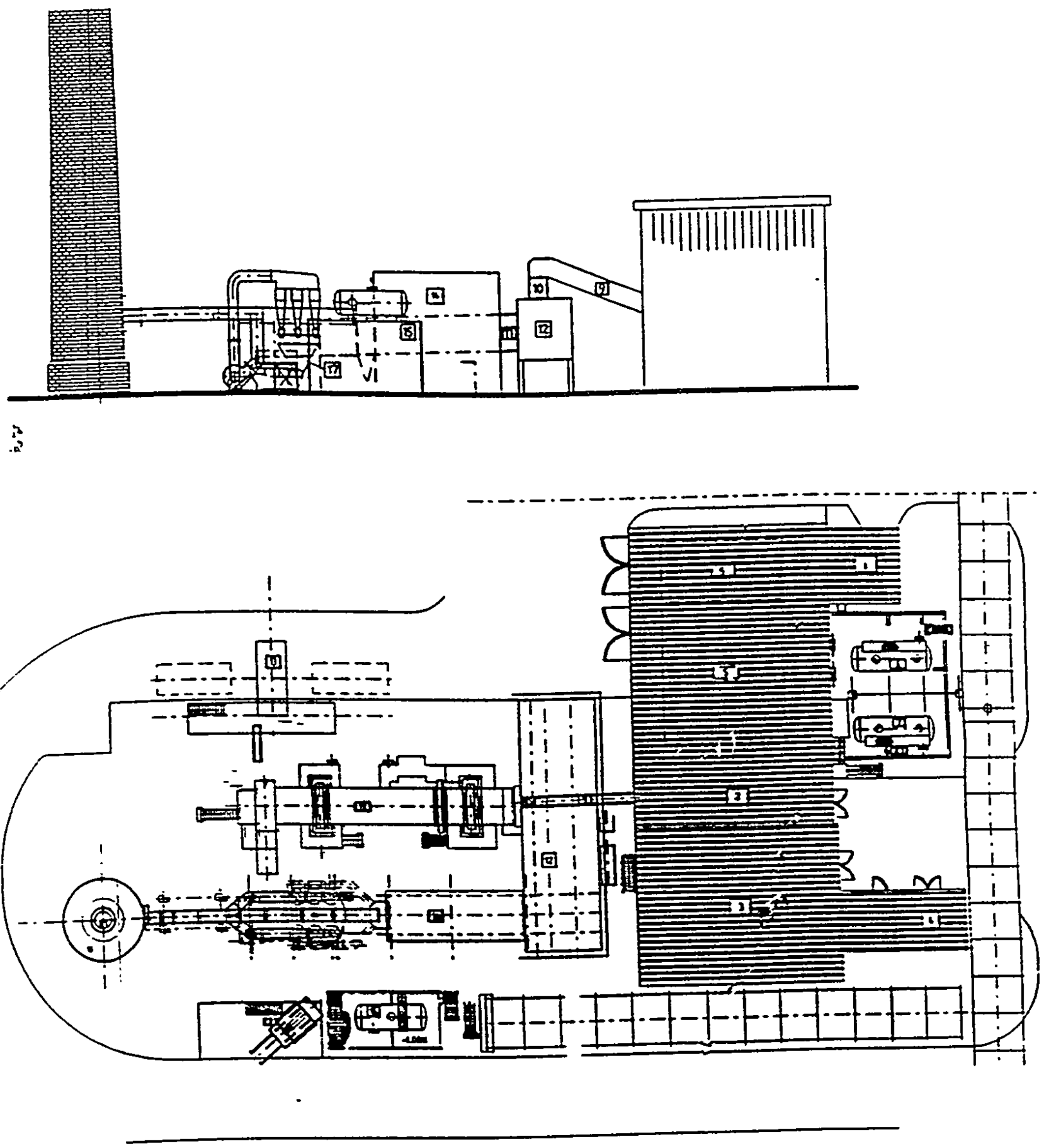
Emissions Controlled by Individual Measurements

Pollutant	RVA Böhlen	17. BImSchV	Sampling Time	Unit
Class I	0.01	0.05	>30, <120 minutes	mg/m^3
Class II	0.01	0.05	>30, <120 minutes	mg/m^3
Class III	0.1	0.5	>30, <120 minutes	mg/m^3
PCDD/F	0.05	0.10	>500, < 960 minutes	ng I-TEQ/m^3
NH_3	5	---	120 minutes	mg/m^3

Class I heavy metals = (Cd + Tl)
Class II heavy metals = total Hg
Class III heavy metals = (Sb + As + Co + Cr + Cu + Mn + Ni + Pb + Sn + V)

[1] = 1 hour mean

- All values are based on dry flue gas @ 101.3 Kpa (29.92 in of Hg) and 0°C (32°F) and, with the exception of CO, are to be corrected to 11 % O_2 only if the actual O_2 exceeds 11%.
- Combustion temperature must be $\geq$ 1.200°C (2.192°F) for $\geq$ 2 seconds after the last air injection.



1 = primary air fan
2 = waste feed system
3 = control building
4 = maintenance building
5 = waste storage pit
6 = liquid waste storage tank
7 = liquid waste storage tank
9 = waste feed conveyor
10 = waste chute
11 = rotary kiln
12 = secondary combustion chamber
13 = ash handling system
14 = waste heat boiler
15 = feed water degasifier
17 = multi cyclone

Fig. 1. Site Plan of the Old RVA Böhlen

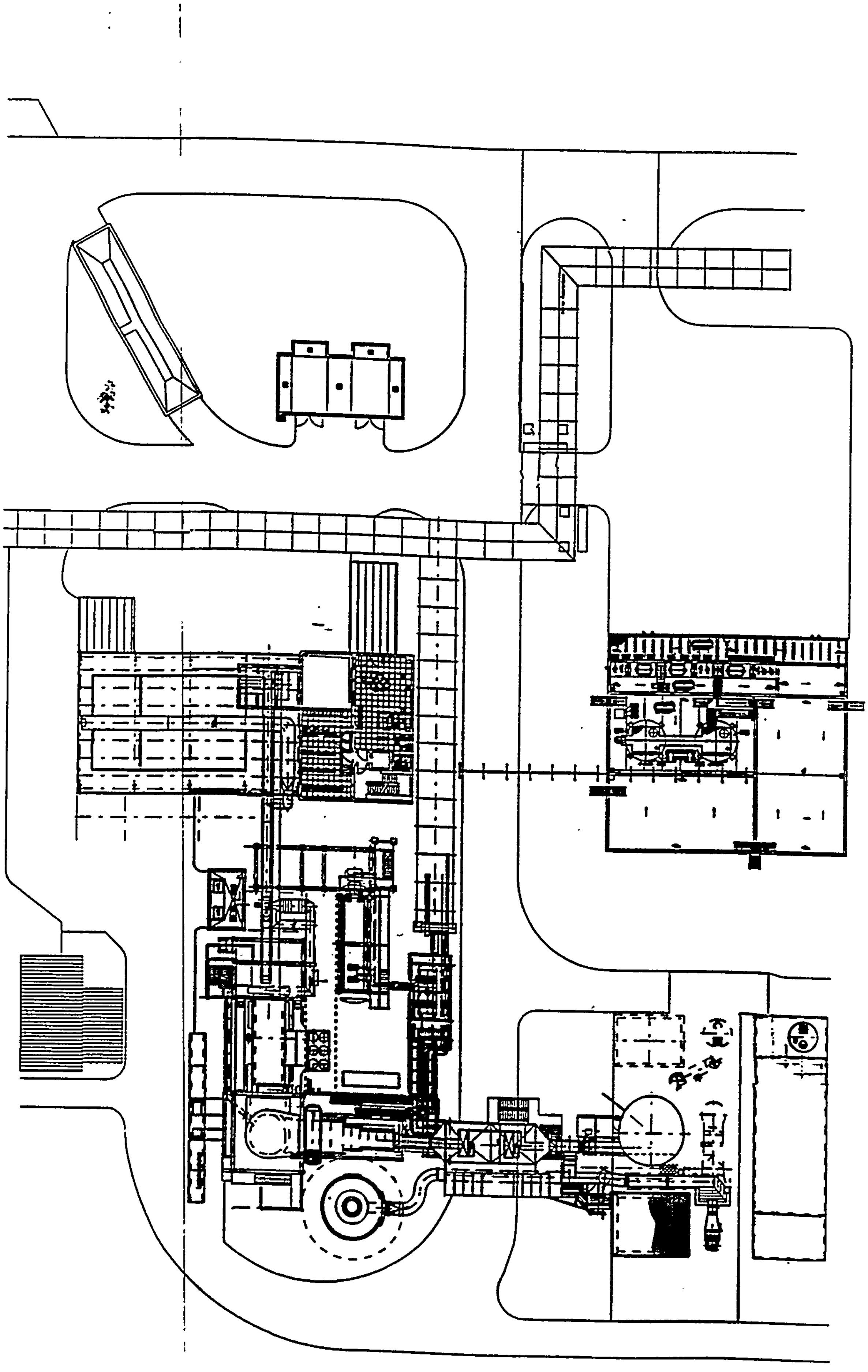


Fig. 2. General Arrangement of the New Hazardous Waste Incineration Plant

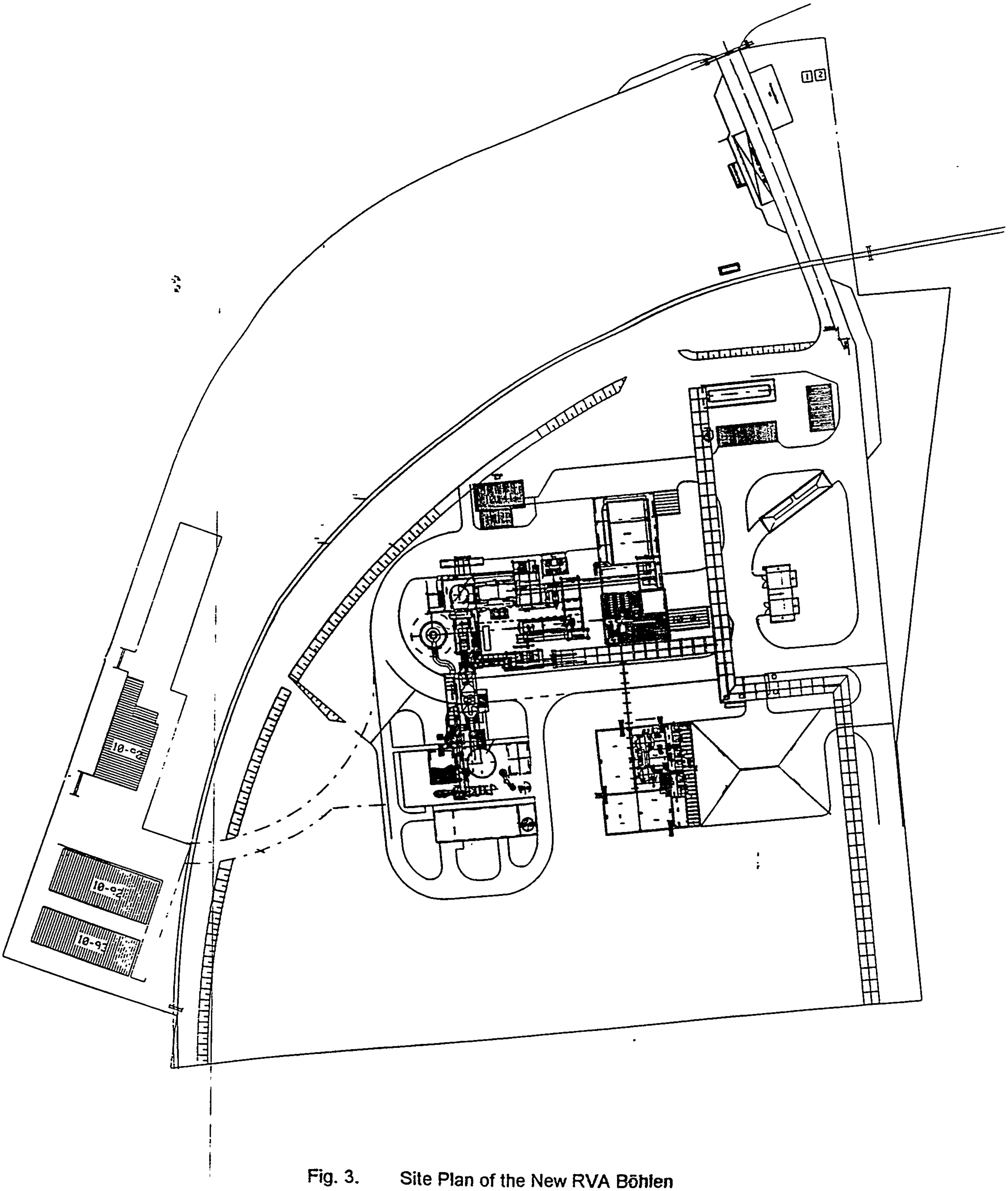


Fig. 3. Site Plan of the New RVA Böhlen

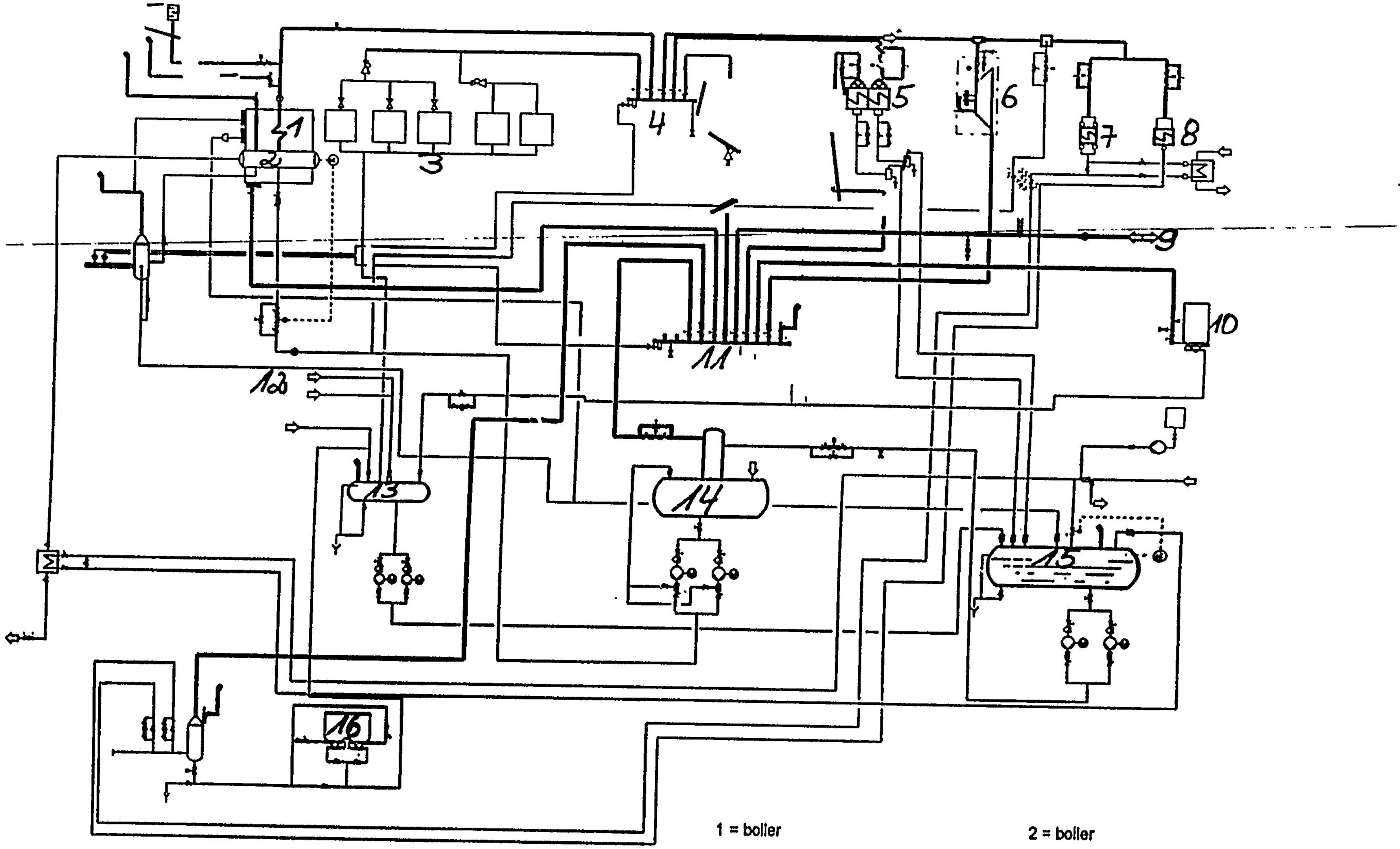


Fig. 4. Water-Steeam-Process Flow Diagram

1 = boiler

2 = boiler

3 = dispersion steam for burnes and lances

4 = HP steam distribution 21 bar / 260-280°C

5 = air preheater

6 = turbine for ID fan

7 = flue gas reheater 1

8 = flue gas reheater 2

9 = LP-steam

10 = spray dryer

11 = LP-steam distributor 4 8 bar / 230-260°C

12 = from tank storage

13 = condensate storage tank

14 = feed degasifier

15 = feed water storage tank

16 = ACR

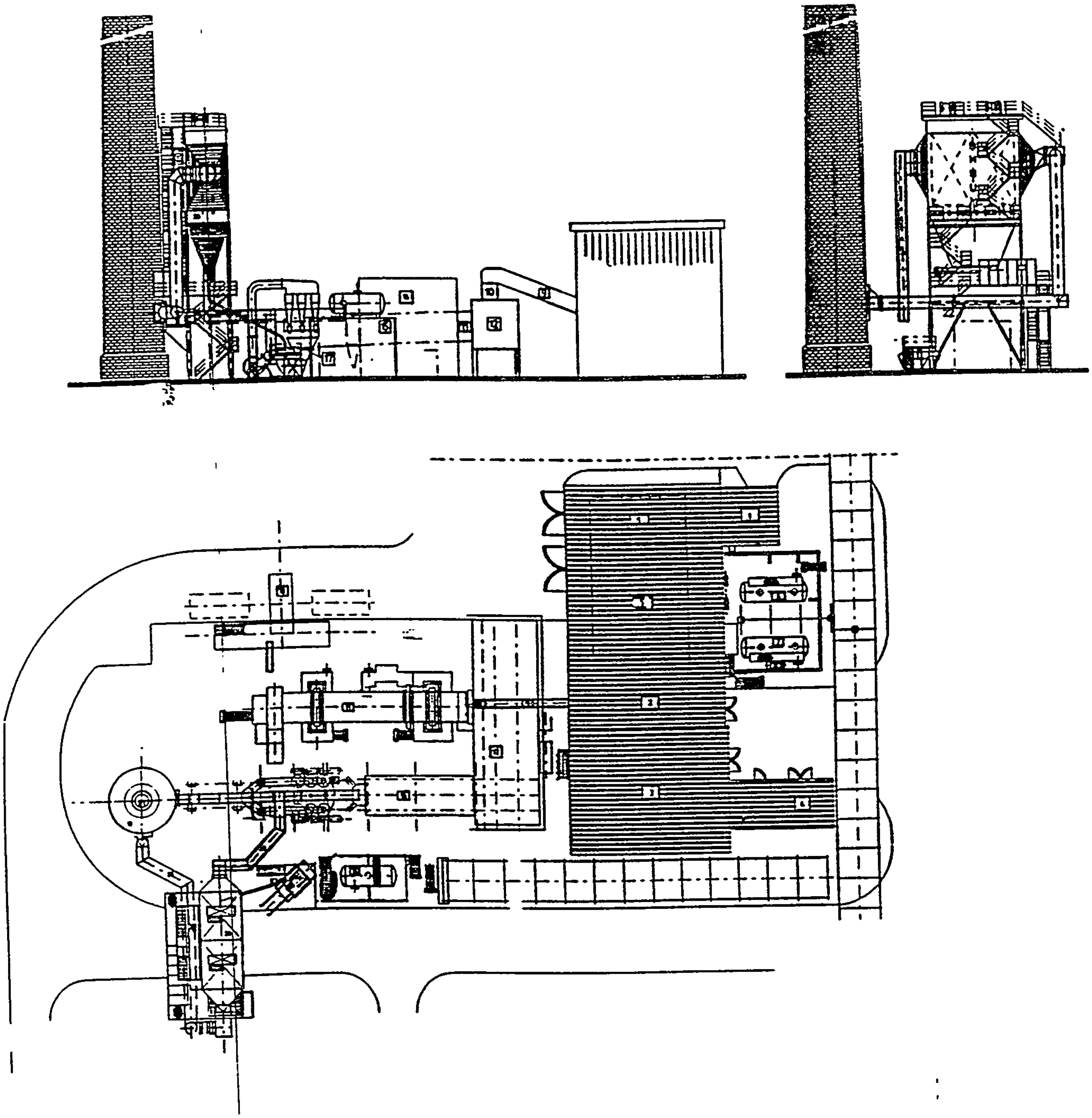


Fig. 5. General Arrangement for the Old Plant With the New ESP

1 = primary air fan
2 = waste feed system
3 = control building
4 = maintenance building
5 = waste storage pit
6 = liquid waste storage tank
7 = liquid waste storage tank
9 = waste feed conveyor
10 = waste chute
11 = rotary kiln
12 = secondary combustion chamber
13 = ash handling system
14 = waste heat boiler
15 = feed water degasifier
17 = multi cyclone
20 = ESP
21 = flue gas duct to stack
22 = interims flue gas duct

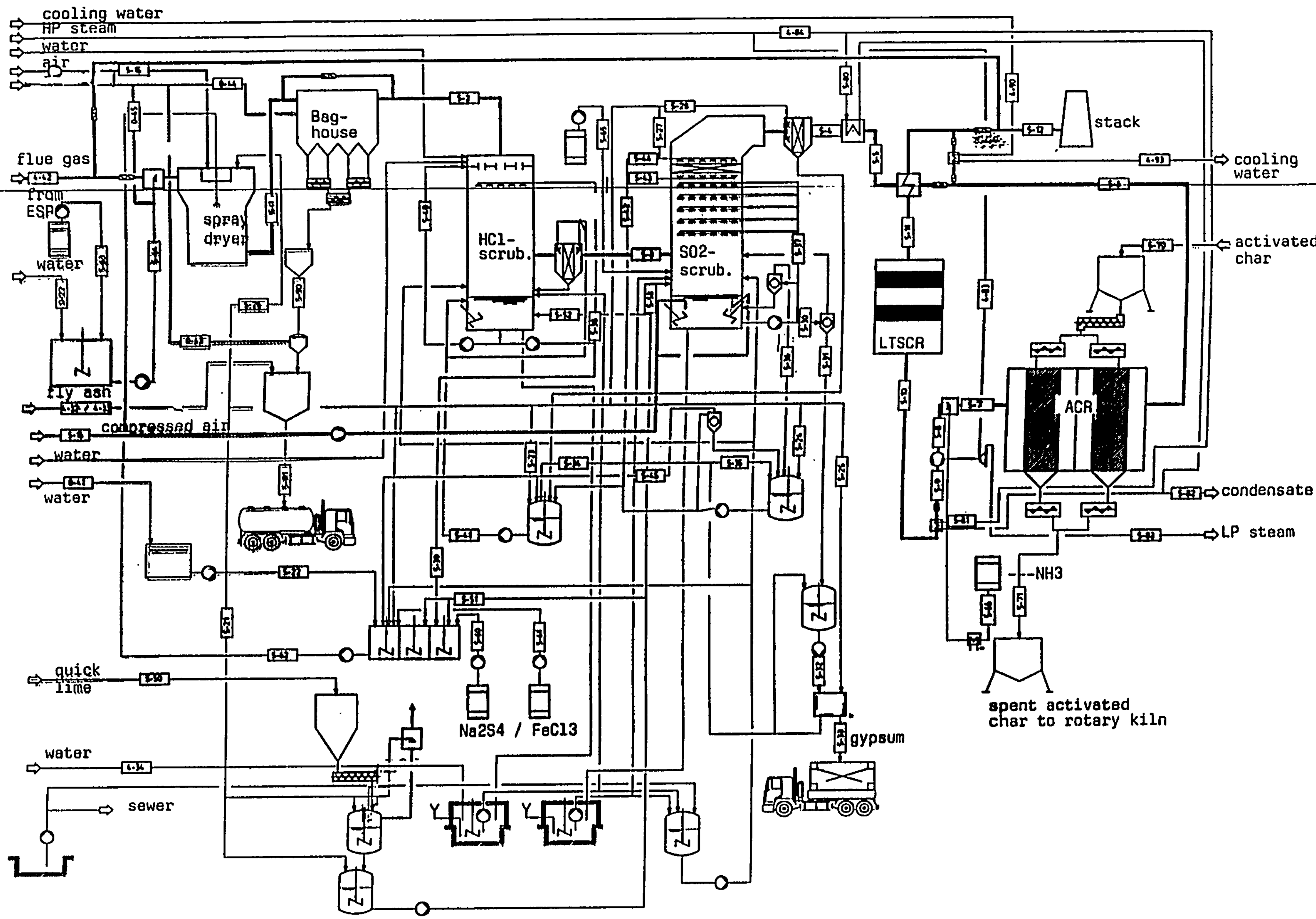


Fig. 6. Process Flow Diagram of the New APC-Plant

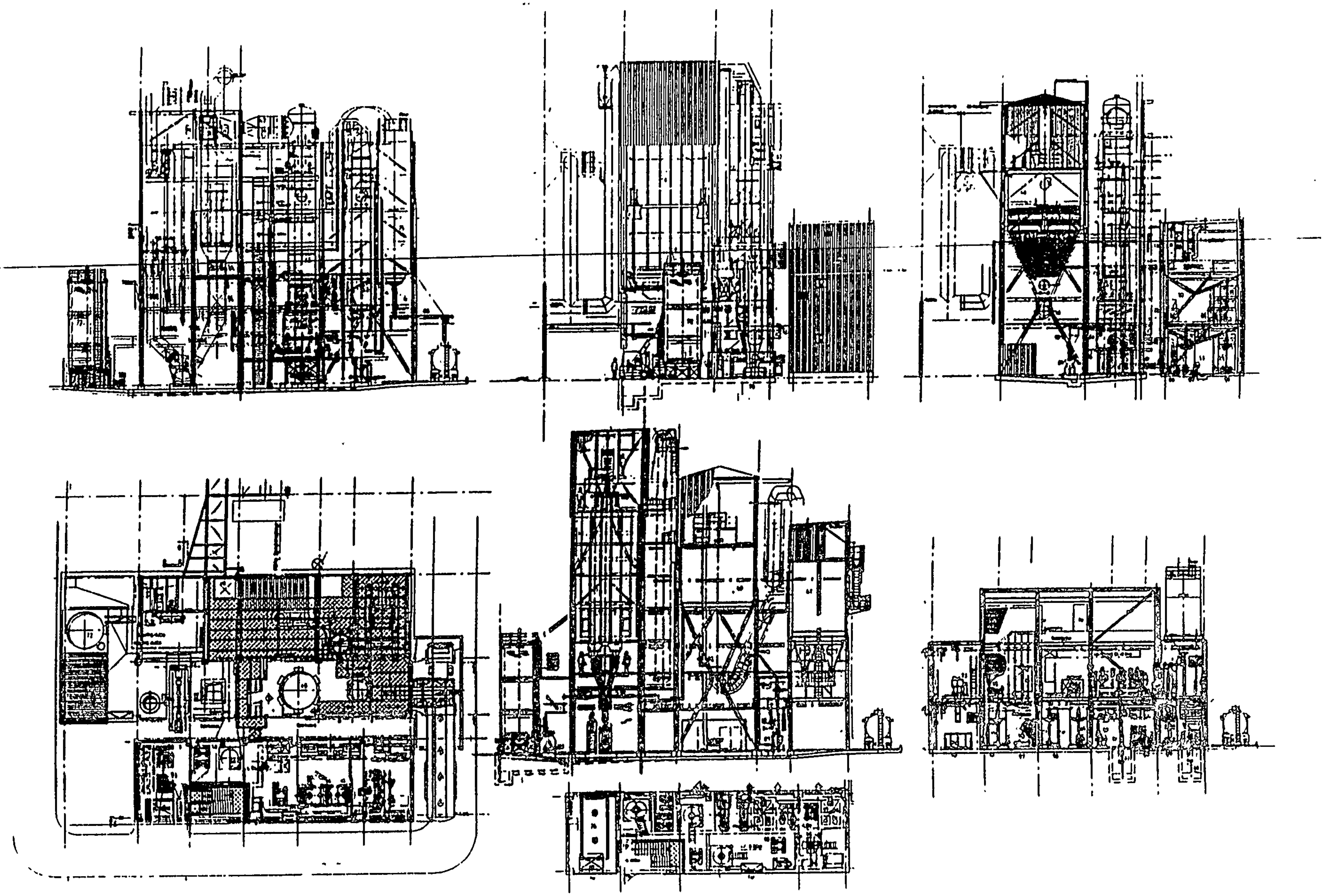


Fig. 7. General Arrangement of the New APC-Plant

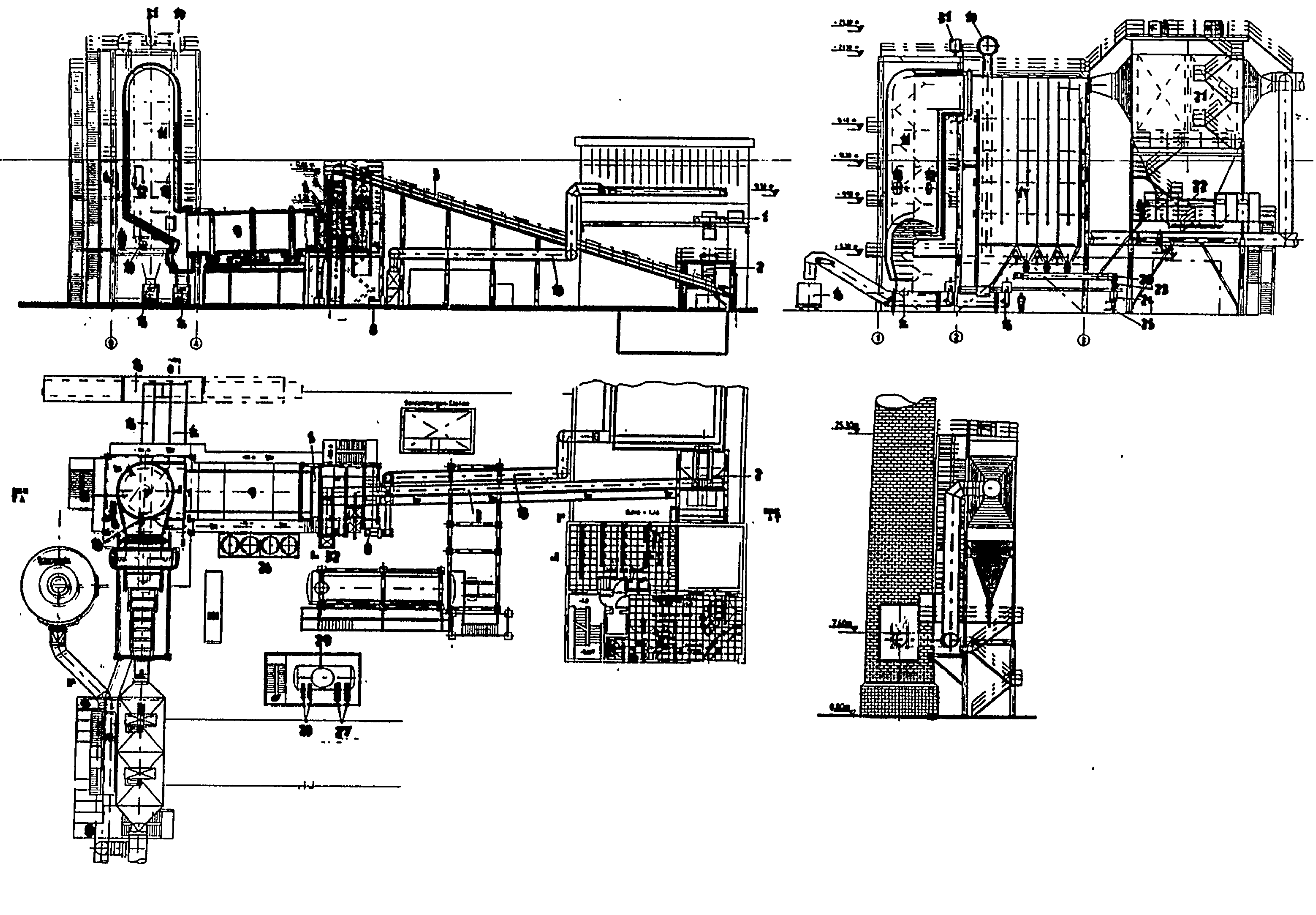
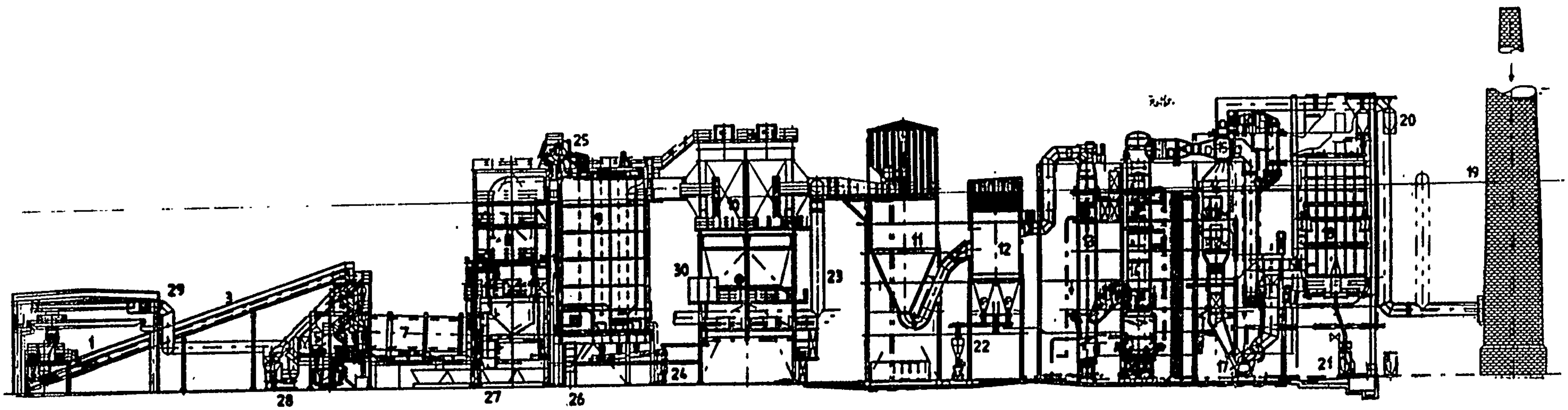


Fig. 8. General Arrangement of the New Incineration



1 = pit building
2 = feed system
3 = waste conveyor
4 = bucket waste feeder
5 = spent activated char feed
6 = burners
7 = rotary kiln
8 = secondary combustion chamber
9 = waste heat boiler
10 = ESP
11 = spray dryer
12 = bag house
13 = HCl-scrubber
14 = SO_2-scrubber
15 = cross-flow heat exchanger
16 = SCR-DeNO$_x$
17 = ID-fan
18 = ACR
19 = stack
20 = activated char feed
21 = spent activated char collection
22 = fly ash / salt collection system
23 = bypass
24 = ash collection boiler and ESP
25 = boiler drum
26 = ash collection boiler
27 = ash collection rotary kiln and SCC
28 = primary air fans
29 = primary air duct

Fig. 9. Side View of the New RVA Böhlen

TECHNICAL SESSION V

Health & Safety

Attaining VPP Star Status: A Case Study of the American Ref-Fuel Waste-to-Energy Facilities

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INTRODUCTION

The Occupational Safety and Health Act of 1970 was enacted into law by the 91st Congress of the United States to address the issue of safety in the workplace, as stated in the OSH Act Section 2(a):

"The Congress finds that personal injuries and illnesses arising out of work situations impose a substantial burden upon, and are a hindrance to, interstate commerce in terms of lost production, wage loss, medical expenses, and disability compensation payments."

Furthermore, Congress declared its purpose in enacting the Act in Section 2(b):

"The Congress declares it to be its purpose and policy, through the exercise of its powers to regulate commerce among the several states and with foreign nations and to provide for the general welfare, to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources."

In the Act, Congress therefore outlines the means by which it intends to achieve the goals set forth in the OSH Act. A review of the listing provided in Section 2(b)(1) of the OSH Act reveals what was assuredly regarded as a proactive approach towards implementation. The plan in part calls for the enhancement of employee/employer relations in the areas of hazard identification and prevention, the identification of necessary training and provisions for such training and the development and promulgation of occupational safety and health standards. Also provided for under Section 2(b)(10) of the Act was "an effective enforcement program which shall include a prohibition against giving advance notice of any inspection and sanctions for any individual violating this prohibition."

In the early 1970s, the predominant management style for achieving the desired results of an organization was still closely associated with the antiquated technique of compliance through enforcement. It was not until the late seventies and early eighties that the threat of the United States losing its front-runner position in the emerging world market forced corporate America reexamine the link between management practice and overall employee productivity and well being. The perceived adversarial climate created by the Occupational Safety and Health Administrations efforts at compliance with the new act emerged as a product of contemporary society as it mirrored the accepted management practices of the era. By the mid eighties, the economic hardships created by the emergence of the global economy had forced a management revolution where traditional ways of doing business were challenged and in many cases abandoned for new ideas. Many of the newly accepted management practices rejected ideas such as the myth that compliance can only be gained through the threat of enforcement. Instead, the new ideas focused on gaining employee trust and commitment through empowerment, by subscribing to the idea that employees were assets and not simple commodities, and that true cooperation between employer and employee was the singularly most important aspect of successful management.

OSHA was no different than the private sector, in that for the agency to achieve its goals, it had to have in place management systems that not only worked within the agency but were compatible with the systems in place for the industries which the agency regulated. OSHA also came to realize that the agency practice of enforcement to gain compliance was not producing the intended results and would not be effective in helping them to realize their goals as promulgated under the OSH Act. Because this understanding became more prevalent as time went on, the Voluntary Protection Programs (VPP) were developed. The Voluntary Protection Programs are implemented under Section 2(b)(1) of the Act, which encourages employers and employees to "reduce hazards, implement new programs, and perfect existing programs for providing safe and healthful working conditions."

This study will integrate an overview of the VPP process with an exploration of the merits of the program based upon measurable benefits to Waste-to-Energy Facilities as well as to OSHA through this cooperative effort.

CORE PRINCIPLES

Safety and Health Excellence

Since the company's inception, management has continually demonstrated a steadfast commitment to the goal of securing a leadership position in the continually developing Waste-to-Energy market. By embracing a common belief system and shared vision, management set the tone for what was to be considered the company "blueprint" for ensuring present and future successes.

The most highly regarded aspect of this "blueprint" was how the company came to establish and prioritize the implementation of its operating philosophy. For the American Ref-Fuel Waste-to-Energy Facility, this was accomplished by first understanding the need to develop and nurture a strong safety and health culture. The operating philosophy makes it very clear that strict attention to safety and health concerns are a prerequisite for accomplishing all other company goals such as operating a profitable organization and optimizing plant performance and throughput. It is a strongly held common belief among American Ref-Fuel employees that as long as safety is integrated into the decision making process and into all activities, positive production and profitability statistics follow as part of a natural progression.

Because American Ref-Fuel operates under the concept that a strong safety culture will act as a catalyst for successful operations on all fronts, the company has enjoyed continuing success in many areas. As a result, American Ref-Fuel has come to lead the Waste-to-Energy business in many categories, including the development of industry standard safety programs and statistics, protection of the environment, tons processed, and profitability, both on an individual and cumulative basis.

Collaboration and Teamwork

From the beginning, American Ref-Fuel management clearly understood that the managerial practices of the past would not provide the framework necessary to succeed in today's business environment. Because of thought processes much like the ones which led to OSHA's realization concerning how to best gain regulatory compliance, American Ref-Fuel early in its existence established a relationship with its employees where cooperation, empowerment and trust were held in highest regard. When American Ref-Fuel was first introduced to the VPP in 1993 by the local New York OSHA office area administrator, it seemed a natural step for the company to pursue participation in the program. American Ref-Fuels core values were about to be put to the test.

VPP PREPARATION

The Self Assessment Process

Once a mutual decision by management and the employees to pursue acceptance into the VPP was made, the process of self assessment commenced. Conducting this part of the process was critical to the desired outcome in that the results would dictate the future course of action. First, the assessment would provide an objective account of the degree to which the safety and health policies outlined in the various company documents were being practiced. Secondly, it would illustrate the resources required to meet the standards of the company if the assessment process showed a disconnect between stated and practiced policy. Finally, the assessment would be used as the primary indicator for the decision whether or not to continue with the process by submitting the application to OSHA and the subsequent scheduling of the on-site review.

The following is the list of areas in which the OSHA evaluation team was interested in reviewing, and around which the self assessment audits were designed and conducted by American Ref-Fuel employees.

- Management Commitment
- Employee Involvement
- Worksite Hazard Analysis
- Hazard Correction and Control
- Training

The process used by American Ref-Fuel to accomplish the self assessments consisted of the following elements:

- Review the applicable chapters of the facility Safety Manuals as well as other related documentation to ensure an understanding of all associated requirements. Update the assessment guidelines with any new requirements as found during the review.
- Conduct random spot interviews with employees to determine whether the standards set are understood and being practiced in the field.
- Conduct physical inspections of the facility to determine if standards are being met. This should include observations specific to the standard being reviewed i.e., lockout/tagout and confined space entry evolutions.
- Document all findings, enter action items into an assessment action item database.

This process proved to be an invaluable experience for each of the facilities undertaking the process. What became readily apparent to management and employees alike was the degree to which this activity furthered the cause of safety and health within each facility. This employee led program review produced valuable recommendations on how to make a good program "Star" quality, and generated the employee enthusiasm and commitment necessary to produce positive results. This is considered as one of the major benefits of involvement in the VPP, as the employee led objective review has improved the safety process as well as formed cooperative bonds within the organization. The following is a short list of improvements made to our safety management systems as a result of VPP and the continuing self-assessment process:

- Improved Hazard Recognition Processes
- Better Tracking Systems and Completion Rates for Action Items
- Improved Incident Reporting
- Increased Levels of Knowledge and Retention Due to Improved Training
- Increased Employee/Management Communications

These improvements and many others were made because the VPP process forced the site to look openly and objectively at its safety and health program. The act of self assessment empowered the employees to create an atmosphere where excellence was expected, and this expectation was bought into and backed by facility management. This idea is probably the most important and self-sustaining benefit achieved.

The VPP Application Process

Coincident with the self assessment process, the employees commenced work on the VPP application. OSHA provided the employee group with the "VPP Application Guidelines" which outlined the application requirements. Aside from the statistical and identification information, the finished application was compiled by mostly using information gathered during the self assessment process, as these categories are common. Table 1 illustrates the requested information categories and what documentary information was included to demonstrate adherence to the VPP standard.

The application was approved by OSHA, and the pre-approval onsite review was scheduled.

VPP Pre-approval Onsite Review

The purpose of the on site review was for the OSHA team to conduct a thorough review concerning the site's management of its safety and health program. There are basically four objectives for the which the review was designed to address:

- Verification- was the information concerning the safety and health program at this site consistent with information supplied in the application.
- Audit- to determine the strengths and weaknesses of the sites current program
- Quality- determine if the program provided sufficient protection from real and potential site hazards
- Recommendation- provided information to the Assistant Secretary of Labor to assist in the final decision

The agenda for the OSHA team followed this outline:

- Opening Conference- this meeting was attended by management, employees, and the OSHA VPP team. It's purpose was to set the tone for the onsite review process, to let the site know what to expect from the team, and to inform the site of what assistance would be needed. The four objectives of the review team were discussed along with proper protocol for the interviews.
- Document Review- this was accomplished in order to verify the information submitted in the application. For each of the line items illustrated in Table 1, supportive documentation was made available to the review team.
- Plant Walkthrough- The purpose of the walkthrough was for the evaluation team to assess the viability of the site's program through visual observation. Any discrepancies found were attended to immediately, and the status of their resolution was reviewed at each days closing meeting.
- Employee Interviews- Interviews were held with management, employee, and contract personnel. The interviews were conducted either one-on-one privately, or out in the field while the employee was in the execution of the job function. The questions surrounded the common themes of employee awareness to job hazards, management's correction and control of hazards at the site, and the proper levels of training which keep the employees safe. Another common theme addressed by the team was that of identified hazards being part of a management process which tracked the hazard from identification through final abatement.
- Closing Conference- This meeting occurred at the conclusion of the on site review. The facility was presented with the review teams findings and a recommendation for program participation which would be sent to the Assistant Secretary of Labor for the final decision. We were also presented with a list of items which were required to be completed in ninety days.

The following are examples of the review teams positive findings:

- Found the training programs to be well planned and executed, exceeding the minimum requirements
- Was impressed by the Performance Development System
- Liked the idea of technicians performing Safety Observations on other technicians
- Found the safety bonus system geared towards rewarding performance
- Rated the Industrial Hygiene Program as excellent

The following are examples of recommendations for improvement:

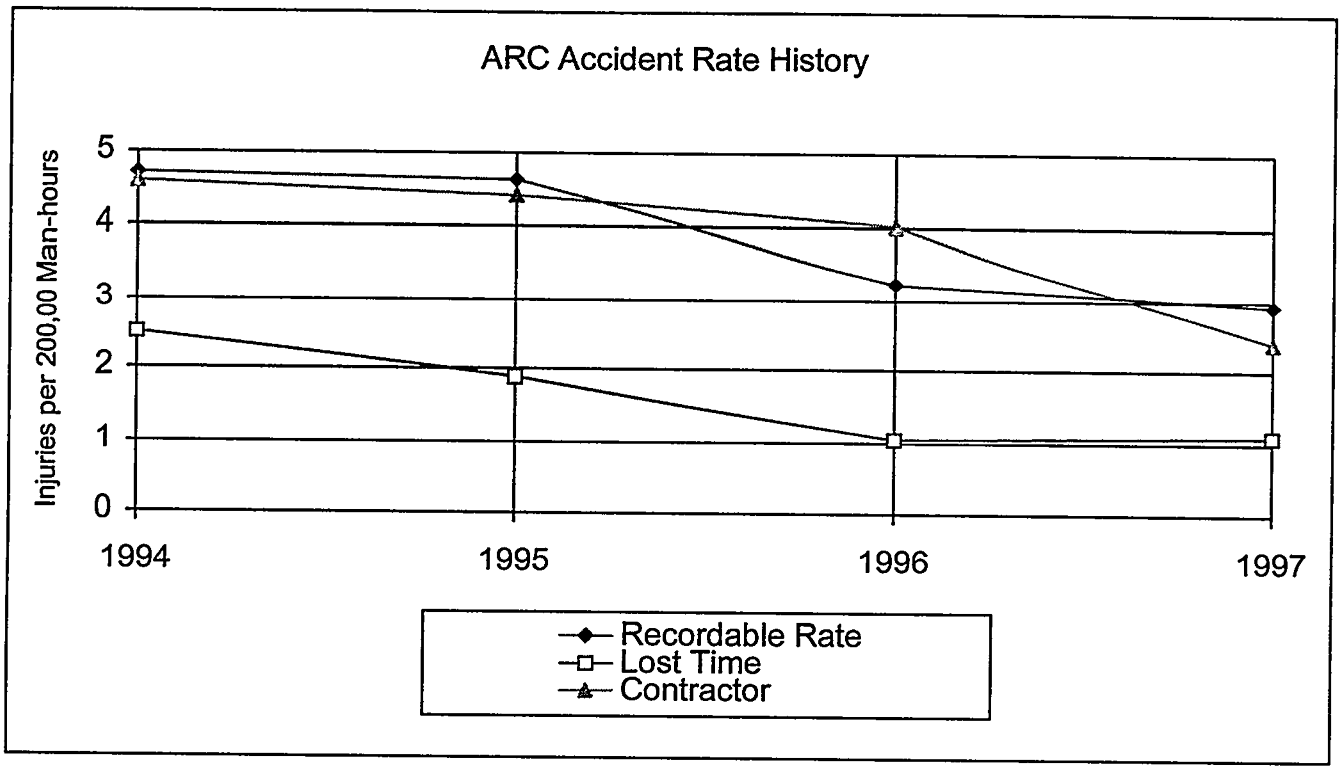
- Perform the annual self-assessments using an integrated team approach
- Ensure persons wearing dust-masks for protection against nuisance dust are clean shaven to assure proper seal
- Ensure personnel understand labeling requirements for chemicals under their control
- For an often used Contractor whose workforce is predominantly Spanish, provide training on a bi-lingual level, and hire a bilingual trainer/supervisor

The American Ref-Fuel Hempstead Facility was awarded the "Star" designation based upon the recommendation of the review team to the Assistant Secretary of Labor. Through the review process, the Hempstead team continually demonstrated by the proper implementation of a well defined safety and health program the kind of commitment necessary to reach its goal of program acceptance at the "Star" level.

Conclusions

The cooperative programs administered by OSHA have inherent benefits. By participating in this process, we have experienced many of them, some obvious in nature and others somewhat subtle.

- Employee Participation in the Safety Process- management has made the statement that they are committed to an effective safety and health program and turned the reigns over to the employees. Cooperation is an essential element as management realized that the workers are the closest to the hazards and that once empowered are better suited for effecting the abatement process. One obvious outcome of this experience was that for a safety and health program to be truly effective, the process must be driven by the employees.
- Self Assessment Process- the objective review conducted to gain participation in the program continues throughout each year, producing an accurate indicator of current conditions. This assessment is also used to measure continuing progress and as a guideline for resource allocation.
- Definite Statistical Improvement- Lower incident and compensation rates.



- Increased Productivity- No longer are we focusing on accident investigation, but accident prevention. This frees much time for involvement in value added activities.
- Incident Severity and Rate- the occurrence rate and associated severity levels of incidents has been reduced. Employee participation in the safety process is a key element.
- Cooperative Relationship with OSHA- It is a great resource to have access to the Cooperative Programs staff within OSHA as there have been instances where benefit has been attained through contact and problem resolution.

- Networking- through the Voluntary Protection Programs Participants Association (VPPPA) Regional and National Conventions, we have been able to share and benchmark with other companies in the program.
- Recognition- In the community and among industry, membership in the VPP means that you are recognized as a leader in safety and health.

The success experienced at the Hempstead facility was soon to be mirrored by the three additional plants making up the American Ref-Fuel fold at that time. As the company has grown, the process of maintaining VPP has proven to be a key element in maintaining one safety and health culture. VPP has helped each of the facilities to maintain its focus on the safety process and to reinforce the reasons why acceptance into the VPP program for all ARC facilities was made a corporate goal- it fits well within the culture of the company, it is aligned with our core values, and it empowers the employees. The end result is a cooperative effort between management, labor, and OSHA which helps each of us to attain the common goal of protecting the American worker. We feel the program works and will continue to work in its spirit.

Table 1. VPP Application Requirements

Heading	Supporting Documentation
1.0 General Information	
1.1 Company Name and Representatives	Provided Names of Company, Plant Manager, Site VPP Representative, and Site Safety Supervisor
1.2 Corporate Name and Representatives	
1.3 Description of Work Performed	
1.4 Company Data	Number of Employees, Union Status, Nested Contractor Information, and SIC Code
1.5 Injury Rates	Injury Statistics for Current and Past 2 Years
2.0 Management Commitment and Planning	
2.1 Commitment	Provided Management Statement
2.2. Organization	Provided Organizational Chart and Job Descriptions
2.3 Responsibility	Provided Management Statement
2.4 Accountability	Provided Management Statement
2.5 Resources	Described Safety and Health Budget
2.6 Planning	Described Safety and Planning Integration
2.7 Contractor Workers	Described Contractor Safety Policy
2.8 Employee Notification	How VVP was Presented to the Employment
2.9 Site Plan	Included Current Site Plan
3.0 Worksite Analysis	
3.1 Pre-Use Analysis	Described FCN and Hazard Analysis Process
3.2 Comprehensive Surveys	Air Quality, Noise, Heat, etc.
3.3. Safety and Industrial Hygiene Inspections	Safety Permit System, Safety Observations, Safety Equipment Inspections, Fire Protection, etc.

Table 1. Continued

Heading	Supporting Documentation
3.4 Job Hazard Analysis	Described the JHA Process
3.5 Employee Notification of Hazards	Near Miss/Safety Suggestion Program
3.6 Accident Investigation	Described Accident Investigation Procedures
3.7 Medical Program	Described the Companies Medical Program
4.0 Hazard Prevention and Control	
4.1 Professional Expertise	Staff Safety Professionals, Certifications
4.2 Safety and Health Rules	Described the Formal Discipline Program
4.3 Personal Protective Equipment	List Standard PPE for Plant Operations
4.4 Emergency Preparedness	Contingency Plan Table of Contents
4.5 Preventive Maintenance	Provided Descriptive Statement
5.0 Safety and Health Training	
5.1 Employee Orientation	Provided Orientation Cover Sheet
5.2 On the Job Training	Provided Job Training Instructions
5.3 Offsite Training	Described Vendor Supplied Training
5.4 Plant Drills	Described the Facility Drill Process
6.0 Employee Involvement	
6.1 Employee Participation	Included Safety Bonus Information
6.2 Safety Committee	Describe Charter, Listed Members
7.0 Program Evaluation	Offered Complete Set For Review During On Site Assessment

Accidental Release Prevention Requirements: Risk Management Programs Under Clean Air Act Section 112(r)(7)

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INTRODUCTION

The Occupational Safety and Health Administration promulgates and enforces regulations that govern the health and safety of our workers. OSHA rules often are considered to govern what happens "inside the fence line," or within the physical boundaries of the facility.

In some ways, the U.S. Environmental Protection Agency takes over where OSHA leaves off. The U.S. EPA is responsible for environmental programs "outside the fence line." The concept is as simple as drawing a line, or is it?

Anyone developing and implementing compliance programs, whether for OSHA or EPA, will tell you nothing is that simple. EPA's recent promulgation of rules pertaining to risk management programs is a case in point.

A new EPA rule is intended to compliment OSHA requirements under the Process Safety Management (PSM) rule. Under the OSHA rule, plant operators developed programs that ensure safe measures are in use when handling certain chemicals. During the past three years, waste-to-energy facilities faced difficult decisions when complying with the PSM requirements.

Plant operators developed programs in particular for the continued use of anhydrous ammonia and chlorine. Anhydrous ammonia is used as part of the Thermal DeNOx systems that clean flue gasses of nitrogen oxides. Some plant operators, after completing the PSM requirements, switched from chlorine because of the added regulatory burden placed on the regulated community by PSM in handling this chemical and the ready availability of substitute chemicals.

Earlier this year, the U.S. EPA promulgated its 112 (r) (7) rule that is intended to "compliment" OSHA's PSM requirements. This is not always the case. Unfortunately, these new Clean Air Act requirements do not always complement, but may instead confuse plant operators. For example, EPA's 112 (r) rule may force plant operators to change, once again, their decisions on the use of selected chemicals.

The U.S. EPA estimates that approximately 66,000 facilities, including the 114 waste-to-energy facilities nationwide, may be affected by the list and risk management planning rules. The facilities include chemical and many other manufacturers, cold storage facilities with ammonia refrigeration systems, public water treatment systems, wholesalers and distributors of these chemicals, propane retailers, utilities, and federal facilities.

REQUIREMENTS OF 112(r)

Section 112(r) of the Clean Air Act calls for regulations that prevent the accidental release of listed chemicals and further minimize the consequences of any such release. The owners and operators of stationary sources producing, processing, handling, or storing such substances have a general duty to identify hazards which may result from such releases using appropriate hazard assessment techniques, to design and maintain a safe facility taking such steps as necessary to prevent releases and to minimize the consequences of accidental releases which do occur.

The U.S. EPA provided a list of substances which, according to the Agency, are known to cause or may reasonably be anticipated to cause death, injury, or serious adverse effects to human health or the environment. The list is amended to this paper. In compiling the list, the U.S. EPA considered the severity of any acute adverse health effect, the likelihood of accidental release, and the potential magnitude of human exposure to the accidental releases of the substances. The list also includes a threshold quantity for the substance. In establishing the threshold quantity, the U.S. EPA considered the volatility, dispersibility, combustibility, and flammability of the substance and the amount of the substance which, as a result of an accidental release, is known to cause or may reasonably be anticipated to cause death, injury or serious adverse effects to human health.

The list EPA promulgated includes 77 acutely toxic chemicals, 63 flammable gases and volatile flammable liquids, and Division 1.1 high explosive substances. The final rule established threshold quantities for toxic substances ranging from 500 to 20,000 pounds. For all listed flammable substances, the threshold quantity is 10,000 pounds, while all explosive substances have a threshold quantity of 5,000 pounds.

REQUIREMENTS OF 112(r)(7)

Section 112(r)(7) requires the U.S. EPA to promulgate release prevention, detection, and correction requirements including monitoring, recordkeeping, reporting, training, vapor recovery, secondary containment, and other design, equipment, work practice, and operational requirements, The regulations make distinctions between various types, classes, and kinds of facilities, devices and systems by taking into account the size, location, process, process controls, quantity of substances handled, potency of substances, and response capabilities present at any stationary source.

The regulations require an owner or operator of a facility to detail the use, operation, repair, replacement, and maintenance of equipment and periodic inspections at a facility. Regulations also require an owner or operator to provide procedures and measures for emergency response after an accidental release of a regulated substance in order to protect human health and the environment.

The regulations requires owners and operators of stationary sources to carry out the following six elements of risk management planning:

(1) An offsite consequence analysis that evaluates specific potential release scenarios, including worst-case and alternative scenarios;

(2) A five-year history of certain accidental releases of regulated substances from covered processes;

(3) An integrated prevention program to manage risk;

(4) An emergency response program;

(5) An overall management system to supervise the implementation of these program elements; and,

(6) A Risk Management Program, revised at least once every five years, that summarizes and documents the above activities for all covered processes.

The Risk Management Program is intended to detect and prevent or minimize accidental releases of a stationary source and to provide a prompt emergency response to any release. The Program consists of numerous requirements that need to be completed by plant operators within three years. First, plant operators need to provide a hazard assessment to assess the potential effects of an accidental release of any regulated substance. This assessment includes an estimate of potential release quantities and a determination of downwind effects, including potential exposures to affected populations. Such assessment includes previous release history of the past five years, including the size, concentration, and duration of releases, and shall include an evaluation of worst case accidental releases.

Second, the Risk Management Program includes a program for preventing accidental release of regulated substances, including safety precautions and maintenance, monitoring, and employee training measures to be used at the source.

Third, a response program must be included that provides for specific actions that will be taken in response to an accidental release of a regulated substance so as to protect human health and the environment. The response program need include procedures for informing the public and local agencies responsible for responding to accidental releases, emergency health care, and employee training.

Several waste-to-energy facilities currently are conducting the analysis necessary to prepare the Risk Management Program. Waste-to-energy facility operators are looking in particular at the impact from the use of ammonia and propane.

After preparation of the Risk Management Program, an owner or operator must register the plan with the U.S. EPA. The Program also is submitted to the Chemical Safety and Hazard Investigation Board, to the State in which the stationary source is located, and to any local agency or entity having responsibility for planning or responding to accidental releases. In addition, the Program must be available to the public.

The U.S. EPA regulations will have added meaning for waste-to-energy facilities as MACT regulations are implemented and the use of either anhydrous or aqueous ammonia, or urea is selected for DeNOx systems.

The U.S. EPA currently is working to develop a reporting mechanism and form to collect the information required by stationary sources under this rule and make the risk management programs available to the general public via "electronic transmission." The detailed information required, potentially complex information to be transmitted, coupled with the wide distribution anticipated make the 112(r) rule an extremely important requirement for the waste-to-energy industry.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
75-07-0	Acetaldehyde	2500	
107-02-8	Acrolein (2-Propenal)	150	5000
107-13-1	Acrylonitrile		20,000
814-68-6	Acrylyl chloride	250	5000
Varies	Alkylaluminums	5000	
107-18-6	Allyl alcohol		15,000
107-05-1	Allyl chloride	1000	
107-11-9	Allylamine	1000	10,000
7664-41-7	Ammonia (anhydrous)*	10,000	10,000
7664-41-7	Ammonia (aqueous solution)*	15,000 (>44% concentration)	20,000 (≥20% concentration)
7790-98-9	Ammonium perchlorate	7500	
7787-36-2	Ammonium permanganate	7500	
7784-34-1	Arsenous trichloride		15,000
7784-42-1	Arsine (arsenic hydride)	100	1000
542-88-1	Bis (chloromethyl) ether or Chloromethyl ether	100	1000
10294-34-5	Boron trichloride	2500	5000
7637-07-2	Boron trifluoride	250	5000
353-42-4	Boron trifluoride compound with methyl ether (1:1)		15,000
7726-95-6	Bromine*	1500	10,000
13863-41-7	Bromine chloride	1500	
7789-30-2	Bromine pentafluoride	2500	
7787-71-5	Bromine trifluoride	15,000	
75-91-2	Butyl hydroperoxide (tertiary)	5000	
614-45-9	Butyl perbenzoate (tertiary)	7500	
75-15-0	Carbon disulfide		20,000
353-50-4	Carbonyl fluoride	2500	

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
9004-70-0	Cellulose nitrate (concentration > 12.6% nitrogen)	2500	
7782-50-5	Chlorine*	1500	2500
10049-04-4	Chlorine dioxide	1000	1000
13637-63-3	Chlorine pentafluoride	1000	
7790-91-2	Chlorine trifluoride	1000	
97-00-7	1-Chloro-2,4-dinitrobenzene	5000	
96-10-6	Chlorodiethylaluminum (diethylaluminum chloride)	5000	
67-66-3	Chloroform		20,000
107-30-2	Chloromethyl methyl ether	500	5000
76-06-2	Chloropicrin	500	
None	Chloropicrin and methyl bromide mixture	1500	
None	Chloropicrin and methyl chloride mixture	1500	
123-73-9	Crotonaldehyde (trans-2-butenal)		20,000
4170-30-3	Crotonaldehyde		20,000
80-15-9	Cumene hydroperoxide	5000	
460-19-5	Cyanogen	2500	
506-77-4	Cyanogen chloride	500	10,000
675-14-9	Cyanuric fluoride	100	
108-91-8	Cyclohexylamine		15,000
110-22-5	Diacetyl peroxide (concentration > 70%)	5000	
334-88-3	Diazomethane	500	
94-36-0	Dibenzoyl peroxide	7500	
19287-45-7	Diborane	100	2500

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
110-05-4	Dibutyl peroxide (tertiary)	5000	
7572-29-4	Dichloro acetylene	250	
4109-96-0	Dichlorosilane	2500	
557-20-0	Diethylzinc	10,000	
105-64-6	Diisopropyl peroxydicarbonate	7500	
105-74-8	Dilauroyl peroxide	7500	
124-40-3	Dimethylamine (anhydrous)	2500	
75-78-5	Dimethyldichlorosilane	1000	5000
57-14-7	1,1-Dimethylhydrazine	1000	15,000
97-02-9	2,4-Dinitroaniline	5000	
106-89-8	Epichlorohydrin		20,000
1338-23-4	Ethyl methyl ketone peroxide (methyl ethyl ketone peroxide; concentration > 60%)	5000	
109-95-5	Ethyl nitrite	5000	
75-04-7	Ethylamine	7500	
371-62-0	Ethylene fluorohydrin	100	
75-21-8	Ethylene oxide*	5000	10,000
107-15-3	Ethylenediamine		20,000
151-56-4	Ethyleneimine	1000	10,000
7782-41-4	Fluorine	1000	1000
50-00-0	Formaldehyde (formalin)	1000 (≥37% concentration based on a PSM interpretation letter dated 7/28/92)	15,000 (solution; no concentration given)
110-00-9	Furan	500	5000
684-16-2	Hexafluoroacetone	5000	
302-01-2	Hydrazine		15,000

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
7647-01-0	Hydrochloric acid (solution, concentration ≥30%)		15,000
74-90-8	Hydrocyanic acid (hydrogen cyanide, anhydrous)*	1000	2500
10035-10-6	Hydrogen bromide	5000	
7647-01-0	Hydrogen chloride (hydrochloric acid, anhydrous)*	5000	5000
7664-39-3	Hydrogen fluoride (hydrofluoric acid, anhydrous)*	1000	1000 (≥50% concentration)
7722-84-1	Hydrogen peroxide (concentration ≥52%)	7500	
7783-07-5	Hydrogen selenide	150	500
7783-06-4	Hydrogen sulfide*	1500	10,000
7803-49-8	Hydroxylamine	2500	
78-82-0	Isobutyronitrile		20,000
108-23-6	Isopropyl chloroformate		15,000
75-31-0	Isopropylamine	5000	
463-51-4	Ketene	100	
78-85-3	Methacrylaldehyde	1000	
126-98-7	Methacrylonitrile (methyl acrylonitrile)	250	10,000
920-46-7	Methacryloyl chloride	150	
30674-80-7	Methacryloyloxyethyl isocyanate	100	
74-83-9	Methyl bromide	2500	
74-87-3	Methyl chloride*	15,000	10,000
79-22-1	Methyl chloroformate	500	5000
453-18-9	Methyl fluoroacetate	100	
421-20-5	Methyl fluorosulfate	100	

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
60-34-4	Methyl hydrazine	100	15,000
74-88-4	Methyl iodide	7500	
624-83-9	Methyl isocyanate*	250	10,000
74-93-1	Methyl mercaptan*	5000	10,000
556-64-9	Methyl thiocyanate		20,000
79-84-4	Methyl vinyl ketone	100	
74-89-5	Methylamine (anhydrous)	1000	
75-79-6	Methyltrichlorosilane	500	5000
13463-39-3	Nickel carbonyl (nickel tetracarbonyl)	150	1000
7697-37-2	Nitric acid	500 (≥94.5% concentration)	15,000 (≥80% concentration)
10102-43-9	Nitric oxide	250	10,000
100-01-6	Nitroaniline (paranitroaniline)	5000	
10102-44-0	Nitrogen oxides (NO; NO_2; N_2O_4; N_2O_3)	250	
10544-72-6	Nitrogen tetroxide (nitrogen peroxide)	250	
7783-54-2	Nitrogen trifluoride	5000	
10544-73-7	Nitrogen trioxide	250	
75-52-5	Nitromethane	2500	
8014-95-7	Oleum (fuming sulfuric acid)	1000 (65% to 80% SO_3 concentration)	10,000 (SO_3 concentration not specified)
20816-12-0	Osmium tetroxide	100	
7783-41-7	Oxygen difluoride (fluorine monoxide)	100	
10028-15-6	Ozone	100	
19624-22-7	Pentaborane	100	
13463-40-6	Pentacarbonyl-iron	250	2500

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
79-21-0	Peracetic acid	1000 (> 60% concentration of acetic acid; peroxyacetic acid)	10,000
7601-90-3	Perchloric acid (concentration > 60% by weight)	5000	
594-42-3	Perchloromethyl mercaptan	150	10,000
7616-94-6	Perchloryl fluoride	5000	
75-44-5	Phosgene (carbonic chloride; carbonyl chloride)*	100	500
7803-51-2	Phosphine (hydrogen phosphide)	100	5000
10025-87-3	Phosphorus oxychloride (phosphoryl chloride)	1000	5000
7719-12-2	Phosphorus trichloride	1000	15,000
110-89-4	Piperidine		15,000
106-96-7	Propargyl bromide (3-bromopropyne)	100	
107-12-0	Propionitrile		10,000
109-61-5	Propyl chloroformate		15,000
627-3-4	Propyl nitrate	2500	
75-55-8	Propyleneimine		10,000
75-56-9	Propylene oxide		10,000
107-44-8	Sarin	100	
7783-79-1	Selenium hexafluoride	1000	
7803-52-3	Stibine (antimony hydride)	500	
7446-09-5	Sulfur dioxide*	1000 (liquid)	5000
5714-22-7	Sulfur pentafluoride	250	
7783-60-0	Sulfur tetrafluoride	250	2500
7446-11-9	Sulfur trioxide (sulfur anhydride)*	1000	10,000
7783-80-4	Tellurium hexafluoride	250	

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Toxic Substances and Threshold Quantities (TQ) for Accidental Release Prevention (OSHA vs. EPA)

CAS No.	Chemical Name	OSHA PSM TQ (lbs) (from 29 CFR 1910.119 Appendix A)	EPA RMP TQ (lbs) (from Table 1 of 40 CFR 68.130)
116-14-3	Tetrafluoroethylene	5000	
10036-47-2	Tetrafluorohydrazine	5000	
75-74-1	Tetramethyl lead	1000	10,000
509-14-8	Tetranitromethane		10,000
7719-09-7	Thionyl chloride	250	
7550-45-0	Titanium tetrachloride		2500
26471-62-5	Toluene diisocyanate (mixed isomers)*		10,000
584-84-9	Toluene 2,4-diisocyanate*		10,000
91-08-7	Toluene 2,6-diisocyanate*		10,000
1558-25-4	Trichloro (chloromethyl) silane	100	
27137-85-5	Trichloro (dichlorophenyl) silane	2500	
10025-78-2	Trichlorosilane	5000	
79-38-9	Trifluorochloroethylene	10,000	
75-77-4	Trimethylchlorosilane		10,000
2487-90-3	Trimethyoxysilane	1500	
108-05-4	Vinyl acetate monomer		15,000

*Required to be on EPA's list by the 1990 Clean Air Act Amendments.

Alphabetical Listing of Regulated Flammable Substances for Accidental Release Prevention (from Table 3 of 40 CFR 68.130)

CAS No.	Chemical Name	CAS No.	Chemical Name
75-07-0	Acetaldehyde†	78-79-5	Isoprene
74-86-2	Acetylene	75-31-0	Isopropylamine†
598-73-2	Bromotrifluorethylene	75-29-6	Isopropyl chloride
106-99-0	1,3-Butadiene	74-82-8	Methane
106-97-8	Butane	74-89-5	Methylamine†
106-98-9	1-Butene	563-46-2	2-Methyl-1-butene
107-01-7	2-Butene	563-45-1	3-Methyl-1-butene
25167-67-3	Butene	115-10-6	Methyl ether
590-18-1	2-Butene-cis	107-31-3	Methyl formate
624-64-6	2-Butene-trans	115-11-7	2-Methylpropene
463-58-1	Carbon oxysulfide	504-60-9	1,3-Pentadiene
7791-21-1	Chlorine monoxide	109-66-0	Pentane
557-98-2	2-Chloropropylene	109-67-1	1-Pentene
590-21-6	1-Chloropropylene	646-04-8	2-Pentene, (E)-
460-19-5	Cyanogen†	627-20-3	2-Pentene, (Z)-
75-19-4	Cyclopropane	463-49-0	Propadiene
4109-96-0	Dichlorosilane†	74-98-6	Propane
75-37-6	Difluorethane	115-07-1	Propylene
124-40-3	Dimethylamine†	74-99-7	Propyne
463-82-1	2,2-Dimethylpropane	7803-62-5	Silane
74-84-0	Ethane	116-14-3	Tetrafluoroethylene†
107-00-6	Ethyl acetylene	75-76-3	Tetramethylsilane
75-04-7	Ethylamine†	10025-78-2	Trichlorosilane†
75-00-3	Ethyl chloride	79-38-9	Trifluorochloroethylene†
74-85-1	Ethylene	75-50-3	Trimethylamine
60-29-7	Ethyl ether	689-97-4	Vinyl acetylene
75-08-1	Ethyl mercaptan	75-01-4	Vinyl chloride*
109-95-5	Ethyl nitrite†	109-92-2	Vinyl ethyl ether
1333-74-0	Hydrogen	75-02-5	Vinyl fluoride
75-28-5	Isobutane	75-35-4	Vinylidene chloride
78-78-4	Isopentane	75-38-7	Vinylidene fluoride
		107-25-5	Vinyl methyl ether

NOTE: All EPA flammable liquids and gases have a common TQ of 10,000 lbs. Materials marked with a dagger (†) are also in Appendix A of toxic and reactive materials under OSHA's PSM rule (29 CFR 1910.119) with TQs less than or equal to 10,000 lbs. Materials marked with an asterisk (*) are required to be on EPA's list by the 1990 Clean Air Act Amendments.

Summary of Coverage Differences Between EPA's RMP Rule and OSHA's PSM Regulation

Chemical Name	OSHA Limits		EPA Limits	
	Threshold Concentration	Threshold Quantity (lb)	Threshold Concentration	Threshold Quantity (lb)
SUBSTANCES ADDED BY EPA				
Arsenous trichloride				15,000
Boron trifluoride with methyl ether				15,000
Chloroform				20,000
Hydrazine				15,000
Isopropyl chloroformate				15,000
Methyl thiocyanate				20,000
Tetranitromethane				10,000
Titanium tetrachloride				2,500
Toluene diisocyanate				10,000
SUBSTANCES WITH LOWER EPA THRESHOLD QUANTITY				
Methyl chloride		15,000		10,000
SUBSTANCES WITH LOWER EPA CONCENTRATION LIMIT				
Ammonia, aqueous	44%	15,000	20%	20,000
Formaldehyde	37%	1,000	none given	15,000
Hydrogen chloride	anhydrous	5,000	30%	15,000
Hydrogen fluoride	anhydrous	1,000	50%	1,000
Nitric acid	94.5%	500	80%	15,000
Oleum	65%	1,000	none given	10,000
EPA's rule for toxic and flammable mixtures not having a specified lower concentration limit will likely cause more process areas to be covered than under OSHA's PSM regulation				
OSHA EXEMPTIONS NOT CURRENTLY ALLOWED BY EPA				
Atmospheric storage and transfer of flammable liquids (ASTFL)	Flammable gas or liquids used solely as hydrocarbon fuels in the workplace	Retail facility	Normally unoccupied remote facility	Oil and gas well drilling or servicing

The Impact Of OSHA Upon Waste-To-Energy Employers

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This paper is prepared for those who are not OSHA specialists. The objective is to provide a broad overview of the requirements and enforcement of the Occupational Safety and Health Act as it applies to waste-to-energy employers.

WHO ARE THE SAFETY AND HEALTH REGULATORS?

The federal Occupational Safety and Health Act ("the Act") [1] governs occupational safety and health among private employers in states subject to federal jurisdiction. This includes private employers who operate facilities under agreements with state or local government agencies.

OSHA addresses only safety and health in employment. It does not regulate public safety.

Twenty-six states have obtained OSHA's approval of their state's plan for the enforcement of safety and health regulation.[2] In those states, private and some public employers are subject to state-administered safety and health programs.

In states subject to federal jurisdiction, the Act is enforced by the United States Department of Labor ("DOL"), through its Occupational Safety and Health Administration ("OSHA"). When employers challenge (or "contest") citations issued by OSHA, the cases are adjudicated by the Occupational Safety and Health Review Commission ("OSHRC"), an independent federal agency which is not part of DOL. OSHRC consists of three Commissioners appointed by the President with the advice and consent of the United States Senate. OSHRC delegates to Administrative Law Judges ("ALJ's") the task of conducting trials on contests of OSHA citations.

In state plans, each state has its own mechanism for enforcing safety and health standards, and for adjudicating citation contests.

WHAT ARE AN EMPLOYER'S OBLIGATIONS UNDER OSHA?

Employers have two main obligations under OSHA. First, they must comply with specific regulations, called standards, which OSHA issues. Standards address particular workplace hazards. Some are quite specific in their requirements. Others are stated more generally in terms of objectives employers are to achieve; these are called "performance standards."

When Congress passed the Act and created OSHA in 1971, it realized that the agency would not have the time or resources to issue a standard governing every hazard to which employees may be exposed in American industry. Desiring to protect employees nonetheless, Congress included in the Act the so-called "General Duty Clause." [3] That provision states:

5(a) Each employer -

(1) shall furnish to each of this employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.

As a practical matter, this section means that employers must protect their employees against hazards that are recognized in the industry as presenting danger. "Recognition" often is established by reference to sources such as national consensus standards (*e.g.*, standards issued by ANSI, ASME, or other similar standards-setting organizations). Thus, waste-to-energy employers should understand that they must keep abreast of developments in the industry as to safety and health, because even though OSHA may not have issued a standard addressing a particular hazard or practice, the employer may be cited for not having taken the precautions to address such a hazard that others in the industry have concluded are prudent.

It is important to understand that there need not be an accident for there to be an OSHA violation. Unlike in other areas of law, such as ordinary negligence, the violation consists of an employer exposing an employee to a prohibited hazard of which the employer knew or should have known. The hazard need not result in an accident for there to be a violation.

STANDARDS OF PARTICULAR CONCERN TO WASTE-TO-ENERGY EMPLOYERS

OSHA has issued so many standards that it would be impossible to include a comprehensive review in this paper. Some of the standards which are of particular interest to waste-to-energy employers are the following:

1) Control of Hazardous Energy Sources, 29 CFR § 1910.147

This standard sets forth detailed requirements for the control of machinery and equipment during operations and maintenance. It is one of the most oft-cited OSHA standards.

2) Permit Entry Confined Spaces, 29 CFR § 1910.146

This standard sets forth requirements for procedures to be followed when entering and working in confined spaces, and when performing rescue within such spaces.

3) Process Safety Management of Highly Hazardous Chemicals 29 CFR § 1910.119

This is one of OSHA's most important recent standards. Where sufficient quantities of those hazardous chemicals listed in the standard are located at a facility, the standard imposes detailed requirements for the development of process hazards analyses, and other procedures, aimed at avoiding catastrophic accidents.

The PSM standard is closely related to a new regulation promulgated by the Environmental Protection Agency under the Clean Air Act, known as the section "112(r)" rule. That rule imposes requirements aimed at avoiding accidental releases of hazardous chemicals.

4) **Hazardous Waste Operations and Emergency Response, 29 CFR § 1910.120**

This standard specifies precautions to be taken at hazardous waste cleanup sites. It also contains requirements for procedures to be implemented in the event of an emergency at any type of industrial facility. It is closely related to OSHA standards on fire safety.

5) **Bloodborne Pathogens, 29 CFR § 1910.1030**

This standard specifies procedures to be taken where an employee may be exposed to bloodborne pathogens. It is important in the waste-to-energy industry where employees may be exposed to medical waste, including sharps.

6) **Occupational Exposure to Cadmium, 29 CFR § 1910.1027**

This standard establishes permissible limits for employee exposure to cadmium, as well as procedures for minimizing and monitoring exposure.

7) **Personal protective equipment, 29 CFR § 1910.132-138**

These standards include requirements for equipment to protect employees from a variety of hazards, including eye and face, respiratory, head, foot, electrical and hand protection. 29 CFR § 1910.132 includes a requirement that the employer perform an assessment of its workplace to determine what hazards requiring personal protective equipment may be present.

CURRENT ISSUES INVOLVING OSHA

1) **Ergonomics**

In recent years, OSHA has become concerned with so-called "ergonomic" hazards. In 1992, it began to develop a proposed standard to address these hazards. However, when the Republicans took control of Congress following the 1994 elections, riders to the legislation authorizing OSHA's budget prohibited the agency from developing the standard.

Now, however, there are no legal impediments to OSHA's work on the issue. Accordingly, the agency has resumed work in developing a proposed standard. It is expected to be highly controversial.

One state plan state - California - is nearing final completion of a standard addressing ergonomics.

2) **Safety and Health Programs**

OSHA has been discussing a possible new, comprehensive standard that would require all employers to develop safety and health programs. Superficially, the concept seems appealing. However, as the details of what OSHA may be contemplating have become known, there is growing concern in industry that OSHA may be preparing to impose a detailed and burdensome new set of requirements upon industry. This issue, too, is expected to be controversial if OSHA determines to move ahead with the development of a proposed standard.

1. 29 U.S.C. § 651, *et seq.*

2. The following states have approved state plans: Alaska, Arizona, California, Hawaii, Indiana, Iowa, Kentucky, Maryland, Michigan, Minnesota, Nevada, New Mexico, North Carolina, Oregon, South Carolina, Tennessee, Utah, Vermont, Virginia, Washington, and Wyoming.

3. Section 5(a)(1) of the Act, 29 U.S.C. § 654(a)(1).

KEY WORDS:

OCCUPATIONAL

HEALTH

SAFETY

OSHA

OSHRC

STANDARDS

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Worker Safety at MRF'S -- Where Are We Going ?

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INTRODUCTION

There is hardly a community in the United States that does not have a material recycling facility to support the area's waste management program. In the past six years, over 500 such facilities have been constructed now employing an estimated work force of over 10,000 persons. The applicability of current OSHA regulations has been a major concern, but lack of data has delayed the implementation of appropriate safety guidelines to address Material Recovery Facilities (MRF's) specifically. Leading MRF designers like RRT, have been directly responsible for advancing the industry's "Best Practices" and have yielded measurable results in quality projects. Unfortunately, many other projects were built without professional engineering guidance. Project were being developed with different interpretations of OSHA and in many cases without the input of qualified individuals and valid data.

In response and through the efforts of many operators and regulators, new guidelines, recommendations and standards have now been instituted to protect the worker. Designers will now follow a newly established "industry practice": ANSI Z245. However, is this enough? European guidelines are stricter. MRF technology keeps changing. Economic pressures are upon the industry. With these changing forces, where are we going? This paper summarizes present trends and major concerns in order to predict future design and operations requirements. This information will be beneficial to system operators, facility owners, equipment manufacturers and system designers in identifying and correcting safety shortfalls in both new and existing man/machine systems and preparing facilities to meet current OSHA safety regulations and future more stringent safety requirements which are expected to be published by the end of 1997.

HEALTH AND SAFETY RISK ASSESSMENT AT RECYCLING FACILITIES

As concluded by R.F. Weston[1] in "Environmental, Economic and Energy Impacts of Material Recovery Facilities", workers at recycling facilities do not appear to be exposed to health or safety hazards when they follow established safety requirements. Parameters analyzed by R.F. Weston included air contaminants, as dust, silica, metals, CO, Hg Vapor; PCBs and pesticides, airborne and surface samples of bacteria and fungi; noise exposure; physical safety hazards and ergonomic stressors. Based on their health and safety risk level these parameters can be classified in:

- Low Risk Parameters. Common air contaminants were found to be of low health risk. Air concentrations of dust, silica, metals, CO, Hg Vapor; PCBs and pesticides were recorded below applicable regulatory standards and in most instances below the detection limits of the recommended test methods.
- Risk Parameters to be Avoided by Following Safety Programs. Noise exposure and physical safety hazards present in MRF's can be avoided by following established OSHA programs. The operations which exceeded regulated noise exposure levels were the truck unloading activities, trommels, glass crushers and can flatteners. Employee noise exposure can be reduced to accepted levels by following the guidelines indicated in the Hearing Conservation Program. Main safety hazards can be avoided by following the Energy Control Program, the Personnel Protective Equipment Program, the Blood Borne Pathogens Program, etc.
- Parameters Requiring Additional Evaluation. Bacteria and fungi airborne samples as well as ergonomic stressors risk factors were parameters defined as to require additional evaluation because of the rapidly developing knowledge in these areas. In the case of bacteria and fungi, regulatory standards or guidelines have not been established yet. Airborne samples of bacteria and fungi were recorded consistent throughout the facility and were rated at one order of magnitude higher than the

one observed outside the facility. Most of the bacteria and fungi species detected were classified as environmental species, which are commonly found in soil and water. Pathogenic micro-organisms detected were of the opportunistic type i.e. they are most likely to affect hypersensitive people or people with compromised immune systems. Some of the pathogenic micro-organisms detected are capable of causing disease at high concentrations, although there is very little information on the required exposure levels for adverse reactions to happen. The main ergonomic stressor identified by R.F. Weston was the improper sorting station design that caused repetitive or awkward motions. Main factors identified to cause extensive repetitive motions were extremely wide sorting belts, lack of foot stools, excessive belt speed and over feeding of recyclable materials.

THE INDUSTRY RESPONSE

The ANSI Z245 Report : Facilities for the Processing of Commingled Recyclable Materials - Safety Requirements

Safety practices at Material Recovery Facilities are currently regulated by the Occupational Safety and Health Administration (OSHA) under the Code of Federal Regulations 29 CFR 1910[2] for general industry. The American National Standards Institute (ANSI) Z245[3] document is independent of OSHA 29 CFR 1910 and is currently being developed to provide detailed information and voluntary standards regarding safety practices at MRFs to be used by operators, engineers, equipment manufacturers and OSHA inspectors. ANSI documents, while voluntary, are typically used for interpretation by both OSHA inspectors and by the legal profession in the settlement of cases. ANSI is recognized by the Federal Government as a major source of National Consensus Industrial Standards. Additionally, ANSI standards are frequently sited in the OSHA regulations, and thus become part of the National Standard for which industry must comply[4]; examples of this include industrial forklifts, balers and compactors.

The ANSI document strives to address in detail, system safety requirements, and is currently in draft form. The intent is to receive approval by the ANSI Board of Standards Review so it can be published by the end of 1997, whereby ANSI can petition OSHA to "incorporate by reference" the documents in accordance with 1 CFR part 51. The legal effect of incorporation by reference is that the material is treated as if it were published in full in the Federal Register. Regarding compliance with ANSI Z245, existing facilities will have 5 years after the approval date to comply with Sections 5, 6, and 7. Section 8, which concerns training, will be effective 18 months after approval. New facilities placed in operation 18 months after the approved date of the standard will have to comply with the entire standard.

The ANSI Z245 report provides two major benefits to the industry. The first, it establishes a complete, standard worker protection approach by including ergonomic factors, system design parameters and real operation safety needs, which were not considered when following the previous general ANSI guidelines. The second benefit is that it provides the facility operators and owners with a set of total system safety guidelines that their engineers/systems providers need to follow. This, for example, will direct the type of acceptable equipment that can meet minimum safety guidelines. Current practice is to rely on equipment vendors for what is purchased, however many vendors exclude from their scope the responsibility to comply with regulations regarding safety. Furthermore, the expertise for engineering and safety issues is typically not held by manufacturers beyond their own machines and disclaimers.

The document covers four major topics and is divided into eight (8) Sections.

- General information and definitions (Sections 1-3).

- Site requirements (Section 4), reserved for future preparation.
- Mobile equipment, physical plant and processing machinery requirements (Sections 5-7).
- Safety programs and Safety requirements that apply to MRFs (Section 8).

Following are the highlights of the principal standards, Sections 5-8:

Mobile Equipment (Section 5): Mobile equipment is classified into two categories: Collection and Transportation Equipment and Powered Industrial Trucks. Each equipment category should be operated in accordance with its related ANSI standard. The major concerns to ensure the safe use of mobile equipment are:

- The employment of certified drivers and equipment operators by facility owners and users. Truck drivers loading or unloading material at the facility should be trained as required by OSHA standards specified in the Code of Federal Regulations Part 29 Subpart 1910.178.
- The accessibility and control of personnel in traffic areas such as the tipping floor and loading docks.
- The importance of awareness training and supervision by employers.
- The use of personal protective gear that meets specified ANSI standards.
- The fabrication and use of mobile equipment that meets specified technical requirements.
- The adequate maintenance and periodical inspections by service providers and employers.
- The report of safety related conditions by employees.

An example of a specific requirement for a piece of mobile equipment, used in or around the facility, is a backup alarm capable of emitting a warning signal 10 dBA above ambient noise level (ANSI/SAE J994b) and a protective shield or cage that will protect the operator from any falling objects.

Buildings and Plant Systems (Section 6): Facility operators are responsible for the safety training and supervision of their employees and the performance of regular maintenance and safety inspection programs. Facilities should have a traffic plan and use all necessary devices to minimize safety risks through the utilization of barriers, signs, separation partitions, communication devices, etc. In addition, the facility operator should designate Special Work Areas and limit employee access within 1.8 m (6 ft.) around them. Special Work Areas are distinctly identified areas where the use of guards and railings is functionally impractical and where specific training of affected employees is effective to avoid hazards within it.

With regard to the engineering of building and plant systems, the following are examples of new standards:

<u>Facility Design Considerations.</u> Building design should account for a minimum of six air changes per hour, have a fire exposure control and evacuation plan.

<u>Tipping Areas</u>. Mobile equipment traffic and sorting activities should be considered when designing tipping areas. Safety markings and signs to be used must comply with ANSI standards, audible alarms must emit a signal of at least 87 dBA or 10 dBA above ambient noise level and visual alarms must be visible from all affected areas. In addition specific signs are required in higher risk areas in order to limit personnel access. Higher risk areas include: unloading pit areas, the tipping floor, bale stacking and storage areas, industrial truck operating areas (such as aisles), etc.

Unloading Pits. As long as toeboards and guardrails which comply with ANSI A1264.1-1989 standards do not interfere with mechanized unloading operations, they should be installed on all sides of unloading pits or bunkers adjacent to walking or working areas. In the case of trucks unloading into pits, warning signs as barricades, stop logs, hand or mechanical signals should be provided.

Visitor/Public areas. Access by public visitors is prohibited during any time the facility is in operation. Access is limited to observation rooms and work areas not in operation.

Material Storage Areas. Fire protection procedures in these areas should follow standards specified in NFPA 101, Life Safety Code. Storage areas layout should provide access routes for employees that consider a minimum of 1.2 meters (4 feet) of separation from mobile equipment operating areas. Floor loading limits and lateral wall loading limits, if applicable, shall be posted. Bale stacking is allowed for stable, homogeneous, properly tied bales. Bales stacks shall be limited to four (4) high, any higher stacks should be arranged in a stair stepped fashion, interlocking fashion or use supplemental restraint devices. Bale storage areas are considered special work areas and have limited personnel access. Bales in stacks should be inspected daily for integrity.

Processing Machines and Systems (Section 7): Facility operators are directly responsible for the compliance of their systems. System engineers, machinery manufacturers, employees and service contractors (for maintenance, modification or remanufacture of machinery) are to follow the standards applicable to them. Major duties for above mentioned parties are:

- Proper operation and maintenance of machinery. The machinery manufacturers and system engineers should provide the system operator with a recommended operations and maintenance manual that includes safety features. The maintenance program must be performed by the system operator. The system engineer should provide adequate work area around each machinery for safe maintenance and inspection.
- Training, supervision and safety audits. The system operators must provide training to their employees, supervision and perform safety audits to verify the correct performance of the system safety features. Employees should only operate equipment for which they have been previously trained.
- Energy Control Program. The operator is responsible to perform an Energy Control Program and lockout/tagout of energy sources prior to performing servicing or maintenance. The machinery manufacturers and system engineer should provide the system operator lockout/tagout instructions compatible with 29 CFR Part 1910.147.
- Operator protection: Work surfaces or platforms at distances equal or less than 2.1 meters (7 ft) from unguarded points of operation should have railings no less than 1067 mm (42 in) high.
- Automatic mode equipment. Equipment functioning in automatic mode should not have its loading chamber accessible to employees.
- Riding on conveyors should not be permitted unless they have been designed for this purpose.
- Access to Special Work Areas within 1.8 meters (6 ft) is restricted to employees with the training and experience to avoid hazards.
- Equipment modifications. The contractor must obtain written permission from the operator to perform any modifications. If applicable, new operation, maintenance or safety precautions instructions will be issued. A label on the modified equipment shall list the contractor's name and the date the equipment was modified.

Control Systems. One of the most advanced features of ANSI Z245 is the controls and energy control systems standards. Aspects covered are control system design guidelines, location and equipment control features:

- Must be labeled.
- Must be designed and located to prevent unintentional activation (i.e. start buttons).
- Must meet minimum dimensions (minimum button surface is 1 inch, full hand controls activation surface is minimum 4.25 in.).
- Must be accessible.
- Must use one master control panel per processing system. It should override local controls with exception of emergency stops and discharge end controls. It should be located in manner that all affected operations are visible from it.
- Emergency buttons must be easily noticeable (in red and of larger size).

Energy controls must meet additional requirements to ensure that machinery will stop right on time, for the period desired and will re-initiate operations without creating any hazardous conditions. Energy controls are used to stop machinery when it is necessary to inspect, maintain, clean, unclog, remove contaminants etc. The most important recommendations are:

- Use of a Power Disconnect (lock in the off position).
- Use of Emergency Stops (E-stop) of the maintain contact type. (should be accessible to all affected employees and within 914 mm or 3 ft. of the Point of Operation or Feed Point Chute).
- Use of Pause/Resume control for regular system stops.
- Use of an interlock on all machinery access doors.
- Provide a key lock switch at discharge points not visible from the operator station.
- Hydraulic and electrical systems must comply with ANSI/NFPA related regulations.

Warnings, Signs and Alarms. Warnings, signs and visual alarms must comply with their related ANSI standards and be placed in areas where they are visible by all affected employees. Audible alarms must provide a pulsing or intermittent signal of at least 87 dBA or be preset to at least 10 dBA above ambient noise level to ensure workers response. System start-up alarms should be audible and visual and provide a initial 5 seconds signaling and a minimum 15 second delay to the start of the main motor. Equipment manufacturers are required to locate specific machinery warning signs on all equipment with moving parts. For example an access point warning would be to locate a sign next to a baler, commanding employees to disconnect and lock out power before opening a baler chamber gate.

Machine Guarding. Guards or enclosures are required for all equipment comprised of moving components which contain a Pinch Point or create a safety hazard. A Pinch Point is a point at which it is possible for a person's member or clothing to be caught between moving parts or between moving and stationary parts of a piece of equipment. Guard access covers should be secured by lock or require hand tools to be opened. Guarding is also used to control material flow particularly during transitions to prevent overflows within a reach of 2.1 m (7 ft.). In the event that it is impossible to install a guard in a point of operation, an E-stop and a control to either reverse, open the pinch point or disengage the mechanism is necessary.

Conveyors. Conveyor safety requirements are as a minimum the existing ANSI/ASME requirements. Equipment manufacturers should provide detailed information on the type, volume and weight the conveyor is capable to transport. Additional safety concerns are:

- Use of guards and skirts (elevated conveyors) to prevent a reach within 2.1 m (7 ft.) of the intersection or transition of conveyors.
- Provide guards for mechanical mechanisms and the return side (bottom) of conveyors.
- Conveyor sections transporting material next to sorting stations should be fully enclosed.
- Conveyor pits should use either an access cover, rails with gates interlocked to an E-stop or all moving elements of the conveyor fully enclosed.
- Sub-floor conveyors are considered Special Work Areas and have restricted access.

Sorting Stations. The sorting station standards section is probably one of the most interesting parts of the ANSI document because in addition to covering traditional safety features, it also includes ergonomic design considerations and engineering design parameters to define the system standards. Engineering parameters to be factored are Average Flow Rate, Material Density, Conveyor Belt Width, Average Belt Speed and Average Burden Depth. Furthermore, the standard recommends that engineers and equipment manufacturers apply ergonomic design features for repetitive physical tasks during their designs. The main factors discussed are:

- Work environment. For proper ventilation, a nominal air flow rate of 0.425 cubic meters (15 cubic meters) per employee or six fresh air changes per hour, whichever is greater, should be provided.
- Safety controls. Installation of E-stops within 0.9 meter (3 ft.) of each employee working position are required. The E-stop should interrupt all upstream feed and any system immediately downstream of the sorting line.
- Layout. The conveyor sort belt height should be no less than 762 mm (30 in.). The conveyor should include a toe cut-out to account for proper sorter posture. The toe cut-out dimensions should be 127 mm (5 in.) deep and 125 mm (5 in.) high. The sorting chute height should be no less than 762 mm (30 in.) on the loading side and 1067 mm (42 in.) on the others. In the event that the conveyor height plus the average burden depth height is greater than 1016 mm (40 in.) a riser should be added.
- Communication. All working positions should be visible from the control panel position and all sort station employees should be able to communicate with the control panel operator.
- Safety Features. Floors should be made of slip resistant material and be easy to clean. Guard rails should be provided for elevated sorting stations according to existing ANSI standards.

Electromagnetic Radiation Equipment. System layout and management should include provisions to maintain worker exposure to electromagnetic field emissions (EMF) under regulated maximum limits. As a minimum, guarding should be installed to prevent access within 1 meter (3 ft.) of the EMF source. The equipment manufacturer is required to provide data regarding field strength and flux density at a radius of 1 meter (3 ft) from the radiation source, both at a continuous average and at maximum continuous power. The system operator is responsible to verify equipment manufacturer information in the field and monitor EMF exposure at a work station closest to the EMF source. The radiation should be monitored for eight hour periods and their weighted average should not exceed the following limits:

- Magnetic Flux ≤ 1 mT (milliTesia) or
- Field Strength ≤ 25 kv/m (if the frequency is less than 100 Hz)
- Field Strength ≤ 625 kv/m (if the frequency is greater than 100 Hz)

Safety Program and Training (Section 8): Facility operators are responsible to perform a hazard assessment survey and an evaluation of the proper methods for controlling these hazards in accordance with industry and regulatory requirements. As a result the facility's engineer in cooperation with the operator should develop a written program which would include all operation, inspection, maintenance and training procedures necessary to comply with existing regulations. In order to comply with the program, the personnel should be trained at the start of new assignments and refresher training should be given periodically as required. Training records detailing date and content should be maintained as required by applicable regulations. The training curricula should comply with OSHA or other federal agency requirements. Training can be classified as general safety training mandatory for all the personnel, detailed safety training for specific positions or awareness training for the recognition and avoidance of hazards. Following is a list of the written safety programs required.

Site Safety Orientation. Includes general work rules and regulations, familiarization with facility processing, explanation of signs and other prevention warnings, the emergency action plan and accident reporting.

Basic Hazard Communications (Hazcom). Used to inform employees about any hazardous material they may be exposed to in the work areas. Material Safety Data Sheets (MSDS) are also used for this purpose. Employees are instructed as how to read and interpret MSDS's information, the location of this information and the facility protection measures.

Walking - Working Surfaces. Employees are trained to recognize and avoid hazards encountered in special work areas of the facility as ladders, platforms aisles, etc.

Spill Response Program. It instructs employees to identify and handle unauthorized material, as for example hazardous waste inadvertently delivered with the recyclable material to the facility.

Blood Borne Pathogens Program. It provides training to employees regarding the hazards of infectious diseases as Hepatitis B or HIV.

Energy Control Program. It explains the risks of unexpected energizing or starting up of a machine and the lockout/tagout procedure.

Confined Space Program. Also called the permit spaces program, it provides training to prevent the hazards of working in confined spaces.

Heat/Cold Stress Program. It provides training to prevent or minimize safety or health risks caused by heat and cold stress.

Personal Protective Equipment Program. The employer should provide personal protective equipment appropriate to the job duties as required by 29 CFR 1910.132 and in compliance with its related ANSI standards.

Hearing Conservation Program. It provides awareness training regarding the hazards of high noise level exposure, prevention and protection instructions.

Traffic Control Program. Employees are trained on basic operational procedures that regulate mobile equipment traffic in the MRF as flow/routes, signals/markings, hazards, vehicle types, pedestrian routes and safety rules. The use of enhanced visibility clothing is an example of compliance.

Material Processing Equipment Program. Previous to the operation or maintenance of any piece of equipment in the facility, the employee must receive a comprehensive training on operation, maintenance and safety procedures.

Ergonomics Program. It provides information on ergonomic risk factors and preventive actions including the description of cumulative trauma disorders, recommended lifting and sorting techniques.

Electrical Safety Practices Program. Awareness training as well as specific training in electrical safety issues are to be provided to all employees according to the levels of risk at which they are exposed. Recommended work practices should comply with NFPA standards.

Fire Safety Program. It includes a fire safety awareness training and a task specific training for employees who are members of the incipient fire response program.

Material Control Program. Training is provided to minimize safety and health risks because of the handling and storage of materials around the facility. Employees are instructed on materials being processed, plant layout, traffic routes, etc.

What Is Happening in Other Countries? The Germany Example

Safety regulations for the Germany Recycling Industry[5] were published in July 1995 to ensure proper work conditions of approximately 11,000 workers employed at 300 sorting plants. The document was prepared by the Committee for Industrial Protection and Safety together with the representatives of the Federal Institute for Industrial Protection, the Federal Institute of Industrial Medicine and the various responsible vocational associations. The major safety concern in this document is to reduce the exposure of workers to micro-organisms (bacteria, fungus, viruses, etc.) that may cause diseases. With these concerns, as well as others, the German regulations for system design are more stringent than the ANSI Z245 report. Examples of the more stringent German regulations are listed below:

- Tipping Floor. In contrast with US standards, German regulations specifically do not allow personnel to sort materials in the tipping floor area. Tipping areas must be physically separated from sorting areas.

- Mobile Equipment. The operator's cabin should additionally include a filtering device or a pressurized air tanks system to ensure proper air quality.

- Mechanical pre-sorting. Trommels and vibrating screens should be enclosed and have dedicated dust collection and exhaust systems.

- Sorting Stations. Standing sorting positions from one side of the belt should be designed considering a reach of 0.6 m (23.6 in.). For sort stations picking from both sides of the belt, the maximum belt width should be 1 meter (39.4 in.). Sorting stations should be designed to be a combination of standing and sitting work stations. The belt speed should not exceed 10 meters/minute (32.8 fpm). Ventilation devices should be periodically checked for micro-organisms present in the air.

- Hygienic Arrangements. The clothing storage areas (lockers) for work clothing and street clothing should be separated by a washroom with showers. Break-rooms are to be accessed by going through wash facilities.

- Physical Examinations. An initial physical screening and follow up examinations should be performed in 12 or 24 month intervals in order to establish a history and a follow up of any changes in physical conditions. This information will be the basis for a better understanding of the potential long term and short term conditions caused by micro-organisms commonly present in recycling manually sorting environments.

What are Present Industry Practices? The RRT Example

The recycling industry growth in the recent years has diversified work conditions and technologies across the country. Many facilities will require extensive retrofits in order to comply with safety standards being developed today, in particular those that were not designed and integrated by a professional engineer. The ANSI Z245 Report will guide the MRF owners' systems engineer when determining upgrade requirements. Facilities designed to exceed the minimum health and safety standards will reward their owners by minimizing lost time accidents and reducing insurance premiums.

Industry safety practices can be classified into two categories: operational practices and system engineering practices. Compliance is achieved when both the operator and system engineer follow established requirements. "Potential Hazards Associated with Municipal Solid Waste Recycling" were well documented[6] in 1991. As a leading systems engineer, RRT has been including in their designs since the early 1990's the safety features only now being enacted by ANSI. Four (4) examples of these features are highlighted below:

Comprehensive Control Systems. The layout of system controls at RRT facilities follow the NFPA 79 Electrical Standard for Industrial Machinery. The process system motor control enclosure (MCE) is housed in a UL inspected, NEMA 12 enclosure using standard IEC/NEMA components including a programmable logic control (PLC) and a modem for remote interfacing. In automatic mode the system sequentially starts equipment in a preprogrammed logic which prevents the feeding of stopped equipment. In the event of a failure occurrence, equipment upstream will be stopped. Upon restarting; equipment will start in sequence in automatic mode after sounding a safety horn. The panel is equipped with mimic status lights indicating process conditions including equipment, emergency stops and pull cord lanyards. The system has a manual mode of operation for maintenance and adjustment activities.

Operator control stations including start/stop buttons, variable speed potentiometers, and E-stops are provided at the sorting stations for local control. Sorting conveyors are equipped with safety lanyards. Additional safety switches are used on various equipment as necessary. Each motor is interfaced with the PLC to signal running equipment through the status of the disconnect. Knife-style disconnects including the capability for local safety lock-out are typically specified. In the event an emergency stop is pushed, all equipment in the process system shuts down. There are emergency stops strategically located throughout the facility for safety purposes. The corresponding E-stop light on the mimic board indicates the specific location of the affected area.

Restricted Pedestrians Access to Mobile Equipment Traffic Areas. In some facilities, materials are floor sorted at the baler infeed areas because elevated sorting platforms are not available, or in other cases pre-sorting of reject material is performed at the tipping floor because of the system design limitations. At RRT facilities, an elevated conveyor serving as an initial quality control station is provided where reject material is sorted and directed to a separate storage area.

Operations, Maintenance and Safety Manuals. Prior to the start-up of any new or modified recycling facility, RRT provides the owner/operator formal operation, maintenance and safety guidelines for the equipment. This includes both hands-on and classroom instructional programs in the following areas:

- Process flow and system operation
- Safety training
- Baler training
- Sorter operations
- Quality control
- Mobile equipment operations
- Maintenance and repair procedures
- Preventive maintenance training
- Housekeeping

Future employees are trained in order to comply with system safety standards, design throughput and quality specifications. RRT's safety training emphasizes the use of personal safety equipment and safety controls including restarting and troubleshooting system failures. Additionally, employees are trained to handle medical wastes and sharps that may have been erroneously disposed with the recyclable material.

Ergonomics Considerations. RRT's ergonomic considerations during the design of recycling sorting systems are intended to minimize risks associated with Repetitive Stress Injuries (RSI's). The main affected areas for MRF workers are the upper extremities and the back. Sorting conveyor design considerations propose to optimize posture and angular deflection of joints while reducing worker's exposure to vibration. As a result, optimum sorting conveyor width, height, side skirt height, chute positioning and dimensions have been determined. Operation parameters, such as sorting belt speed and average burden depth, are correlated to the infeed stream composition in order to determine an optimum presentation of materials. Additionally, sorting station design includes proper lighting and ventilation. Working under ergonomically correct standards promotes a healthy work environment, improves productivity rates and reduces operating costs.

A comparison of ANSI Z245, German and RRT sorting station design standards is presented in Table 1. Similar design standards among all sources were observed for factors as ventilation, illumination, working height, toe cut-out room and chute height. Differences were observed for sorting belt width, sorting belt speed and burden depth considerations. The observed regulatory agencies trend is the use of narrower, slower and more heavily loaded sorting belts. The potential adverse effect of the institution of these standards is the considerable increase of operation costs because of the lower productivity per worker.

- Belt widths recommended in the ANSI and German documents were rated at 60 to 80% of present industry practices. RRT standards are based on ergonomic design consideration in addition to extended time and motion studies[7] in existing facilities. These case studies were oriented to define sort station design standards that maximize productivity by providing the most comfortable work station.
- The importance of setting appropriate burden depth levels should not be underestimated. Systems running at high burden depths offer a poor presentation of materials thereby increasing sorting difficulty. Determination of optimum burden depth depends on the type of material being sorted and the stream composition, e.g. the optimum burden depth for a residential fibers mix is different from a commingled containers stream.

- Belt speed considerations were only found in the German document as they are still being developed for the ANSI Z245 report. The recommended German sorting belt speed is 40% to 50% of RRT standards. RRT case studies indicate that for different composition streams sorting belt speeds should vary between 80 - 100 fpm. These higher speeds ease burden depths and have not been shown to be detrimental to the employee. As such ANSI Z245 does not limit speed of belt travel.
- RRT includes among its standards, chute design considerations depending on the material being sorted. Practical experience shows that "toss-across" chutes are more appropriate for commingled containers sorting lines, while "toss-to-the-side" chutes provide better ergonomics for paper lines.

During 1996, fifty sorting systems designed and built by miscellaneous companies around the nation were analyzed by RRT. Most of them presented one or more deficient ergonomic design or operating features which were reflected in lower sorting rates and higher work force requirements. Commingled containers sort rates were typically recorded to be below 75% of acceptable sorting standards and as low as 35%. Major ergonomic design considerations leading to poor ergonomic conditions were thick burden depth, low sorting belt heights and the use of floor sorting operations. All of these pose safety risks to the worker.

- Thick burden depth was observed because of poor engineering and in some cases lack of engineering. Sorters were frequently observed "rummaging" through or "digging" into the material instead of sorting.
- Low sorting belt heights were observed at facilities where sorting stations were added to existing baling systems. Low sorting belt height and high burden depth situations often occur simultaneously. These systems record the lowest productivity standards.
- Floor sorting operations are frequent for commercial fiber streams (old corrugated containers mixed with trash) when mechanical means of separation were not available.

CONCLUSIONS

Workers at recycling facilities do not appear to be exposed to health and safety hazards when they follow prescribed safety requirements and facilities are properly designed. The development of safety standards specific to the recycling industry will provide comprehensive safety coverage for the worker. ANSI Z245 addresses these issues clearly for the engineer and operator. The main improvement over current standards will be the optimization of employee work conditions by the integration of ergonomics, safety and health features. These improvements come with a cost and with the continuing increase in manual sorting costs, research and experimentation on mechanical sorting separation systems will be further stimulated. The technology of recycling facilities will also be further expanded through the extensive use of integrated logic controls including energy controls and alarm systems. Maintenance, employee training and housekeeping operations will become more important as their role in the prevention of health and safety risks becomes more explicit. Further research will be performed in order to obtain a better understanding of the health risks associated with micro-organisms exposure and ergonomic stressors in recycling operations. It is the opinion of the authors that future requirements will adopt the "good, generally accepted practices" already found in the German regulations. Certainly many of these measures will derive mixed views. Controversy with regard to the analysis for justification of cost versus savings will continue as the industry matures.

ACKNOWLEDGMENT

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Table 1. Sorting Station Design Standards[1]

Parameters	ANSI Z245 Report version 2/10/97	German Regulations[3]	RRT Design Standards
1. Ventilation	6 fresh air changes per hour 0.43 m^3/minute-employee (15 cfm/employee) or		6 fresh air changes per hour
2. Ilumination		500 lux (46.45 foot-candles/ft^2)	538 lux (50.00 foot-candles/ft^2)
3. Sorting Conveyor			
3.1 Sorting belt width			
a. Picking from one side of the belt	$\leq$ 0.46 m (18 in.)	$\leq$ 0.60 m (23.6 in.)	$\leq$ 0.76 m (30 in.)
b. Picking from both sides of the belt	$\leq$ 0.91 m (36 in.)	$\leq$ 1.00 m (39.4 in.)	$\leq$ 1.52 m (60 in.)
3.2 Sorting belt height	$\geq$ 0.76 m (30 in.)		= 0.86 m (34 in.)
3.2 Side skirt height	$\leq$ 0.26 m (10 in.)		0.10 - 0.15 m (4 - 6 in.)
3.3 Working height[2]	$\leq$ 1.02 m (40 in.)		
3.4 Toe cut-out	depth = 0.13 mm (5 in.) height = 0.13 mm (5 in.)		depth $\geq$ 0.13 mm (5 inches)[4] height $\geq$ 0.13 mm (5 inches)
3.4 Chutes height	loading side $\geq$ 0.76 m (30 in.) other sides $\geq$ 1.07 m (42 in.)		0.97 - 1.02 m (38 - 40 in.)
4. Sorting belt speed		10 m/min (32.8 fpm)	containers 18.3 - 30.5 m/min (60 - 100 fpm) paper 24.4 - 36.6 m/min (80 -120 fpm)
5. System controls	E-stops at 1m (3 ft) from each work station		Lanyard and local control panel
6. Flooring	Slip resistant material		Diamond plating floors
7. Platforms	Guard rails, toe plates		Guard rails, toe plates. Chains are provided on all ladders.
7. Additional considerations		Sorting stations should be a combination of standing/sitting work. Padded belt frame.	Drop chutes have a "rolled" or "square" edge avoiding sharp edges to hurt employees

1 This table compares US ANSI standards (2/10/97), German LASI standards and RRT standards.
2 Is equal to the conveyor belt height plus the side skirt height. If the working height exceeds the specified limit a riser should be provided.
3 As indicated in "Guidelines of Industrial Protection in Commodity Sorting Plants" 1995.
4 Conveyors legs are supported by platform steel avoiding the use of many legs. This provides spacious foot room underneath the conveyor and facilitates cleaning.

TECHNICAL SESSION V

Ash Utilization

Ash Recycling - The Coming of Age!

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INTRODUCTION

A major concern of the Waste-To-Energy (WTE) industry is ash disposal and the uncertainty of controlled long term ash management. Ash management costs have risen steadily over the last ten years making it the fastest rising cost segment of the WTE industry. The challenge of how to curb the rising cost while maintaining the protection of human health and the environment has been accomplished by responsibly recycling the ash on a commercial basis.

American Ash Recycling Corp. (AAR), utilizing the Duos Engineering (USA), Inc. patent pending ash recycling technology, has promoted ash recycling on a commercial basis in the United States. An important product of the processing and recycling of non-hazardous municipal waste combustor (MWC) ash is Treated Ash Aggregate (TAA). Additionally, ferrous and non-ferrous metals are recovered and unburned materials removed and returned to the WTE facility for re-combustion. The TAA is sized and then treated by the WES-PHix® immobilization process in order to reduce the potential solubility and environmental availability of the metal constituents of the MWC ash. The TAA is available for commercial use in such applications as an aggregate substitute in roadway materials, asphalt and concrete applications, as structural fill, and as landfill cover.

Commercial and technical considerations that must be addressed before ash can be beneficially recycled are: permitting requirements, physical and chemical characteristics, potential end uses, environmental concerns (product safety), product market development, and economic viability. True recycling only occurs if all of these considerations can be addressed.

This paper presents the details of AAR's most recent experience in the development of an ash recycling facility in the State of Maine and the associated beneficial use of the TAA product. Each of the considerations listed above are discussed with a special focus on the permitting process. A major component of the permitting process involved the development of a comprehensive life-cycle human health and environmental risk assessment to evaluate the potential long term effects which may arise from the beneficial use of AAR's TAA product. The extensive analytical data required in both the development of the risk assessment and the physical and chemical characteristics of the TAA will be reviewed. AAR's process and the permitted beneficial uses of the TAA product are explored as well as the methodology and overall approach utilized in the development of the project.

PROCESS DESCRIPTION

The process description outlined below is based on Duos Engineering (USA), Inc., an AAR affiliated company, patent pending design.

Incoming MWC ash will be received at the designated material input staging area of AAR's ash recycling facility. From there, the ash is conveyed to initial screening, which separates it into two size gradations consisting of less than and greater than 3", for further processing.

The larger size gradation is conveyed to a slow speed, high torque shredder for size reduction. After being reduced to a proper size, it is combined with the smaller of the two size gradations. The combined material stream next passes magnetic separation which extracts the ferrous metals. The ferrous metals are directed to the ferrous cleaning unit where any ash adhering to the metal is removed. The removed ash is reintroduced into the process for further processing.

After magnetic separation, the remaining material is screened into the two sizes: less than 3/8" and greater than 3/8". The smaller fraction is treated using the patented WES-PHix® chemical immobilization process and subsequently conveyed to the TAA storage area. The larger fraction is directed to the Windzifter®, which uses proprietary air separation technology to remove unburned combustibles such as paper, plastic, and wood from the ash stream.

The unburned combustibles are then discharged through air locks and conveyed to a controlled storage area. The unburned stream is then returned to the MWC for recombustion. After the unburned combustibles are removed, the material flows to the eddy-current separator for non-ferrous metal removal. The remaining material (after non-ferrous metal removal) is conveyed to a crusher where it is reduced to 3/8" or less. This material is reintroduced to the process at a point prior to magnetic separation for further processing and ferrous and non-ferrous recovery. The non-ferrous material is conveyed to the MartinTag non-ferrous cleaner which uses a proprietary metals cleaning technology to remove any residual ash. The cleaned non-ferrous metals are then separated into their individual components, i.e., brass, copper, coins, and aluminum.

The process is designed to keep the material in a continuous loop until substantially all metals and unburned combustibles have been removed and the remaining ash has reached a uniform size gradation. The ash is then treated with the WES-PHix® chemical immobilization process in order to produce the final product, TAA, which is suited for beneficial use.

PERMIT REQUIREMENTS

In order to utilize the TAA, beneficial use permits are typically required. Several states have developed beneficial use regulations of MWC ash while many others are in the process. The main concern of any environmental agency is: What is the effect on human health and the environment when beneficially using this product? A myriad of other issues must be addressed during the permitting process but the main question of the safety of the product must be answered in a scientifically defensible way.

This paper focuses on AAR's most recent experience in the State of Maine for obtaining environmental permits. The three permits required for AAR to operate and beneficially use their product within the State were: 1) Solid Waste Processing Facility Permit, 2) Minor Source Air Permit, and 3) Special Waste Utilization License (Beneficial Use).

The Processing Facility permit application was typical for processing facilities as was the Air Permit. The Air Permit was required because of AAR's use of the Windzifter®, which removes the unburned material from the ash. The Windzifter® utilizes a baghouse to control any discharge of particulates to the air but since it has a potential to emit, a minor source air permit was required. The Beneficial Use permit is product specific and unique, therefore, it will be discussed in detail.

The following requirements must be met in order to obtain a Beneficial Use Permit:

- The beneficially used waste-derived-product must perform equivalently to the material it is replacing;

- The beneficial use shall produce a product which meets or exceeds the generally accepted product specifications and standards for the same product produced using a raw material; and
- The beneficial use will not pollute any waters of the state, contaminant the ambient air, constitute a hazard to health or welfare or create a nuisance during and after the active life of the project.

The Maine Department of Environmental Protection (DEP) requires the following material be included as part of the Beneficial Use of a Special Waste Permit application:

1) General description of the waste-derived-product and its proposed use;
2) Specific information regarding the physical, chemical or biological characteristics of the waste-derived-product;
3) The quantities, by weight and/or volume of the solid waste and waste-derived-product;
4) Waste characterization plan - analytical data demonstrating that the solid waste is non-hazardous;
5) Demonstrated Product Markets. The following information may be submitted in support of this requirement: a) Contract to purchase proposed product; b).Description of how the proposed product will be used; c) Demonstration that the proposed product complies with industry standards and specifications for that product; d) Other documentation that a market for the proposed product or use exists;
6) Demonstration that the nature of the proposed use of the waste-derived-product constitutes a beneficial use rather than disposal;
7) Description of the operation of the facility which is proposing to use the solid waste and the product produced or the manner in which the waste shall be used. The complexity and degree of detail of the description will vary depending on the magnitude and complexity of the process;
8) A description of how the solid waste and the waste derived product will be stored;
9) A technical comparison of the waste derived product and the virgin material it is replacing. An evaluation shall demonstrate that the physical and chemical properties of the materials are comparable and that the waste derived product will serve as an effective substitute for the analogous raw material. This demonstration may include a discussion of the risks and drawbacks and an assessment of similar application of the proposed beneficial use; and,
10) Records and Annual Reporting.

AAR submitted the permit applications to the Maine DEP after detailed discussions which outlined the specific information that would be acceptable in order to meet all of the requirements. The most difficult question to answer in a scientifically defensible way was: Is this material safe to human health and the environment when beneficially used in the requested applications? AAR approached this question, in agreement with the DEP, by performing a chemical characterization of the TAA and a comprehensive human health and environmental risk assessment (HRA) based upon the chemical constituents found in the characterization report. The HRA evaluated the potential long-term environmental effects which may arise from the beneficial use of TAA.

CHEMICAL CHARACTERISTICS OF TAA

In order to obtain specific information regarding the physical and chemical characteristics of both the ash and TAA, MWC ash from an operational waste-to-energy facility in Maine was transported to the AAR Nashville facility for processing in October 1995. Composite samples of the MWC ash were collected prior to processing and multiple composite samples of TAA were collected as well. TAA samples were collected after 10, 20 and 30 tons of the aggregate were produced. All of the composite samples were forwarded to the State University of New York (SUNY) for both physical and chemical characterization. A characterization report titled "Chemical and Physical Characteristics of AAR's Processed Ash Aggregate Produced from Maine Energy Recovery Company's MWC Combined Ash[1]" was prepared by the University (Roethel, 1995) which detailed the analytical results, analytical methods, and the appropriate quality control/quality assurance data.

Figure 1 outlines the analyses which were performed on TAA and leachates reported in the study. A broad spectrum of analytical analysis was performed on the TAA in order to demonstrate to the Maine DEP the complete TAA characterization. The chemicals of concern, as determined in Roethel, 1995, that were used in the risk assessment include metals and dioxins/furans analysis. The metals considered in the HRA were: arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc. Metal leachate data was obtained in accordance with the US EPA Monofilled Waste Extraction Procedure, more commonly known as EPA Method SW-924. This multiple extraction leaching test is significantly more predictive of how TAA will behave in the environment than the TCLP test.

Dioxin/furan data were obtained from samples of TAA. This data was used in exposure scenarios which evaluated direct contact with TAA and served as the basis of the modeled airborne particulate concentrations and deposition rates. Actual dioxin leachate data was obtained from the US EPA's Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills, Co-disposal Sites[2], September 1987. The dioxin leachate data did not represent AAR's TAA but were provided as a worst-case approximation of leaching from landfills when municipal solid waste and MWC ash are deposited together.

In establishing the inorganic composition of the ash and TAA, samples were digested using hydrofluoric and boric acids (HF/H_3BO_3) which is a departure from the standard EPA total metal digestion protocol incorporating nitric acid (HNO_3). This modification was undertaken to permit an analysis of metals bound within a siliceous matrix which would not be digested if nitric acid were utilized. Typically, the concentrations measured using the more aggressive HF/H_3BO_3 digestion technique are higher, increasing between 10%-30% above those determined using HNO_3. This was done to determine the true total metals concentrations.

Dioxin and furan concentrations were determined for duplicate samples of TAA. Toxicity Equivalent Factors (TEF's) were used to express the concentration of the different isomers and homologs of dioxin/furans as an equivalent amount of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

The physical characterization showed that the AAR process yields a uniform product, consistently achieving a particle size distribution appropriate for a diverse array of applications. The data indicated the aggregate is well graded, consisting of about 30 percent gravel, 65 percent sand size particles, and 8 percent fines (smaller than 200 mesh). The particle size distribution and percent volatile matter are both very similar to existing TAA data produced at AAR's Facility in Nashville, TN. The data in this investigation, the previous data gathered by AAR and the completed HRA all suggest the use of TAA is an environmentally acceptable beneficial use strategy.

HUMAN HEALTH AND ENVIRONMENTAL RISK ASSESSMENT

In order to demonstrate to the Maine DEP that the TAA would not pollute any waters of the state, contaminate the ambient air, constitute a hazard to health or welfare or create a nuisance, Radian International (Radian) performed a comprehensive HRA to evaluate the potential long-term environmental effects which may arise from the beneficial use of TAA.

The HRA, titled "Assessment of Potential Human Health and Environmental Effects from the Beneficial Use of American Ash Recycling Corporation's Treated Ash Aggregate[3]" (Roffman, 1995), was a major component in the permitting process. The data utilized in the HRA came from the Roethel, 1995, Characterization Report.

The HRA was conducted in accordance with applicable US EPA and Maine DEP risk assessment guidelines. The risk assessment evaluates the human health and environmental risk associated with the TAA from the time of creation to its beneficial use in roadways, landfills and other potential uses including its final reuse or disposal. The HRA included life cycle analyses which examined stages in the processing and proposed usage of the TAA during which releases may occur. For each stage, a human health risk assessment and an environmental risk assessment were performed for potentially affected receptors. To ensure that potential secondary effects were not overlooked, not only direct contact of receptors with TAA, but also potential impacts on local air and water quality were evaluated in the risk assessments.

The risk assessment presents estimated human health and environmental risks resulting from exposure to chemical constituents in AAR's TAA for the following stages in the potential uses of TAA:

- Loading and unloading of TAA
- Storage of TAA;
- Transportation of TAA;
- Production of asphalt paving material containing TAA;
- Use of TAA as a protected subbase in a roadway;
- Use of TAA as a commercial protected structural fill;
- Use of TAA as daily cover and final cover for landfills;
- Use of TAA as an aggregate substitute in asphalt or concrete materials; and
- Final use or disposal of paving materials containing TAA.

Potential health risks to workers and potentially affected residential receptors were evaluated for each of these stages, when applicable. The exposure pathways considered for this risk analysis are as follows:

- Worker exposure to constituents of TAA by accidental ingestion and inhalation;
- Worker exposure to TAA constituents dissolved in rainwater runoff;
- Inhalation of airborne particulates emitted from a TAA processing facility by residents living near the facility;
- Residential exposure to soils potentially impacted by deposition of particulates of TAA emitted from storage piles, processing plants and the erosion of roadways; Residential exposure of soils potentially impacted by overland transport of TAA constituents via runoff from 100 percent TAA storage piles, and storage piles containing mixtures of 40 percent TAA encapsulated with asphalt or cement;
- Residential exposure to TAA constituents which have been leached from storage piles, roadway

subbase, and landfills utilizing TAA as a daily or final cover. This scenario assumes that the constituents enter a groundwater system which is used for typical residential purposes, including drinking and bathing;

- Exposure to TAA constituents in a surface water body potentially impacted by overland transport from 100 percent and 40 percent TAA storage piles;
- Exposure through the food chain. This scenario assumes food is grown in soils impacted by releases from a TAA processing facility, from storage piles, and from roadway deterioration.

These potential risks were quantified by applicable US EPA risk assessment equations. They used predictive computer models which utilized the physical and chemical data developed in Roethel, 1995.

Throughout the HRA conservative assumptions were employed so that the US EPA concept of a "Reasonable Maximum Exposure (RME)" was maintained. RME's are defined as "the highest exposure that is reasonably expected to occur" for a given exposure pathway. The HRA, therefore, uses exposure factors which are likely to overestimate potential risks, so that the health of the public is safeguarded.

Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of potential exposures to constituents detected in the TAA. Results of the exposure assessment are combined with chemical-specific toxicity information to characterize the potential human health risks. Table 1 presents the appropriate exposure factors employed in the risk assessment calculations. The exposure assessment consists of the following steps:

- Identification of potentially exposed populations and exposure pathways as described above;
- Determination of exposure concentrations which are estimates of the chemical concentrations to which persons (receptors) may be exposed. In this HRA, exposure point concentrations consist of the following:

    1) Determination of soil exposure point concentrations from both deposition and runoff, and
    2) Determination of groundwater exposure point concentrations employing ground water modeling using specific input parameters, groundwater fate and transport data and mass input.

- Air emission exposure point concentrations and deposition derivations were determined using the following:

    1) Emission rate derivations which include:
    Truck loading and unloading of TAA;
    Transport of TAA;
    Material handling at a production facility;
    Storage of TAA;
    Particulate emissions from a mixing plant;
    Emissions associated with roadbed decomposition.

    2) Deposition rate derivations which describe the rate at which particulate matter settle out of the atmosphere onto the ground. This requires knowledge of the average particle size,

the particle density, the viscosity of the air, and the gravitational constant.

3) Particulate concentration modeling using the US EPA Industrial Source Complex-Short Term (ISCST2)[4] model to estimate potential maximum ground-level concentrations of TSP
and PM10. The dispersion modeling requires specification of the following parameters:

Source data;
Receptor Data;
Meteorological data;
Model options;
Exposure point concentrations.
Determination of surface water exposure point concentrations; and
Potential food chain exposure.

Risk Effects

The potential risks assessed in the HRA include both noncarcinogenic (non-cancer) and carcinogenic (cancer) health effects. Each risk is shown as a numeric value which is subsequently compared to US EPA acceptable criteria.

Noncarcinogenic health effects are characterized by a value known as the Hazard Quotient. According to the US EPA guidelines, if the Hazard Quotient is greater than unity (>1), "there may be concern for potential health effects", and when the Hazard Quotient is less than one (<1), "it is unlikely for even sensitive populations to experience adverse health effects". It is, therefore, desirable that:

$$\text{Hazard Quotient} < 1$$

The ratio of the Intake to Reference Dose is termed a Hazard Quotient and is a measure of the potential health effect of a given exposure. Therefore,

$$\text{Hazard Quotient} = \text{Intake} / \text{Reference Dose}$$

Carcinogenic risks are expressed as a probability of contracting cancer. This probability is defined as an "incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen". Incremental refers to the fact that the cancer risk is in excess of the individual's normal risk without this exposure. The means by which intake is converted to a probability of carcinogenic risk is the Carcinogenic Slope Factor (CSF). To compute the probability of contracting cancer, the intakes are multiplied by the chemical-specific CSF's. Therefore,

$$\text{Carcinogenic Risk} = \text{Dose} \times \text{CSF}$$

The US. EPA states that its carcinogenic risk goal is 1×10^{-6} to 1×10^{-4} where a carcinogenic risk of 1×10^{-6} is equivalent to one excess incidence of cancer in 1,000,000 persons and a 1×10^{-4} risk indicates a risk of one in 10,000 individuals.

Risk Assessment Results

The potential health risks associated with the production and utilization of TAA were in every instance less than the US EPA acceptable criteria for both carcinogenic and noncarcinogenic risks.

The data indicate the potential noncarcinogenic health risks or Hazard Quotient incurred if individuals are exposed to the chemical constituents of 100% TAA storage piles and in environmental media affected by migration of these constituents from the pile, are less than the US EPA acceptable criteria.

The maximum carcinogenic risks to workers and nearby residential adults and children in the considered exposure scenarios were within the US EPA acceptable range.

Results of the LEAD 5 Model

Potential risk to children exposed to lead in residential soils were evaluated by the US EPA's LEAD 5 model. This exposure situation assumed that TAA is blown from storage piles, roadways, and an asphalt mixing plant and that the particulates are then deposited on soils near these sources. It is further assumed that young children play in this soil outdoors, and that soil dusts infiltrate their homes so that they are exposed both outdoors and indoors for a period of six years. US EPA default values were assumed for other media the child may be exposed to, such as contributions from food, waters, and air. It should be noted that the US EPA default values for water and air concentrations in the LEAD 5 model are greater than lead concentrations estimated in the HRA for these media.

Table 2 shows the results of the LEAD 5 model which indicate that the total lead blood level is below the current US EPA acceptable level of 10 μg/dl.

HRA Summary

Human health and environmental risks resulting from exposure to chemical constituents for the following stages in the life of the TAA were assessed in this study: the storage and handling of the TAA, the production of a TAA/asphalt mixture, the use of TAA as a roadway subbase, use as commercial structural fill, and the final disposition of TAA/asphalt or cement paving materials.

Results of this study indicate that both potential noncarcinogenic and carcinogenic risks are well within US EPA recommended goals for all exposure situations evaluated in this HRA. Review of the specific risks shows that much of the estimated risk arises from direct worker contact with 100 percent TAA. The worker exposure scenarios assume that a worker's hands and the full length of both arms are completely covered with TAA every workday for 25 years, i.e., the worker wears no gloves, long-sleeved shirts, or other protective equipment. These risks can easily be reduced by proper administrative and engineering controls.

The HRA confirms the potential carcinogenic and non-carcinogenic risks to residents resulting from air emissions, rainwater runoff, structural fill, and leaching from piles, and roadways are well below US EPA criteria.

Despite the conservative assumptions made throughout the HRA the potential human health risks as well as the potential ecological impacts resulting from the utilization of TAA in storage piles, processing plants, structural fill, roadways and landfills, are within acceptable ranges. Risks are overestimated following conservative US EPA guidance in order to assure that if error occurs, the error is on the side of safety. The findings of the HRA indicate the potential risks associated with the use of TAA as a product are well within or below US EPA guidelines.

POTENTIAL END USES

The potential end uses for any new product must be determined prior to submitting the permit application. Based upon extensive study and years of commercial operation AAR has determined that TAA is suitable for use as:

- Base and sub-base under roads and other paved surfaces,
- Aggregate for asphalt manufacturing,
- Structural fill material,
- Substitute aggregate in concrete; and,
- Daily landfill cover and closure materials.

PRODUCT MARKETABILITY

AAR has developed a Marketing Plan which is based upon its experience in successfully marketing the TAA and ferrous and non-ferrous metals produced at its Nashville, Tennessee ash recycling facility. AAR has sold, to a variety of end users, more than 260,000 tons of TAA produced to date. TAA is readily accepted by industry based upon its proven similarity in engineering and structural characteristics to natural aggregate. Based upon geographic location, the cost of TAA is typically lower than natural aggregate. In addition, the concept of recycling a material versus using a non-renewable natural resource is an attractive bonus to using TAA.

For the Maine project, AAR was able to demonstrate to the DEP the marketability of the TAA by contracting with a Scarborough, Maine paving company to purchase all of AAR's production. The company has over fifty years experience in the paving and construction industry and upon evaluating the TAA determined it met their strict standards of acceptability as a replacement for natural aggregate.

In addition to the TAA produced by AAR's process, metals are also recycled and sold. The process separates, cleans, and sizes both ferrous and non-ferrous metals which ensures the highest value is received. Again, AAR's experience over the last three and a half years of commercial operation has enabled it to develop a marketing plan for its recycled products that has been proven to be successful.

CONCLUSIONS

The Beneficial Use Permit, the Solid Waste Processing Facility Permit, and the Minor Source Air Permit for the production and beneficial use of TAA in the State of Maine were issued in July 1996. The permitting process is a lengthy and detailed procedure which requires critical reviews of all data, detailed studies, marketability, financial stability, as well as economic feasibility of the overall project. AAR was able to demonstrate the environmental safety of their product and the project's economic feasibility to the satisfaction of the Maine DEP.

New technologies are constantly faced with challenges starting with the initial concept all the way through to commercial operations. This is especially true for complex issues like MWC ash recycling. Environmental rules and regulations are often conservative to ensure the protection of human health and the environment, yet even with the strict requirements, AAR was able to successfully demonstrate the safety of utilizing their TAA. With the permit approvals for a new facility in the State of Maine, the beneficial use of ash is broadening and can be held up as a model for future projects.

In the hierarchy of integrated waste management, recycling is the major preference over landfilling. AAR's ability to recycle virtually 100% of the incoming MWC ash helps to meet the nations goals of reduction and recycling. AAR has met the challenge of curbing the high cost of ash management while maintaining the protection of human health and the environment with its proven commercial ash recycling technology. AAR's technology and experience on a commercial basis has demonstrated that ash recycling has finally come of age!

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[3]Roffman, H. K., 1995. Assessment of Potential Human Health and Environmental Effects from the Beneficial Use of American Ash Recycling Corporation's Treated Ash Aggregate, December.

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TABLE 1

Exposure Factors Employed in Risk Assessment Calculations.

Dermal Contact with Soils / TAA	Child Resident	Adult Resident	Adult Worker
Skin Surface Area (sq. cm./event)	3910	3120	3120
Soil to Skin Adherence Factor (mg/sq. cm.)	1.0	1.0	1.0
Absorption Factor (unitless)	Chemical dependent	Chemical dependent	Chemical dependent
Exposure Frequency (days/year)	350	350	250
Exposure Duration (years)	6	24	25
Body Weight (kg)	15	70	70

Ingestion of Soils	Child Resident	Adult Resident	Adult Worker
Ingestion Rate (mg/soil/day)	200	100	NA
Absorption Factor	1.0	1.0	NA
Exposure Frequency (days/year)	350	350	NA
Exposure Duration (years)	6	24	NA
Body Weight (kg)	15	70	NA

Dermal Contact with Groundwater / Runoff	Child Resident	Adult Resident	Adult Resident
Skin Surface Area (sq. cm./event)	NA	19400	4240
Exposure Frequency (days/year)	NA	350	150
Exposure Duration (years)	NA	30	25
Exposure Time	NA	0.5	0.5
Body Weight (kg)	NA	70	70

Ingestion of Groundwater	Child Resident	Adult Resident	Adult Worker
Ingestion Rate (l/day)	NA	2	NA
Exposure Frequency (days/year)	NA	350	NA
Exposure Duration (years)	NA	30	NA
Body Weight (kg)	NA	70	NA

Inhalation of Particulates	Child Resident	Adult Resident	Adult Worker
Inhalation Rate (cu.m./hr)	NA	0.83	0.83
Exposure Time (hours/day)	NA	24	8
Exposure Frequency (days/year)	NA	350	250
Exposure Duration (years)	NA	30	25
Body Weight (kg)	NA	70	70

TABLE 1

Exposure Factors Employed in Risk Assessment Calculations.

Ingestion of Surface Water	Child Resident	Adult Resident	Adult Worker
Contact Rate (L/hour)	0.05	0.05	NA
Exposure Time (hrs/day)	2.6	2.6	NA
Exposure Frequency (days/year)	350	350	NA
Exposure Duration (years)	6	24	NA
Body Weight (kg)	15	70	NA

Dermal Contact with Surface Water	Child Resident	Adult Resident	Adult Worker
Skin Surface Area (sq. cm./event)	9310	19400	NA
Exposure Time (hrs/day)	2.6	2.6	NA
Exposure Frequency (days/year)	350	350	NA
Exposure Duration (years)	6	24	NA
Body Weight (kg)	15	70	NA

Food Chain Exposure	Child Resident	Adult Resident	Adult Worker
Ingestion Rate (mg/day)	NA	Chemical Specific	NA
Exposure Frequency (days/yr)	NA	350	NA
Exposure Duration (years)	NA	30	NA
Body Weight (kg)	NA	70	NA

TABLE 2

Summary of Human Health Risks Results of US EPA Lead5 Model Runs.

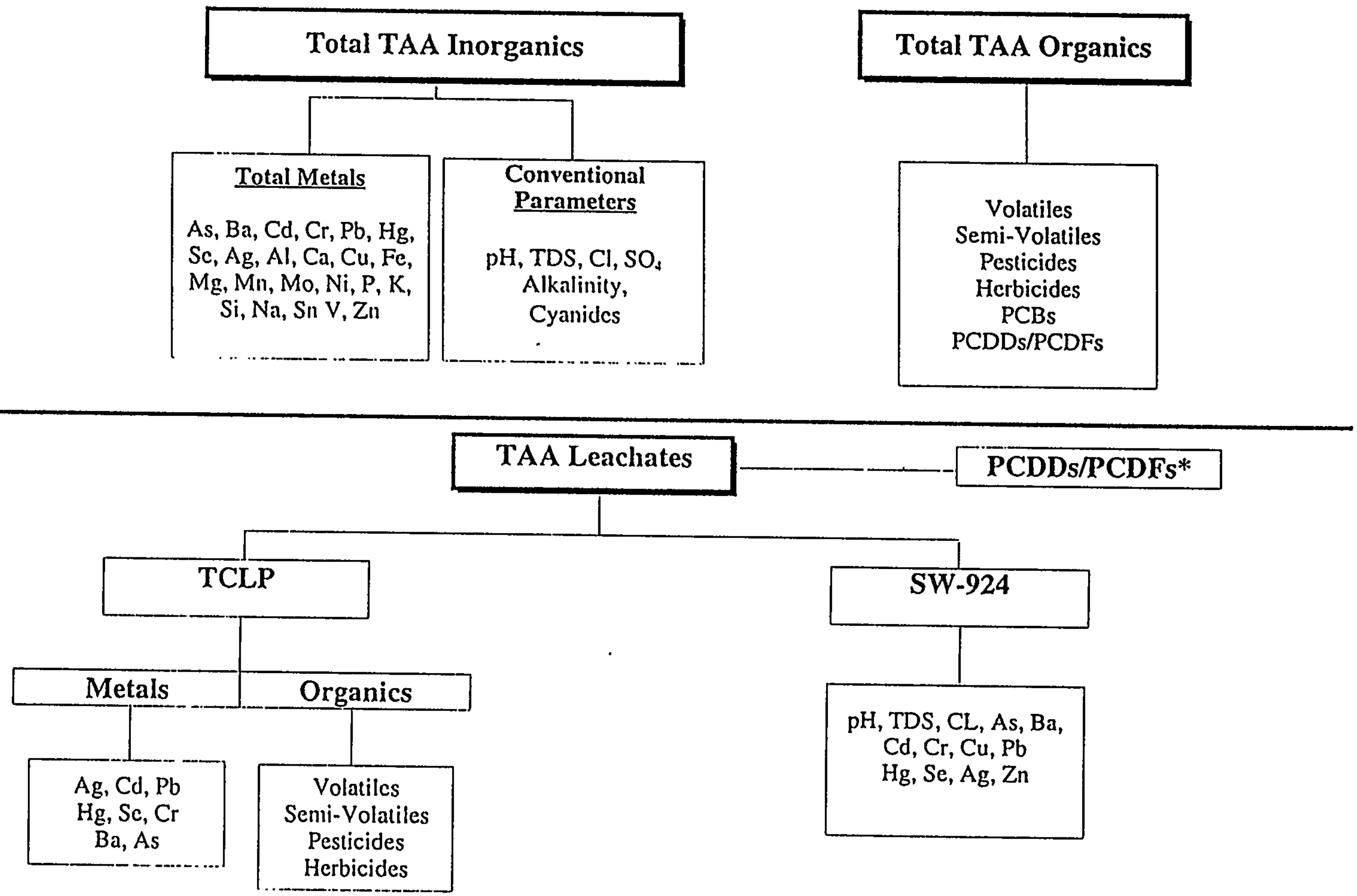
AGE	CHILD BLOOD LEAD LEVELS (ug/dl)		
	Deposition from 100% TAA Storage Pile Soil Lead = 12.0 mg/kg	**Deposition from Roadway Soil Lead = 0.112 mg/kg**	**Deposition from Asphalt Mixing Plant Soil Lead = 4.9 mg/kg**
0.5-1	1.68	1.57	1.62
1-2	1.35	1.24	1.29
2-3	1.36	1.26	1.30
3-4	1.40	1.30	1.34
4-5	1.44	1.33	1.38
5-6	1.47	1.36	1.41
6-7	1.53	1.42	1.47

AGE	CHILD BLOOD LEAD LEVELS (ug/dl)	
	Overland Transport 100% Ash Storage Pile Soil Lead = 7.0 mg/kg	**Deposition from 40% TAA Storage Pile Soil Lead = 4.8 mg/kg**
0.5-1	1.63	1.61
1-2	1.30	1.28
2-3	1.32	1.30
3-4	1.36	1.34
4-5	1.39	1.37
5-6	1.42	1.40
6-7	1.49	1.47

Current US EPA Blood Lead Level Crtierion is 10 ug/dl.

FIGURE 1

TOTAL AND LEACHATE ANALYSES PERFORMED ON TAA



* PCDDs/PCDFs in leachates for the daily municipal landfill cover scenario originate from actual leachate samples collected from municipal landfills which also accepted municipal waste combustor ash, as reported in the U.S.EPA Report: Characterization of MWC Ashes and Leachates from MSW Landfills, Monofills and Co-Disposal Sites, EPA 530-SW-87-028, Oct. 1987.