CINTEC-TREDI INC.

CINTEC-TREDI's

CIRCULATING FLUIDISED BED COMBUSTOR

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APPENDICES

1. INTRODUCTION AND CONTACTS

The CFBF (Circulating Fluidised Bed Combustor) unit allows thermal destruction of organic contaminants, such as PCBs, contained in soils, sludges, solid or liquid wastes, with a removal efficiency exceeding 99.9999%. Trial burns and commercial contracts were performed with this unit.

The CFBC is designed to treat from 500 to 5,000 kg/hr (1,200 to 12,000 lb/hr). It comprises seven (7) modules that can be easily transported. When assembled, it occupies a surface of 20 x 25 m (65 x 82 ft) and reaches to a height of 18 m (58 ft).

Several spare parts from a second CFBC unit are included (see appendix 2).

Plant job books and training manuals are available. They contain a full description of the system, technical specifications of the equipment, process diagrams, operations and maintenance procedures, and a list of supplies for each component.

Upon request, Cintec could provide full technical support and expertise for the assembling and start-up of the incinerator.

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2. CFBC TREATMENT EXPERIENCE

In 1996, using the CFBC unit, Cintec-Tredi has succefully completed a PCB remediation project at Baie Comeau, Québec. The project was conducted under a "*Certificat d'autorisation*" (C.A.) by the *Ministère de l'Environnement et de la Faune du Québec*.

Previously, an American firm, Ogden Environmental Services (OES), used a CFBC unit for a large remediation project:

- In May 1984, trial burns were conducted in San Diego, California, to destroy various organic compounds: hexachlorobenzene, trichlorotrifluoroethane (freon 113), carbon tetrachloride and trichlorobenzene.

- In September 1988, trial burns on PCB contaminated soils were done at Swanson River, Alaska. In June 1989, the U.S. EPA granted to OGDEN a permit to destroy toxic substances in the CFBC unit.

- In March 1989, evaluation trial burns were done in Fullerton, California, to treat soils contaminated with carbon tetrachloride.

- In February and July 1989, two trial burns were done in Stockton, California, to treat soils contaminated with No. 6 fuel oil and napthtalene.

Cintec-Tredi unit differs from the one used by OES in the use of an improved solids feed system and a dry scrubber system.

2.1 Baie-Comeau Project

The project was in operation from September 1996 to February 1997. Following completion of the thermal treatment, the project site was restored to its original condition and returned to its owner (Hydro Québec). The project scope included treating the following wastes:

- Liquids (> 10% PBC): 225 MT
- Liquids (< 10% PBC): 45 MT
- PCB-contaminated Soils: 2,600 MT
- PCB-contaminated Debris: 80 MT

A dry scrubber was used at Baie-Comeau to treat the very high levels of HCl generated (about 50 Kg/hr) from the treatment of highly contaminated BCB-liquids. A propane auxiliary fuel system was used for startup and system "idling".

Table 2.1 Baie Comeau Demonstration Test Results

Parameter	Federal Limit @ 11% O_2 (dry)	Tests Results[(a)] @ 7% O2 (dry)
Stack Emission		
Particulate Matter (mg/Nm^3)	50	1.5[(a)]
HCl (mg/Nm^3)	75	3[(a)]
PCB (mg/kgPCB-input)	1.0	0.002
PCDD + PCDF (2,3,7,8-equip, ng/Nm^3)	12.0	0.023[(a)]
Liquid Discharges	N/A	None are discharged from the process
Solid Discharges		
PCB (mg/kg)	0.5	< 0.1
PCDD + PCDF (2,3,7,8-equiv, µg/kg)	1.0	0.012

Note "<" denotes none detected, and the figure given is the detection limit. Each datum reported is the average of data taken from thrice replicated tests.

[(a)] Dry scrubber operation affected measured results. See the discussion in the text for clarification.

Note, in particular, the very low levels of contamination in the treated solids. This seems to be typical of the CFBC technology; between the Swanson River and Baie-Comeau projects, more than 1,500 treated solid samples were analyzed for PCB content. Not a single sample contained as much as 0.1 mg-PCB/kg.

The test results demonstrate that the Cintec-Tredi CFBC can easily meet the federal emission limits with respect to emission of PCB, PCDDs and PCDFs, and particulate: Note that Baie-Comeau emissions are unusually low due to the use of the post-combustion dry scrubber.

Table 2.2 Baie Comeau Operating Conditions and stack Gas Composition

CFBC Process Conditions	Operating Conditions
Operating Conditions	
Residence Time (sec)	1.68
Combustor Temperature (°C)	943
Soil Feed Rate (kg/hr)	2,936
PCB Feed Rate (kg/hr)	88.5[(b)]
Limestone Feed Rate (kg/hr)	
Flue Gas O_2 (%-wet)	10.1
Stack Gas Composition	
CO (mg/Nm^3)	21
CO_2 (%)	5.7
NO_3 ($mg\text{-}NO/Nm^3$)	81
SO_2 (mg/Nm^3)	2

(b) PCB were fed as liquids. The soil contained negligible quantities of PCB.

2.2 San Diego Trial Burns

In 1984, trial burns were conducted in San Diego on liquids contaminated with hexachlorobenzene, trichlorotrifluoroethane (freon 113), carbon tetrachloride, and trichlorobenzene. These tests were supervised by California State authorities. It was concluded that the unit can achieve required destruction efficiencies and that it represents a potential technology for the destruction of contaminated wastes.

Table 2.3 San Diego Efficiency for the Various Contaminants Tested.

Parameter	Destruction Efficiency								
Sampling time	09:15	09:15	14:39	14:39	19:50	19:55	23:18	23:24	07:07
Average combustion chamber temperature (°F)	1425	1425	1550	1595	1450	1450	1550	1330	1300
Fuel flowrate	55	55	70	69	59	58	72	74	74
Contaminants									
Toluene	98.55	98.63	96.36	97.00	91.05	93.41	97.39	96.92	99.78
Hexachlorobenzene	99.9996	99.9994	99.9999	99.9999	>99.999	>99.9999	99.9999	99.9999	99.9929
Ethybenzene	99.9985	99.9993	99.9990	99.9992	99.9968	99.9974	99.9992	99.9991	99.9993
Xylene	99.9988	99.9994	99.9983	99.9989	99.9921	99.9938	99.9978	99.9973	99.9996
Trichlorobenzene	99.973	99.970	99.982	99.985	99.946	99.974	99.984	99.982	99.999

2.3 Swanson River Project

In September 1988, trial burns on PCB contaminated soils were done at Swanson River, Alaska. This project, conducted under operating permits issued by the USEPA and the Alaska Department of Environmental Conservation (ADEC), ran from 1988 to 1992. It involved treating more than 100,000 MT of contaminated soil and approximately 3,000 m3 of contaminated debris and secondary waste (e.g., oversized rocks, PPE, ect.). The demonstration testing requires for the USEPA and AEDC operating permits was conducted in September 1988. The resulting TSCA permit allowed soil treatment rates of 3,990 kg/hr at 870°C and 4,116 kg/h at 940°C.

Table 2.4 Swanson River Demonstration Tests Results

Parameter	Federal Limit @ 11% O_2 (dry)	Tests Results @ 7% O_2 (dry)	
		Series 1	Series 2
Stack Emission			
Particulate Matter (mg/Nm^3)	50	18	43
HCl (mg/Nm^3)	75	195	194
PCB (mg/kgPCB-input)	1.0	< 1	< 0.8
PCDD + PCDF (2,3,7,8-equip, ng/Nm^3)	12.0	< 3	< 2
Liquid Discharges	N/A	None are discharged from the process	
Solid Discharges			
PCB (mg/kg)	0.5	< 0.009	< 0.012
PCDD + PCDF (2,3,7,8-equiv, µg/kg)	1.0	< 0.17	<0.2

Table 2.5 Swanson River Operating Conditions and Stack Gas Composition

Parameter	Operating Conditions	
Operating Conditions	Series 1	Series 2
Residence Time (sec)	1.68	1.50
Combustor Temperature (°C)	871	927
Soil Feed Rate (kg/hr)	3,840	4,116
PCB Feed Rate (kg/hr)	2.2[(a)]	2,16[(a)]
Limestone Feed Rate (kg/hr)	77	77
Flue Gas O2 (%-wet)	5.0	4.2
Stack Gas Composition		
CO (mg/Nm^3)	17	13
CO_2 (%)	8.7	8.9
NO_3 ($mg\text{-}NO/Nm^3$)	116	118
SO_2 (mg/Nm^3)	40	66
[(a)] PCB fed to the CFBC were from the contamination in the soil (about 600 ppm).		

2.3 Fullerton Project

Through its "Superfund Innovative Technology Evaluation Program", U.S. EPA had selected the CFBC unit in 1986 to conduct demonstration trials for treating contaminated soils extracted from the "McColl" site in Fullerton, California. The trials were completed in March 1989, and lasted 31 h over four days.

During the trial burns, contaminated soils from the McColl site, as well as soils contaminated with carbon tetrachloride, were successfully treated.

Treated soils and combustion gases were sampled and analyzed by the U.S. EPA which concluded that the trial burns were successful.

Table 2.6 Fullerton Operating Conditions

Parameter	Operating Conditions		
	Test 1	Test 2	Test 3
Combustion temperature (°F)	1721	1726	1709
Residence time, s	1.54	1.52	1.55
Soils federate, lb/h	325	170	197
Carbon tetrachloride, lb/h	0	0	0.22
Oxygen, % dry basis	11.0	9.9	11.8
CO, ppm	30	30	26
Total hydrocarbon, ppm	5	1	2
SO_2 neutralization capacity, %	>95%	>95%	>95%
NO_2, ppm	49	58	48
CO_2, % dry basis	9.9	11.9	9.2
HCl emission, lb/h	<0.0090	<0.0085	<0.0098
Particulate matter, gr/dscf at 7% O_2	0.0041	0.0044	0.0035
Combustion efficiency, %	99.97	99.97	99.97
Destruction and removal efficiency, %	-	-	99.9937

Treatment of Soils Contaminated with No. 6 Fuel Oil and Trial Burns of Soils Contaminated with Naphthalene

2.4 Stockton Projects

Two separate projects were undertaken in Stockton, California in 1989.

The first involved treating 11,000 tonnes of soils contaminated with No. 6 fuel oil from February to June 1989. All the treated soils were analyzed before being returned to the same site. When the project was terminated, the site had reclaimed its original state and was declared acceptable without restrictions.

Table 2.7 Treatment of Soils Contaminated with No.6 Fuel Oil in Stockton

Parameter	Operating Conditions		
	Test 1	Test 2	Test 3
Combustion temperature (°F)	1588	1588	1587
Residence time, s	1.8	1.8	1.8
Soils federate, lb/h	4000	4000	4000
Soil hydrocarbon concentration, ppm	2130	1160	3450
Oxygen, % dry basis	13.6	13.6	13.6
CO, ppm at 7% O_2	28.0	25.4	23.6
Hydrocarbon emissions, ppm at 7% O_2	< 2	< 2	< 2
SO_2, lb/day	16.6	12.0	24.2
SO_2, ppm at 7% O_2	84	61	123
NO_x, lb/day	7.4	7.3	6.7
NO_2, ppm at 7% O_2	52	52	47
CO_2, % dry basis	7.0	6.6	6.9
Particulate matter, gr/dscf at 7% O_2	0.045	0.046	0.045
Combustion efficiency, %	99.989	99.990	99.990

In July 1989, a test burn was conducted in the same unit on soils contaminated with naphthalene. The results showed that the CFBC unit can reach destruction efficiencies higher than all the limits set by the U.S. EPA and local authorities.

Table 2.8 Treatment of Soils Contaminated with Napthalene in Stockton

Parameters	Operating Conditions		
	Test 1	Test 2	Test 3
Naphthalene concentration, ppm	4314	4730	4106
Destruction and removal efficiency, %	>99.9960	>99.99956	>99.9958

3. CFBC PROCESS DESCRIPTION

3.1 Overview

The CFBC technology (Circulating Fluidised Bed Combustor) is an advanced generation of incineration technology that uses high velocity air to entrain circulating solids in a highly turbulent combustion loop. Initially developed in Finland during the 1960s for the production of energy from low rank fuels, CFBC technology has been successfully adapted for the incineration of a variety of organic wastes and residues.

The success of this technology is based on the fact that combustion takes place uniformly under very high turbulence and that contaminated wastes in solid, liquid, semi-liquid and/or gas states can all be simultaneously treated. This turbulence ensures excellent mixing and gas-solid contact. Each particle is heated and subjected to uniform temperatures and oxygen levels. High boiling points organics (such as Aroclor 1260) rapidly vaporize from the soil matrix and are fully oxidized. This behavior is independent of soil properties and/or grain size. CFBC technology results in the efficient oxidation of organic wastes at temperatures lower than those of other incineration processes without high temperature post-combustion like conventional processes. Other significant advantages include:

- Reduced NO_3 emissions due to the lower operating temperature (870 vs. 1200°C); no risks of slagging in a post-combustion chamber;

- Possibility of injecting limestone ($CaCO_3$) into the bed for the *in situ* capture of sulphur and/or chlorine for low levels of contamination, thus eliminating the use of a scrubber;

- No risk of toxic gas fugitive emissions because there are no rotary seals. The system is air tight;

- Safety in case of power failure: no toxic emissions are generated, since the waste feed is stopped and all previously fed wastes have already been oxidized. The system can be restarted in a matter of minutes. There is NO "Thermal Relief Valve".

- Over the last 15 years, CFBC technology has been tested and operated successfully for the treatment of soils contaminated with No. 6 fuel oil, naphthalene, PCB at low and high concentrations (in commercial-scale equipment), and a variety of refractory organochloride compounds such as Freon 113, chlorobenzenes, and carbon tetrachloride (in pilot-scale equipment).

A schematic configuration of Cintec-Tredi's 36-in, commercial CFBC is show in Figure 3.1. Solid waste of appropriate size (0-20 mm, or 0 – ¾ in.) is introduced into the combustor loop at the loop seal where it contacts the hot circulating solids stream exiting the hot cyclone. Gas, liquids and sludge are injected directly into the lower section of the CFBC via injection lances. Circulating solids are then entrained in the combustor chamber of high velocity air (> 6 m/sec).

- 6 – 12 mm (1/4 – 1/2) in.) particles bubble at the bottom of the bed until they are removed from the CFBC by means of a water-cooled solids removal system. Solids in this size range have a residence time in the combustor of approximately an hour;

- 50 µm – 6 mm (1/500 – ¼ in.) particles are circulated until they are either removed with the larger particles or attrited to fines. These solids have a combustor residence time of ten's of minutes.

- Particles less than 50 µm (< 1/500 in.) escape the cyclone with the hot flue gas, are cooled to baghouse temperatures, collected in a fabric filter turn-baghouse, and conveyed to the solids removal system. They have a residence time in the combustion loop of a few seconds.

The CFBC is comprised of seven modules within a metal structure containing process equipment. All modules are designed so they can be easily transported on roads and public highways. Assembled, the CFBC unit has a foot print area of 20 x 25 m (65 ft x 82 ft). The stack elevation is 18-m high (59 ft). Figure 3.2 is an isometric representation of the unit.

The principal CFBC components include a combustion loop (combustion chamber, loop seal, and cyclone), a flue gas cooler, and a baghouse for the base case and a stack. Characteristics of some of the major system components are described in Table 3.1. Design parameters for the CFBC system are given in Table 3.2.

For descriptive convenience, the CFBC is divided into systems a number of system, which are described on the following pages.

Table 3.1 Key Characteristics of Major Equipment Items

System Feature	Capacity or Size
Projected TTU system operating factor	85% (7,500 hr/year)[(a)]
Combustor Material of Construction	Carbon-steel vessel internally lined with 13" (34 cm) of insulating and abrasion-resistant refractory
Combustor Internal Dimensions	diameter: 36 inches (0.91 mm) height: 35 feet (10.7 m)
Maximum thermal duty	10 MM Btu/hr (2930 kJ/sec)
Maximum feed system capacity	5,500 kg/hr
Feed screen equipment size	6-ft x 12-ft, with 2 cm screen
Burner capacity	Startup burner: 9 MMBtu/hr (2630 kJ/sec) Fuel lances: 12 MMBtu/hr (3500 kJ/sec)
Baghouse air to cloth ratio	1.5:1
Maximum capacity (each baghouse)	7,700 m^3/hr
Condenser/Carbon column	not applicable
ID fan specifications	Suction: 55 in-wg Flow: 9,300 m^3/hr at 175°C Power: 150 hp
Treated Soil Handling capacity	5,500 kg/hr
Liquid storage capacity	coolant tank: 3,785 I
Liquid generation rate	no liquids are generated[(b)] and thus no wastewater treatment is required

(a) Greater than 90% on-line <u>at full throughput</u> was routinely demonstrated during the Swanson River project.
(b) The CFBC requires no makeup water – its cooling is self-contained and no quench water is required for flue gas cooling

Table 3.2 Basic CFBC Design Values

Parameter	Minimum	Nominal	Maximum
Combustion Temperature (°C)	780	870	1050
Reference Feed stocks	Clay or silt with up to 25% moisture Sand with up to 15% moisture Gravel with up to 8% moisture		
Residence Time (sec)	1.40	1.70	2.30
Air Preheat (°C)		350	
Baghouse inlet temperature (°C)	120	175	260
Auxiliary Fuel	Natural gas, Propane, or fuel oil		
Soil Throughput (kg/hr)	500	4,500	6,000
Stack Particulate (mg/Nm^3)	-	-	< 25
Structure	Modularized for ease of transportation and site installation		
Process water requirements	No process water is required		
Ambient design temperature (°C)	-40	-	45
Wind speed (km/hr)	-	-	175
Seismic Category	-	3	-
Relative humidity	0	-	100

3.2 Combustion Loop

The destruction of the hazardous organic constituents within the waste feed takes place in the combustion loop. The combustion loop consists of the components listed below:

- Combustion Chamber
- Cyclone
- Loop Seal
- Expansion Joint
- Air Distributor Plate
- Refractory lining

The combustion chamber consists of a carbon steel vessel to contain the combustion of the hazardous materials. The cyclone removes particulate from the combustor flue gas and returns them to the combustion chamber via the loop seal. The loop seal prevents backflow of combustion gases into the bottom of the cyclone. All of these components refractory lined, protecting the combustion loop vessel from abrasion and high temperatures. Vessel surface temperatures are typically maintained less than 60°C.

The distributor plant evenly distributes air across the combustion chamber base and prevents treated solids from entering the windbox below. The expansion joint prevents thermal expansion from damaging the carbon steel combustion loop or its supports.

Fuel, limestone, and solid waste are individually metered into the combustion loop through a 12-in (30 cm) rotary valve in accordance with predetermined feed rates. The rotary valve provides the pressure boundary. The solid feed and limestone are gravity fed into the loop seal where they mix with the recirculating bed solids and flow back into the combustion chamber. Fuel oil is introduced into the combustion loop through fuel lances. The limestone absorbs acid gases, with the nonhazardous neutralized salts being removed with the treated solids.

Coarse treated solids are removed from the base of the combustion chamber via a water-cooled, variable speed, ash[1] cooler. Fine treated solids escape the cyclone and exit the combustion loop. They are cooled and then filtered through fabric filters and mixed with the treated solids discharged from the ash cooler.

The combustion loop is equipped with secondary air ports, which allow a portion of the combustion air to be introduced above the base of the combustor. This allows for staged combustion and reduced levels of NO_3 formation. The combustion loop is instrumented with redundant temperature and pressure instrumentation, which allows reliable operation even in the event of instrument failure.

3.3 Air Induction System

The air induction system provides air for fluidization, combustion, loop seal purges, and cooling of the flue gas. In addition, the system provides a means of controlling the combustion loop

[1] The product is treated solids, not ash. However, the terminology, taken from the power generation industry, seems to persist.

pressure balance, allowing the system to be operated slightly sub-atmospheric. The flue gas is returned to the atmosphere via the stack.

Atmospheric air is introduced into the system from the 50 HP FD fan. The air is divided into two paths: startup burner air, which does not pass through the FGC air preheat system and combustion air, which is preheated to 350°C. Upon exiting the preheater, the combustion air is split into primary and secondary air. The primary air flows to the distributor through air injection nozzles and then into the base of the combustion chamber. Secondary air can be injected at several levels above the primary combustion zone to minimize NO_3 formation.

Loop seal purge air is supplied by a dedicated 7 psig, 10 hp compressor. These purges are backed up by (1) combustion air from the FD fan and (2) emergency purge air from the compressed air system.

Clean flue gas discharged from the baghouse filter system flows to the 150 HP ID fan through a flow control damper. The position of this damper is controlled to maintain the system pressure balance so that the solids feed port in the combustion loop is always slightly sub-atmospheric. From the discharge of the ID fan, the flue gases flow to the stack, where they are sampled for gas analysis and discharged to the atmosphere. The stack is equipped with sampling ports for conducting any required sampling.

3.4 Auxiliary Fuel System

The auxiliary fuel system has three functions: (1) to heat the combustion loop from ambient temperature to operating temperatures on a 40-60°C#hr temperature ramp. (2) to provide supplemental fuel to maintaining combustion loop temperatures during waste treatment, and (3) to maintain the combustion loop at operating temperatures while idling.

To accomplish these functions, the auxiliary fuel system consists of the following subsystems: a startup burner, a set of fuel lances, and independent fuel supply train supplying each system.

<u>Startup Burner Subsystem</u>

The startup burner is a air atomized fuel oil burner located in a dedicated process penetration in the combustion loop about 1.5 m above the distributor. It provides the combustion heat necessary to raise the combustion loop temperatures to a point where the fuel will burn directly in the fluidised bed. The burner is capable of 10:1 turndown to provide uniform and controlled heating of the combustion loop. During heat-up, the startup burner provides most of the system fluidizing gases.

When not in use, the burner may be withdrawn from the combustion chamber to minimize damage from the fluidised bed.

<u>Fuel Lance Subsystem</u>

The fuel lance subsystem consists of (1) redundant gas lances co-located with secondary air ports. The lances may be operated together or individually depending on process requirements. Both the lances are purged with air when not in use to prevent plugging.

Fuel Supply Trains

The startup burner and the lance/distributor subsystems are supplied via separate NFPA-approved gas trains. The fuel supply trains are equipped with the following features:

variable-speed fuel pumps
fuel flow rate measurement
fuel safety shutoff systems (pressure switches, position switches, and in, in the case of the startup burner, UV flame detection)
diagnostic instrumentation

3.5 Flue Gas Cooling System

The principal function of the FGC (Flue Gas Cooler) is to reduce the flue gas temperature from the cyclone exit temperature (up to 1050°C) to temperatures acceptable to the downstream components (baghouses and ID fan). The FGC consists of a three-section heat exchanger, cross-duct connected the cyclone outlet to the FGC inlet, an inlet expansion joint, and a fines discharge subsystem. The FGC is operated at a sub-atmospheric pressure so that any leakage of either ambient air or coolant is into the flue gas.

FGC Heat Exchanger

The heat exchanger consists of three sections. The first section is a water-cooled section which functions to reduce the flue gas temperature sufficiently to eliminate the necessity of using high-temperature metals in subsequent sections. The second section is an air-cooled section which preheats the combustion air to about 350°C. The third stage of the FGC is air-cooled heat exchanger which controls the FGC flue gas outlet temperature. The cooling air blower is capable of sufficient turndown to provide a constant FGC outlet temperatures despite widely varying heat loads in the flue gas (due to the varying fines content of the flue gas). All heat transfer section are equipped with soot blowers to remove any fines which accumulate on the heat transfer surfaces. The soot blowers are operated intermittently by a local timer.

Cross Duct

The cross duct connects the CFBC cyclone outlet to the FGC inlet. It is refractory lined and contains an expansion joint to prevent damage from thermal strains.

Fines Collection and Discharge

The fines hopper at the base of the FGC collects fines that have separated from the flue gas. The fines are discharged from the FGC through a conventional rotary valve air-lock and are mixed with the combustor discharge solids.

3.6 Baghouse Filter System

The flue gas particulate exiting the CFBC cyclone is filtered from the flue gas stream using high-efficiency fabric filters. The baghouse filter system receives the cooled, particulate-laden flue gas from the heat exchanger, filters it to remove entrained fine particulate and releases it to the ID fan. The separated fines are conveyed through a rotary valve pressure lock and discharged to the treated solids handling system. The baghouses normally operate at 175 - 200°C but are able to tolerate excursions of up to 260°C for up to 1 hour. The flue gas exiting the baghouse system meets all federal, state, and local emissions requirements regarding particulate content.

The baghouse contains 72 fabric filter bags. The baghouse is divided into 4 quadrants, with 18 bags in each quadrant. Each quadrant has its own flue gas discharge plenum but all share a common ash hopper.

Cleaning is accomplished by pulsing a reverse flow of high-pressure air through a venturi nozzle into a portion of bags. The baghouse filter cleaning is controlled by the measured filter differential pressure, with a cleaning cycle initiated when the filter DP exceeds 6 in-wg. The baghouse filter system is protected from damage by control system interlocks which terminate CFBC operation whenever the baghouse filter DP is too high (indicated plugged filters), too low (indicating a broken filter) and when the flue gas inlet temperature is too high.

Fines removed from the baghouse filters are collected in a heat-traced (to prevent moisture condensation) fines hopper and discharged to the solids handling system through a conventional rotary valve air-lock.

3.7 Flue Gas Monitoring

The thermal treatment system is equipped with (1) an in-situ oxygen monitor and (2) an extractive system supplied by Beckman measuring O_2, CO, CO_2, and total hydrocarbons (THC) and (3) a second extractive system for measuring HCl and H_2O. The in-situ oxygen monitor is used for both process control and for a waste feed interlock. The extractive systems are used for monitoring and interlock generation.

<u>In-situ Oxygen Monitor</u>

The O_2 probe is a solid state, high-temperature oxygen detector. The plant is designed with two alternate probe locations – in the FGC immediately after the water-cooled section and in the flue gas ducting at the discharge of the FGC. For this project, the probe will be located in the FGC. This provides the most rapid response to changing the gas oxygen levels.

The O_2 probe is a highly reliable device with no moving parts. Located in the FGC, it has a typical response time (to 90%) of about 20 seconds. The CFBC control system uses the O_2 probe signal to control the solids feed rate.

<u>Extractive Analysis – Beckman</u>

The extractive flue gas analysis system consists of (1) an extraction subsystem, (2) a sample gas conditioning subsystem, and (3) flue gas analysis.

The sample gas extraction system consists of an in-stack sintered-metal filter, an electrically-heated sample hose and a double-diaphragm sample gas pump. The sample pump provides the suction to pump 15-30 Ipm of flue gas through the in-stack sintered-metal filter and down the heated sample hose. A condenser (part of the gas conditioning subsystem) is located immediately upstream of the sample pump to remove some of the moisture in the flue gas sample.

The sample extraction system is equipped with a "blowback" feature which injects 30 psig air into the heated sample line to clean the fines off of the stack sintered-metal filter. It is operated by a "sample blowback" push-button on the analyzer system control panel.

The sample extraction system is also plumbed so that calibration gas, which is normally introduced directly to the analyzers, can be introduced at the inlet end of the heated sample hose. This feature is controlled by a two-way valve located between the inlet end of the heated sample hose and the in-stack sintered-metal filter. It is used to check the mechanical integrity of the system.

The gas conditioning subsystem consists of (1) condensers to remove moisture in the sample gas, (2) a coalescing filter to remove condensed water droplets, (3) filtration to remove particulate in the gas, and (4) conditioned sample gas pressure control.

The analyzer subsystem contains six gas analyzers supplied by Beckman Industrial. These analyzers and their normal operating ranges are given below:

Table 3.3 Analyzers and Operating Ranges

CFBC P&ID Tag No.	Beckman Model Number	Gas Component	Operating Range
AT-0704	755	O_2	0 – 25%
AT-0706	864	CO_2	0 – 25%
AT-0703	865	CO	0 – 250 ppmv
AT-0705	400A	THC	0 – 100 ppmv
AT-0701	951	NO_3	0 – 250 ppmv
AT-0707	864	SO_2	0 – 250 ppmv
The "shaded" analyzers are not contained in the proposed system but can be provided if desired.			

The DCS uses the CO and CO_2 monitor signal to calculate the "combustion efficiency", which TSCA defines as CO_2 / (CO + CO_2). In the DCS, the combustion efficiency value is identified as AT-0711.

Extractive System – HCl

The HCl extractive system uses a dedicated high-temperature (> 180°C) extraction system to remove a sample of the stack gas. The sample is filtered in a *in-situ* sintered metal filter to remove particulate. The hot sample stream is passed through the HCl and then through the H_2O analyzers. Note that the H_2O analyzer signal is necessary in order to calculate (in the DCS) the HCl signal on a dry basis. This subsystem was supplied by Servomex and uses the following monitors:

Table 3.4 Monitors for the HCl extractive subsystem

CFBC P&ID Tag No.	Model Number	Gas Component	Operating Range
AT-070	2510	HCl	0-100 ppmv
AT-0708	2500	H_2O	0-20 %(v)

The DCS uses the HCl and H_2O monitor signals to calculate a corrected HCl "dry" reading. The corrected HCl value is defined as AT-0709 in the DCS.

3.8 Treated Soil Handling System

The Treated Soil Handling System consists of the following components:

- the bed ash knifegate valve (XV-1001), and
- water-cooled twin screw solids cooler/conveyor (H-1001),
- the two sequential fines conveyors (H-1004 and H-1005),
- the solids bucket elevator (H-1006),
- the treated solids storage building, and
- related piping and valving.

Hot treated solids are delivered to the solids cooler/conveyor (ACC) from the base of the combustor through the knifegate stufoff valve XV-1001. The ACC is a variable-speed, water-cooled screw conveyor. Its speed is used to control the rate of solids discharge from the CFBC. The bed ash is conveyed to the first fines conveyor and at the same time cooled to less than 150°C. Fines from the FGC enters the discharge end of the ACC. The first fines conveyor moves the cooled bed ash along with the fines from the flue gas cooler and from the baghouse to the second fines conveyor, which is identical to the first. Finally the treated solids are discharged to the ash bucket elevator and conveyed to the treated solids storage building. Treated solids samples can be taken from the process at the inlet to the bucket elevator.

Upon entering the solids storage building, the treated soil is re-humidified using a water mist. The water flow rates to this misting system are adjusted to re-humidify the solids on 7-10% moisture. This moisture content has been found to be nearly ideal for subsequent backfilling and compacting of the treated soils. The misting water flow rate will be adjusted to provide re-humidified solids with acceptable compaction properties.

The solids removal system has a design capacity of 5.5 MT/hr., limited by the thermal capacity of the solids cooler/conveyor. The system can be operated at throughputs as high as 9 MT/hr for limited periods of time without damage. Operation of the solids removal system is interlocked to (1) prevent operation of any conveyor unless all downstream conveyors are properly operating (via zero-speed switches), and (2) prevent operation of the ACC unless coolant flows are adequate.

All conveyors are completely enclosed to control fugitive emissions of dust. In addition, the second ash conveyor (H-1005) is equipped with a sampling port to allow the collection of a grab sample of treated soil. In normal operation, treated soil samples are collected every 6 hours and composited.

3.9 CFBC Cooling System

The CFBC uses a water-glycol mixture to provide cooling for (1) the first stage of the FGC and (2) the solids cooler/conveyor. Coolant flow is provided by redundant 60 psig, 750 lpm, 15 hp coolant pumps. Heat removed from the CFBC systems is discharged to the atmosphere via finfan cooler. The system is completely closed, with the coolant being stored in a 1000-gal coolant surge tank.

The cooling system is instrumented with pressure, flow and temperature instrumentation to provide both diagnostic information concerning proper system functioning and interlock signals to protect components from over-temperatures.

3.10 Compressed Air Supply

Compressed air for both process and instrument uses is provided by a dedicated 500 m^3/hr, 150 psig, 100 hp air compressor. All of the compressed air is oil-free and dried to -40°C to minimize potential problems with moisture condensation during winter operation. The system is instrumented with pressure switches to provide alarms and interlocks in the event of malfunction.

Instrument air is regulated to 90 psig and is stored in a 40 m^3 receiver. This air is used to power plant pneumatic instrumentation. In the event of compressor failure, the receiver has storage capacity to maintain plant control for about 90 minutes. The instrument air pressure is interlocked, causing a plant shutdown if there is inadequate instrument air pressure.

Process air is used throughout the CFBC for purging. It is also used to power the FGC soot blowers and the baghouse filter blowbacks.

3.11 Solids Feed System

The solids feed system consists of subsystems of variable-speed feeders for metering the PCB-contaminated soils, metering limestone, and shredded debris solids. The three feed streams are combined and conveyed to the CFBC. It also provides a pressure seal at the CFBC (to prevent inleakage of air or outleakage of combustion gases). The soils feeding system is identical to that used for OES's Stockton project and consists of the following components:

- A mass-flow wet soil feed hopper (T-0250), with a 17.4 yd^3 storage capacity;
- A variable-speed belt feeder (H-0251) and a Delumper (H-0252), designed to make uniform the discharge of the wet soil from the end of the belt;
- A waste weigh belt (H-0253), equipped with a 0-5,000 kg/hr load cell and belt scrapers, to accurately monitor the waste feed rate;
- An elevating bed conveyor (H-0254), equipped with belt scraper, to elevate the feed to the level of the CFBC feed port; and
- A sealing screw (H-0255), which conveys the wet soil into the CFBC while providing a pressure seal isolating the feed system from the CFBC combustion gases.

In normal operation, the weigh belt signal is used to control the belt feeder speed in closed loop, the feed rate setpoint being determined by process requirements.

The limestone feed system consists of:

- a 35-ton limestone storage silo (T-0202), which is equipped with a bid activator, and is loaded pneumatically by a limestone delivery truck;
- a variable-speed 0-200 lb/hr limestone feeder (T-0204) discharging onto a limestone screw conveyor (H-0202), which discharges the limestone unto the debris conveyor (H-0262).

The Debris Feeder consists of:

- A mass-flow debris feed hopper (T-0260)

- a variable-speed belt feeder (H-0261), which discharges to

- a 15-m long belt conveyor which conveys the debris (and the limestone) to waste weigh belt (H-0253).

3.12 Dry scrubbing system

The system is conceived in a modular fashion to facilitate erection and dismantling. It consists of:

- a filter module 3 x m 15 m tall comprising two filters or baghouses combined in one common casing with a dividing wall;
- a 3 660 mm diameter silo 15 m tall (35 ton capacity) for storage of hydrated lime;
- a pipe module comprising two (2) reactors and piping between the first filter and the second reactor and between the second filter and induced draft fan. This module measures 1.2 m x 3.2 m x 15 m.

The whole installation requires a 9 x 7 m footprint.

To enable the treatment of high levels of acidity in combustion gases, the scrubber system comprises two (2) treatment stages.

Each stage has:

- a venturi reactor with ascending flow,
- a filter system or baghouse.

The filtered gases cooled to 140°C are directed by a 406 mm diameter pipe to the first stage of the scrubber system. The gases then travel through the two (2) dry scrubbing stages connected in series.

The treated gases exiting the second scrubbing stage are drawn up by a 40 HP induced draft fan. A modulating shutter at the entry of the fan insures a constant negative pressure of an equivalent 15 m water head on the connecting pipe between the CFBC and the scrubbing system.

The induced draft fan pumps the gases to the atmosphere via a 457 mm diameter x 18.3 m tall exhaust stack.

The cone on the top of the silo has two exits that connect to variable speed feeders for each reactor.

Salts precipitating from the reaction between the gases and the hydrated line, as well as excess line, captures in each filter are recirculated in each reactor by a rotary valve to minimize hydrated lime consumption. A second rotary valve under the hopper enables the residues to be emptied in a container located under the baghouse module.

Activated carbon can be injected in the second reactor or scrubbing stage, if required. This additional system permits the adsorption of eventual traces of dioxin-furans.

The scrubbing system includes instrumentation that insures regulation and protection of the system. These instruments are connected to a programmable control system including a screen. This control system is connected to the central control system for the CFBC to link the scrubbing system to the incineration process.

3.13 Process Control

The thermal treatment system is controlled by (1) an Allen-Bradley PLC system for motor control and (2) a Rosemount System 3 distributed control system (DCS) for analog process control. The DCS also provides (1) the operator interface, (2) interlock control, (3) alarming, and (4) data acquisition, logging and alarming. The control elements interfacing with the DCS are summarized in Table 3.5.

The DCS is equipped with a sophisticated self-monitoring capability which essentially eliminates unexpected failures. Should a failure occur, the plant is automatically (and safely) shut down. In 35,000 hours of operation at Swanson River, 0.6 hour of production was lost due to DCS failures.

- Interlocks, Waste Feed Cutoff and Transient Response
- The CFBC interlock system has two functions:
- to protect the equipment from damage due to either component failure or operator error, and
- to prevent treatment of PCB-contaminated wastes unless the appropriate process conditions are satisfied.

Table 3.5 CFBC Control System Control Functions*

Process Parameters Controlled	Parameters Alarmed, Displayed & Recorded	Interlock System Inputs
Combustion Air Flowrates	FD Fan Pressure and Temperature	Combustion Loop Temperatures (HIGH/LOW)
Combustion Air Preheat Temperature	ID Fan suction	Combustion Loop DPs (LOW)
Baghouse Inlet Temperature	Combustor Temperatures (11)	Combustion Air Flow (LOW)
Combustion Loop Operating Pressure	Combustor Pressures	Baghouse Temperature (HIGH)
Startup Burner Fuel Flowrate	FGC (flue gas side) – Temps & pressures	Baghouse DP (HIGH)
Lance/Distributor	FGC coolant temperatures	Flue Gas Oxygen (LOW)
Waste Feed Rate	Air Preheater Temperatures	Flue Gas CO (HIGH)
Combustor Bed Inventory	Solid Cooler/Conveyor coolant Temperatures	Flue Gas HCl (HIGH)
Flue Gas Oxygen Level	Baghouse Temperature and DP	Combustion Efficiency (LOW)
	Flue Gas Composition (O_2, CO_2, CO, etc.)	Coolant temperatures (HIGH)
		Compressed Air Pressures (LOW)
		Residence Time (LOW)
		Any Motor Failure

*The CFBC combustion loop residence time is calculated from the measured process flows entering the combustion loop. These include combustion air and fuel flows and moisture feed (from the measured waste feed rate) and CO_2 generated by the limestone feed. These flows are corrected for CFBC operating temperature and pressure and used to calculate a residence time. Since the combustion loop is leak-tight, this calculational procedure yields an accurate measure of the residence time.

The system logic is organized to maximize the throughput of the facility. That is, the control system response to a process fault or out-of-range condition is to minimize the frequency of system shutdowns. In order of preference, the protection system will:

- Terminate waste feed rate, holding combustion loop temperatures constant
- Terminate auxiliary fuel flow rate, and finally
- Terminate all system operation

The PCB-waste interlocks proposed for use in this project are listed in Table 3.6. Except for the stack HCl interlock, these interlocks are identical to those required by the TSCA permit used at Swanson River. Note that many of the interlock values have time delays or averages included. The intent is to allow the control system or the CFBC operators time to respond to process transients without adversely impacting the environment.

The interlock logic is designed to avoid "single-point" thermocouple failures from initiating interlock response. (Combustion loop thermocouples are subjected to significant erosion problems and thermocouple failure indicates as an out-of-range temperature. Since the thermowell-thermocouple assemblies can be replaced without shutting the facility down, the objective is to stay at operating temperatures while repairs are effected.) Single-point failure is eliminated by requiring multiple thermocouples to be simultaneously out-of-range for an interlock to be activated.

Note that by a combination of intrinsic CFBC properties and control system configuration, even upon loss of electrical power the CFBC "fails-safe". Upon loss of power (or, for that matter, failure of either the CFBC FD or ID fan), the following automatically and instantly occurs:

- all waste feeding and feed conveyors STOP
- all fuel flows STOPS
- all blowers STOP
- all flow control valves except the ID fan damper CLOSE
- the ID fan damper fails "as-is", which allows
- the ID fan to maintain system suction as it coasts down (being larger than the FD fan, it remains in motion longer)

Table 3.6 CFBC TSCA Interlocks

Tag (6)	Description	Setpoint
TIC-0600	Fuel Feedrate Monitor	DB(a) > 50°C, with 60-sec delay
WIC-0201	Waste Feedrate Monitor	DB > 500 kg/hr, qh with 60-sec delay
PDIC0429	Combustor Inventory Monitor	DB > 5 in-wg, with 60-sec delay
FIC-0100	Total Combustion Air Monitor	DB > 150 Nm^3/hr, with 60-sec delay
PIC-0407	Combustion Loop Pressure Monitor	DB > 2 in-wg with 60-sec delay
ASL-0126	Flue Gas Oxygen LOW	4.5% with 2-min delay 3.0% instantaneous
ASH-0703	Flue Gas CO HIGH	112 mg/Nm^3 with 2-min delay 180 ng/Nm^3 instantaneous
ASH-0709	Flue Gas HCl HIGH	75 mg/Nm^3, 1-hour average 150 mg/Nm^3 instantaneous
ASL-0711	Combustion Efficiency	99.9% with 2-minute delay 99.8% instantaneous
TSL-TOP	Combustor Outlet Temperature	927°C, with 2-minute delay 900°C instantaneous
TSH-TOP	Combustor Outlet Temperature	1065°C
TSH-0161	Baghouse Temperature	260°C
RES-TIME	Gas Residence Time	1.65 sec with 2-minute delay 1.50 sec instantaneous
WSH-0253	Waste Feedrate	4,000 kg/hr, 1-hour average 4,500 kg/hr instantaneous

DB = Deviation Band alarm. TSCA regulations require that waste feeding be terminated upon failure of a critical process monitor. Since monitor failure will certainly result in a deviation band alarm, the requirement is satisfied.

The entire CFBC remains under sub-atmospheric pressure for about 90 seconds as the ID fan coasts to a stop. Thus there are no fugitive emissions vented to the atmosphere. Note that there is no emergency stack vent to release any partially-reacted waste products.

At this point, the fluidised bed is a stagnant mass of treated soil and limestone, which maintains its temperature for several hours. Any waste products in the bed are thus (1) confined to the stagnant bed, (2) still at combustion temperatures, and (3) exposed to combustion air residing in the system. They are fully oxidized by the time the ID fan has come to rest.

3.14 CFBC Quality Control

CFBC operations are conducted following written protocols, which include:

- an integrated operating procedure, which described both normal and transient operating procedures. It also includes checklists for documenting proper system operation.

- written maintenance procedures which define all necessary scheduled maintenance. These procedures consist of a mixture of pre-formatted checklists for frequent (monthly or oftener) and individual procedures for less frequent procedures.

- a formal Quality Control Assurance Plan, which defines system calibration requirements.

These protocols are based on several years of field experience treating PCB contaminates and have proven to be highly effective at efficiently managing CFBC operations.

APPENDIX 1

CINTEC-TREDI'S CFBC UNIT MAJOR EQUIPMENT LIST

CINTEC-TREDI'S CFBC UNIT
MAJOR EQUIPMENT LIST

EQUIPMENT NO.	EQUIPMENT DESCRIPTION	MAXIMUM CAPACITY[1]	NOMINAL CAPACITY[1]	NO. ITEMS
C-0101	Forced Draft Fan	8,000 Lb/Hr	7,600 Lb/Hr	1
C-0103	Induced Draft Fan	9,100 Lb/Hr	8,900 Lb/Hr	1
C-0104	Loop Seal Fan	300 SCFM	200 SCFM	1
C-0105	Air Blast Fan	15,000 Lb/Hr	10,000 Lb/Hr	1
Y-0101	Stack	18 In-Dia		
H-0202	Sorbent Feed System	200 Lb/Hr	100 Lb/Hr	1
Y-0203	Sand Hopper	1,000 Lb	1,000 Lb	1
D-0401,2,4	Combustion Loop/Cyclone	2,000 °F	1,600 °F	1
I-0401,2,4	Refractory Lining	2,000 °F	1,600 °F	1
Y-0401	Air/Gas Distributor	37 Air & Gas Tuyers		1
Y-0601	Burner System	9 MM Btu/Hr		1
Y-0602	Gas Lance System - Liquid Lance Injection System	9 MM Btu/Hr	8 MM Btu/Hr	1
Y-0701	Emission Monitoring Syst.	CO, CO_2, THC, O_2, NO_x, SO_2, HCl, Opacity		1
D-0802	Cross Duct w/Refrac.	2,000 °F	1,600 °F	1
E-0801	Flue Gas Cooler	4-6 MM Btu/Hr	3.5 MM Btu/Hr	1
F-0901	Baghouse	3,000 Lb/Hr	2,000 Lb/Hr	1
	Dry scrubbing system comprising: - Filter module with two (2) baghouses - Sorbent Silo 35 ton capacity - Pipe module with 2 reactor chambers - Activated carbon injection system		Two-stage treatment with a total 99.75% efficiency. Operation Temperature Ranges 266 °F –311 °F	3
H-1001	Ash Cooler Conveyor	12,000 Lb/Hr	3,000 Lb/Hr	1
H-1004	Ash Screw Conveyor	12,000 Lb/Hr	10,000 Lb/Hr	1
XV-1001	Ash Drain Valve	12,000 Lb/Hr	300 Lb/Hr	2
Y-1101	Control System	Distributed Digital		1
D-1301	Coolant Surge Tank	300 PSIG	150 PSIG	1
E-1301	Coolant Heat Exchanger	7.5 MM Btu/Hr	5 MM Btu/Hr	1
P-1301,2	Coolant Pump	190 GPM	160 GPM	2
Y-1301	Compressed Air System	300 SCFM	160 SCFM	1
M-0XXX	Fabric Expansion Joints	At Large		2
		Refractory Ducts		
M-OYYY	Metal Expansion Joints	Air, Ash, Flue Gas Ppg		12
OTHER EQUIPMENT AND MATERIALS				
Motor controls		Misc. 1 to 150 HP.		20
Valves/Manual		All Inclusive		165
Valves/Motor		All Inclusive		3
Valves/Control		All Inclusive		11
Piping		All Greater than 2"		All > 2"
Instruments		All Inclusive		All
Control Room Trailer		8'6"W x 36'6"L		1
Rack Room Trailer		8'6"W x 32'3"L		1
Type V (inclined belt) Feed System				1
Misc. Spares				All

**Including all existing hardware and software.

[1]Foregoing capacities for informational purposes only. Seller makes no guarantee that "as is" equipment will achieve these ratings.

CINTEC-TREDI'S CFBC UNIT
MAJOR EQUIPMENT LIST (cont.)

EQUIPMENT NO.	EQUIPMENT DESCRIPTION	EQUIPMENT MATERIALS/ SPECIFICATIONS
C-0101	Forced Draft Fan	Three stage centrifugal, cast iron and steel construction
C-0103	Induced Draft Fan	Five stage centrifugal, cast iron and steel construction
C-0104	Loop Seal Fan	Nine stage centrifugal, cast iron and steel construction
C-0105	Air Blast Fan	One stage centrifugal, cast iron and aluminum construction
Y-0101	Stack	18" steel pipe, standard schedule
H-0202	Sorbent Feed System	Steel and stainless steel construction
Y-0203	Sand Hopper	Steel construction
D-0401,2,4	Combustion Loop/Cyclone	3/8 in. A36 shell with reinforced supports
I-0401,2,4	Refractory Lining	9" insulating brick (Green G-20), 4 ½" hardface (Green KX-99)
Y-0401	Air/Gas Distributor	310 stainless steel
Y-0601	Burner System	Peabody 150 SCFM complete igniting and safety system
Y-0602	Gas Lance System	Peabody 150 SCFM complete igniting and safety system
Y-0701	Emission Monitoring Sys.	Complete Beckman CO, CO_2, O_2, NO_x, SO_2 integrated system + HCl and opacimeter
D-0802	Cross Duct w/Refrac.	Steel and stainless steel construction
E-0801	Flue Gas Cooler	Steel and stainless steel construction
F-0901	Baghouse	Steel shell, gore-tex on fibreglass bags
H-1001	Ash Cooler Conveyor	Hollow flight water cooled, steel and 310 SS construction
H-1004	Ash Screw Conveyor	Steel and abrasion resistant steel construction
XV-1001	Ash Drain Valve	304 stainless steel
Y-1101	Control System	Distributed control, redundant, Rosemount RS-3 or equal
D-1301	Coolant Surge Tank	Steel weldment, ASMC code vessel
E-1301	Coolant Heat Exchanger	Finned tube, forced draft fans
P-1301,2	Coolant Pump	Stainless steel Ingersolrand or equal
Y-1301	Compressed Air System	Two stage rotary, oil free, Atlas-Copco
M-OXXX	Fabric Expansion Joints	Polyester reinforced neoprene
M-OYYY	Metal Expansion Joints	304 SS bellows with abrasion liners
OTHER EQUIPMENT AND MATERIALS		
Motor controls		Allen Bradley
Valves/Manual		Sizes ½ to 8 inches (supply per parts availability)
Valves/Motor		Sizes to 12 inches (various suppliers)
Valves/Control		Fisher or equivalent
Piping		Steel construction
Instruments		Various manufacturers, temperature, pressure, etc.
Control Room Trailer		Steel, double wall construction
Rack Room Trailer		Steel, double wall construction
Type V (inclined belt) Feed System		Weigh belt, tramp metal removal magnet, sealing screw auger feed mechanism
Misc. Spares		As available