THE IMPACT OF AIR POLLUTION CONTROL SYSTEM DESIGN ON MUNICIPAL WASTE INCINERATOR EMISSIONS

A CASE STUDY

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ABSTRACT

The use of semi dry scrubbing systems to control acid gases and other pollutants from waste combustors has become an accepted international environmental strategy in countries that incinerate Municipal Solid Wastes (MSW). This paper will examine and compare, two MSW facilities in Korea utilizing this technology. It will also discuss various environmental concerns (impacts) relative to a system in operation for three years versus a system scheduled to go into operation later this year.

Based on these two projects, the suitability of semi dry scrubbing technology to attain present and more stringent performance requirements will be discussed. Selection of specific equipment and major components relative to system design performance standards in affect at the time of the installation will also be examined.

Since the semi dry scrubber system is crucial in maintaining the facilities ability to reduce waste and/or produce energy, while keeping within the design performance standards, it will be discussed in more detail. The system's dual fluid atomizer, including its performance and the impact it has on reagent utilization, system economics and maintainability will also be discussed in detail. Finally, the overall configuration of the scrubber vessel is examined as is the impact that this configuration has on the system performance.

INTRODUCTION

The disposal of municipal solid waste is a major environmental issue in the Republic of Korea (South Korea). In a country of only 38,175 square miles of land mass, much of it mountainous terrain, there are 45,000,000 people. This aspect makes the use of waste incineration an important part of an overall waste management strategy and maintains the country's strong political policy to meet or exceed current NSPS.

This paper examines the air pollution control strategies of two municipal incineration plants. The first of these plants is the Chang-Won City Urban Refuse Incineration Plant, in operation since January, 1995, and the second is the Taejeon City (No. I) Refuse Incineration Plant to be commissioned later this year. Chang-Won City, located in the south east corner of Korea, west of Pusan City, is mainly an industrial area with a population of approximately 350,000 people. Surround by a chain of mountain peaks, Taejeon is a city of 1,250,000 people, located in the western portion of mid-central Korea. As a city, it has committed its political and industrial strengths to become the "2nd administrative capital of Korea".

The Chang-Won plant was built (under license of Volund) and is operated by Halla. The Taejeon City plant, having a KHI boiler, was built in conjunction with Hanjin Engineering & Construction and LG Construction Co., Ltd. The semi dry scrubbing systems for both plants were supplied by Belco Technologies Corp. in cooperation with its local Korean partner, Shin Saeng Plant Industry & Engineering Co., Ltd (SPECO). In addition to the acid gas, heavy metals, dioxin and particulate removal system required for Taejeon, it also required a DeNOx reduction system. This system was supplied by BELCO's parent company, LAB of Lyon, France. again in cooperation with SPECO.

AIR POLLUTION CONTROL EQUIPMENT

The air pollution control equipment for both facilities consists of a semi dry scrubber followed by a pulse jet fabric filter. The flue gas from the incinerator enters the top of the semi dry scrubber through a series of flow tubes. In each flow tube, calcium hydroxide is introduced through a dual fluid nozzle in a finely atomized liquid form. This reagent mixes with the flue gas and reacts with the acid gases to form solid particulate. As the flue gas and reaction products flow downward in the scrubber, the reaction products are completely dried. Although a relatively small portion (5-10%) of the particulate drops into the hopper located under the scrubber vessel, most of the particulate is carried to the fabric filter where the flue gas passes through filter bags. The filter bags separate the solid particulate from the gas producing a clean gas stream which exits the plant through the stack. A sketch of the system layout is shown in Figures 1.a and 1.b.

Calcium hydroxide slurry, which is utilized to react with the acid gases, is delivered to the facility in solid form. It is stored in a silo. The calcium hydroxide is metered into a tank where it is mixed with water to form a solution of approximately 12-15% by weight calcium hydroxide. This solution is pumped to the top of the vessel where it is metered through the dual fluid nozzles and into the semi dry scrubber. Additional cooling water, if required, is also added. Compressed air is used to atomize this liquid stream into the finely atomized droplets required for acid gas reactions and proper drying. This systems equipment is also shown in Figure #1.

The systems (Chang-Won/Taejeon) have been designed respectively to treat a maximum of 58,000/65,640 Nm^3/hr of flue gas at a temperature of 200/220 °C. A complete summary of the design emissions requirements is shown in Figure 2.a (Chang-Won) and 2.b (Taejeon).

SEMI DRY SCRUBBER DESIGN CONSIDERATIONS

The design of the semi dry scrubber for this process necessitates the satisfaction of two major criteria. First the reagent slurry must be atomized to produce a droplet spectrum that provides for the optimum acid gas absorption and reaction. Second, the vessel must be configured to ensure that the droplets evaporate and the reaction products produced dry before reaching the wall of the vessel or exiting the vessel. This prevents buildups which would impede the operation of the system.

The semi dry scrubber utilizes dual fluid nozzles to atomize the lime slurry. A total of 3 nozzles for Chang-Won and 4 for Taejeon were provided. Flue gas entering the vessel is equally divided into separate gas streams. Each gas stream passes through a "flow tube" where a dual fluid nozzle sprays the atomized slurry concurrently downward with the gas flow. A sketch of this arrangement is shown in Figure #3. The cool liquid contacting the hot flue gas induces turbulence and mixing. At the same time, a typical gas velocity reduction of approximately 90% occurs as the flue gas enters the main body of the scrubber vessel. The combination of these two items induces a thorough mixing of the reagent and acid gases. During this mixing, the acid gases are absorbed by the reagent, creating solid particulate and removing the acid gases from the flue gas stream.

In order for this reaction to occur efficiently the droplet spectrum from the dual fluid nozzles must be such that the droplets are not too small and therefore flash dry nor are they too large, which reduces the surface area available for reaction and causes a problem with particle drying. A useful measurement of the droplet spectrum is the sauter mean diameter (SMD). The SMD is defined as the droplet diameter which has the same surface to volume population as the entire droplet population. This number helps define the size distribution of the droplets. A wide size distribution, which is not desirable for semi dry scrubbing, will have a higher SMD than a narrow size distribution of droplets. Field testing on this process has shown that an SMD of 60 to 70 microns produces a droplet spectrum which does not have an excessive amount of large droplets and also does not have too many fine droplets. A typical droplet spectrum for the Belco atomizing nozzle is shown in Figure #4.

Overall geometry of the scrubber vessel is also an important consideration. The vessel must be designed so that the flue gas expands and utilizes as much of the vessel as possible for drying of the particulate. The unit must also be designed, to consider the trajectory of the large droplets, so that they do not reach any wall surface before drying. The flue gas exit from the vessel is arranged so that the gas is turned out of the vessel without disturbing the gas flow patterns in the vessel and without the use of any internal turning devices which would create a point of buildup for solids. The key design parameters for these vessels, which incorporate the above items are shown in Figure 5.a and 5.b.

FABRIC FILTER DESIGN CONSIDERATIONS

Fabric filters were chosen as the particulate control device for these plants. The selection of a fabric filter, instead of an electrostatic precipitator, was based on several benefits associated with this type of particulate control. First, for these size plants, the fabric filter has a smaller foot print, which is extremely important since the units were to be installed inside the incinerator building and second, due to secondary acid gas removal in the filter cake in the fabric filter less reagent consumption is required. Finally, the better removal efficiency of a fabric filter on very fine particulate tends to result in lower trace metal levels and dioxins since these pollutants seem to be more concentrated on fine particulate.

Although this last requirement was not critical Chang-Won facility, it was for Taejeon. Generally speaking a fabric filter provides greater flexibility for achieving future emission limitations.

A pulse jet fabric filter with 4 modules was selected for both plants. Having 4 modules allows for maintenance to be performed in one of the modules while the remainder of the modules remain in service to filter the flue gas. Detail information for each fabric filter unit (project) is provided in Figure 6.a and 6.b.

ADDITIONAL EQUIPMENT

In addition to the semi dry scrubber and pulse jet fabric filter, several other items were required to provide a complete the air pollution control system. These items include the reagent preparation equipment, pumps, and compressors and in the case of Taejeon, an SCR.

The reagent preparation system consists of a hydrated lime storage silo, a rotary valve for metering the hydrated lime, and a slurry storage tank. The hydrated lime is metered into the slurry storage tank while a fixed amount of water is also added to the slurry storage tank. This produces a slurry with a concentration of approximately 15% by weight.

A series of slurry pumps are provided to pump the slurry to the injection level and to meter the slurry into the vessel. The first slurry pump circulates the slurry to the injection level. This pump supplies more slurry than required by the scrubber so that a continuous recirculation loop back to the slurry storage tank is provided, with sufficient slurry to maintain a velocity of 1.25 m/sec to 2.0 m/sec. This prevents either settling and pluggage of the slurry piping or abrasion due to high velocities. The second slurry pump is utilized to meter the correct amount of slurry to the atomizing nozzles. Based on the acid gas emission level, a signal is sent to this pump to either increase or decrease the amount of slurry flow.

Water pumps are supplied to provide additional cooling water to the spray nozzles if the amount of water in the slurry is insufficient to maintain the scrubber outlet gas temperature desired.

Air compressors are provided to supply the air required for atomization of the lime slurry. These compressors also provide cleaning air for the pulse jet fabric filter. A sketch of the auxiliary equipment is provided in Figure #7.

The SCR (DeNO$_x$/DeDXN) system, installed on the Taejeon City project only, was supplied to reduce levels of nitrogen oxides (essentially NO and NO$_2$) formed in the combustion process. The SCR is located downstream of the semi dry scrubbing system where it benefits from its (SDA/FF) efficiency in capturing particulate, acid gases, heavy metals, and

PCDD/PCDF's. This benefit increases and prolongs the service life of the SCR's catalyst. The SCR system includes the following:

- A flue gas reheat system; the reaction temperature is selected to operate the facility in conditions that optimize cleaning performance, catalyst service life and operating costs. For this purpose, the only additional energy required comes from the steam produced in the facility, maximizing the recovery of energy from the flue gases.

- An ammonia injection system combined with mixing devices designed to distribute evenly the ammonia in the flue gases.

- The reaction vessel, composed of a chamber with several successive layers. The number of layers is determined by the required performance.

The SCR cataylst is composed of titanium oxide (TiO_2) extruded blocks filled with active elements: vanadium and tungsten oxides (V_2O_5 and WO_3). These blocks are assembled in identical modules so that they can be interchanged on the different reactor levels, thus prolonging the service life of the catalyzers.

- The ammonia used by the reaction may be stored, depending on the specific site conditions and the quantities to be used, in pure liquid NH_3 cylinders or 25% aqueous NH_4OH solution tanks. In the second case, the solution is evaporated directly upstream of the reaction vessel or in a separate evaporator, operating with hot air or even flue gases.

- A perfected injection regulation system which accounts for the effective NO_x content upstream and downstream from the system, is used in the reaction vessel to introduce only the quantity of ammonia that is strictly necessary for the reaction and thus prevent excess ammonia emission from the stack.

SYSTEM OPERATION AND PERFORMANCE

The Chang-Won incineration plant was placed into operation in January, 1995. System performance has been excellent, with acid gas emissions well below the allowable levels. Testing was performed in February, 1995 to substantiate the emission levels of the system. This performance test showed that the system was maintaining emission levels well below the levels that were required. A summary of these emissions tests is provided in Figure #8. A major contributing factor in the excellent emission levels is the on-line servicing capability of the systems. The dual fluid nozzles can be serviced while the equipment is in service without an interruption of slurry flow. Therefore, acid gas emissions are not effected by the servicing of the atomizers.

The APC system has also been operating well with no indications of any type of problems. It was important to verify that the semi dry scrubber was indeed drying the reaction products and that no solids buildups were occurring inside the vessel. This was verified in two manners. First additional testing was performed in June, 1995 to measure the moisture content of the material exiting the scrubber vessel hopper. This testing indicated that the material had a moisture content of 2% to 3%. This indicates a dry product. An internal inspection of the scrubber was performed in October, 1995 during the first scheduled plant outage. This inspection showed that the material accumulation on the walls of the vessel was very light (less than 1 cm thick), and that the material was dry and flaky. This confirmed that the semi dry scrubber is operating without solid buildup. Reliability has been excellent and maintenance cost minimal.

The Taejeon incineration plant, originally on a fast track construction schedule, was to be commission the APC system in July/August, 1997. However, due to delays unrelated to the APC equipment plant commissioning has been set back until the 3rd quarter of 1998. The vessel and its inlet duct had to be reconfigured several times during the design phase to allow it to fit into the already designed and nearly completed incinerator building super structure.

SUMMARY

These two projects illustrate the trends and progression of emission limitations in Korea. Chang-Won, commissioned into service over 4 years ago, was subject to fairly lax regulations, having no performance criteria for some key pollutants (mercury and dioxins). On the other hand, the APC system at Taejeon is a good example of the evolution of emmissions standards in the Korean waste incineration industry. It demonstrates the trend towards lower emission levels of regulated pollutants (particulate, HCl, SO_2), and for regulations of pollutants which were not previously regulated (NO_x, Hg, other metals, and Dioxins).

The successful operation of the Chang Won and several other recent projects demonstrates the technological improvements achieved by semi dry scrubbing systems based on more than a decade of combined commercial operation in North America and around the world. It further demonstrates that modern systems can maintain mandated emission levels and operate reliably. These projects illustrate how attention to the proper design considerations will result in a system which is reliable and also maintains emissions comfortably within the mandated emission levels.

FIGURE #1.a

CHANG-WON CITY
AIR POLLUTION CONTROL SYSTEM

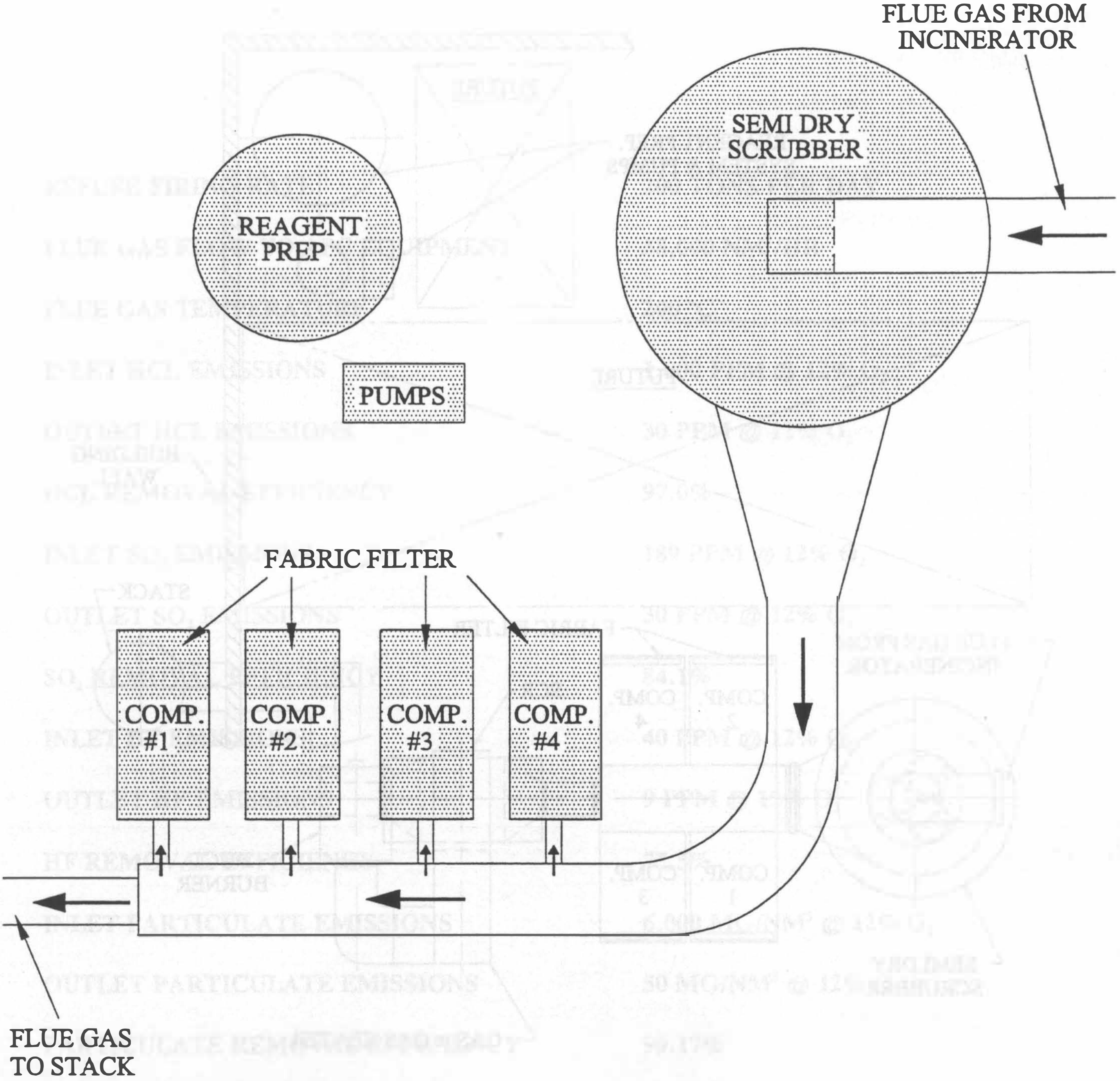

FIGURE #1.b

TEAJEON CITY AIR POLLUTION CONTROL SYSTEM

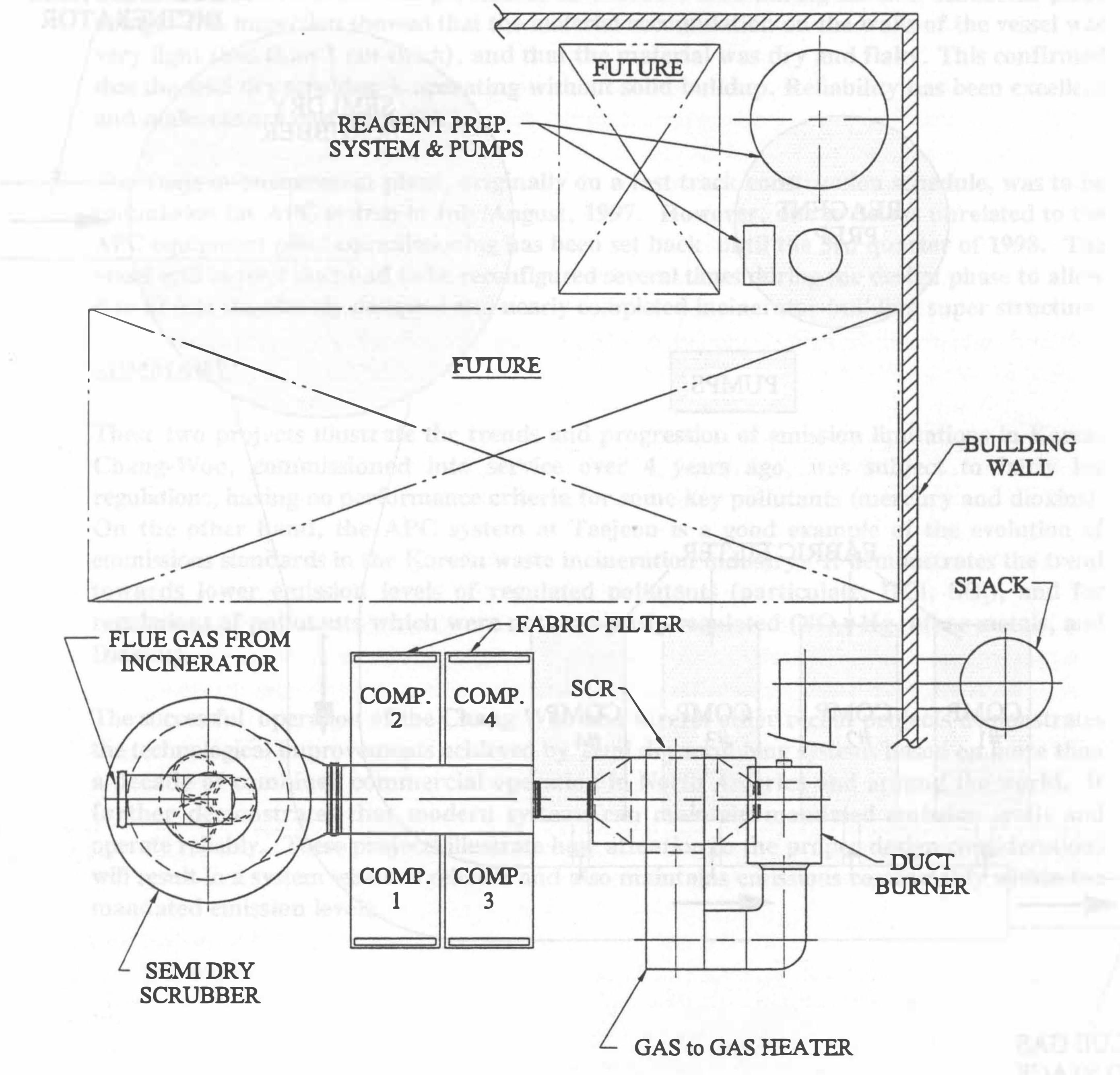

FIGURE #2.a

CHANG-WON CITY
SYSTEM DESIGN PARAMETERS
(Emissions are at Fabric Filter Outlet)

REFUSE FIRING RATE	200 TONS PER DAY
FLUE GAS FLOW TO APC EQUIPMENT	58,000 NM^3/HR
FLUE GAS TEMPERATURE	200 °C
INLET HCL EMISSIONS	1,000 PPM @ 12% O_2
OUTLET HCL EMISSIONS	30 PPM @ 12% O_2
HCL REMOVAL EFFICIENCY	97.0%
INLET SO_2 EMISSIONS	189 PPM @ 12% O_2
OUTLET SO_2 EMISSIONS	30 PPM @ 12% O_2
SO_2 REMOVAL EFFICIENCY	84.1%
INLET HF EMISSIONS	40 PPM @ 12% O_2
OUTLET HF EMISSIONS	9 PPM @ 12% O_2
HF REMOVAL EFFICIENCY	77.5%
INLET PARTICULATE EMISSIONS	6,000 MG/NM^3 @ 12% O_2
OUTLET PARTICULATE EMISSIONS	50 MG/NM^3 @ 12% O_2
PARTICULATE REMOVAL EFFICIENCY	99.17%

FIGURE #2.b

TAEJEON CITY (I)
SYSTEM DESIGN PARAMETERS

(Emissions are at Fabric Filter Outlet)

REFUSE FIRING RATE	200 TONS PER DAY
FLUE GAS FLOW TO APC EQUIPMENT	65,640 NM^3/HR
FLUE GAS TEMPERATURE	220 °C
INLET HCL EMISSIONS	1,100 PPM @ 12% O_2
OUTLET HCL EMISSIONS	10 PPM @ 12% O_2
HCL REMOVAL EFFICIENCY	99.09%
INLET SO_2 EMISSIONS	200 PPM @ 12% O_2
OUTLET SO_2 EMISSIONS	10 PPM @ 12% O_2
SO_2 REMOVAL EFFICIENCY	95.0%
INLET HF EMISSIONS	20 PPM @ 12% O_2
OUTLET HF EMISSIONS	1.12 PPM @ 12% O_2
HF REMOVAL EFFICIENCY	99.40%
INLET Hg EMISSIONS	1,000 UG/M^3 @ 12%
OUTLET Hg EMISSIONS	50 UG/M^3 @ 12%
Hg REMOVAL EFFICIENCY	95.00%
INLET DIOXIN EMISSIONS	5.0 NG/NM^3 TEQ
OUTLET DIOXIN EMISSIONS	0.1 NG/NM^3 TEQ
DIOXIN REMOVAL EFFICIENCY	98.00%
INLET PARTICULATE EMISSIONS	10,388 MG/NM^3 @ 12% O_2
OUTLET PARTICULATE EMISSIONS	10 MG/NM^3 @ 12% O_2
PARTICULATE REMOVAL EFFICIENCY	99.90%

FIGURE #3

DUAL FLUID NOZZLE DESIGN

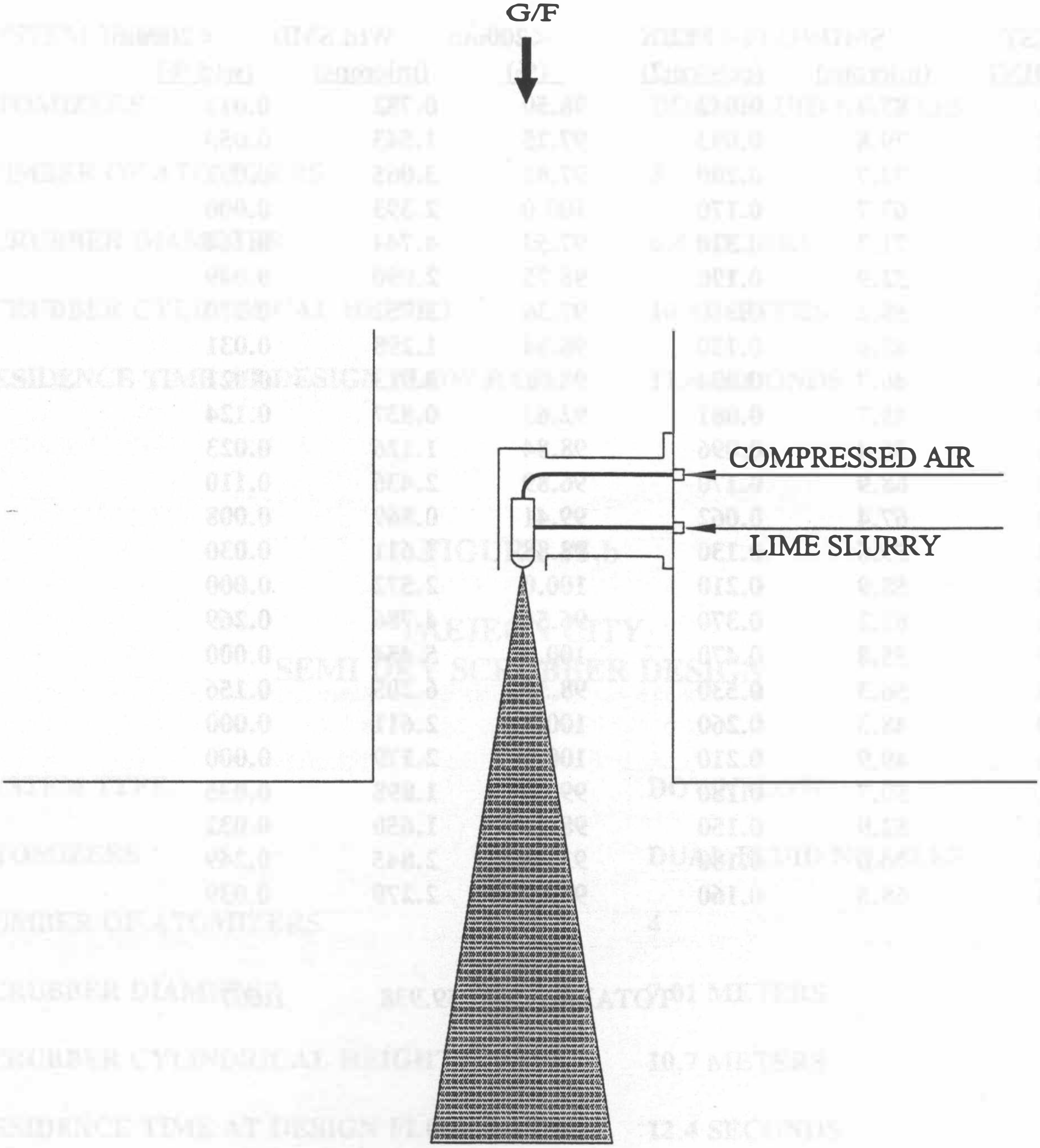

FIGURE #4

TYPICAL DROPLET SIZE INFORMATION

TEST POINT	SMD (microns)	FLUX (cc/s/cm2)	<200um (%)	Wtd SMD (microns)	<200um (wtd %)
01	87.4	0.043	98.50	0.782	0.013
02	79.8	0.093	97.25	1.543	0.053
03	73.7	0.200	97.81	3.065	0.091
04	67.7	0.170	100.0	2.393	0.000
05	71.3	0.320	97.53	4.744	0.164
06	52.9	0.190	98.75	2.090	0.049
07	58.2	0.310	97.36	3.752	0.170
08	48.0	0.130	98.84	1.298	0.031
09	46.7	0.094	98.91	0.913	0.021
10	49.7	0.081	92.63	0.837	0.124
11	56.4	0.096	98.84	1.126	0.023
12	68.9	0.170	96.89	2.436	0.110
13	67.4	0.062	99.41	0.869	0.008
14	59.6	0.130	98.88	1.611	0.030
15	58.9	0.210	100.0	2.572	0.000
16	62.2	0.370	96.51	4.786	0.269
17	55.8	0.470	100.0	5.454	0.000
18	56.3	0.530	98.58	6.205	0.156
19	48.3	0.260	100.0	2.611	0.000
20	49.9	0.210	100.0	2.179	0.000
21	50.7	0.180	99.08	1.898	0.035
22	52.9	0.150	98.96	1.650	0.032
23	76.0	0.180	93.35	2.845	0.249
24	68.5	0.160	98.82	2.279	0.039
			TOTALS	59.938	1.667

FIGURE #5.a

CHANG-WON CITY
SEMI DRY SCRUBBER DESIGN

SYSTEM TYPE	DOWNFLOW
ATOMIZERS	DUAL FLUID NOZZLES
NUMBER OF ATOMIZERS	3
SCRUBBER DIAMETER	6.4 METERS
SCRUBBER CYLINDRICAL HEIGHT	10.1 METERS
RESIDENCE TIME AT DESIGN FLOW RATE	11.6 SECONDS

FIGURE #5.b

TAEJEON CITY
SEMI DRY SCRUBBER DESIGN

SYSTEM TYPE	DOWNFLOW
ATOMIZERS	DUAL FLUID NOZZLES
NUMBER OF ATOMIZERS	4
SCRUBBER DIAMETER	7.01 METERS
SCRUBBER CYLINDRICAL HEIGHT	10.7 METERS
RESIDENCE TIME AT DESIGN FLOW RATE	12.4 SECONDS

FIGURE #6.a

CHANG-WON CITY
FABRIC FILTER DESIGN

FABRIC FILTER TYPE	PULSE JET
NUMBER OF MODULES	4
NUMBER OF BAGS PER MODULE	216
TOTAL NUMBER OF BAGS	864
BAG DIMENSIONS	127 MM DIAMETER BY 4.5 M LONG
TOTAL CLOTH AREA	1,551 M^2
AIR TO CLOTH RATIO	1.0 M/MIN
BAG MATERIAL	RYTON FELT WITH RASTEX SCRIM

FIGURE #6.b

TAEJEON CITY (I)
FABRIC FILTER DESIGN

FABRIC FILTER TYPE	PULSE JET
NUMBER OF MODULES	4
NUMBER OF BAGS PER MODULE	210
TOTAL NUMBER OF BAGS	840
BAG DIMENSIONS	152 MM DIAMETER BY 4.88 M LONG
TOTAL CLOTH AREA	1,962 M^2
AIR TO CLOTH RATIO	0.89 M/MIN
BAG MATERIAL	543 G/M^2 RYTON, SELF SUPPORT FELT

FIGURE #7.a

CHANG-WON CITY
REAGENT AND COMPRESSED AIR DELIVERY

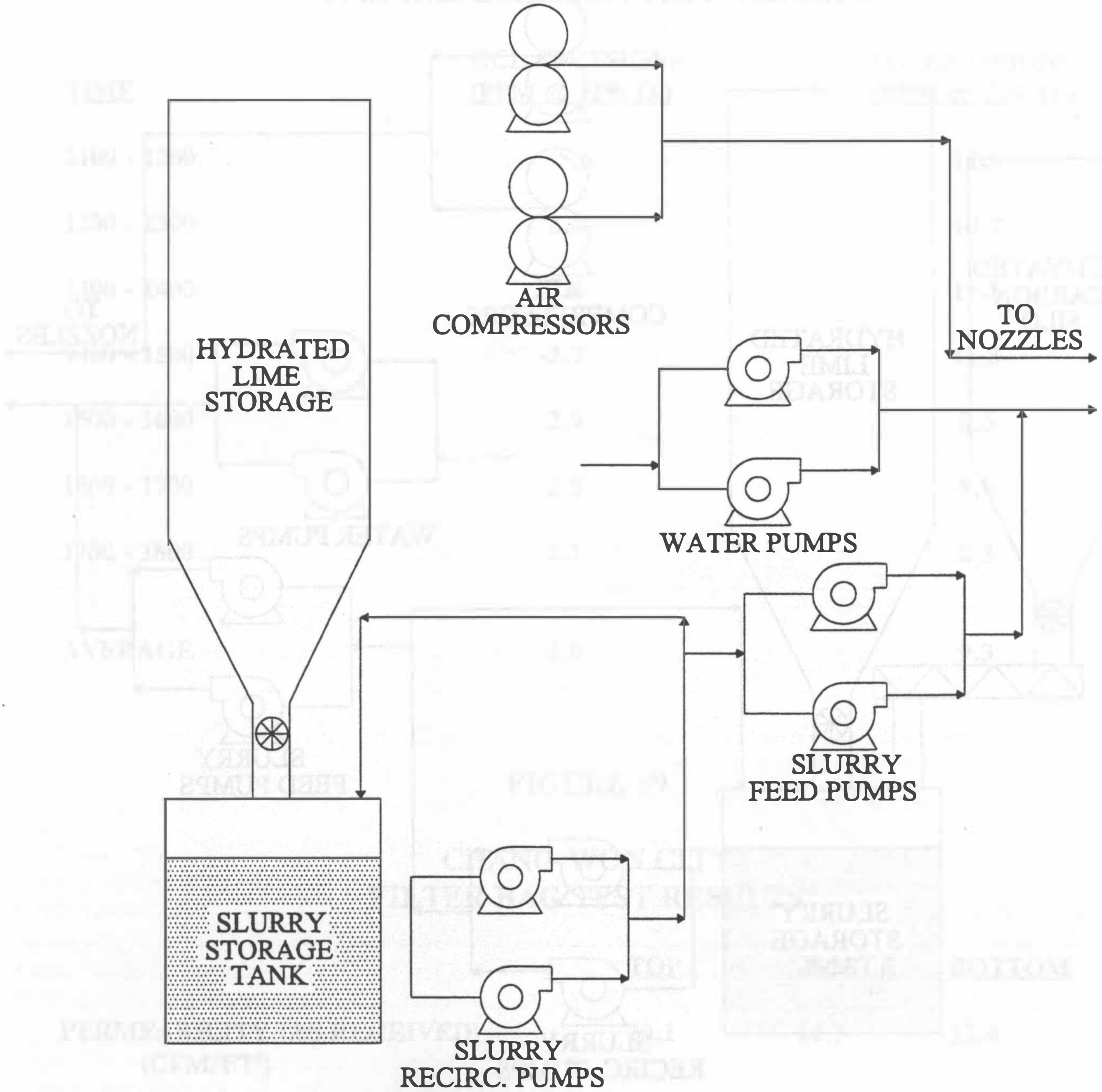

FIGURE #7.b

TAEJEON CITY (I)
REAGENT AND COMPRESSED AIR DELIVERY

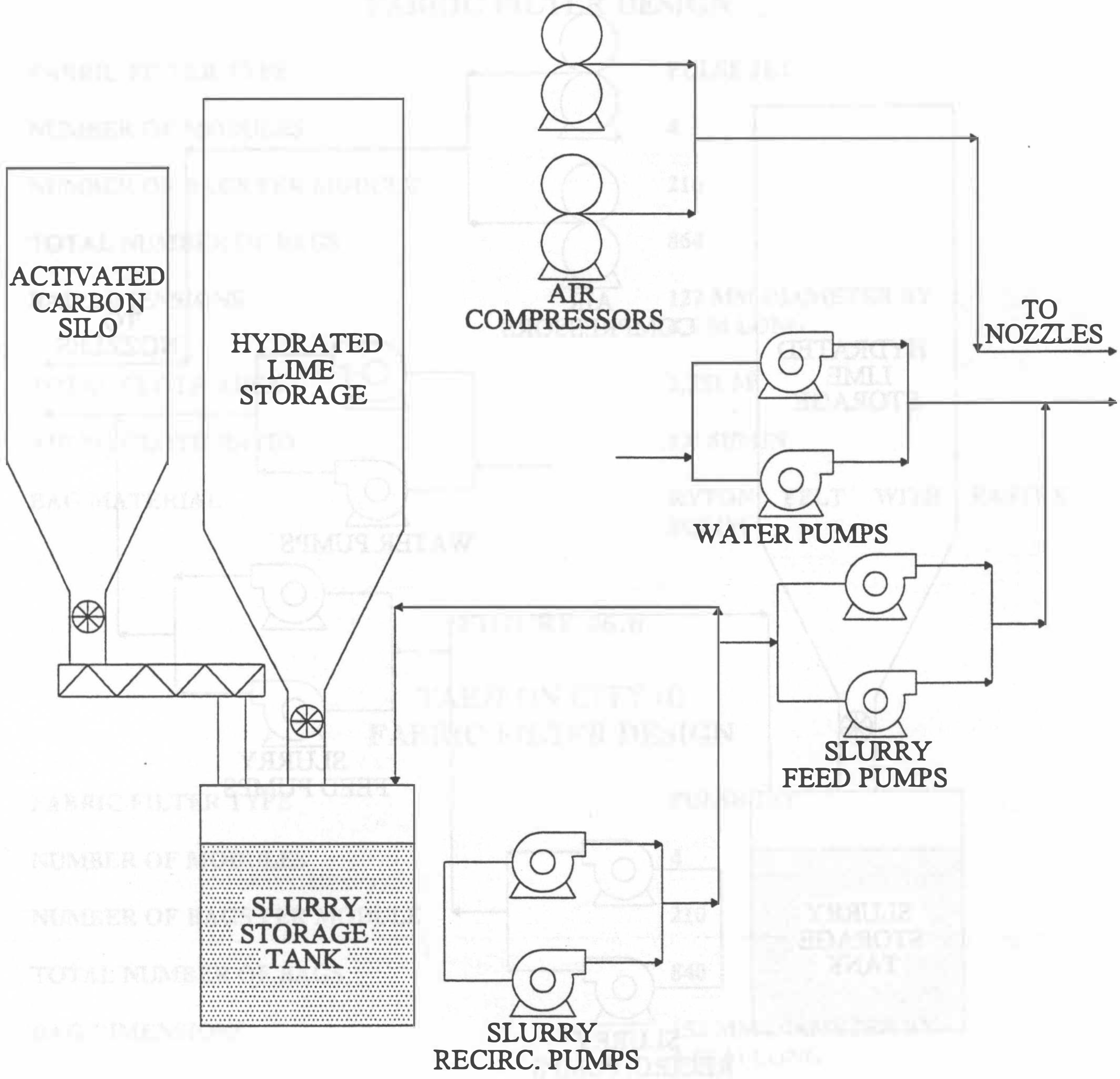

FIGURE #8

CHANG-WON CITY
ACID GAS EMISSION TEST RESULTS

TIME	HCL EMISSIONS (PPM @ 12% O_2)	SO_2 EMISSIONS (PPM @ 12% O_2)
1100 - 1200	5.6	11.6
1200 - 1300	2.4	10.7
1300 - 1400	2.6	11.8
1400 - 1500	2.7	11.3
1500 - 1600	2.9	8.5
1600 - 1700	2.8	8.9
1700 - 1800	2.1	2.3
AVERAGE	3.0	9.3

FIGURE #9

CHANG-WON CITY
FILTER BAG TEST RESULTS

	TOP	MIDDLE	BOTTOM
PERMEABILITY (AS RECEIVED) (CFM/FT^2)	20.1	14.7	12.4
PERMEABILITY (VACUUMED) (CFM/FT^2)	28.3	23.3	22.0
MULLEN BURST PROFILE (LB/IN^2)	319	311	307