PILOT SCALE TESTING OF A COHPAC UNIT AT THE SEMASS WASTE-TO-ENERGY FACILITY

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ABSTRACT
The SEMASS Resource Recovery Facility (SEMASS) is a processed refuse fuel (PRF) waste-to-energy plant serving much of Southeastern Massachusetts, Cape Cod, and the surrounding area. The project was originally developed by Energy Answers Corporation in the early 1980's, utilizing its PRF technology. The first two units have been in operation since 1988. In 1993 the addition of a third unit was completed. SEMASS is owned by SEMASS Partnership, a Massachusetts limited partnership, restructured in 1996 to exist between American Ref-Fuel of SEMASS, L.P. (Ref-Fuel), and ArkMass, Inc.

Each unit is capable of processing a nominal design value of 1000 tons per day of municipal solid waste (MSW). Units 1 and 2 are equipped with means to achieve good combustion control, a spray dryer absorber, and an electrostatic precipitator (ESP). Unit 3 also has a spray dryer absorber, but has a fabric filter instead of an ESP and a urea injection selective non-catalytic reduction (SNCR) system as its primary means of emissions control. A review of data from the facility indicated that in order to achieve compliance with the Environmental Protection Agency's Municipal Waste Combustor (MWC) Rule (40 CFR Part 60, Subpart Cb), which is known as the Maximum Achievable Control Technology (MACT), improved emission performance would be required from the ESPs on Units 1 and 2.

The great expense and technical difficulties of replacing the ESPs on Units 1 and 2 with conventional fabric filters in an operating plant forced Ref-Fuel to consider other alternatives. The option selected was to install a COHPAC, or COmpact Hybrid PArticulate Collector. COHPAC is designed to supplement the emissions control achievable by an operating ESP. This innovative technology was developed by the Electric Power Research Institute (EPRI) and is marketed by a number of companies, including Hamon Research-Cottrell (H R-C). Several COHPAC units are in operation on coal-fired utility boilers, but none have been installed on a waste-to-energy facility to date. Before committing to a full scale COHPAC Addition Project, Ref-Fuel decided to evaluate the technology via a nine-month pilot test program. In this manner the impact of the specific conditions existing at SEMASS could be determined. This paper describes this pilot test program, including some of the design issues considered in a waste-to-energy application. Although not demonstrated on a commercial scale, the emission performance data indicates that compliance with the MWC Rule requirements is possible on the pilot scale operation. Finally, recent progress on a full scale COHPAC application at SEMASS is outlined.

BACKGROUND
The SEMASS Resource Recovery Facility (SEMASS) is a processed refuse fuel (PRF) waste-to-energy plant serving much of Southeastern Massachusetts, Cape Cod, and the surrounding area. Utilizing its PRF technology Energy Answers Corporation developed the project in the early 1980's. The first two units have been in operation since 1988 and the addition of a third unit was completed in 1993. SEMASS is owned by SEMASS Partnership, a Massachusetts limited partnership, restructured in 1996 to exist between American Ref-Fuel of SEMASS, L.P. (Ref-Fuel), and ArkMass, Inc.

Each unit is capable of processing a nominal design value of 1000 tons per day of municipal solid waste (MSW). Units 1 and 2 are equipped with means to achieve good combustion control, a spray dryer absorber, and an electrostatic precipitator (ESP). Unit 3 also has a spray dryer absorber, but has a fabric filter instead of an ESP and a urea injection selective non-catalytic reduction (SNCR) system. A review of data from the facility indicated that in order to achieve compliance with the Environmental Protection Agency's Municipal Waste Combustor (MWC) Rule (40 CFR Part 60, Subpart Cb), which is known as the Maximum Achievable Control Technology (MACT), improved emission performance would be required for Units 1 and 2. A comparison of typical emissions performance for the spray dryer absorber / ESP-equipped SEMASS Units 1 and 2 versus the USEPA MACT standards is presented in Table 1. Previous tests at the plant have demonstrated that the existing system could successfully achieve the MACT standards for acid gases. As can be seen, additional control was needed for lead. The ESPs have, on occasion, been negatively impacted by trace components in the fuel stream that caused the fields to lose power. Since the process includes front-end shredding it is nearly impossible to isolate the suspect material from entering the boilers. If it is discovered, via an ESP performance degradation, that this material has entered the system, it is even harder to remove it from the mixed and shredded fuel in storage piles. A number of suspect materials have been identified including carbon fibers, static bags, fiberglass, and certain other manufacturing waste products. Prior to the implementation of the MACT standards, several studies were conducted to identify ways in which the ESPs performance could be enhanced. None of these studies, however, provided confidence that the flue gas cleaning systems on Units 1 and 2 could consistently achieve the MACT standards.

In addition, Massachusetts has also proposed a very aggressive mercury emission requirement of 28 ug/dscm @ 7% O_2 with no percent reduction allowance in their State Implementation Plan (SIP). This is more stringent than the applicable USEPA rule.

Various alternates were considered to supplement the existing equipment. It was decided that the main criteria to be achieved by the selected alternative would be:

(1) to reliably provide the environmental performance required; and
(2) to be cost effective for both American Ref-Fuel and for the communities contracted with SEMASS, which are responsible for a substantial portion of the retrofit costs.

The initial thought was to replace the ESPs with fabric filters which are common in the waste-to-energy industry. The performance of Unit 3 at SEMASS, which has such a particulate control device, provided an incentive for this approach. However, the great expense and technical difficulties of replacing the ESPs on Units 1 and 2 with conventional fabric filters in an operating plant forced Ref-Fuel to consider other options. A COHPAC, or COmpact Hybrid PArticulate Collector, was evaluated as an alternative to a traditional fabric filter. A test program was formulated to verify whether such a design could improve lead and opacity emissions. After the proposed Massachusetts SIP became known, activated carbon injection was added to this demonstration project to address mercury and dioxin emissions.

The COHPAC technology, which is shown in Figure 1, is designed to supplement the emissions control achievable by an operating ESP. The approach is to install a high air-to-cloth ratio pulse jet collector between the existing electrostatic precipitator and the stack. The new equipment acts as a final collection or polishing system. Since the ESP still acts as the primary particulate collection device, the new COHPAC unit can be designed with less cloth and a smaller footprint than a new fabric filter alone could be. Among the advantages identified for using COHPAC at SEMASS were the following:

(1) the capital cost would be reduced, by as much as 50%, versus that of a full size conventional fabric filter;
(2) the plant outage time required for installation would be less than that of a full scale fabric filter;
(3) the area required by the new COHPAC equipment was less than that of a new fabric filter and could be fit on the existing plant site;
(4) the COHPAC technology was similar to that of a typical fabric filter and, therefore, would not require extensive operator training; and
(5) COHPAC at SEMASS was expected to meet or exceed all of the new MACT requirements.

This innovative technology was developed by the Electric Power Research Institute (EPRI) and is marketed by a number of companies, including Hamon Research-Cottrell (H R-C). Several COHPAC units are in operation on coal-fired utility boilers, but none have been installed on a waste-to-energy facility to-date. Before committing to a full scale COHPAC Addition Project, Ref-Fuel decided to evaluate the technology via a nine-month pilot test program. In this manner the impact of the specific conditions existing at SEMASS could be determined.

COHPAC PILOT PROJECT

In order to verify expected performance of a COHPAC unit in a waste-to-energy application, American Ref-Fuel decided to conduct a nine-month pilot test program at the SEMASS Facility. An agreement was reached with Hamon Research-Cottrell to conduct this test. In April

1998, a 1 MW pilot plant facility was installed downstream of the electrostatic precipitator on Unit 1 at SEMASS. The equipment was operated essentially full time for the remainder of the year, approximately nine months.

The test program was intended to demonstrate proof of concept of the COHPAC technology in the SEMASS waste-to-energy application. A number of concerns were identified at the start of the program:

(1) Could this technology achieve the USEPA MACT requirements at SEMASS? (This goal was later revised to address the incremental requirements of the proposed Massachusetts SIP.)
(2) Could the performance of the pilot plant be extrapolated to predict the performance of a full size unit?
(3) How would the COHPAC unit respond to ESP upset conditions seen at this plant in the past? If an ESP suffered a degradation in performance could the COHPAC unit allow operations to continue at the then existing loads and still maintain emissions at their required levels until the ESP stabilized and returned to normal performance?
(4) What bag life could be expected in this application?
(5) Was the proposed on-line cleaning technology using a rotating arm appropriate for this environment?
(6) What extra pressure drop would the COHPAC unit add to the existing flue gas system, both initially and over time? Could the existing induced draft (I.D.) fans be used without major modifications or complete replacement?
(7) Was the COHPAC concept compatible with activated carbon injection technology that was required by the stringent State of Massachusetts mercury requirement?
(8) Could a full size COHPAC unit be installed for both Unit 1 and Unit 2 within the space available at the plant? Could this installation be done in a cost effective manner, while also minimizing the impact on normal plant operations?; and finally
(9) If deemed successful via the pilot plant testing, could a full size system be designed, installed, and made operational within the time constraints imposed by the MACT schedule?

The primary goal of the test program was to answer each of these concerns. If satisfactory results were obtained, a full-scale project would be initiated.

The transportable pulse jet pilot plant system was provided by Hamon Research-Cottrell, and was the same design utilized by EPRI on other COHPAC pilot plant facilities. This system uses Hamon Research-Cottrell's Low Pressure/High Volume (LPHV) pulse cleaning technology, which has been successfully utilized on full scale conventional and COHPAC operating installations. Figures 2, 3, 4, & 5 show views of the COHPAC pilot unit installed at the SEMASS Facility.

The pilot plant is designed to handle flue gas flow rates of up to 5,000 acfm, which represents about 2% of the normal flow per unit, while operating at conventional four fpm filtration rates. Due to the pilot plant fan limitations, in order to simulate full size COHPAC operation, the pilot unit had all but 12 of the filter bags blanked out of service. Figure 6 shows a typical tube sheet. The normal gross air-to-cloth ratio could be tested while at elevated filtration rates of 6.5 to 10 fpm.

To ensure proper simulation of all full scale operating conditions, the area surrounding the installed bags was closed to simulate higher insterstitial, or can, velocities. The achieved values of about 600 – 800 fpm are higher than normally experienced with conventional four fpm filtration rates. The casing of the pilot unit was also modified by installing an insulated spool piece section to allow testing with full length, or 25', filter bags. Temperature drops across the pilot unit were minimized by insulating both the outside of the casing, as well as the voids left in the corners of the casing when the inner annulus tunnel was installed for the higher can velocities.

Remote monitoring of the pilot plant was provided via the use of a data logger system and PLC developed by Southern Research Institute (SRI) under contract to Hamon Research-Cottrell. This system was similar in design to the one provided previously by SRI to Southern Company Services (SCS) for the Miller Steam Plant COHPAC Pilot Plant Program. Data screens indicate typical operating conditions such as inlet and outlet flue gas temperatures, boiler load, inlet and outlet opacities, pulse pressures and pulse frequencies, air-to-cloth ratios, and tube sheet pressure drops. These parameters were continuously monitored and reported by H R-C to the plant in monthly progress reports.

TEST RESULTS

During the nine month operating period for the COHPAC pilot plant, various data was collected on system performance. Formal stack tests were conducted in July and November of 1998 to determine emission levels achievable relative to the new MACT standards.

Emission testing was completed for a number of pollutants including particulate, acid gases, and dioxins/furans, although the control of heavy metals was the primary concern. In addition, opacity was monitored on a continuous basis so that cleaning cycle characteristics and the impact of an unexpected reduction of ESP performance could be monitored. This information, along with other operating data, was used to evaluate the Facility's performance with COHPAC to determine whether the MWC MACT emission requirements could be achieved. As the pilot project progressed, the State of Massachusetts proposed its State Implementation Plan calling for certain requirements that were more stringent than the USEPA MACT requirements. With regard to the COHPAC project, the most significant of these was a proposed mercury limit of 28 ug/dscm corrected to 7% O_2, with no provision for an emission reduction limit. The COHPAC pilot project test plan was subsequently revised to evaluate these potential requirements.

The first series of tests was completed in July, 1998. A compliance test for one of the three processing trains was scheduled at that time. It was decided that while the testing crew was on site, some preliminary test data could be obtained from the COHPAC pilot unit. The intent of this testing program was to screen and evaluate general performance and identify any areas of concern with testing logistics and emissions for the pilot unit. The COHPAC equipment had been in operation for more than 2,000 hours at the time of this testing effort. Table 2 summarizes the emissions data from this testing program. Particulate control was very good, well within the required performance levels. It was noted that the SO_2 concentrations were above the levels defined by MACT. However, since the spray dryer absorber, located upstream of the COHPAC unit, is primarily responsible for controlling acid gas concentrations, the main interest during this test was the impact that the COHPAC equipment would have on the acid gases that entered it. HCl and SO_2 reduction were not significant across the COHPAC filter. This is thought to result from most of the lime being collected in the ESP. Fly ash collected from the ESP hoppers normally is progressively darker toward the later or downstream fields. This implies that most of the lime and salts of reaction are collected in the initial fields of the ESP. The small quantity of fly ash collected from the COHPAC unit was also quite dark and did not contain significant amounts of lime. The lead emission concentration, one of the Facility's main concerns, was substantially reduced from the range observed during compliance testing without the COHPAC filters. This result offered strong support to the theory that much of the lead emitted was associated with very fine fly ash that was not readily captured in the ESP. Results for the other metals analyzed, in general, also showed excellent control.

The measured mercury and dioxin emission concentrations did not achieve targeted emission levels as defined by the USEPA MACT emission guidelines. No mercury reduction was observed across the COHPAC filter. There were two reasons why this may have occurred. (1) During early operation of the COHPAC pilot, before testing was conducted, it was observed that there was a large temperature drop of about 60 to 80°F across the COHPAC unit. Concern was expressed that this additional cooling of the flue gas in the pilot unit might bias the mercury and dioxin measurements at the COHPAC outlet and show artificially high reduction results. In order to avoid this expected problem it was decided to raise the scrubber outlet temperature during the test runs. The goal was to simulate the anticipated COHPAC outlet temperature that would occur under normal operating conditions. Unfortunately, this action also raised the temperature profile throughout the flue gas cleaning system downstream of the spray dryer absorber. The temperatures into, through, and out of the ESP, and into the COHPAC pilot unit were all higher than expected under normal operation. Control that normally occurs in the ESP may have been negatively impacted, resulting in less mercury and dioxin capture. It is suspected that this increase in temperature could have actually caused a re-release of mercury and dioxins previously captured in the ash in the ductwork, ESP, and COHPAC pilot unit. (2) In addition, this test series was completed without the injection of activated carbon. Therefore, these results were not entirely unexpected.

The results of these tests, together with the proposed Massachusetts MACT requirement, caused a change in priorities for future testing. It was decided that the more comprehensive future testing program would include activated carbon injection. It would also focus more on mercury and dioxin control, and less on lead control, as was originally anticipated.

Prior to the November tests the COHPAC unit was carefully inspected. The goal was to identify the causes of the large temperature drop across the COHPAC pilot that had created problems with the July testing. Once the causes were found, actions were taken to eliminate them, or at least to minimize their impact. Large temperature drops of the flue gas have been a problem with modular pilot plants due to their inherent high ratio of equipment outer surface area to total gas stream being treated. However, in this case many areas of potential ambient air in-leakage into the ductwork and casing around test ports and connections were also found. Extra insulation was installed and as many of the identified sources of in-leakage were sealed as was practical. Adding insulation in the corner areas of the COHPAC unit and reducing in-leakage of ambient air reduced the total flue gas temperature drop across this unit to less than 20°F.

As a result of the July testing, a carbon injection test skid was obtained from Norit Americas, Inc. to be used in the subsequent testing effort in November, 1998. Provisions for activated carbon injection included two separate injection locations:

(1) the spray dryer absorber inlet; and
(2) the COHPAC inlet.

The spray dryer absorber inlet would allow injection of activated carbon at a location that is typical in waste-to-energy facilities. A second location, downstream of the ESP at the COHPAC inlet, was also fitted with an injection port. Testing these two locations was expected to help to determine the optimal carbon injection location. The thickness of the filter cake of the COHPAC bags was also intentionally increased. Although this caused a higher tube sheet pressure drop, the expectation was that a thicker filter cake would aid mercury and dioxin absorption, the two issues of primary concern identified during the July tests.

A complex testing schedule was formulated, primarily focused on demonstrating mercury and dioxin control. The test conditions are defined in Table 3. These were the two areas of primary concern, as identified during the July test program. Activated carbon would be added at various rates at one or both of the injection ports. To simulate increased particulate levels and also ESP upset conditions, two fields of the ESP were powered down during selected test runs. Test run duration for the dioxin testing was shortened from the standard 4-hour runs to 3-hour runs to allow for testing flexibility and an increased number of tests. Activated carbon injection rates were chosen with the intent of determining proof of concept, and were not designed to optimize the system's performance. As expected, the results did not clearly define the most economical carbon injection point. However, flexibility was demonstrated by showing that carbon could be added at more than one point for adequate mercury control. Prior to this test program the COHPAC bags had been in operation more than 5,000 hours. Tables 4 & 5 present the results of the November testing program. Table 4 presents the results for mercury, dioxins, and lead, while Table 5 contains the results for other metal emissions.

Consistent mercury control was measured, with all test results within the Massachusetts proposed requirement of 28 ug/dscm, corrected to 7% O_2. The percentage of mercury captured in the ESP was not determined. However, reduction across the COHPAC filter was shown. Increased levels of activated carbon injection at the SDA inlet may have resulted in less mercury in the flue gas reaching the COHPAC. However, the structure of the tests did not permit verification of this theory. No significant differences in mercury control were observed during the simulated ESP upset tests.

Table 4 also presents dioxin data from the November tests. Dioxin control was very responsive to the addition of activated carbon. All test results were well within the USEPA MACT requirement of 60 ng/dscm, corrected to 7% O_2. The COHPAC appeared to control dioxins very well even during the simulated ESP upset conditions.

All metals tested demonstrated excellent control with the COHPAC unit with no discernable change from the July testing, with the exception of mercury. Lead and cadmium reduction percentages were consistently in the high 90s. Most of the other metals were captured in the ESP, resulting in relatively low levels entering the COHPAC equipment. Therefore, control of these pollutants was not as dramatic across the COHPAC. Simulated ESP upset conditions appeared to result in elevated metals emissions at the COHPAC inlet, as more fly ash passed through the ESP without being captured. Despite these simulated ESP upset conditions, excellent control was measured at the COHPAC outlet.

In addition to the specific testing programs conducted in July and November, operating conditions and performance data were continuously recorded and analyzed. The COHPAC pilot plant was operated for nine months to provide enough time to evaluate the system and its operating characteristics, especially relative to the issues of concern identified at the start of the program.

As mentioned earlier, certain materials in the SEMASS fuel have, on occasions, disrupted the performance of the ESPs. The ability of the COHPAC pilot plant to respond to these conditions was of great interest during the entire evaluation period. When these ESP upsets occur the COHPAC inlet particulate loading is expected to rise from less than 0.0025 gr/dscf to as high as 1 gr/dscf in a matter of minutes. Performance of the COHPAC filter was monitored to determine if the cleaning mechanism and basic design concept would be capable of handling these operating extremes. It must be able to respond to reasonably anticipated operational swings without damage, and without forcing a reduction in the boiler waste processing rate. Continuous monitoring results, as well as formal test results, indicate that the COHPAC pilot plant responded well to these upset conditions.

It was found that, while the filter cleaning cycle did need to increase during an ESP upset, the bags did not plug nor fail. It is expected that the bag life will be at least two years. Pressure drop was also closely monitored during the operating period. An increase in the pressure drop across the COHPAC filter over time was a concern, due to limitations in the margin of the existing I.D. fans. No significant pressure drop increases or other problems were observed. Finally, the filters themselves are not a standard design typically used in the waste-to-energy industry and some operational experience with them was desired. Other than some minor plugging issues when high levels of carbon were introduced downstream of the ESP at the COHPAC inlet, no problems in these areas were identified.

The conclusions reached via the nine-month pilot plant testing program were as follows:

(1) The SEMASS Facility equipped with COHPAC technology, in conjunction with the existing flue gas cleaning equipment and activated carbon injection, could meet the new MACT emission requirements, as well as the additional constraints imposed by the State of Massachusetts SIP.
(2) Due to the care taken in scaling important model parameters, the pilot plant results led Ref-Fuel to believe that a full size unit could successfully achieve the MACT requirements.
(3) The COHPAC pilot plant responded well to ESP upset conditions, as shown by continuous monitoring, as well as formal stack tests.
(4) The Vendor selected to supply a full scale COHPAC unit, Hamon Research-Cottrell, provided a two-year guarantee on bag life.
(5) No problems were observed with the on-line cleaning design employing a rotating arm to supply cleaning air to the bags.
(6) Performance over the entire test program, as well as a system pressure drop guarantee from Hamon Research-Cottrell which was later verified by a model study, confirmed that the existing I.D. fans could be used with a full scale COHPAC unit without major modifications or complete replacement.
(7) The November stack testing proved the compatibility of the COHPAC technology with activated carbon injection.
(8) Preliminary design and construction evaluations by Hamon Research-Cottrell and American Ref-Fuel led to the belief that a full scale COHPAC unit could be installed in the available space in a cost effective manner; and finally
(9) Preliminary evaluations confirmed that a full size COHPAC Addition Project could be implemented within the time constraints defined by the MACT regulations.

These conclusions led American Ref-Fuel to proceed with the COHPAC concept in order to satisfy the new environmental requirements defined by MACT.

CURRENT STATUS

Based upon the successful results obtained in the pilot plant test program, American Ref-Fuel awarded a contract to Hamon Research-Cottrell to design, supply, and install full scale COHPAC systems on both Units 1 and 2 at the SEMASS Facility. This state-of-the-art installation will represent the first application of the COHPAC technology to a waste-to-energy facility.

A major challenge for the new project was to design the system for and to install the equipment within a restricted amount of available space. The space available was a courtyard located between the boiler building and the ductwork for the various units. All ductwork is routed to a single, multiple flue concrete stack. Figure 7 shows the system layout within the existing plant. Construction of the majority of the COHPAC equipment was planned to proceed with no disruption of normal plant operations. This is in spite of the fact that all major components must be hoisted over operating equipment to their final location. Modification of existing ductwork, including final COHPAC ductwork tie-ins were planned to occur during regularly scheduled unit outages at the plant.

The COHPAC system is designed to utilize the available space. The ductwork to and from the new equipment is routed to accomplish the following objectives:

(1) direct the flue gas from the ESP outlets to the new COHPAC filters and return it to the existing induced draft fans;
(2) minimize the system pressure drop in order to allow use of the existing I.D. fans with no or minimal modifications; and
(3) minimize the amount of structures to be erected to support the new ductwork.

The COHPAC design will have three isolatable compartments for each boiler unit. These compartments will be located within a common structure containing a common center wall that will separate the flue gas for each unit. This design reduces the space requirements and overall cost. The design basis for the SEMASS full scale COHPAC system is included in Table 6.

The filter bags for this installation are to be constructed of a 16 oz., nominal weight, P-84 / PPS (i.e. Ryton / Procon) felt composite fabric. Although various bag materials may be able to achieve the MACT requirements, this fabric was selected for the pilot plant based upon the relatively short time available for testing, the design operating conditions, and the need to install the most efficient fabric commercially available without utilizing a membrane coating. Conventional fabrics may be installed in the full scale system as test bags for future evaluation. Conventional Ryton (PPS) fabric has recently been installed in a few test compartments of the existing pulse jet fabric filter on Unit 3 at SEMASS to allow evaluation on that system. The majority of the compartments still have woven fiberglass bags installed. The P – 84 / PPS composite fabric was selected due to its demonstrated ability to provide high filtration efficiency, reduced pressure drop, and an anticipated long bag life.

As shown in Figure 8 the bags in a LPHV pulse jet collector are retained in the tube sheet through the use of a conventional snap-band top. Although the bags are basically round, they become oblong in shape, once the bottom pans have been sewn in and they have been installed into the tube sheet. The cage design consists of two pieces for ease in removal from the 25' long filter bags and to reduce the overall height of the walk-in plenum. The cages are constructed of 9 gauge, pre-galvanized wire for long life and extra strength, with 14 vertical wires for additional support of the fabric.

Figure 9 shows a two piece cage being inserted into a typical tube sheet arrangement. The cage top flange has also been specially designed to sit upon the top of the tube sheet surface and to allow maintenance personnel to walk upon it without causing damage to the top of the bag. Guide plates on the sides of the cages provide both a means of additional support at the connection, as well as ease in making the connection between both cage halves. The LPHV design employs a rotating arm that supplies the bag cleaning air. Therefore, no cleaning air blow pipes are installed as in a conventional pulse jet system. No fixed pipes have to be removed to allow an unobstructed bag inspection. Time required to replace bags is also reduced.

A flue gas bypass was deleted from the initial design of the SEMASS full scale COHPAC system. Instead each unit is equipped with one poppet-type purge air damper. This will allow the introduction of cooler ambient air into the compartments should the inlet flue gas temperature exceed the fabric temperature limitation of 375°F. This type of damper configuration has been successfully used on many fabric filter installations, including utility COHPAC units.

A 1/12th scale physical flow model of the COHPAC system was build and tested by Hamon Research-Cottrell at their in-house modeling facility, located in Branchburg, New Jersey. The scope of the model included the ductwork from the ESP outlet flange to the I.D. fan inlet flange for both Unit 1 and Unit 2. The purpose of this effort was to optimize the system ductwork layout. Among the issues considered were:

(1) to identify whether any flow control devices were required to maintain good flow distribution and, if so, where to locate them;
(2) to minimize the system pressure drop;
(3) to verify that the flow distribution to the I.D. fans was uniform;
(4) to study the impact of opening the tempering air damper upon high COHPAC inlet flue gas temperature; and
(5) to determine whether any significant ash dropout from the flue gas flow would occur within the interconnecting ductwork.

The results of the modeling study confirmed that the design would achieve the desired performance in all of the areas of concern. Hamon Research-Cottrell provided a guarantee of a 9" w.c. pressure drop across the entire new equipment scope of supply.

A remote monitoring system will be utilized to monitor the full scale installation, similar in concept to the systems installed on Alabama Power's E.C. Gaston Units 2 and 3 COHPAC Systems. Real-time monitoring of the system operation, along with current and long-term trend analysis will be provided. This system will provide both SEMASS and Hamon Research-Cottrell the ability to remotely monitor the COHPAC system operation. Several screens will be designed for this specific application to provide both real-time and long-term trend displays. Information that is expected to be monitored and stored on an independent PLC / data logger will include boiler load, steam flow, air flow, ESP exit and COHPAC outlet flue gas temperatures, inlet and outlet opacities, pressure pulses, cleaning frequencies, and pressure drops. Additional parameters may be added and evaluated in the future.

The full scale COHPAC systems for both Units 1 and 2 are currently in the design and construction phase at the SEMASS Facility. The current schedule anticipates system start-up in June, 2000.

CONCLUSIONS

A 1 MW scale COHPAC Pilot Plant was installed and tested for nine months at the SEMASS Facility. The emissions results were excellent. High removal efficiency was measured for particulate and all metals tested except mercury. However, when activated carbon was added to the flue gas stream, mercury and dioxin control was also very good. These results predict that it is possible for the SEMASS Facility equipped with COHPAC technology to meet the new MACT requirements. The results of the pilot plant test program led to the decision by American Ref-fuel to install full size COHPAC units on boilers 1 and 2 at SEMASS. This is the first application of this technology in a waste-to-energy plant. The design and construction is currently in progress, with an anticipated system start-up in June, 2000.

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Table 1: Comparison of SEMASS Units 1 and 2 Typical Emissions Versus USEPA MACT Guidelines			
Pollutant	Units[1]	SEMASS Units 1 and 2[2] Typical Emission Concentration	USEPA MWC MACT Emission Concentration[3]
Particulate	gr/dscf	0.002 – 0.007	0.012
CO	ppmdv	90 – 170	200
SO_2	ppmdv	45 – 80	29 or 75% reduction
HCl	ppmdv	25 – 80	29 or 95% reduction
NO_x	ppmdv	180 – 210	250
Dioxins/furans	ng/dscm[4]	25 – 150	60
Cadmium	µg/dscm	10 – 30	40
Lead	µg/dscm	200 – 750	440
Mercury	µg/dscm	30 - 90	80 or 85% reduction

Notes:

1. All values are corrected to 7% O_2.
2. Units are equipped with a spray dryer absorber and an ESP.
3. MACT requirements for ESP-equipped RDF Facilities.
4. Dioxins/furans means total tetra-through octa-chlorinated dibenzo-p-dioxins and dibenzofurans.

Table 2: July COHPAC Emissions Test Results			
Pollutant	Units	COHPAC Inlet	COHPAC Outlet
Particulate	gr/dscf	0.019	0.0010
HCl	ppmdv	122	144
SO_2	ppmdv	82	54
Antimony	µg/dscm	---	1.8
Arsenic	µg/dscm	---	<0.39
Beryllium	µg/dscm	---	<0.081
Cadmium	µg/dscm	---	<0.057
Chromium	µg/dscm	---	<0.13
Cobalt	µg/dscm	---	<0.064
Copper	µg/dscm	---	1.9
Lead	µg/dscm	---	2.3
Manganese	µg/dscm	---	1.8
Molybdenum	µg/dscm	---	2.9
Nickel	µg/dscm	---	0.36
Selenium	µg/dscm	---	<0.48
Tin	µg/dscm	---	5.8
Vanadium	µg/dscm	---	<0.16
Zinc	µg/dscm	---	15
Mercury	µg/dscm	82	88
Dioxins	ng/dscm	---	112

Notes:
1. All data is corrected to 7% O_2.
2. Dioxins include total tetra-octa dibenzo-p-dioxins and dibenzofurans.
3. The average air-to-cloth ratio was 8.9 ft/min.

Table 3: November COHPAC Emissions Test Program		
Test Case	Activated Carbon Injection Location	ESP Status
1	COHPAC Inlet	Normal
2	COHPAC Inlet and SDA Inlet	Normal
3	COHPAC Inlet and High Injection Rate at SDA Inlet	Normal
4	SDA Inlet	Simulated ESP Failure
5	COHPAC Inlet and SDA Inlet	Simulated ESP Failure

Table 4: November COHPAC Emissions Test Results

	Test Case	COHPAC Inlet	COHPAC Outlet	Percent Reduction[4]
Mercury[1]	1	43	4.1	90
	2	19	2.3	87
	3	6	2.6	56
	4	11	2.4	75
	5	10	1.1	89
Dioxins[2]	Test Case	COHPAC Inlet	COHPAC Outlet	Percent Reduction[4]
	1	63	1.5	97
	2	23	1.0	98
	3	24	1.3	90
	4	29	0.8	95
	5	13	4.6	48
Lead[1]	Test Case	COHPAC Inlet	COHPAC Outlet	Percent Reduction[4]
	1	680	3.2	99.1
	2	348	2.6	99.3
	3	368	3.0	99.2
	4	1476	3.1	99.8
	5	1558	2.8	99.8

Notes:

1. All concentration data is reported as ug/dscm corrected to 7% O_2.
2. All data is reported as ng/dscm. Total tetra-octa Dibenzo-p-dioxins and Dibenzofurans, corrected to 7% O_2.
3. The average air-to-cloth ratio was 7.3 ft/min.
4. The value listed is the average of the percent reductions of multiple runs. Therefore, it may not correspond to the percent reduction obtained from the average inlet and average outlet values listed in the table.

Table 5: November COHPAC Metals Emissions Test Results			
Metal	COHPAC Inlet	COHPAC Outlet	Percent Reduction[4]
Antimony	140	<1.30	>99
Arsenic	11	<0.40	>94
Beryllium	<0.07	<0.09	N/A
Cadmium	32	<0.15	>99
Chromium	3.5	<0.48	>77
Cobalt	0.25	<0.091	>48
Copper	68	9.2	71
Manganese	7.2	2.3	63
Molybdenum	2.4	<0.46	>69
Nickel	4.6	2.3	57
Selenium	<0.34	<0.30	>46
Tin	103	19	70
Vanadium	<0.33	<0.17	>51
Zinc	1791	16	98

Notes:
1. Results represent the average of five test cases.
2. All concentration data is reported as ug/dscm corrected to 7% 0_2
3. The average air-to-cloth ratio was 7.3 ft/min.
4. The value listed is the average of the percent reductions of all tests. Therefore, it may not correspond to the percent reduction obtained from the average inlet and average outlet values listed in the table.

Table 6: COHPAC Design Conditions	
Total Number of RDF Boilers	Three
Total Number of COHPAC Units	Two
Design Gas Volume per Unit	250,000 acfm (normal) / 311,000 acfm (maximum)
Normal Operating Temperatures	300 to 375° F (surges to 400° F)
Design Inlet Ash Loading (@ ESP Outlet)	0.001 to 0.015 lb/hr
Number of Compartments per Boiler	Three
Number of Bags per Compartment	484
Total Number of Bags per COHPAC Unit	1,452
Total Bag Length	25' -- 0"
Equivalent Bag Diameter (Oblong-shaped)	4.9"
Fabric Type	P-84 / PPS Composite
Fabric Weight	Nominal 16 oz.
Fabric Finish	Singed on One Side
Cage Design	Two Piece Construction
Cage Material	9 Gauge, Pre-Galvanized Wire
Design Air-to-Cloth Ratio	5.7 fpm
Type of Pulse Jet Cleaning System	On-line Low Pressure / High Volume (LPHV)
Cleaning Air Source	Three 50% Low Pressure Positive Displacement Blowers (Two Operating with One Common Spare)
Guaranteed Outlet Opacity	10% maximum on a six minute average

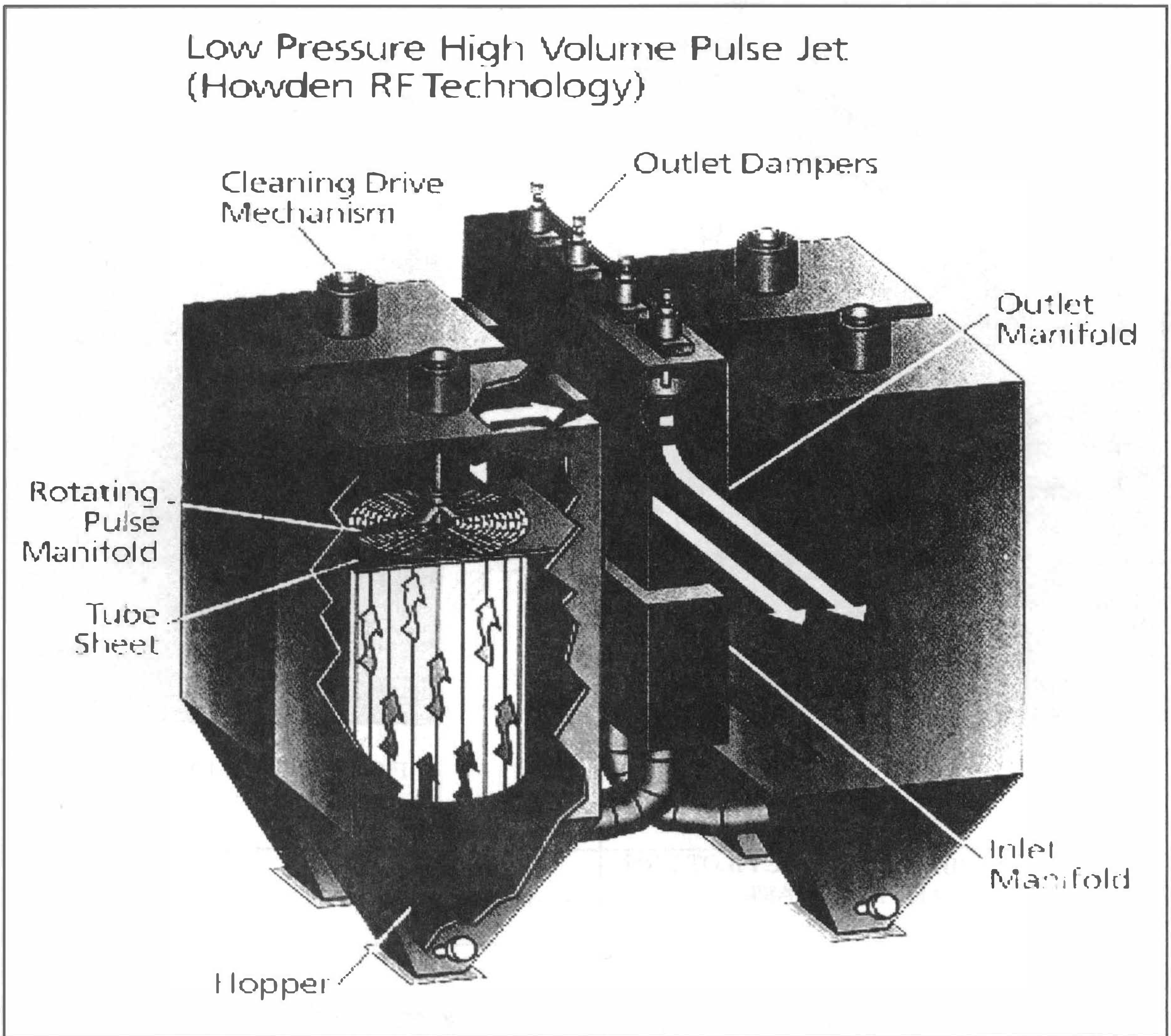

FIGURE 1: BASIC COHPAC TECHNOLOGY

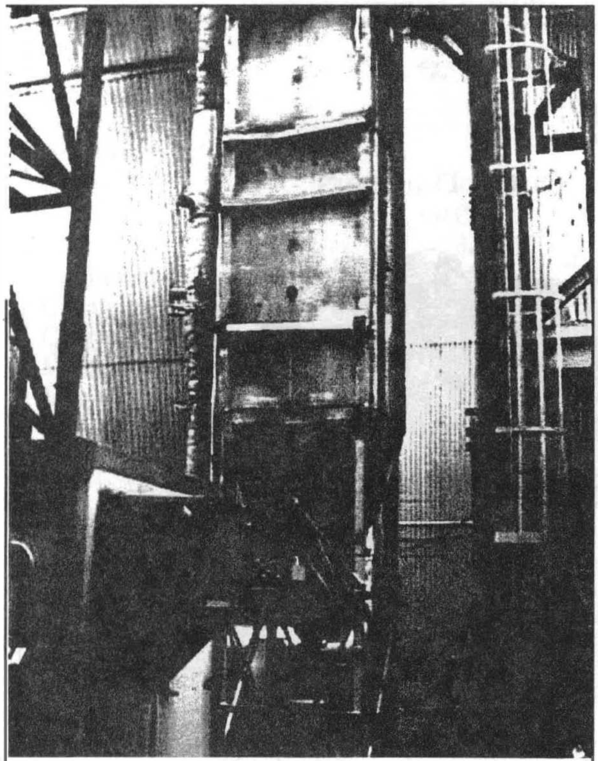

FIGURE 2: SIDE VIEW OF COHPAC PILOT UNIT INSTALLED AT SEMASS

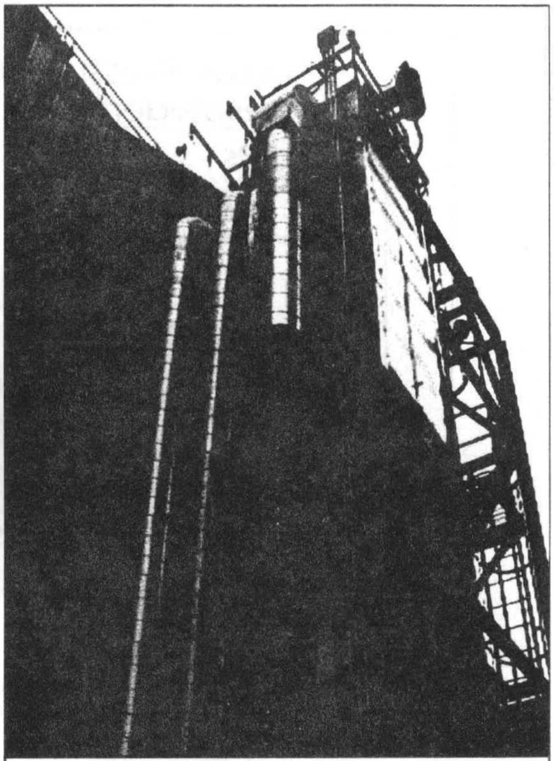

FIGURE 3: VIEW OF COHPAC PILOT UNIT SHOWING CLEANING AIR PIPING

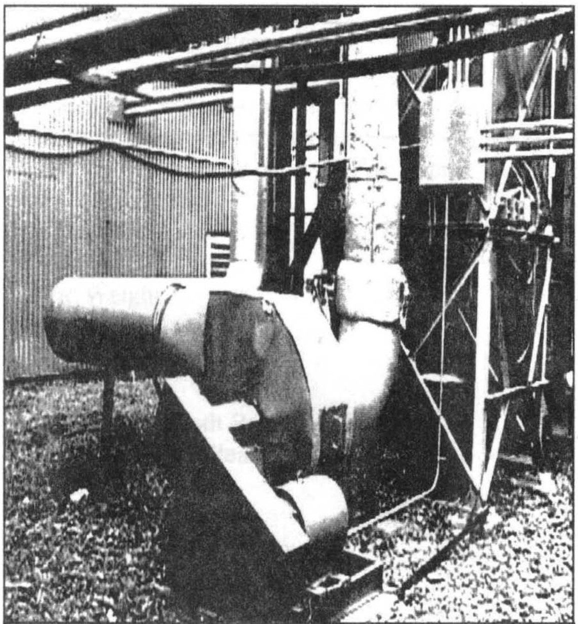

FIGURE 4: COHPAC PILOT UNIT INDUCED DRAFT FAN

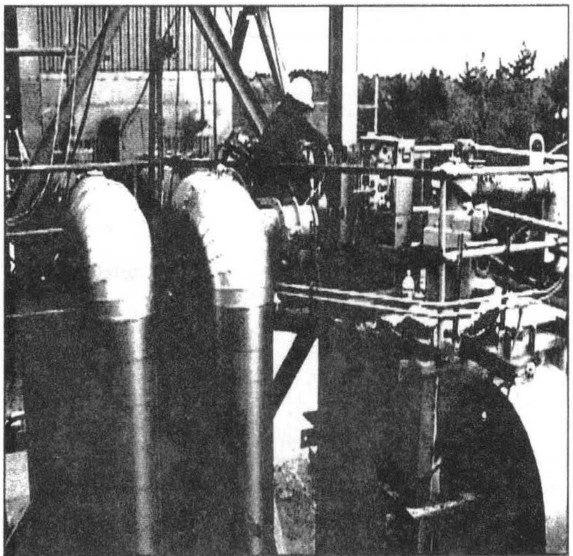

FIGURE 5: TOP OF COHPAC PILOT UNIT SHOWING TIE-INS TO FLUE GAS DUCTWORK AND CLEANING ARM DRIVE MECHANISM

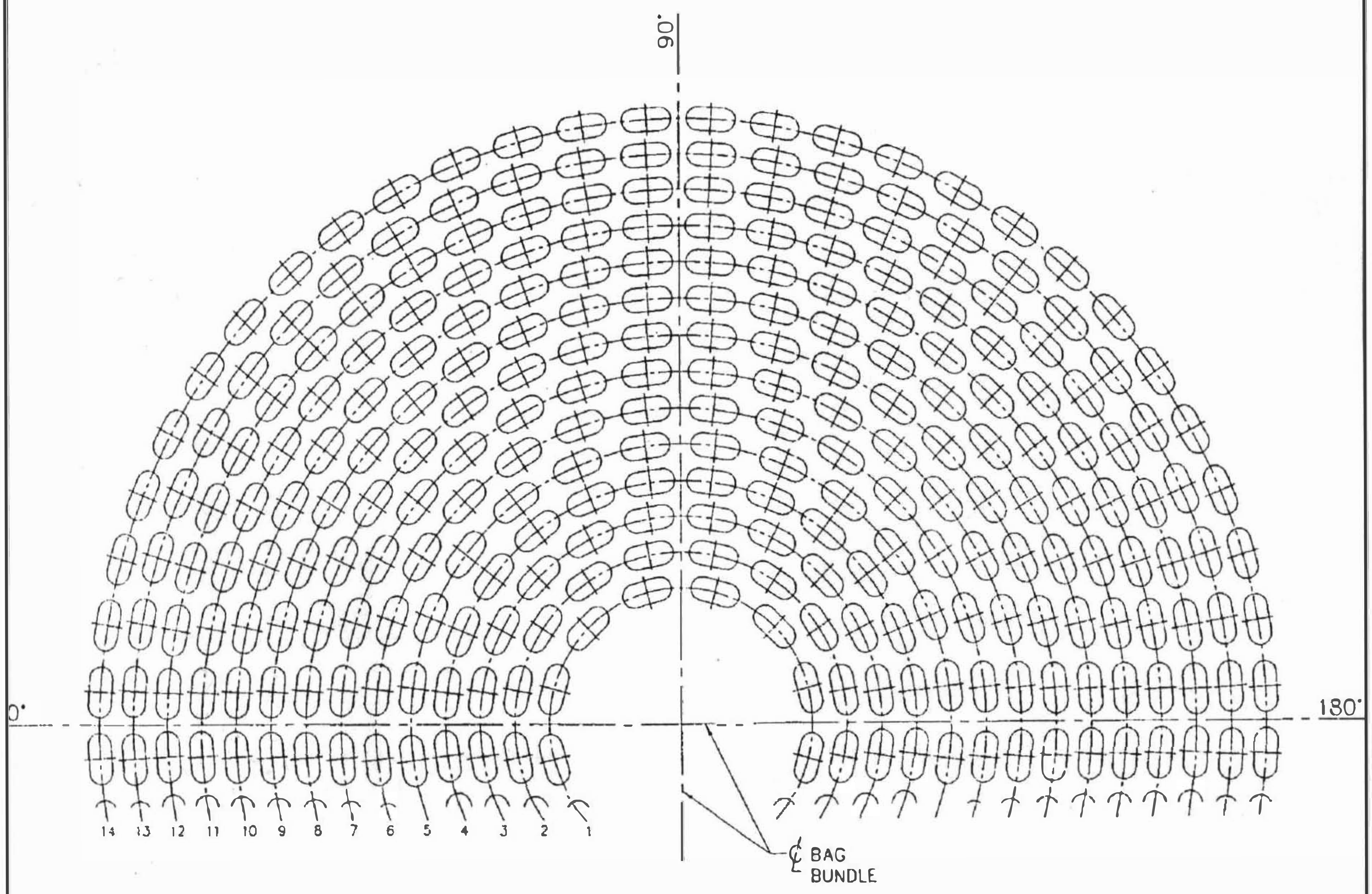

FIGURE 6: TYPICAL 14 ROW TUBESHEET

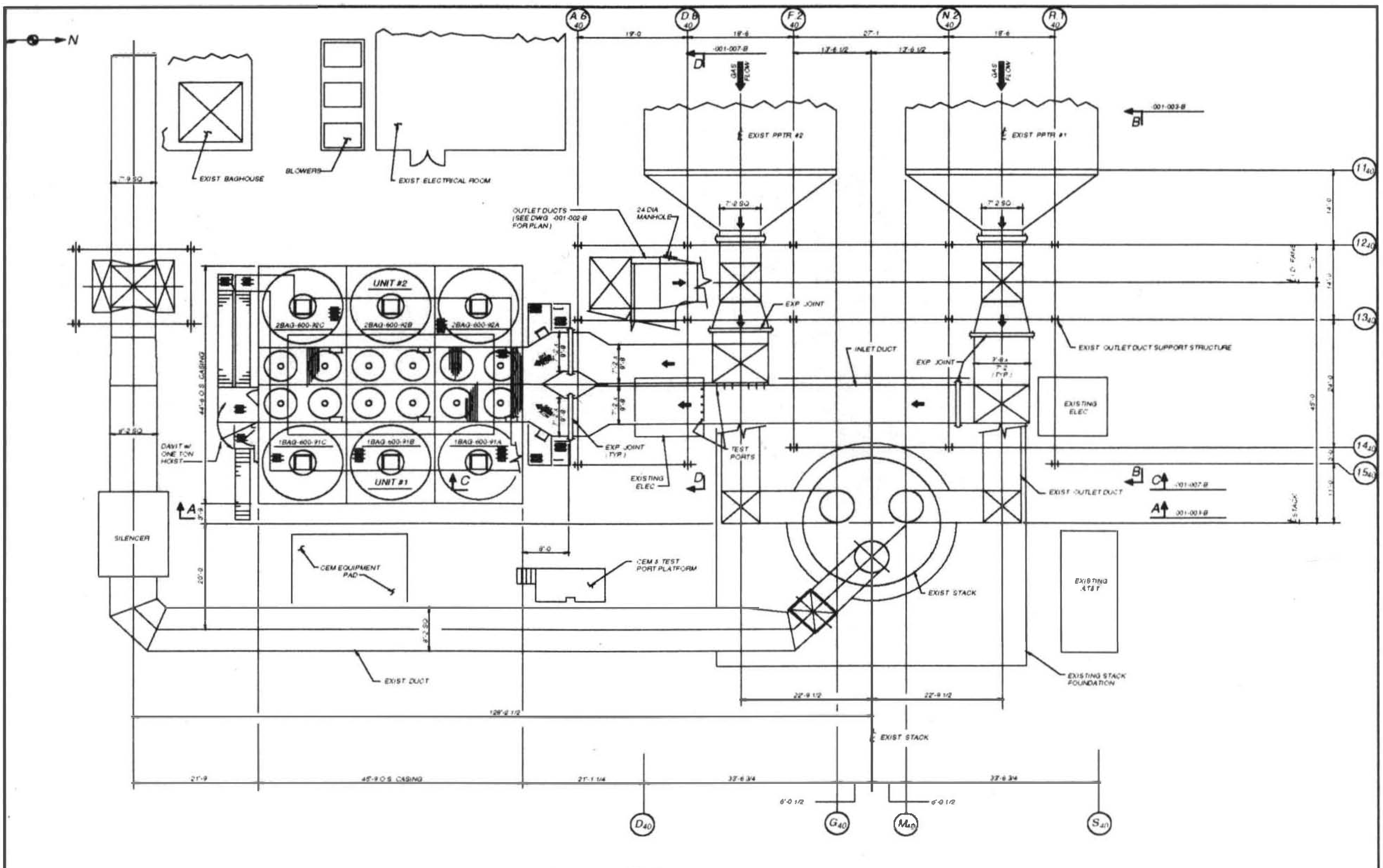

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FIGURE 7: FULL SIZE COHPAC LAYOUT FOR UNITS 1 AND 2

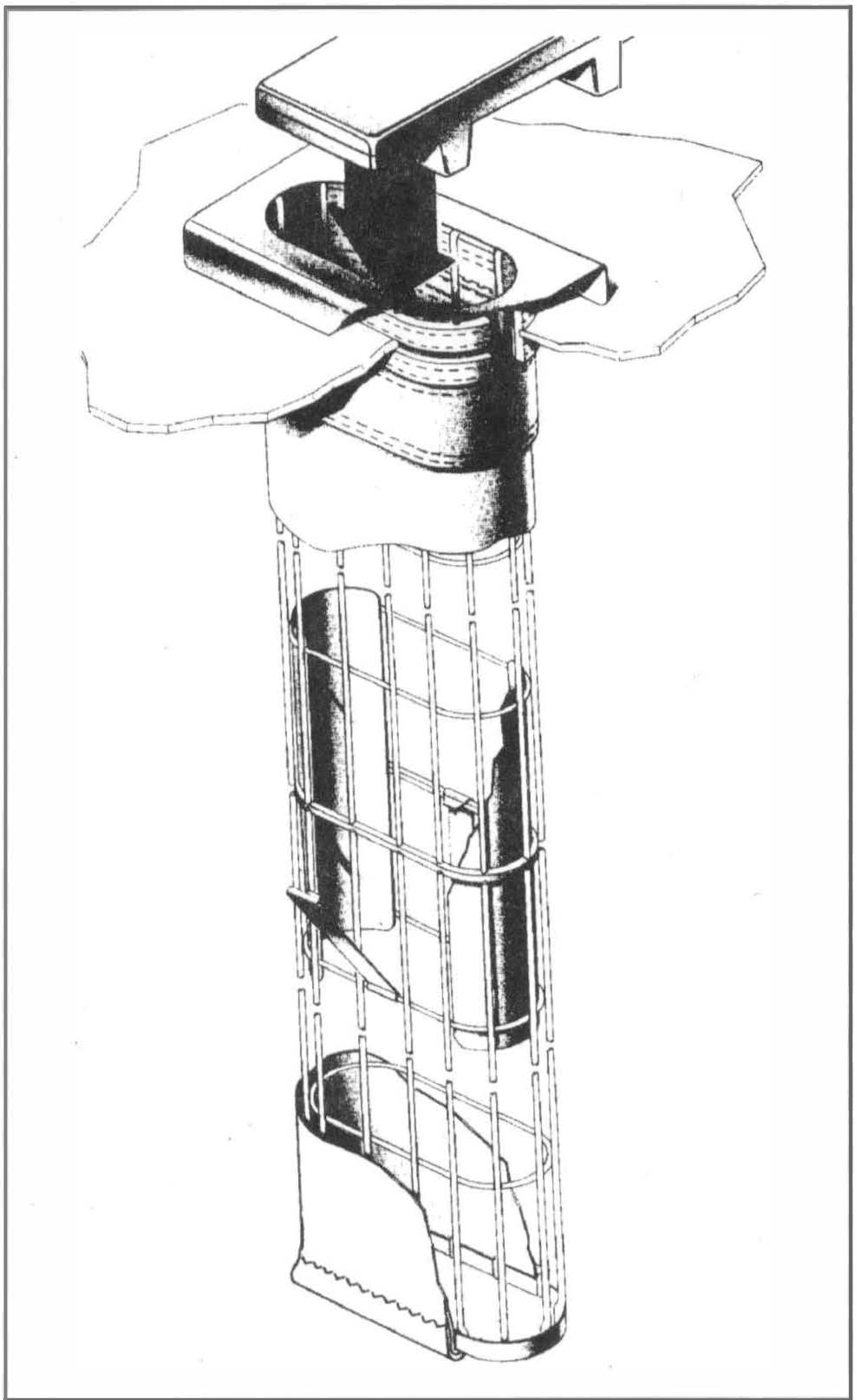

FIGURE 8: FILTER BAG AND CAGE ARRANGEMENT

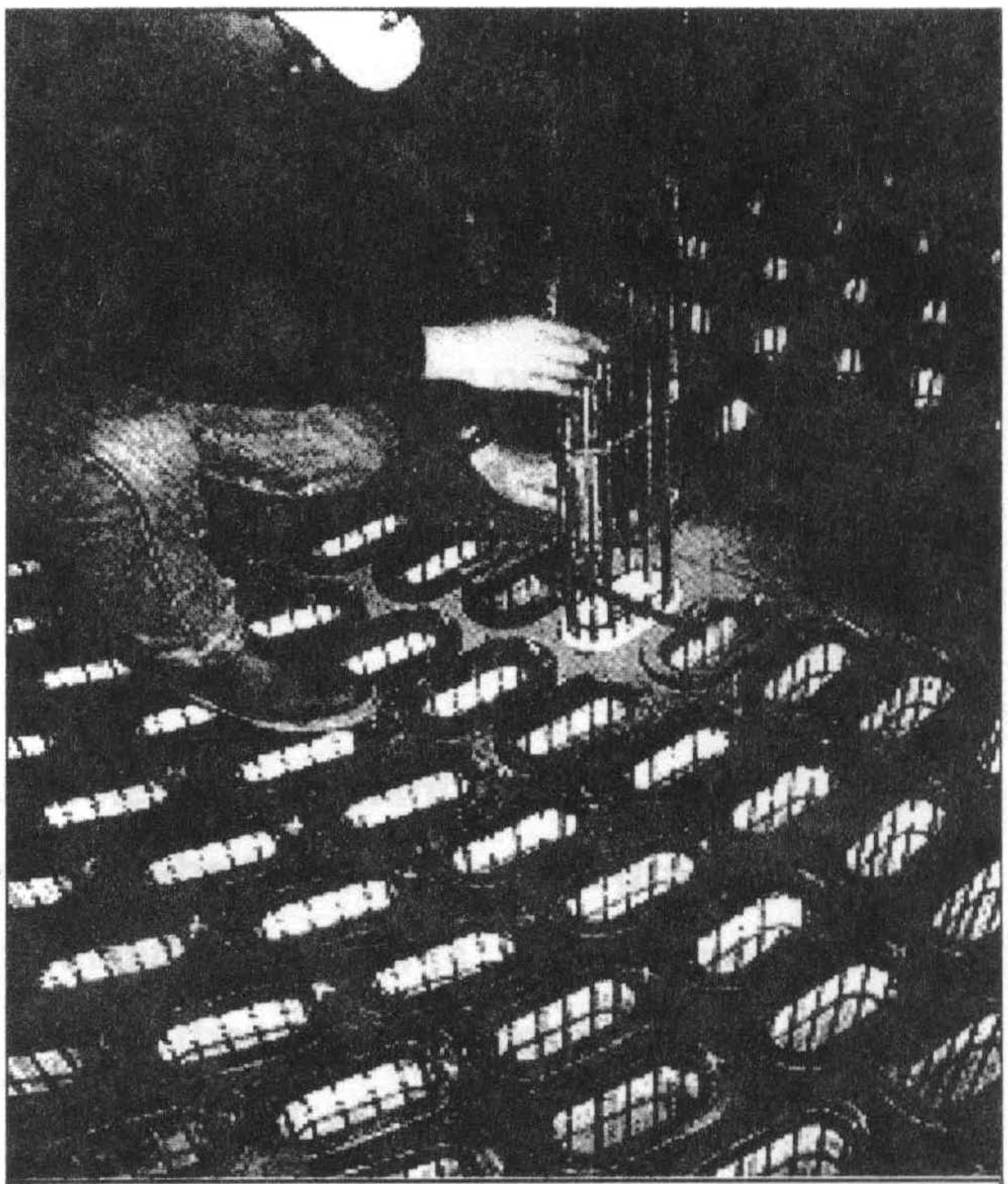

FIGURE 9: INSERTION OF TWO PIECE CAGE INTO BAG