KBN

October 12, 1992

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Division of Air
Resources Management

Mr. Clair H. Fancy, P.E.
Chief, Bureau of Air Regulation
Florida Department of Environmental Regulation
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Re: City of Gretna Waste-To-Energy Facility; FDER File No. AC20-212334

Dear Mr. Fancy:

On September 22, 1992, the City of Gretna (Gretna) and its representatives met with the Florida Department of Environmental Regulation (FDER) to discuss the Notice of Intent to Deny for the above referenced project. Based on this meeting and with the FDER's concurrence, Gretna is submitting additional information in order to satisfy the concerns of the FDER technical staff. Information is presented for each of the eight items listed in the Notice of Intent to Deny. Information is also presented for several additional items discussed at the meeting.

1. Significant Changes Made to the Original Application

As explained to FDER staff, KBN's approach to developing the emission rates presented in the original application for several pollutants was based on an emission level to avoid PSD review, even though the facility design is capable of achieving much lower emission levels. This approach is generally preferable to applicants in that it provides the least stringent permit requirements, while avoiding the level of analysis and review which would be required for a PSD permit. In retrospect, this approach was possibly not the best, in light of EPA's position on the PSD major source list categories and FDER's and the public's sensitivity to municipal waste combustor (MWC) facilities. Each pollutant is discussed in the following paragraphs in terms of the proposed revised emission rates and the rationale for meeting these rates.

It is emphasized that the facility design has not changed from the original application except in the case of nitrogen oxides; only emission rates have been revised to reflect more realistic maximum emissions. In the case of NO_x, a selective non-catalytic reduction (SNCR) system has been added to the facility design in order to achieve NO_x control.

Particulate Matter (PM)– The PM emissions in the original application were based on the most stringent emission standard applicable to the source, which is the Florida standard and the NSPS (40 CFR 60, Subpart E) of 0.08 gr/dscf. However, the spray dryer/fabric filter (SD/FF) technology to be employed at the facility can achieve much lower levels. This is documented in the NSPS for large MWC's (40 CFR 60, Subpart Ea), which sets an NSPS level of 0.02 gr/dscf based on the SD/FF technology. Indeed, new large MWC combustors are being permitted for PM emissions in the 0.01 to 0.015 gr/dscf

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range based on best available control technology (BACT). Therefore, Gretna has proposed a revised PM emission rate of 0.02 gr/dscf, which reduces emissions to well below 100 tons per year (TPY). The proposed technology is capable of achieving this level. See response under item 3 below for additional information.

Sulfur Dioxide (SO_2)-- The calculation of uncontrolled SO_2 emissions in the original application was in error, resulting in higher uncontrolled emissions (184.8 lb/hr) than those based on the sulfur contents of the fuels (125.0 lb/hr). In addition, a higher SO_2 control efficiency of 88% (as compared to 75% previously) has been used based on the SD/FF technology and United McGill's guarantee (see Attachment A). As in the case of PM, the SD/FF technology has proven capable of achieving this level of SO_2 control on MWC combustors. Based on these considerations, the proposed emission rate for maximum SO_2 emissions of 30.0 lb/hr and 65.7 TPY is considered to be readily achievable. Also, test data from RDF facilities, including the Dade County Resource Recovery facility, have shown that on average only half of the sulfur in the RDF is converted to SO_2 in the combustion process. The remaining sulfur is converted to sulfate salts and other compounds. Thus, we have some safety margin in the design of the control equipment. Finally, a continuous SO_2 monitor will be employed on the facility in order to demonstrate compliance with the SO_2 limits.

Nitrogen Oxides (NO_x)-- The original application estimates were based on an average uncontrolled NO_x level of 200 ppm. This design basis has not been changed. However, an SNCR system has been added to the design, at a basic equipment cost of approximately $357,000 dollars. The system will be designed to reduce NO_x emissions by up to approximately 60 percent, resulting in maximum annual average NO_x emissions of 0.18 lb/MMBtu, and 23.2 lb/hr on a 30-day rolling average. Vendor information from Nalco/FuelTech, one potential SNCR vendor, is included in Attachment A. A continuous NO_x monitor will be employed at the facility in order to demonstrate compliance with the NO_x limits.

It is also noted that Gretna is willing to further reduce its maximum annual operating hours to 7,920 hr/yr in order to provide greater assurance that the PSD review threshold level of 100 TPY will not be exceeded. This limitation results in maximum annual NO_x emissions of:

$$23.2 \text{ lb/hr} \times 7{,}920 \text{ hr/yr} / 2{,}000 \text{ lb/ton} = 91.9 \text{ TPY}$$

Carbon Monoxide (CO)-- CO emissions have been revised to more realistically reflect the actual expected emissions from the auger combustor unit. CO emissions are primarily a function of combustor efficiency. Based on the auger combustor design, which includes a high temperature afterburner designed for 2,000°F for 2 seconds, the combustion efficiency should be very high with resultant low CO emissions. Actual CO emissions are expected to be less than 100 ppm. The CO emissions from the facility were therefore revised to a maximum of 130 ppmv or 22.4 lb/hr. Based on the revised maximum operating hours, the maximum annual average CO emissions will be:

$$22.4 \text{ lb/hr} \times 7{,}920 \text{ hr/yr} / 2{,}000 \text{ lb/ton} = 88.4 \text{ TPY}$$

A continuous CO monitor will be employed at the facility in order to demonstrate compliance with the CO limits. This monitor will also be used by the plant operator to operate the auger combustor in the most efficient manner and to minimize emissions.

Dioxin/Furans– Emissions of this pollutant were revised to reflect the NSPS for large MWC combustor units, (i.e., 30 ng/dscm). Based on the auger combustor with afterburner design, and the SD/FF control system, this level should be readily achievable. The SD/FF system has been determined by EPA to be the best demonstrated technology for reducing MWC organic emissions.

FDER staff have also requested that additional information concerning the auger combustor design be submitted. Provided in Attachment B are several documents which provide this information. This includes the patents issued for the auger combustor; articles by Professor Alex Green and Robert E. Fitch; and a color picture of the auger combustor system that was set up as a prototype unit.

2. Market for Contaminated Recyclables

Gretna is willing to commit to a daily maximum combustion quantity (RDF + TDF) of 237.6 TPD and a maximum daily RDF combustion amount of 230.0 TPD. The following discussion is based on this maximum combustion quantity.

A wide range of variables are encountered in determining the processing capacity of this household-municipal-solid-waste-to-energy facility. Determination of the quantity of MSW to be received at this facility is highly dependent upon two primary factors:

1. Daily combustion quantity.
2. Quantity of recovered products marketed.

The quantity of recovered products marketed will be dependent upon the composition of the MSW received and the degree of recovery accomplished by hand-separation of said MSW. Since Gretna expects to obtain household MSW from both urban and non-urban sources, large variances in the composition of the MSW are expected. The degree of recycling to be implemented at these sources cannot be determined at this time; therefore, additional variances will be experienced.

Determination of the quantity of MSW to be received at this facility will not only be highly subject to and dependent upon the composition of the MSW received but will be dependent on the extent of the recyclable markets to be developed. Gretna believes that it has developed a market for the sale of all non-combustible recyclables to be recovered. However, it should be noted that this facility will have no desire to invest in the storage of large quantities of combustible recyclables that it cannot sell immediately. Therefore, the processing volume of this facility will be also be limited by the quantities of recyclables that can be immediately sold or combusted.

As an example, in the event only 50 TPD of recovered products can be sold on a daily basis, and in the event 12 TPD of material are returned to the landfill, and in the event 230.0 TPD are combusted, then the total flow-through volume will be limited to 292.0 TPD.

However, it should be noted that it is to Gretna's economic advantage to rapidly develop markets for the sale of the maximum quantity of recovered products.

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MSW COMPONENT CLASSIFICATION AND DISPOSITION

PAPER - Paper will be separated, classified, and baled in three major categories: Newspaper, Corrugated Paper, and Mixed Paper. Gretna is in receipt of preliminary sales/purchase agreements for approximately 100 TPD of recycled paper, of which CONFIDENTIAL copies are attached (see Attachment C).

METALS - Metals will be separated, classified, and placed in open-top containers in categories such as aluminum, copper, brass, ferrous, and non-ferrous metals for sale to out-of-state vendors. Gretna is in receipt of preliminary sales/purchase agreements for all metals to be recovered from this facility of which CONFIDENTIAL copies are attached (see Attachment C).

GLASS - Glass will be separated and classified by three major colors for placement in open-top containers for sale to local vendors. It is anticipated that portions of the glass will be sold as a concrete aggregate.

PLASTICS - Plastics will separated, classified, and baled in three major categories: PET (1), HDPE (2), and Mixed (all others). PET and HDPE may later require color classification. Founders of a proposed plastic recycling entity that will produce post-consumer plastic flakes and pellets have agreed in principle to purchase up to 25 tons per day of recycled plastics from this facility. This operation is anticipated to be completed during the first year of operation of the proposed facility. A certain quantity of plastic will be required to encapsulate flyash during the first year of operation for transfer to the local landfill.

WOOD - A small wood-yard chipping operation entity will be located adjacent to the proposed facility. All wood and yard waste will enter this facility where wood chips and ground bark will be produced for resale to the local paper companies and wood fuel users. All wood fines and residue as well as the majority of all yard waste will be utilized as RDF.

RDF - The RDF will be comprised of textiles, food waste, yard waste, wood, other inorganics, paper, plastics, and tires. (Please see the following projections and graphs.)

TIRES - Sufficient pollution control equipment has been included in the plant configuration to utilize recycled rubber tires as a supplemental fuel to provide up to 25 percent of the heat required for the boiler. However, it should be noted that tires are considered to be a supplemental fuel only which the Operator will utilize only on an "as needed" basis. Therefore, tires have not been included in the projected MSW composition calculations.

HOUSEHOLD HAZARDOUS - Household hazardous material to be received at the facility has been estimated to be less than two percent (2.0%) by weight of all MSW received. All hazardous material will be hand-separated, collected, weighed, and placed in open-top containers for later return to its originating source.

← Tires were part of MCFB combustion calcs. ?

How do they det. orig. source?

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MSW COMPOSITION ANALYSIS

Composition data referred to herein are based upon information obtained from Marion County, Florida. Although the composition of this data varies somewhat from data published in national publications, it is believed that with certain refinements and adjustments, such data can readily be utilized to demonstrate the concepts utilized to determine projected distributions and subsequent system design components.

Although total recycling efficiency will not be determined until the system becomes operational, after review of other similar operating entities Florida Reduction Corporation (the Operator) believes that it will be successful in implementing adequate hand-recycling techniques to achieve the following minimum levels of performance.

The efficiency of recycling or the degree of extraction of recovered products and the control of the RDF composition are key determining factors in the following analysis. Therefore it is believed that the proposed hand-separation system will yield the following minimum efficiencies and results.

Table 1 reflects the projected MSW composition versus the projected MSW distribution. MSW composition is based upon the Marion County analysis and is utilized to determine the projected distribution of each component of the MSW to be received.

The projected distribution of the MSW is classified into RDF, Recovery, and Landfill. Distribution percentages of each component are first determined and then said distribution percentages are utilized throughout the remaining analysis for varying quantities of MSW projected to be received.

Projected distribution obtained from Table 1 is summarized as follows:

	TPD	Percent
Components Recovered:	141.4	34.3%
RDF	230.0	55.8%
Components to Landfill:	40.9	9.9%
Total MSW Received:	412.1	100.0%

Table 2 is presented to demonstrate the change in distribution when approximately 75% of the paper products have been recycled or removed from the MSW before it is delivered to the facility.

Projected distribution from Table 2 is summarized as follows:

	TPD	Percent
Components Recovered:	89.9	31.5%
RDF	160.7	56.4%
Components to Landfill:	34.6	12.1%
Total MSW Received:	285.2	100.0%

The resultant percentages obtained for this configuration of MSW are then utilized to determine the total quantity of MSW required to generate 230.0 TPD of RDF for the auger combustion unit.

A similar analysis is used to demonstrate the effects of removing specific components of the MSW prior to delivery to the facility, with each result normalized for the receipt of 230.0 TPD of RDF.

A graphical summary is presented to demonstrate the quantity of MSW required when other MSW components are removed. All variances reflect quantities normalized to the receipt of a daily RDF of 230.0 TPD.

In the attached bar graph, each column reflects the projected balance of components of MSW to be received after the cumulative removal of each item.

It should be noted in the graph that removal of each specific component is cumulative. As an example, in the first column, entitled 412.4/None, non-recycled MSW is projected. However, in the second column, entitle 408.3/Paper, approximately 75 percent of all paper components have been removed and the total MSW received is normalized to yield 230.0 TPD of RDF. The next column, entitled 403.0/Aluminum, reflects a condition wherein the majority of the aluminum has been removed prior to delivery to the facility, etc...

Although the analysis is lengthy, in essence, the graphs reflect the quantity of MSW required to be received to provide the facility with a constant RDF quantity of 230.0 TPD.

<u>PROJECTED SOURCES OF MSW</u>
Although inter-local agreements have not been finalized at this point, nor can they be finalized until the air construction permits are issued by FDER, Gretna has offered to accept all Household MSW (approximately 80 TPD) generated in Gadsden County. Gadsden County tipping fees are presently $44.00 per ton. The operator has offered to accept up to 80 TPD of MSW from the City of Quincy at a rate of $35.00 per ton, with annual cost escalations of approximately five percent.

Therefore, in the event the State of Florida discontinues funding the counties with capital expenditures, it is believed that these counties cannot properly dispose of their MSW at rates as low as $35.00 per ton to be initially charged by Gretna. It should be noted that Gretna prefers to accept non-recycled MSW at the proposed facility.

It is believed that the proposed facility can readily provide MSW disposal services for at least six surrounding counties.

In the event that a sufficient quantity of MSW cannot be obtained from the local area, it has been determined that the economics of MSW at this facility will provide means for obtaining of MSW from more remote and southern locations within the State of Florida. It is anticipated that reciprocal agreements will be negotiated with all suppliers of MSW such that approximately 10 percent - 15 percent (by weight) of all MSW received by Gretna can be returned to the originating source.

It is believed that Gretna and/or the operator will be successful in obtaining sufficient quantities of MSW within the State of Florida to render this project economically feasible.

3. Air Emissions Equipment/Vendor Design Information

Gretna's August 5, 1992, submittal to FDER contained a letter from United McGill Corporation which guarantees the 0.02 gr/dscf PM emission limit can be met with a SD/FF system. Gretna is also considering using an existing Therm-O-Flex baghouse unit. The specifications for this existing unit are provided in Attachment A. It is noted that although this is an existing unit, new bags will be installed. Gretna will commit to using either the United McGill system, the Therm-O-Flex unit, or an equivalent system.

Information concerning the type of fans and fan curves is provided in Attachment D. There will be two forced-draft fans and one induced-draft fan. These fans will be of the centrifugal type, or equivalent. The forced-draft fans are to provide fresh air into the primary auger combustion chamber and the afterburner unit, and they are therefore located adjacent to these units. The induced-draft fan is located between the baghouse and the stack. Based on preliminary design specifications, the fan sizes are 20,000 acfm for the forced-draft fan to the primary chamber, 30,000 acfm for the force-draft fan to the afterburner unit, and 65,000 acfm for the induced-draft fan at the stack.

4. SO_2 and NO_x Continuous Emission Monitors

Gretna's August 5, 1992, submittal to FDER contained information from Thermo Environmental Instruments Inc., concerning a flue gas analyzer. This information is repeated in Attachment E. The Model D12000 In-Situ Stack Multigas Analyzer System can measure CO, NO_x, and SO_2 emissions, and is a standard application on incinerators. CO_2 can also be measured for combustion control. Analyzer specifications are also contained in Attachment E. Gretna will commit to using this analyzer, or an equivalent reference method analyzer.

5. Carbon Monoxide Continuous Emission Monitor

Gretna will commit to using the Thermo Environmental Model D12000 analyzer, or equivalent, for measuring CO emissions on a continuous basis.

6. NO_x Control System

As discussed under item 1 above, NALCO/Fuel Tech has guaranteed to meet the proposed NO_x emission level using the NO_xOUT process. The vendor information which supports this is contained in Attachment A. Gretna certifies that it will use this technology, or equivalent, to meet the NO_x emission level. The proposed maximum NO_x emission rate has now been reduced to 91.9 TPY.

7. MSW Weighing Equipment/Vendor Design Information

Fuel entering the combustor is fed through a batch weighing and control system which accomplishes two functions:

1. Create a consistent weight of each fuel charge fed to the combustor. The overall feed rate is then adjusted by changing the frequency of these charges.

2. Provide simple and precise measurement of the total fuel feed to the machine. Each individual charge of fuel to the combustor is counted, as is the cumulative weight of those charges.

These data are inputs to the distributed control system which accomplishes all control, alarm monitoring, data logging and reporting for the entire plant. The fuel feed rate would be constantly displayed to the operator, automatically printed on the hourly log as the present feed rate, and printed on the daily log as the average fuel feed rate for the day, and the exact cumulative total weight of fuel fed to the unit for that day. Historical archives in the control system could also be configured to store the daily totals, and keep a running total of fuel weight throughput for any extended time period.

The proposed weight scale is the Merrick System T Model 1411 (see Attachment F) which will be calibrated to ± 2.0 percent. Gretna's August 5, 1992, submittal to FDER had shown that the fuel input option B (shown in Figure 1 of the August 5 submittal and is repeated in Attachment F) will have a maximum fuel charging rate of 237.6 TPD. Therefore, 237.6 ±2.0 percent will be less than 250 TPD charging rate limit.

8. Lack of Mercury Emission Control

The application did not specifically discuss the control of mercury and air toxics. However, the proposed facility will employ the most advanced technology for control of almost all of these pollutants. The following design features of the project, which have not changed from the original application, will effectively control these pollutants:

- Front-end processing of MSW to produce RDF fuel is known to remove many of the metals, plastics, batteries and other materials which create toxic air pollutants in the flue gases. Toxic emissions from RDF combustors are known to be less than toxic emissions from mass-burn facilities.
- EPA has chosen the SD/FF control as the most effective method for the reduction of heavy metals from MWC unit flue gases, including mercury. The SD acts to remove some of the acid gas toxics, while also reducing the temperature of the gas stream. When the FF is operated below 300°F, the metals (including a significant portion of the mercury) condense out onto the fine PM in the gas stream. The FF system then provides the most effective means of removing fine PM from the gas stream. Gretna's FF will be operated at temperatures below 300°F.
- Based on the facility design, Gretna's proposed mercury emissions are very low. The proposed emission rate is actually based on the average of the actual mercury test data from the Palm Beach County resource recovery facility, which is an RDF facility with a SD/ESP control system. Gretna believes it can meet this average rate as a maximum limit because of the use of a FF in place of the ESP system. An ESP does not result in as effective fine PM control. The average emissions from the two Palm Beach County units was 0.000035 lb/MM Btu. This limit would be the lowest limit of any operating or permitted MWC unit in Florida.

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Further, the proposed emission rate is equivalent to approximately 27 μg/Nm³ (refer to Attachment G for calculations), and less than 30 lb/yr. This level is much lower than the permitted mercury emission rate for the Lee County facility, which was permitted at 140 μg/Nm³ and 660 lb/yr. The Lee County facility is a mass burn facility.

Because the proposed emission limit for Gretna is already very low, no further control technology is considered necessary. If necessary, based on stack testing after the facility becomes operational, Gretna will install a mercury control system or undertake other measures (i.e., battery recycling) necessary to meet the proposed emission limit.

FDER has indicated concerns in the areas of air emissions during emergency shutdown, ash management plan, and fugitive dust emissions due to truck traffic. These issues are addressed in the following:

Air Emissions During Emergency Shutdown

The auger combustor will be capable of spontaneous shutdown without resorting to bypassing the normal flow configuration. During emergency shutdown, fuel charging will immediately cease. The exhausts from the primary chamber and the afterburner unit will be isolated by shutting off the forced-draft fans to stop all combustion air flow which will prevent further combustion. As a result, no emissions will occur during emergency shutdown conditions.

Ash Management Plan

FLY-ASH--All fly-ash will be collected and stored in covered containers while on the premises. During the first year of operation, or until such time as the new outdoor product manufacturing entity is completed, it will be necessary for Gretna to encapsulate the fly-ash for disposal in the local landfill. After such time it is anticipated that all fly-ash will be consumed by said outdoor product manufacturing entity. It should be noted that it is anticipated that Gretna will be successful in negotiating reciprocity agreements for the return of certain quantities of fly-ash and bottom ash with the respective suppliers of MSW.

BOTTOM-ASH--All bottom-ash will be collected and stored in covered containers for later removal. All bottom ash will eventually be utilized as either a plastic and/or concrete material (filler) supplement. Approximately fifteen to twenty-five percent (by weight) of said ash may be utilized in the manufacture of concrete blocks and/or outdoor building products such as fence posts, car-stops, etc. It is anticipated that all bottom-ash will be utilized by either/or the concrete product manufacture or the plastic outdoor building product manufacturer after the first year of operation of this facility.

During the first year of operation, all ash collected will be encapsulated and disposed of off-site at the Quincy landfill. In the succeeding years, a portion of the total ash will be taken to a concrete plant or will be used as filler in plastic encapsulated structural products.

Fugitive Dust Emissions

The paved road and area on the proposed plot plan are shown in Attachment H.

They have already said That they would do Battery Recycling

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Both bottom ash and flyash will be collected into enclosed storage bins (large dumpsters). Prior to collection in the storage bins, all transferred processes are enclosed to minimized fugitive dust emissions. When each storage bin is filled, the bins are covered then moved by fork lift into a waiting area. The fork lift will be operated on paved roads only, between the bottom ash and flyash collection points (at the primary combustion chamber and the baghouse areas) and the waiting area.

Fugitive dust emissions from moving the ash storage bins are expected to be minimal. The storage bins will be enclosed; therefore, spillage of ash will not occur during the storage bin transferring process. Vehicular traffic will be confined to the paved surface; therefore, fugitive dust is not generated.

Gretna and its representatives look forward to meeting with the FDER on October 13th to discuss this information.

If you have any questions or comments on this submittal, please contact either me or Mr. Tai Tang of my staff at your earliest convenience.

Sincerely,

David A. Buff

David A. Buff, M.E., P.E.
Principal Engineer
Florida Registration 19011

SEAL

DAVID A. BUFF
CERTIFICATE NO. 19011
STATE OF FLORIDA
REGISTERED ENGINEER

DAB/dmpm

Enclosures

cc: Tai Tang
Harry Meshaw
John Mathews
Mayor Evelyn Rollins
Harold Knowles
Jewell Harper, EPA Region IV
Chris Shaver, NPS
File (2)

Both bottom ash and flyash will be collected into enclosed storage bins (large dumpsters). Prior to collection in the storage bins, all transferred processes are enclosed to minimized fugitive dust emissions. When each storage bin is filled, the bins are covered then moved by fork lift into a waiting area. The fork lift will be operated on paved roads only, between the bottom ash and flyash collection points (at the primary combustion chamber and the baghouse areas) and the waiting area.

Fugitive dust emissions from moving the ash storage bins are expected to be minimal. The storage bins will be enclosed; therefore, spillage of ash will not occur during the storage bin transferring process. Vehicular traffic will be confined to the paved surface; therefore, fugitive dust is not generated.

Gretna and its representatives look forward to meeting with the FDER on October 13th to discuss this information.

If you have any questions or comments on this submittal, please contact either me or Mr. Tai Tang of my staff at your earliest convenience.

Sincerely,

David A. Buff, M.E., P.E.
Principal Engineer
Florida Registration 19011

SEAL

DAB/dmpm

Enclosures

cc: Tai Tang
Harry Meshaw
John Mathews
Mayor Evelyn Rollins
Harold Knowles
Jewell Harper, EPA Region IV
Chris Shaver, NPS
File (2)

Table 1. MSW Composition Versus Projected Distribution

Component	Total MSW Received	Projected Distribution					
		Recovery		RDF		Landfill	
	TPD	TPD	%	TPD	%	TPD	%
Newspaper	44.5	17.8	40.0	24.5	55.1	2.2	4.9
Corrugated Paper	39.0	16.4	42.1	20.7	53.1	1.9	4.9
Mixed Paper	85.6	34.3	40.1	47.1	55.0	4.3	5.0
Aluminum	4.7	3.3	70.2	0.0	0.0	1.4	29.8
Glass	15.8	12.7	80.4	0.0	0.0	3.2	20.0
Plastics	54.8	27.4	50.0	24.7	45.1	2.7	4.9
Wood	21.4	12.8	59.8	8.1	37.9	0.4	1.9
Non-Ferrous Metal	5.1	3.1	60.8	0.0	0.0	2.1	41.2
Ferrous Metal	22.7	13.6	59.9	0.0	0.0	9.1	40.1
Food Waste	35.1		0.0	33.4	95.2	1.8	5.1
Yard Waste	36.4		0.0	34.6	95.1	1.8	4.9
Textiles	18.8		0.0	17.9	95.2	0.9	4.8
Other Inorganics	20.1		0.0	19.0	94.5	1.0	5.0
Household Hazardous	8.1		0.0		0.0	8.1	100.0
TOTAL	412.1	141.4	34.3%	230.0	55.8%	40.9	9.9%

Note: TPD = Tons Per Day.
(%) = Percent of Each Component Received.

Table 2. MSW Composition Versus Projected Distribution

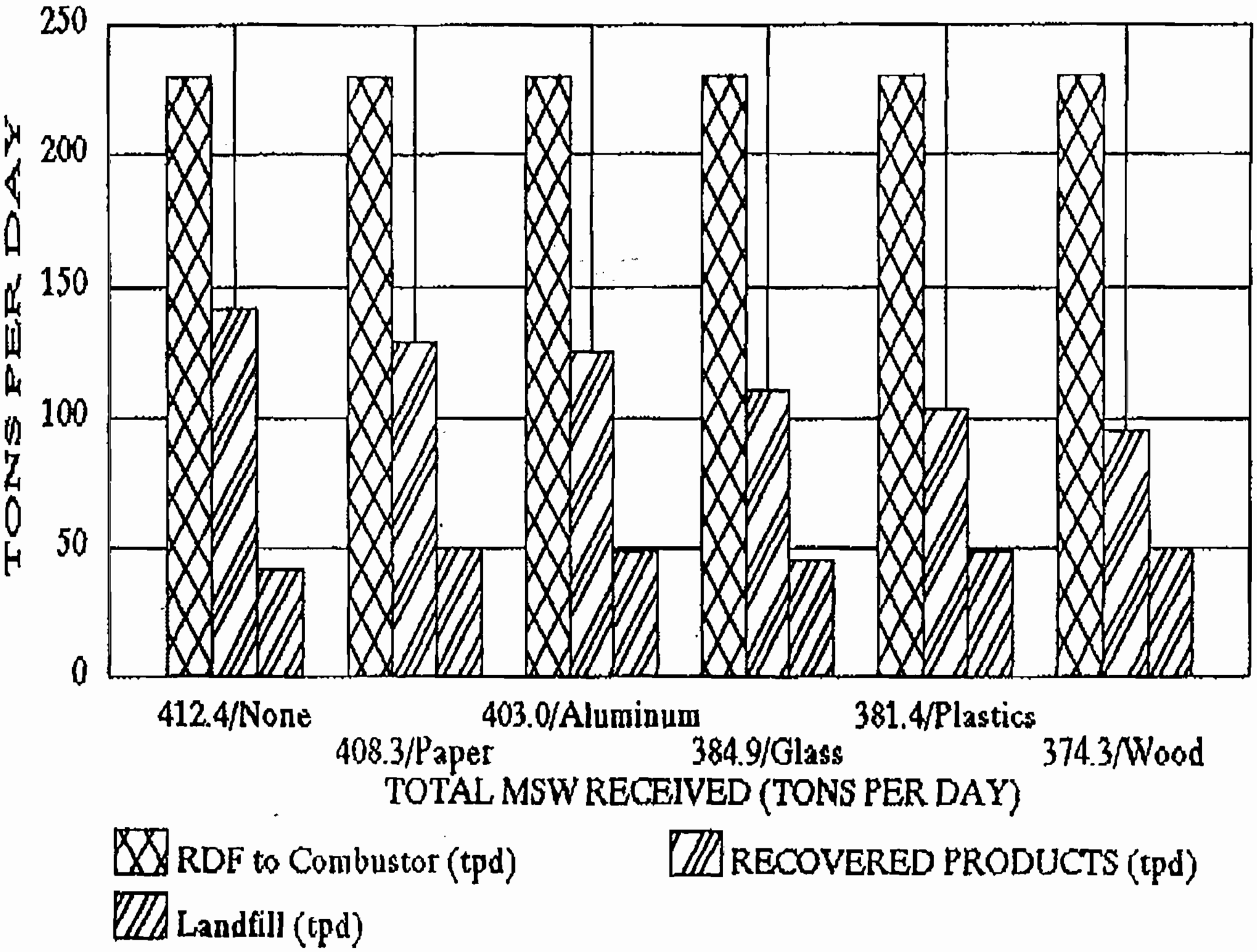
Component	Total MSW Received	Projected Distribution					
		Recovery		RDF		Landfill	
	TPD	TPD	%	TPD	%	TPD	%
Newspaper	11.1	4.4	40.0	6.1	55.0	0.6	5.0
Corrugated Paper	9.7	4.1	42.0	5.1	53.0	0.5	5.0
Mixed Paper	21.4	8.6	40.0	11.8	55.0	1.1	5.0
Aluminum	4.7	3.3	70.0	0.0	0.0	1.4	30.0
Glass	15.8	12.6	80.0	0.0	0.0	3.2	20.0
Plastics	54.8	27.4	50.0	24.7	45.0	2.7	5.0
Wood	21.4	12.8	60.0	8.1	38.0	0.4	2.0
Non-Ferrous Metal	5.1	3.1	60.0	0.0	0.0	2.0	40.0
Ferrous Metal	22.7	13.6	60.0	0.0	0.0	9.1	40.0
Food Waste	35.1	0.0	0.0	33.3	95.0	1.8	5.0
Yard Waste	36.4	0.0	0.0	34.6	95.0	1.8	5.0
Textiles	18.8	0.0	0.0	17.9	95.0	0.9	5.0
Other Inorganics	20.1	0.0	0.0	19.1	95.0	1.0	5.0
Household Hazardous	8.1	0.0	0.0	0.0	0.0	8.1	100.0
TOTAL	285.2	89.9	31.53%	160.7	56.34%	34.6	12.13%

Note: 75% Reduction In Paper Products Received.

TPD = Tons Per Day.
(%) = Percent of Each Component Received.

GRETNA WASTE TO ENERGY PLANT

MSW COMPOSITION versus PROJECTED DISTRIBUTION



Note: "X" AXIS REPRESENTS CUMULATIVE TONS RECEIVED PER DAY AFTER SPECIFIED ITEMS REMOVED EXTERNALLY PRIOR TO RECEIPT. amsw99e1

ATTACHMENT A

EMISSION CONTROL SPECIFICATIONS AND VENDOR'S GUARANTEES

United McGill
Corporation 1779 Refugee Road. P.O. Box 820, Columbus, Ohio 43216-0820, 614/443-0192, Fax: 614/445-8759

July 23, 1992

Engineered Systems and Equipment
P.O. Box 180517
Casselberry, FL 32718-0517

Attention: Jim Holloway

Subject: RDF & TDF Project in Gretna, FL

Dear Mr. Holloway:

In response to your request for guarantee information on the Florida Waste Reduction RDF - TDF Incineration project in Gretna, FL, we have outlined the emission limits that we would guarantee with our Spray Dry Scrubber - Fabric Filter System.

Inlet Conditions

Gas Volume=70,100 ACFM
Temperature=400°F
SO_2 Inlet=184.8 lbs/HR
HCl Inlet=50.4 lbs/HR

Guaranteed Emission Limits

SO_2 - 88% Removal or 50 PPM outlet, whichever is less stringent
HCl - 80% Removal or 50 PPM outlet, whichever is less stringent
Particulate - 0.02 Grs/DSCF Outlet

The above emission limits simply confirms that United McGill can achieve the requirements the customer presently has permitted with a Spray Dry Scrubber-Fabric Filter System. Please keep in mind, more stringent outlet emissions can be guaranteed with a Spray Dry Scrubber-Fabric Filter System if required.

Since the customer is considering using an existing Fabric Filter, there are a few things they need to keep in mind. First, the Fabric Filter needs to be sized properly. The approximate cloth area needed for this project would be around 20,000 ft^2. Other factors that effect sizing are cloth selection, particulate loading, and can velocity. The Fabric Filter should also have a bypass and have multiple compartments to allow for service of a compartment while the system is on line.

If there are any questions to above information, please do not hesitate to call.

Sincerely,

UNITED McGILL CORPORATION

Dan Grieshop

Daniel J. Grieshop
Sales Engineer
Air Pollution Control Group

DJG/mg
2130C

cc: E. Brabham/FF Correspondence
J. Childress

DATA SUMMARY FOR THE THERM-O-FLEX BAGHOUSE AND FILTER

Design Conditions	
Maximum Flue Gas Flow Rate	49,600 acfm
Total Filter Area	40,480 ft^2
Flow Rate/Filter Area Ratio	1.23:1
Maximum Outlet Dust Loading	0.02 gr/dscf
Therm-O-Flex Filter	
Series	8022
Number of Modules	5
Bags	
Total Quantity	880
Per Module	176
Material	Fiberglass, Teflon® coated
Diameter (inches)	8
Length (ft)	22
Air Flow Regulation	
Inlet	Butterfly (manual)
Reverse Air Valve	Air operated, solenoid controlled
Reverse Air Flow Control	Butterfly (manual)
Reverse Air Control	Butterfly, solenoid controlled
Timer	W.P. design
Hopper	Pyramid
Differential Pressure	Pressure gauge for each module
Recording Equipment	Bailey point round chart, temperature

NALCO FUELTECH
Technology for a renewed environment ™

NALCO FUEL TECH
PROPOSAL NO. 92-C-144

FOR

KBN ENGINEERING
GADSEN COUNTY PROJECT

SEPTEMBER 30, 1992

NALCO FUELTECH
Technology for a renewed environment ™

KBN Engineering
Gadsen County Project

September 30, 1992
Proposal #92-C-144

PROCESS DESIGN TABLE

No. Units	One (1)
Type	Waste Combustor
Fuel Fired	RDF
Fuel Analysis	
Component	
	%By Weight
Moisture	29.84
Noncombustibles/Ash	12.48
Carbon	29.41
Hydrogen	6.91
Oxygen	20.43
Nitrogen	0.46
Sulfur	0.21
Heating Value Btu/lb, Design HHV	6000
Heat Input From Fuel	128×10^6
Uncontrolled NOx	245 PPMVD @7%O_2
	0.45 #/mmBtu
	58 #/hr
Percent NOx Reduction	50
Controlled NOx	98 PPMVD @7%O_2
	0.18 #/mmBtu
	23 #/hr
Flue Gas Temp. @ Injection*	1900-2000°F
Estimated NOxOUT A Flow GPH	13.7

*Process engineering has calculated that for optimum performance of the NOxOUT Process at this temperature, the outlet duct should be 84"ID x 26' long.

NALCO FUEL TECH SCOPE OF SUPPLY

1 NOxOUT A storage tank, 6,000 gallon nominal capacity fourteen days storage.

1* Circulation Module (SLP3-C) with redundant pump

1* Mixing/Metering Module (SLP3-M-RP) with redundant pump

1* Distribution Module (SLP3-D-3)

3* Injectors

Engineering

NFT will provide process engineering and the following drawings and information:

- P&ID
- Skid arrangements
- Foundation loads
- Tank arrangement
- Interface drawings
- Injector locations
- Electrical drawings and bill of materials
- Pump performance curves
- O&M manuals

*See specification sheets for details

The circulation, metering and distribution modules will be skid mounted with all equipment, piping, instruments, electrical and controls shop assembled. Installation by others will require interconnecting mechanical and electrical. Size, weight and electrical requirements are specified on the equipment specification sheets.

All control devices require field installation.

COMMERCIAL TERMS AND CONDITIONS, P.2

Performance Guarantee

All guarantees or warranties granted in this proposal shall be contingent upon the buyer fully providing all buyer services and materials.

Nalco Fuel Tech guarantees as follows:

> This performance guarantee will be extended when the system is operated in accordance with the conditions specified in the process design table included in this proposal, including an uncontrolled NOx emission not to exceed 0.45 lbs per mmBtu heat input.
>
> Nitrogen oxide, maximum emission, (calculated as NO_2) shall not exceed 0.18 lbs per mmBtu heat input.
>
> Ammonia slip will not exceed 10 ppm above baseline, calculated at 7% oxygen.

Other specifics of this guarantee are included in Section Three of the Site License Agreement included as part of this proposal.

ATTACHMENT B

ADDITIONAL INFORMATION ON THE AUGER COMBUSTOR SYSTEM

United States Patent [19]

Tyer et al.

[11] **4,009,667**

[45] **Mar. 1, 1977**

[54] **INCINERATOR FOR COMBUSTIBLE REFUSE**

[76] Inventors: **Robert C. Tyer**, 7254 Old Plank Road, Jacksonville, Fla. 32205; **Larry C. Bruce**, 1800 Kingsley Ave., Orange Park, Fla. 32073

[22] Filed: **May 5, 1975**

[21] Appl. No.: **574,706**

[52] U.S. Cl. .... **110/8 A; 110/8 C; 110/110; 110/165 R; 165/87; 110/10**

[51] Int. Cl.² **F23G 5/12**

[58] Field of Search .... 110/7 R, 8 R, 10, 14, 110/110, 165 R; 165/87

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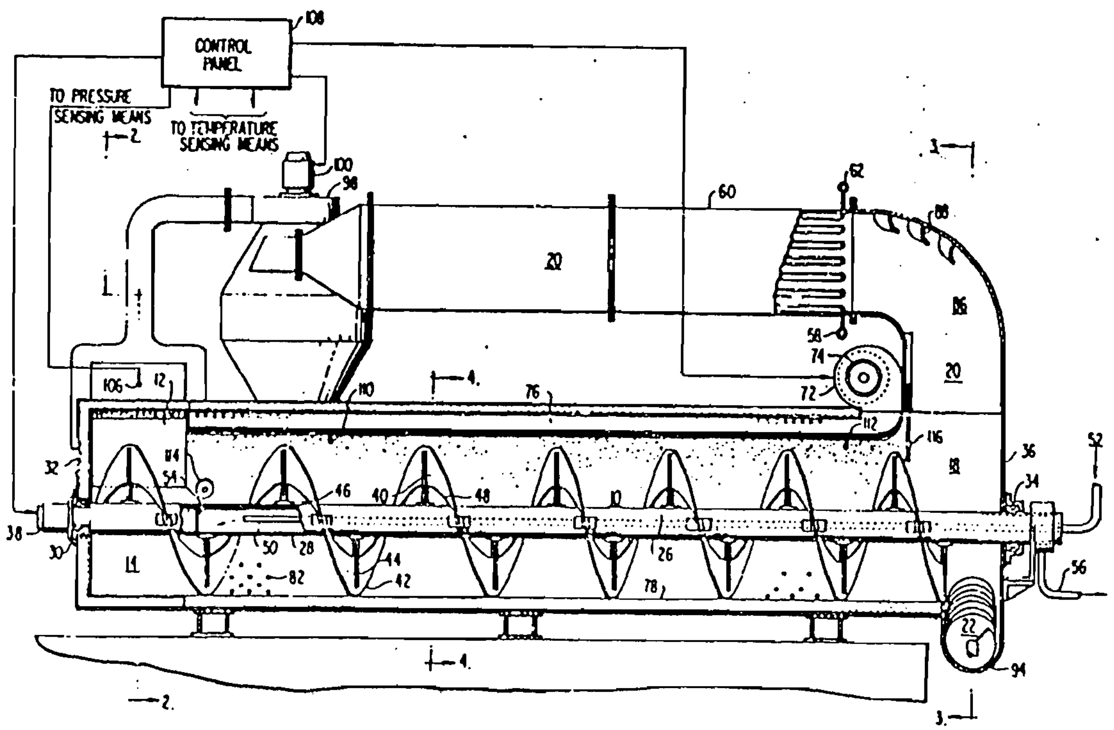
Primary Examiner—Kenneth W. Sprague
Attorney, Agent, or Firm—Edwin E. Greigg

[57] **ABSTRACT**

An incinerator having a variable speed auger to continuously feed refuse into and through a combustion chamber and into a water filled ash receptacle. Preheated combustion air is supplied through tangential openings in and along the combustion chamber walls, with the hottest air supplied at the combustion chamber inlet. The auger has a water cooled hollow shaft and a heat resistant flight concentrically spaced away from the auger shaft by support members. The pitch of the auger flight gradually decreases from the inlet end to the discharge end of the combustion chamber. The exhaust gases pass through heat exchangers and dust collectors before being emitted from the incinerator. A portion of the exhaust gas is recirculated by a blower to an air curtain in the front of the inlet unit to preheat the entering refuse.

21 Claims, 6 Drawing Figures



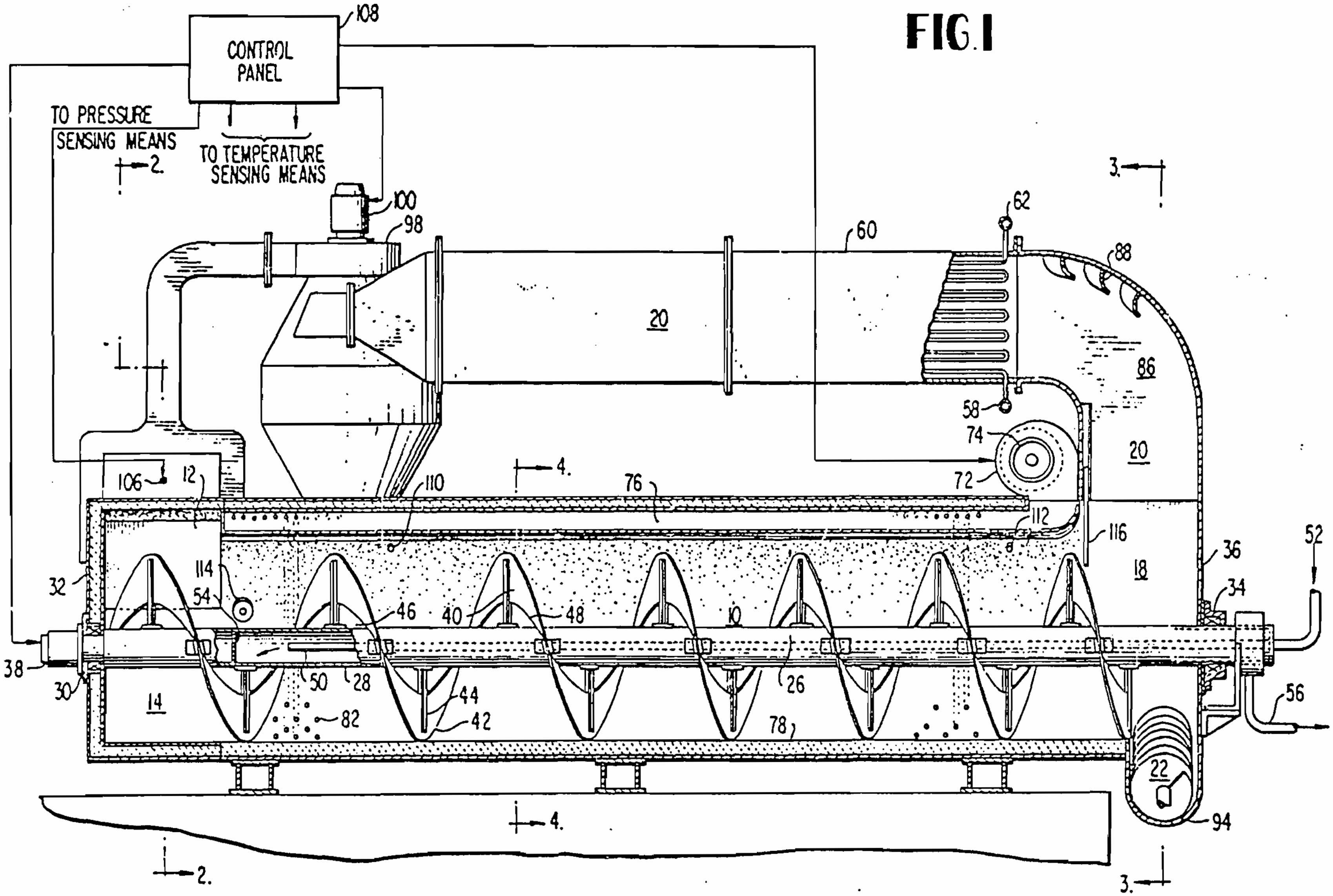
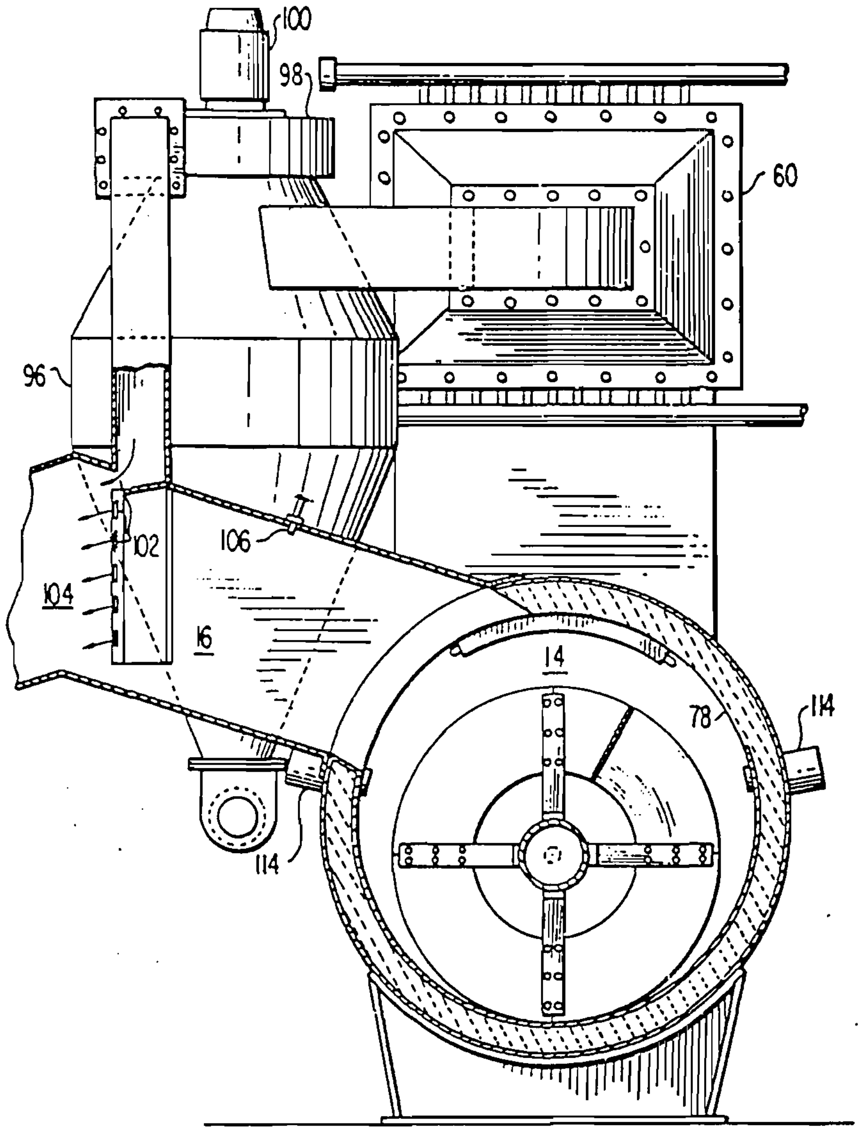

CONTROL PANEL
TO PRESSURE SENSING MEANS
TO TEMPERATURE SENSING MEANS
108
100
98
60
62
88
86
20
58
74
72
110
76
112
116
106
12
114
54
46
40
48
10
36
34
52
32
38
30
50
28
26
14
82
44
42
78
56
22
94
18
2.
3.
4.

FIG. I

FIG.2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60
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106
104
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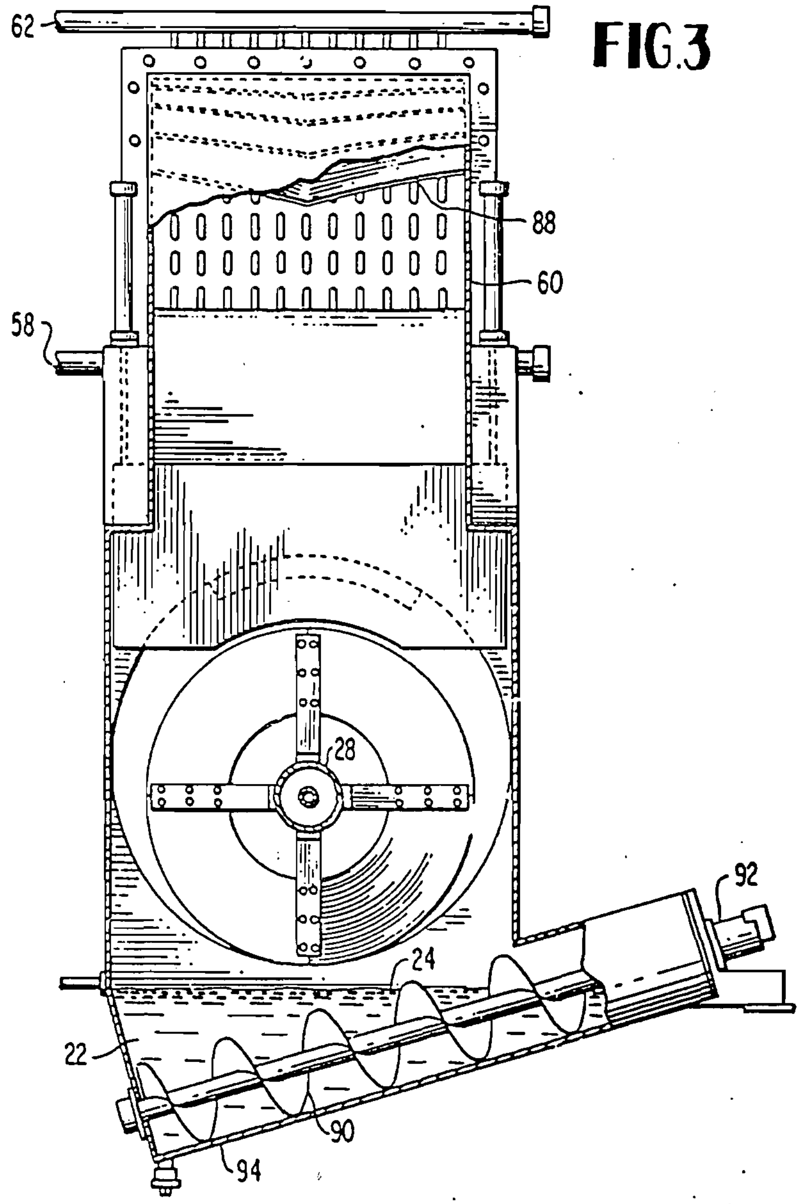
78
114
114

FIG.3


62
88
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58
28
92
24
22
90
94

FIG.4

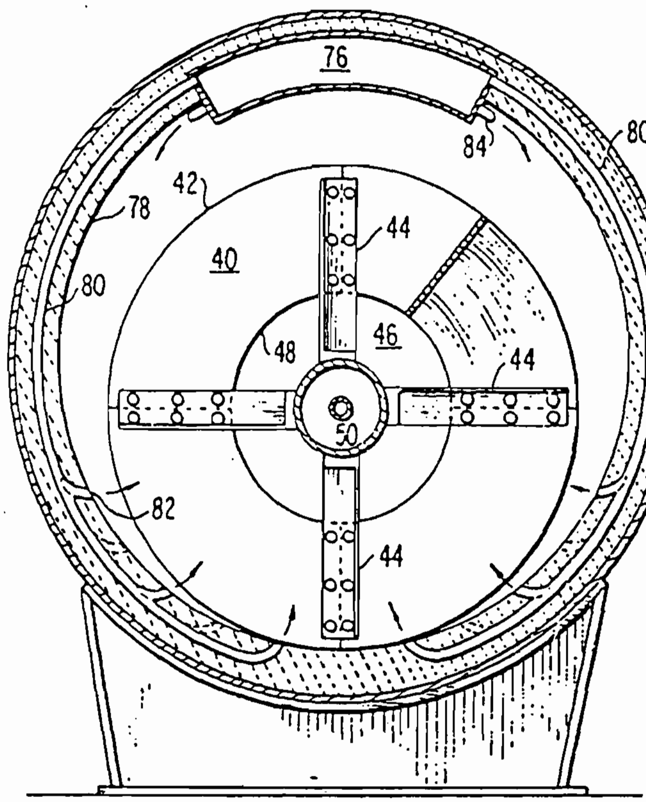


FIG.5

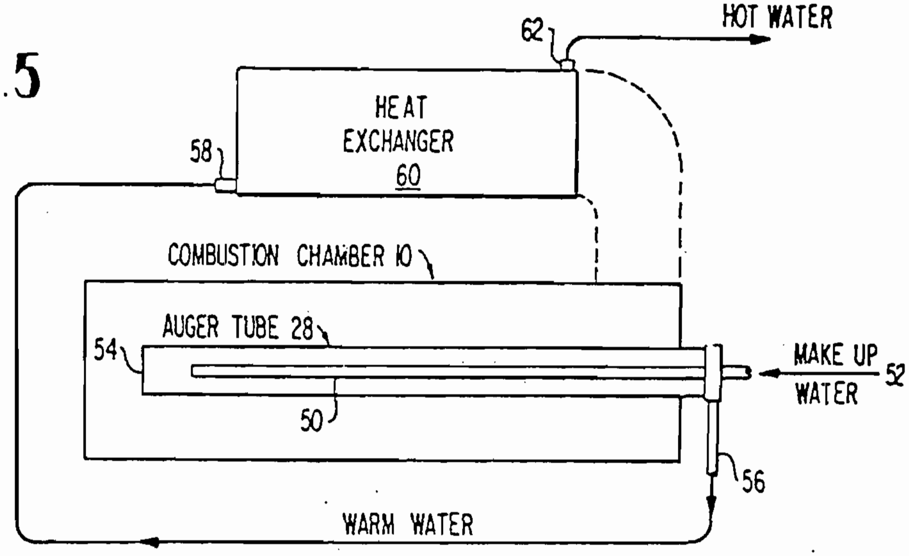
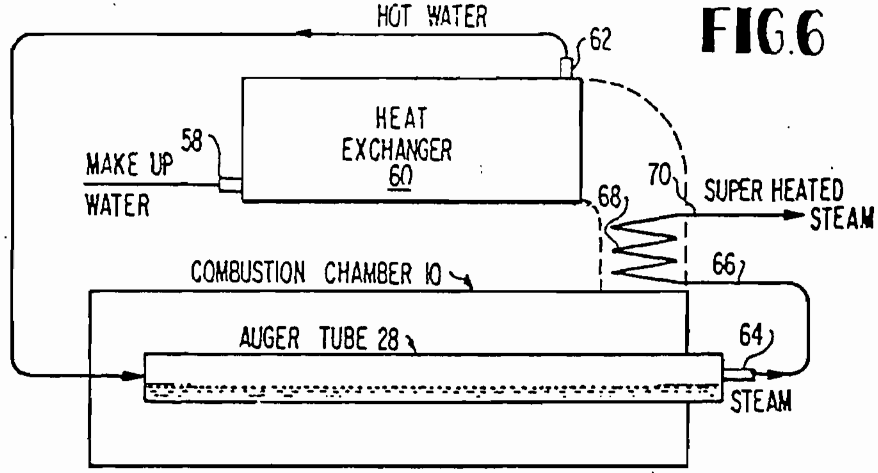


FIG.6



INCINERATOR FOR COMBUSTIBLE REFUSE

BACKGROUND OF THE INVENTION

The invention relates generally to incinerators, and more particularly to continuous controlled movement of combustible refuse into, and through, a combustion chamber by a rotating auger conveyor.

The use of an auger to convey combustible refuse through the combustion cycle results in very accurately controlled movement of refuse through the combustion chamber, in comparison to presently used rotary kiln incinerators. However, if the auger flight is integral with the auger shaft, with no spacing between them, the passage of air through the refuse is restricted, and it is necessary to introduce air into the combustion chamber through the auger shaft and/or auger flight. Also, it is necessary to supply cooling means for the auger flight as well as for the auger shaft. As a result, this type of auger is expensive to manufacture, requiring much welding, and equally expensive to repair or replace parts.

The auger construction used in the present invention overcomes these disadvantages by incorporating an annular space between the auger shaft and auger flight. Thus air can move freely in the combustion chamber except for the space occupied by the auger shaft, and air can be introduced solely through the combustion chamber walls rather than through the auger shaft and flight assembly.

With such an arrangement, the auger flight can be very simply constructed of single sheets of heat resistant material, requiring little or no welding. Different materials can be used for various sections of the auger flight to correspond to the heat to which the auger flight will be exposed in that section of the incinerator. The placement of a section of the auger flight is also made correspondingly easier and less expensive.

Therefore, one object of the present invention is to provide an incinerator which includes a rotatable conveyor having spiral flights to continuously feed refuse into and through the combustion chamber wherein complete combustion can be effected without the need of supplying air through the rotatable conveyor shaft or spiral flights.

It is a further object of this invention to provide an incinerator with a rotatable conveyor having spiral flights, which flights are of simple construction and do not require a cooling means for normal operation, and which can be easily repaired or replaced.

A still further object of this invention is to provide a means for preventing smoke and combustion gases from being emitted from the open inlet to the combustion chamber of this incinerator.

Yet another object of this invention is to provide a means of selectively pre-heating combustion air admitted to the combustion chamber, so that the hottest air is admitted at the inlet end of the chamber to quickly heat incoming refuse, and cooler air is admitted to the exhaust end of the chamber to effect more complete combustion.

Still another object of this invention is to provide a means for moving the combustible refuse through the combustion chamber at a slower rate at the outlet end of the chamber than at the inlet end of the chamber, to effect better combustion of particulate smoke at the outlet end of the chamber, and to compensate for the reduction in volume of the refuse during combustion.

BRIEF SUMMARY OF THE INVENTION

The incinerator for burning combustible refuse disclosed herein has a horizontally disposed stationary cylindrical combustion chamber. Refuse is introduced into an inlet portion of the incinerator from a feed hopper, and conveyed through the furnace by a rotating auger, which also conveys the residue remaining out the other end of the combustion chamber, where it drops into a water filled ash receptacle. The cooled residue is then removed from this ash receptacle by a helical screw mechanism for disposal elsewhere.

Air for combustion is supplied by a fresh air inlet blower through a hot air manifold extending substantially the length of the combustion chamber and forming a top inner portion of the combustion chamber wall. The bottom wall of this hot air manifold is uninsulated to effect good heat transfer from the combustion chamber to the air flowing in the manifold. The air is introduced into the lower part of the combustion chamber through hot air pipes spaced uniformly along both sides of the manifold, and extending around the combustion chamber to randomly spaced openings in the lower part of the combustion chamber, with each hot air pipe connected between the manifold and one air inlet opening.

Air for combustion is also introduced into the top of the combustion chamber through uniformly spaced openings along both vertical sides of the hot air manifold which project downward into the combustion chamber. This air is introduced tangentially to the inner wall of the combustion chamber and is directed downwardly by the curvature of the wall to effect good mixing of air with the refuse. Also, this air flow prevents refuse from sticking to the top inner sides of the combustion chamber.

Air supplied by the fresh air inlet blower enters the hot air manifold near the exhaust end of the combustion chamber, and is heated as it flows counter to the travel of the refuse which is introduced at the inlet end of the combustion chamber. Thus, while approximately equal volumes of air are supplied along the length of the combustion chamber, the hottest air is supplied to the inlet end, and the coldest and densest air is supplied near the outlet end of the combustion chamber. The hot air supplied at the inlet end quickly heats the incoming refuse; the cooler, denser air supplied at the outlet end supplies more oxygen to effect total combustion and prevent emission of smoke.

The helical shaped auger flight is disposed concentrically about a supporting water cooled hollow shaft extending the length of the combustion chamber, and is spaced from the shaft by support members at uniform intervals along the shaft. This open area between the auger flight and the auger shaft allows air to circulate more freely, both radially and longitudinally.

The auger shaft is positioned rotatably and off-center from the longitudinal axis of the combustion chamber toward the bottom of the combustion chamber. This positions the outer edge of the auger flight very close to the bottom of the combustion chamber, so that essentially all of the refuse is moved through the combustion chamber, and none drops to the bottom and remains there. Also, this off-center placement of the auger shaft creates space between the auger and the top inner side of the combustion chamber to allow combustion gas to flow freely to the other end.

The pitch of the auger flight is varied from a maximum at the inlet end to a minimum at the outlet end of the combustion chamber, to compensate for the decrease in volume of solid particulate matter throughout the length of the combustion chamber as the refuse is burned.

The hollow auger shaft is cooled by passing water through it, in either a single or a double pass arrangement. In the double pass arrangement the hollow auger shaft contains a concentric pipe or smaller diameter extending the length of the combustion chamber. Cold water enters through the smaller pipe, flows the length of the combustion chamber, and then flows back to the same end as it entered in the annular space between the two pipes. The hot water leaving the auger shaft is then passed through a heat exchanger disposed in a passage for exhaust gases from the combustion chamber where this water is further heated and the exhaust gases are cooled.

Alternatively, where a supply of steam is desirable, a single passed arrangement of cooling water through the auger shaft can be used. Cold water is first passed through the above mentioned heated exchanger in the exhaust gas passage, and then introduced into one end of the hollow auger shaft. Saturated steam is then drawn out of the other end of the auger shaft and passed through a superheater coil in the exhaust gas passage disposed between the first mentioned heated exchanger and the combustion chamber, to superheat the steam. The exhaust gases leaving the above mentioned super-heater are passed through a centrifugal dust collector before being exhausted to the atmosphere.

A portion of the exhaust air leaving the dust collector is diverted by a blower to an air curtain located in the refuse feed hopper, creating an air pressure therein sufficiently high to prevent the flow of combustion air or gases out of the inlet side of the combustion chamber. At the same time, this hot exhaust gas pre-heats the refuse entering the incinerator.

Variable speed drives, such as hydraulic motors, or DC electric motors, are used as the drive means for the auger, the fresh air inlet blower, and the exhaust air blower. In operation, the speed of the auger drive motor can be controlled in dependence on the temperature sensing means located near the exhaust end of the combustion chamber, to assure complete combustion of the refuse. Likewise, the output of the fresh air inlet blower can be varied by varying the speed of its drive motor in dependence on a temperature sensing means located near the inlet end of the combustion chamber to assure that the air entering the combustion chamber at that point has been properly pre-heated in the hot air manifold. Since the exhaust air blower operates to oppose the pressure produced by the fresh air inlet blower, its speed can be varied the same as the fresh air inlet blower. Alternatively, the output of the exhaust air blower can be controlled in dependence on a directional air pressure sensing means disposed in the inlet hopper between the air curtain and the inlet section of the combustion chamber to increase the output to the exhaust air blower whenever reverse flow of air through the inlet hopper is sensed.

For start up of this incinerator, all fired igniters are disposed in the combustion chamber walls near the inlet combustion chamber to start the combustion of the refuse. Also during start up, a movable plate vertically disposed between the combustion chamber and the passage for exhaust gases, can be lowered to partially block passage of exhaust gases from the combustion chamber, thereby retaining heat in the combustion chamber to shorten the start up period.

These and other objects of the present invention will become more apparent to those skilled in the art from the following more detailed description and study of the appended drawings herein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of the incinerator with parts of the combustion chamber and exhaust passage being shown broken away to show other parts in detail;

FIG. 2 is a cross-sectional end view of the inlet end of the incinerator taken along lines 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view of the exhaust end of the incinerator, taken along lines 3—3 of FIG. 1;

FIG. 4 is a cross-sectional view of the combustion chamber, taken along lines 4—4 of FIG. 1;

FIG. 5 is a water flow diagram for a double pass cooling arrangement for the auger tube; and

FIG. 6 is a water flow diagram for a single pass cooling arrangement for the auger tube used for steam generation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIGS. 1–3 show a horizontally disposed stationary cylindrical combustion chamber 10 having an opening 12 in the inlet section 14 through which combustible refuse is fed from a feed hopper 16. The outlet section 18 has an upward-extending passage 20 for exhaust gases and a downward extending section defining an ash receptacle 22 which is filled with water to a predetermined level 24. Extending the length of the combustion chamber is a rotatable auger 26 having a tubular axis 28 supported at the inlet end 14 by bearing 30 mounted to the front wall 32 and at the outlet end 18 by another bearing 34 mounted to the rear wall 36, and driven by an hydraulic motor 38. The spiral flight 40 of the auger 26 extends from the front wall 32 to the ash receptacle 22, so that when the auger 26 is rotated, the auger flight 40 will convey combustible refuse entering from the feed hopper 16 through the combustion chamber 10, and deliver the solid residue to the ash receptacle 22. As can be seen in FIG. 1, the pitch of the auger flight 40 is greatest at the inlet section 14, and becomes gradually less toward the outlet section 18, to compensate for the reduction in volume of the refuse which takes place during combustion. The tubular axis 28 is positioned off center of the axis of the combustion chamber 10 so that there is minimum clearance between the outer edge 42 of the auger flight 40, to assure movement of essentially all of the refuse through the combustion chamber 10.

As shown in FIG. 1, the auger flight 40 is comprised of individual segments which are joined together and concentrically spaced from the tubular auger shaft 28 by a plurality of support members 44, so that an open annular space 46 is formed between the inner edge 48 of the auger flight 40 and the auger shaft 28. This open space 46 allows air to freely move upward through the combustion chamber 10 as well as along the auger shaft 28 to the outlet section 18. Different materials having different heat resistant characteristics can be used in forming these sections of the auger flight 40. For example, in the inlet portion, where there is little heat, carbon steel could be used, while stainless steel or a refractory alloy could be used in the rest of the combustion chamber 10.

The tubular auger shaft 28 is water cooled and the advantages of this type of construction will be now described. FIG. 1 shows an incoming water pipe 50 concentrically mounted within the tubular auger shaft 28 and connected to a source of cooling water 52. Water flows through this water pipe 50 the length of the combustion chamber 10, then reverses direction by reason of the baffle 54 and flows back and out the same end of the shaft 28 through the water outlet pipe 56. This water outlet pipe 56 connects to an inlet 58 of a heat exchanger 60 disposed in the exhaust gas passage 20, as shown in the water flow diagram of FIG. 5. After being further heated in this heat exchanger 60, the hot water is removed for use or storage elsewhere through a hot water pipe 62.

FIG. 6 shows an alternate cooling water arrangement that can be used where a source of steam is desired. In this alternate arrangement, cool water first enters the heat exchanger 60 through the inlet 58, flows out of the heat exchanger 60 through outlet pipe 62 which is connected to the end of the tubular auger shaft 28 at the end of the incinerator. In this arrangement, the inlet pipe 50 and the baffle or blocking partition 54 are omitted. Steam is generated from the hot water entering the tubular auger shaft 28, and is drawn off at a steam outlet 64 on the exhaust end of the shaft 28, which is connected to an inlet 66 of a steam superheater coil 68 disposed in the exhaust gas passage 20 between the exhaust end of the combustion chamber 10 and the heat exchanger 60. The dry steam flows from the superheater coil 68 through an outlet 70 for use elsewhere.

Combustion air is supplied to the combustion chamber 10 by a fresh air inlet blower 72 driven by a hydraulic motor 74, through a hot air manifold 76 disposed within and extends longitudinally along the top of the combustion chamber 10. This hot air manifold is formed of heat resistant metal to form a passage shaped in cross-section as an annular segment to conform to the inner wall 78 of the combustion chamber 10, with an open end at the exhaust end of the combustion chamber 10 to receive air from the fresh air inlet blower 72 and a closed end at the inlet end of the combustion chamber 10. The bottom of the hot air manifold 76 is uninsulated from the combustion chamber 10 so that the air flowing in the manifold 76 can be preheated before entering the combustion chamber 10. A first plurality of hot air pipes 80 extends at uniform intervals from both sides of the hot air manifold 76 through the refractory inner wall 78, around the combustion chamber to randomly spaced openings 82 in the lower portion of the combustion chamber 10, which direct the air radially inward and upward through the combustion chamber. A second plurality of short hot air pipes 84 extend along at uniform intervals from both sides of the hot air manifold 76 to direct air tangentially along the top sides of the combustion chamber 10.

Turning again to FIG. 1 it will be noted that there is shown a curved portion 86 of the exhaust gas passage 20 in which a plurality of inwardly projecting baffle plates 88 are disposed on the inside of the outermost curved wall to serve as preliminary dust collector traps, to trap a portion of the solid particulate matter in the exhaust gas and allow it to fall into the ash receptacle.

The solid particulate matter which falls into the ash receptacle 22 is cooled by the water therein, and then removed by a rotatable auger 90 which extends downward into the ash receptacle 22, and driven by a motor 92, as shown in FIG. 3. This ash receptacle 22 has a sloping end wall and a semi-circular sloping bottom 94 concentric to and in close proximity with the ash removal auger 90, so that essentially all solid particulate matter which enters the ash receptacle is directed to the ash removal auger 90.

Solid particulate matter is also removed from the exhaust gases in a dust precipitator 96 disposed near the outlet end of the exhaust gas passage 20.

Also, as shown in FIG. 2, an exhaust gas blower 98 driven by a hydraulic motor 100 directs a portion of the exhaust gas which leaves the dust precipitator 96 to a plurality of inlets 102 in the feed hopper 16 forming an air curtain 104, so that the air pressure of the air curtain 104 is approximately equal to the air pressure of the combustion air in the combustion chamber 10. This prevents the backward flow of exhaust gases and smoke from the combustion chamber 10. Also, this exhaust gas preheats the incoming combustible refuse.

A directional air pressure sensor 106, (FIG. 1) disposed within the feed hopper 12, senses a backward flow of combustion air and increases the speed of the hydraulic motor 100 for the exhaust gas blower 98 by a control means in the control panel 108.

A temperature sensor 110, disposed on the inner wall 78 of the combustion chamber 10 near the inlet to the combustion chamber 10 is connected to a control means in the control panel 108 to regulate the speed of the hydraulic motor 74 driving the fresh air inlet blower 72 proportional to the temperature sensed by sensor 110, to assure that the air which enters the inlet end of the combustion chamber 10 is sufficiently pre-heated.

In a similar manner, a temperature sensor 112, disposed on the inner wall 78 of the combustion chamber 10 near the exhaust end of the combustion chamber 10 is connected to a control means in the control panel 108 to regulate the speed of the hydraulic motor 38 for the auger 26 in dependence on the exhaust end combustion chamber temperature, to assure complete combustion and reduce the smoke emission from the combustion chamber 10.

There is best shown in FIG. 2, two oil fired ignitors 114 which are disposed in the inner wall 78 of the combustion chamber 10 near the inlet section 14 to initiate combustion of the refuse on initial start up of the incinerator. Also, a movable plate 116, vertically disposed on a side of the exhaust gas passage 20 at the exhaust end of the combustion chamber 10, can be lowered during the start up period to partially block passage of exhaust gases from the combustion chamber 10, thus retaining heat in the combustion chamber 10 and thereby reducing the start up time.

What is claimed is:

1. An incinerator for burning combustible refuse which comprises:

a horizontally disposed stationary cylindrical combustion chamber means having an inlet end for receiving refuse and an outlet end for discharging exhaust gases and residue;

ignition means adjacent said inlet end for igniting the refuse;

screw conveyor means extending through the length of said chamber means for moving refuse therethrough;

air supply means for supplying combustion air under pressure;

stationary hot air manifold means, extending substantially the length of said chamber means in heat exchange relationship therewith, said manifold means having distributing means for admitting approximately equal volumes of air along the length of said chamber means; and

means for delivering said air under pressure from said air supply means to said manifold means adjacent the outlet end of said chamber means;

whereby the air is selectively pre-heated as it flows longitudinally through said manifold means counter to the flow of refuse through said chamber means, with the hottest air being admitted at the inlet end of said chamber means to quickly heat incoming refuse, and cooler, denser air containing more oxygen being admitted at the outlet end of said chamber means, to effect total combustion and prevent emission of smoke.

2. An incinerator, as described in claim 1, wherein:

said chamber means further includes an inner cylindrical side wall of refractory material;

said manifold means is positioned in said chamber means in an area above said screw conveyor means; and

said manifold means includes longitudinally extending, opposed side walls having curvilinear air distributing means for feeding air upwardly into a lower portion of said chamber means, said curvilinear air distributing means being confined in said inner side wall of said chamber means.

3. An incinerator, as described in claim 2, wherein said side walls of said manifold means further include air distributing means for feeding air into an upper portion of said chamber means tangentially to said inner wall of said chamber means, whereby the air is directed downwardly by the curvature of said inner wall to effect good mixing of air with the refuse, and the flow of air along said inner wall prevents refuse from sticking to said inner wall.

4. An incinerator, as described in claim 1, which further comprises a water-filled ash receptacle means adjacent the outlet end of said chamber means for receiving residue therefrom.

5. An incinerator, as described in claim 4, which further comprises ash removal means for removing cooled residue from the ash receptacle means, said ash removal means including:

a rotatable helical screw conveyor extending across and downward into said ash receptacle means, wherein said ash receptacle means has a semicircular sloping bottom concentric to, and in close proximity with, said helical screw conveyor; and

a drive means for rotating said helical screw conveyor.

6. An incinerator, as described in claim 1, wherein said screw conveyor means comprises a rotatable auger which includes:

a tubular axis;

a spiral flight disposed about said tubular axis; and

a plurality of support members connecting and supporting said spiral flight in spaced concentric relation to said tubular axis, said spiral flight and said tubular axis defining an open annular space around said tubular axis.

7. An incinerator, as described in claim 6, wherein said tubular axis is positioned off-center from the longitudinal axis of said chamber means toward the bottom of said chamber means, whereby an outer edge of said spiral flight is positioned very close to the bottom of said chamber means to move essentially all of the refuse through said chamber means.

8. An incinerator, as described in claim 6, wherein said spiral flight of said rotatable auger has a larger pitch at said outlet end of said chamber means and a smaller pitch at said outlet end of said chamber means to compensate for a reduction in volume of the refuse during combustion.

9. An incinerator, as described in claim 6, which further comprises:

a variable speed drive means for said rotatable auger;

temperature sensing means for sensing combustion gas temperature at said outlet end of said chamber means; and

a control means to regulate the speed of said conveyor drive means in proportion to a combustion chamber outlet temperature sensed by said temperature sensing means.

10. An incinerator, as described in claim 1, further comprising a means for partially blocking said outlet end of said chamber means during start-up of the incinerator.

11. An incinerator, as described in claim 1, which further comprises hopper means adjacent the inlet end of said chamber means for feeding refuse thereinto, said hopper means having an air curtain means for diverting at least a portion of the exhaust gases discharged from said chamber means, to preheat incoming refuse and prevent emission of combustion gases from the inlet end of said chamber means.

12. An incinerator, as described in claim 11, in which said curtain means further comprises:

a blower;

a variable speed drive means for said blower;

a directional air pressure sensing means disposed between said curtain means and said chamber means; and

a control means to regulate the speed of said variable speed blower drive means in proportion to a pressure sensed by said pressure sensing means.

13. An incinerator, as described in claim 11, in which said curtain means comprises:

an exhaust gas blower;

a variable speed drive means for said exhaust gas blower; and

a control means to regulate the speed of said variable speed drive means for said exhaust gas blower in proportion to a combustion chamber inlet temperature sensed by said temperature sensing means.

14. An incinerator, as described in claim 1, in which said air supply means comprises:

a fresh air inlet blower;

a variable speed drive means for said fresh air inlet blower;

temperature sensing means for sensing combustion air temperature adjacent said inlet end of said chamber means; and

a control means to regulate the speed of said variable speed drive means for said fresh air inlet blower in proportion to a combustion chamber inlet temperature sensed by said temperature sensing means.

15. An incinerator, as described in claim 1, which further comprises:
precipitator means for removing solid particles from the exhaust gases; and
conduit means for conducting the exhaust gases from the outlet end of said chamber means to said precipitator means.

16. An incinerator, as described in claim 1, which further comprises:
heat exchanger means for receiving heat from the exhaust gases discharged from the outlet end of said chamber means; and
conduit means for conducting the exhaust gases from the outlet end of said chamber means to said heat exchanger means.

17. An incinerator, as described in claim 1, which further comprises means for introducing water into and out of said tubular axis, said means for introducing water including:
an inlet pipe of smaller diameter than said tubular axis, concentrically disposed within said tubular axis, extending from one end of said tubular axis through said tubular axis to said inlet end of said chamber means; and
a water outlet means connecting to said tubular axis at the same end as said inlet pipe.

18. An incinerator, as described in claim 17, which further comprises:
heat exchanger means for transferring heat from the exhaust gases discharged from the outlet end of said chamber means to water circulated therethrough;
gas conduit means for conducting the exhaust gases from the outlet end of said chamber means to said heat exchanger means; and
water conduit means for connecting said water outlet means of said tubular axis to a water inlet of said heat exchanger means.

19. An incinerator, as described in claim 1, which further comprises means introducing water into and out of said tubular axis, said means for introducing water including:
a water inlet means at one end of said tubular axis; and
a steam outlet means at an opposite end of said tubular axis.

20. An incinerator, as described in claim 19, which further comprises:
heat exchanger means for transferring heat from the exhaust gases discharged from the outlet end of said chamber means to water circulated therethrough;
gas conduit means for conducting the exhaust gases from the outlet end of said chamber means to said heat exchanger means, said gas conduit means including a superheater steam coil disposed therein;
water conduit means for connecting said water inlet means of said tubular axis to a water outlet of said heat exchanger means; and
steam conduit means for connecting said steam outlet means of said tubular axis to a steam inlet of said superheater coil.

21. An incinerator for burning combustible refuse which comprises:
a horizontally disposed stationary cylindrical combustion chamber means having an inlet end for receiving refuse and an outlet end for discharging residue and exhaust gases;
ignition means adjacent said inlet end for igniting said refuse;
screw conveyor means extending through the length of said chamber means for moving refuse at a decreasing rate from the inlet end to the outlet end of said chamber means as the volume of refuse is reduced by combustion, to effect better combustion of particulate smoke at the outlet end of said chamber means, said screw conveyor means including a rotatable auger having a longitudinal axis and a spiral flight concentrically disposed about said auger axis, said spiral flight having a larger pitch at the inlet end of said chamber means and a smaller pitch at the outlet end of said chamber means; and
air supply means for supplying combustion air to said chamber means.

* * * * *

United States Patent [19]
Tyer et al.
[11] 4,315,468
[45] Feb. 16, 1982

[54] CONTROL SYSTEM FOR A SINGLE AUGER STARVED-AIR COMBUSTOR

[75] Inventors: Robert C. Tyer, Baldwin, Fla.; Robert E. Fitch, Kent; Gordon H. Tucker, Enumclaw, both of Wash.
[73] Assignee: The Boeing Company, Seattle, Wash.

[21] Appl. No.: 148,374
[22] Filed: May 9, 1980
[51] Int. Cl.³ F23K 3/00
[52] U.S. Cl. ..... 110/101 CF; 110/190; 110/186; 110/267
[58] Field of Search ..... 110/185-187, 110/190, 101 CF, 203-205, 210-212, 248, 255, 276, 267, 101 CA

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Primary Examiner—Henry C. Yuen
Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner

[57] ABSTRACT

A control system for a starved-air combustor wherein a combustion chamber is divided into a plurality of combustion chamber zones with separate overfire and underfire airflows being individually provided for each zone. Fuel is fed to the combustor in selectable constant weight batches and the supply of underfire air is proportional to the rate at which an auger rotates to convey the fuel through the combustor. Overfire air is supplied to each combustion zone in an inverse relationship to the variance of a sensed temperature within the zone from a predetermined temperature.

8 Claims, 11 Drawing Figures

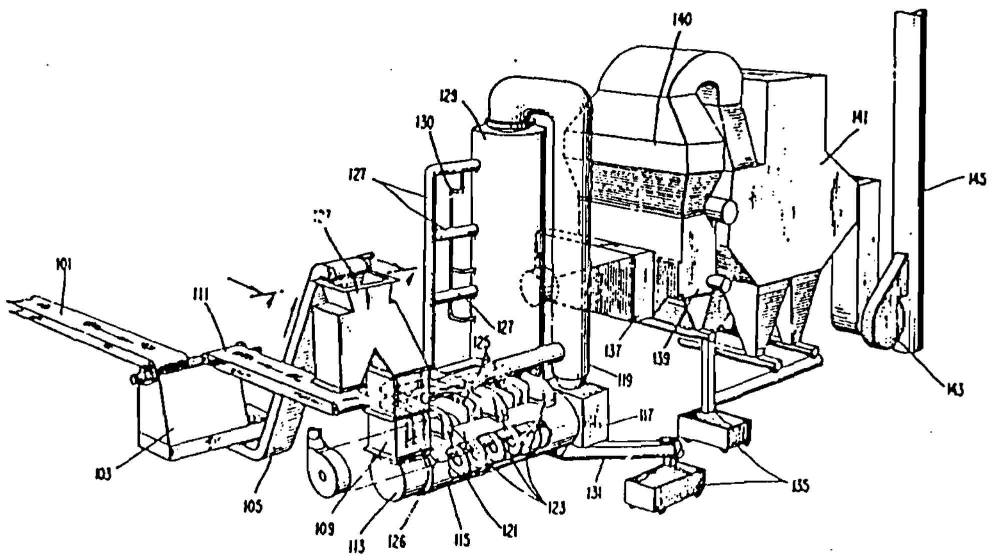
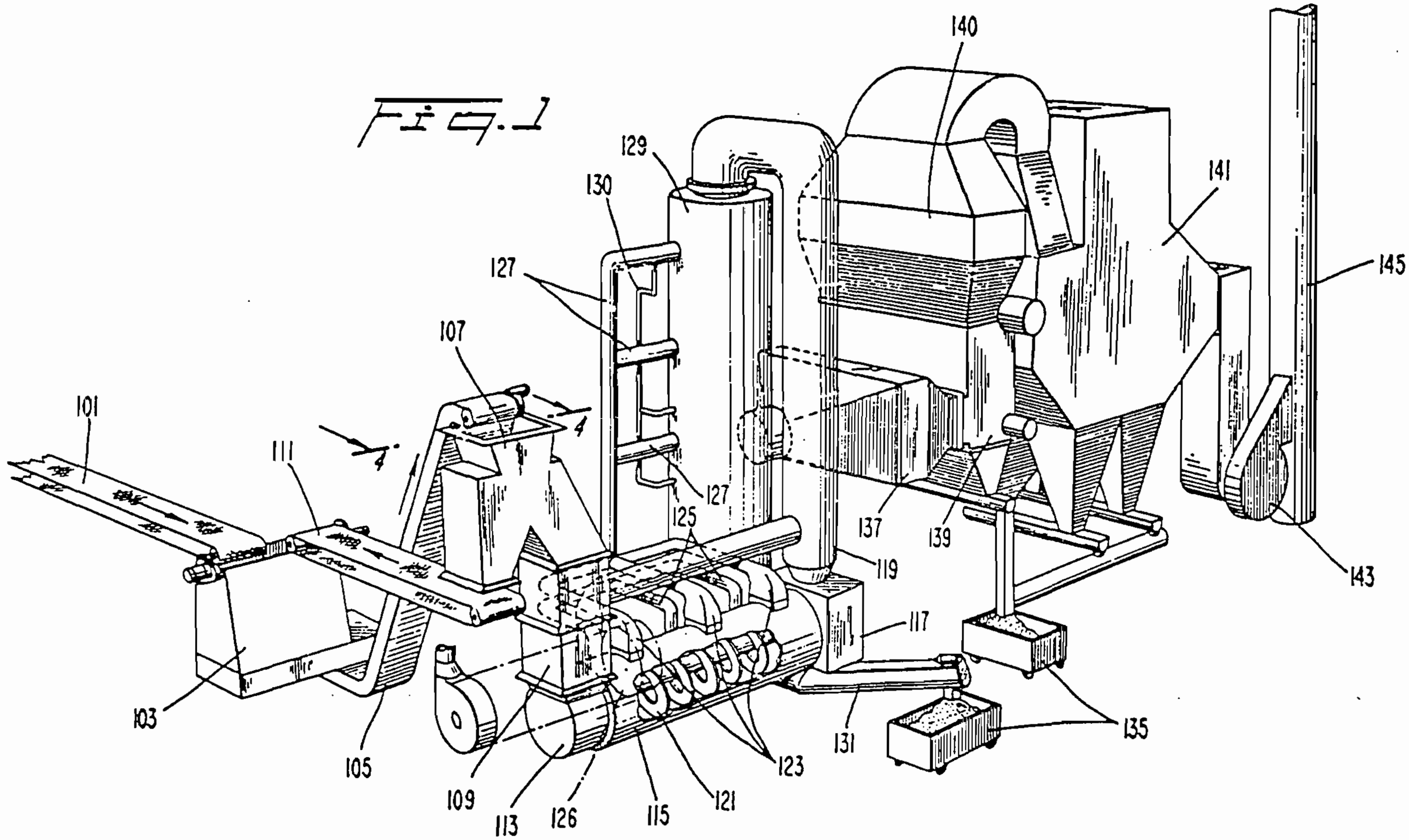


Fig. 1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141
143
145
4

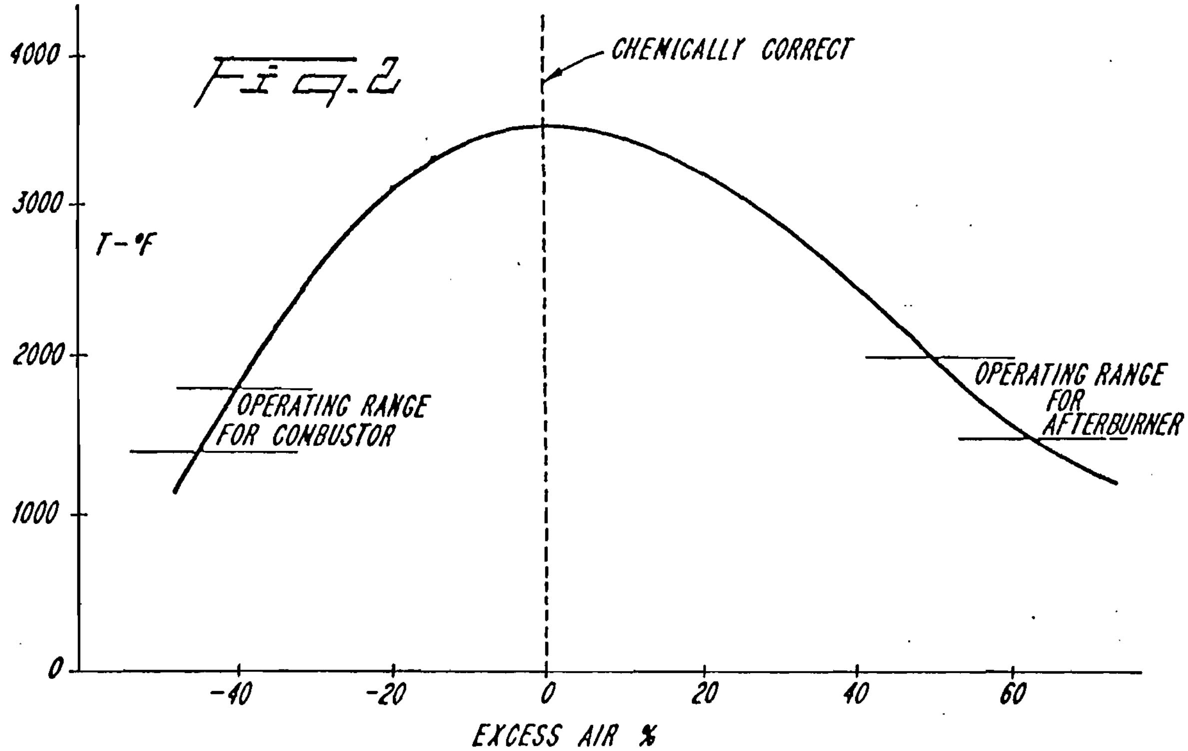

4000
3000
2000
1000
0
T - °F
CHEMICALLY CORRECT
OPERATING RANGE
FOR COMBUSTOR
OPERATING RANGE
FOR
AFTERBURNER
-40
-20
0
20
40
60
EXCESS AIR %

FIG. 2

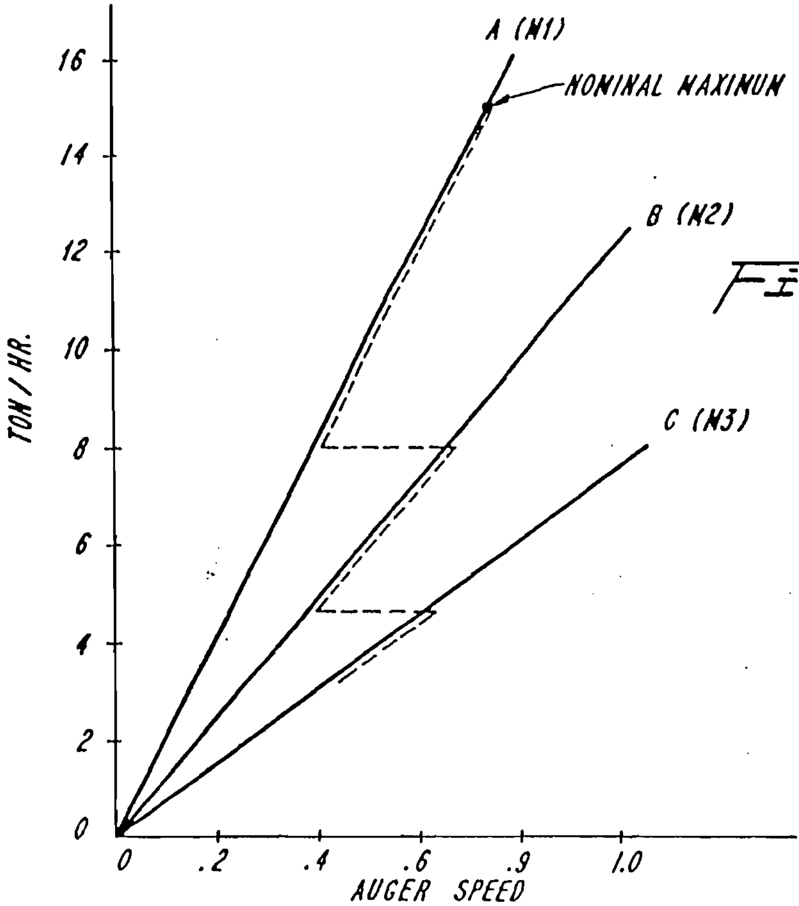

A (M1)
NOMINAL MAXIMUM
B (M2)
C (M3)
16
14
12
10
8
6
4
2
0
TON / HR.
0
.2
.4
.6
.9
1.0
AUGER SPEED

FIG. 3

Fig. 4

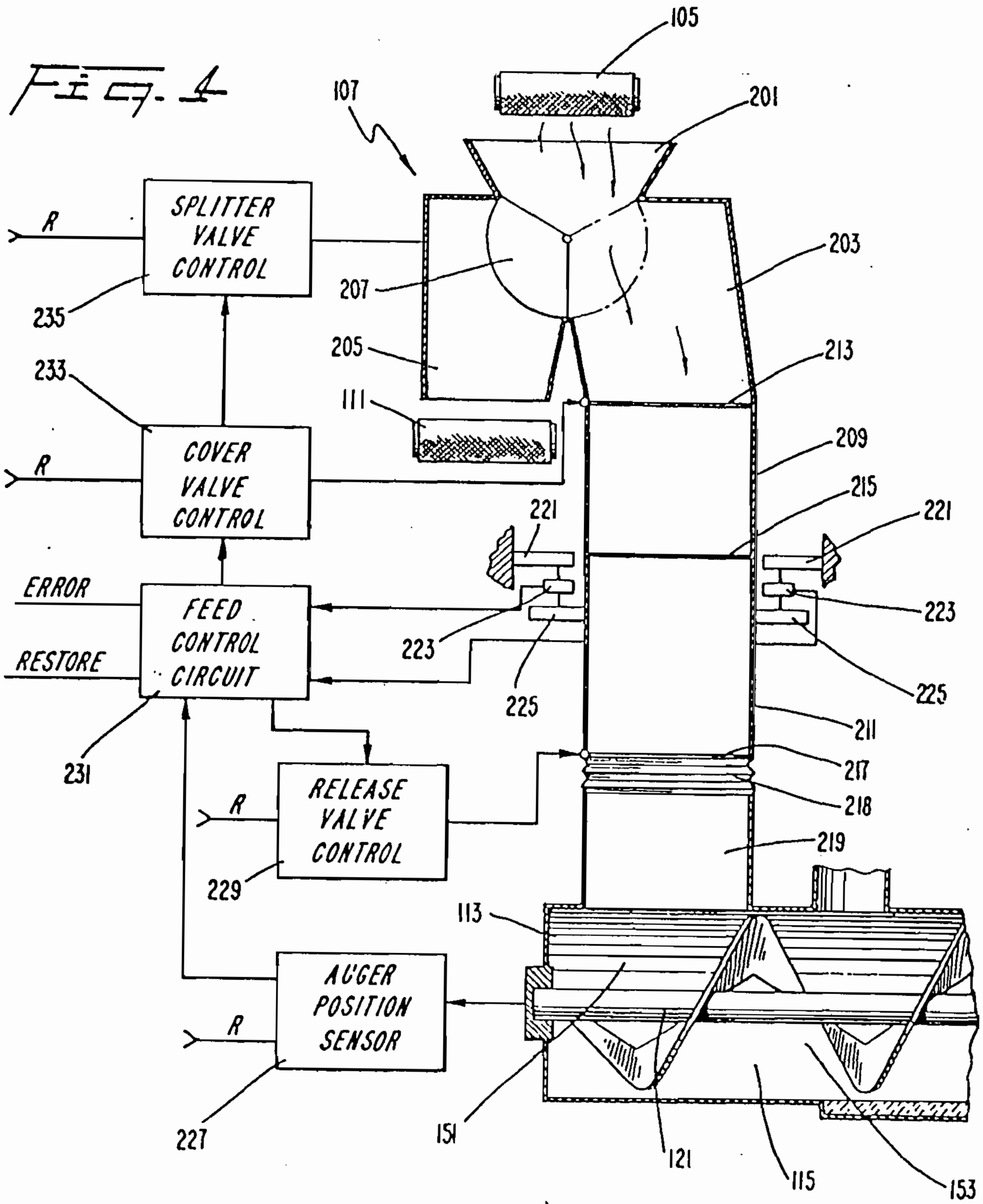

105
107
201
203
207
205
213
111
209
215
221
221
223
223
225
225
211
217
218
219
113
121
115
151
153
SPLITTER VALVE CONTROL
235
R
COVER VALVE CONTROL
233
R
FEED CONTROL CIRCUIT
ERROR
RESTORE
231
RELEASE VALVE CONTROL
R
229
AUGER POSITION SENSOR
R
227

Fig. 5

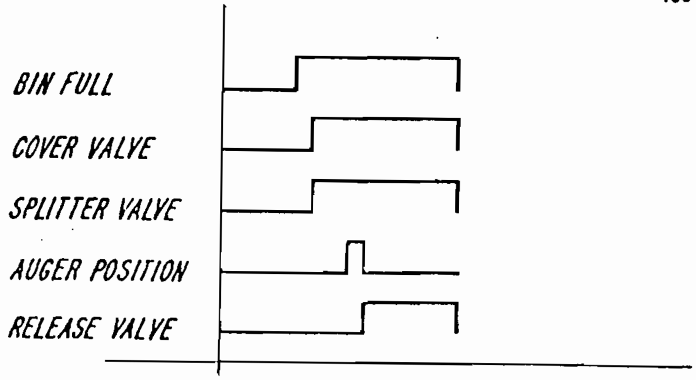

BIN FULL
COVER VALVE
SPLITTER VALVE
AUGER POSITION
RELEASE VALVE

Fig. 6

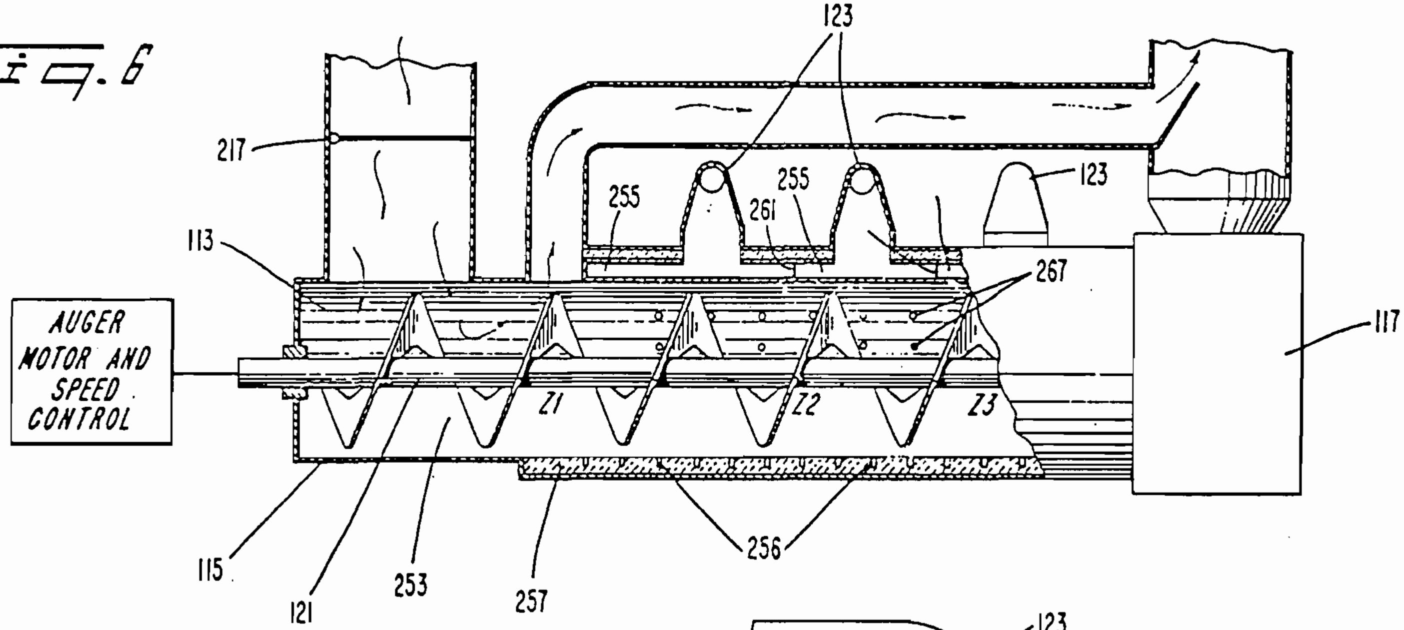
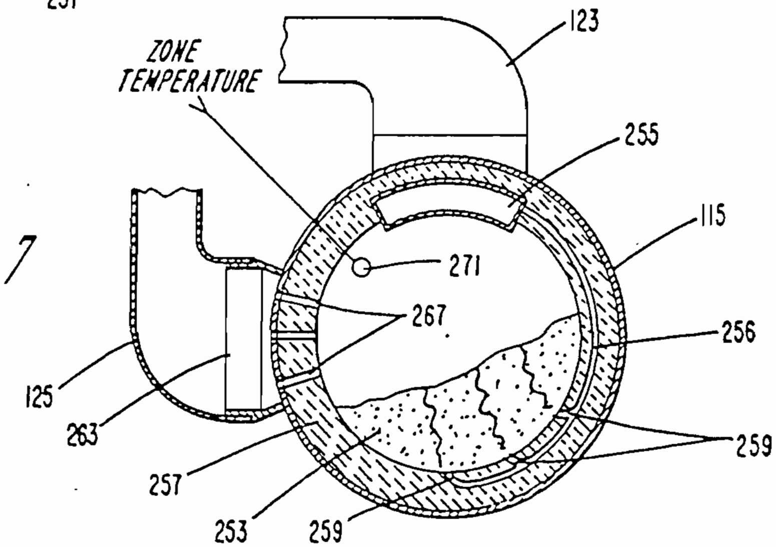

123
217
255
255
261
123
267
113
AUGER MOTOR AND SPEED CONTROL
Z1
Z2
Z3
117
115
121
253
257
256

Fig. 7


ZONE TEMPERATURE
123
255
115
271
267
256
125
263
257
253
259
259

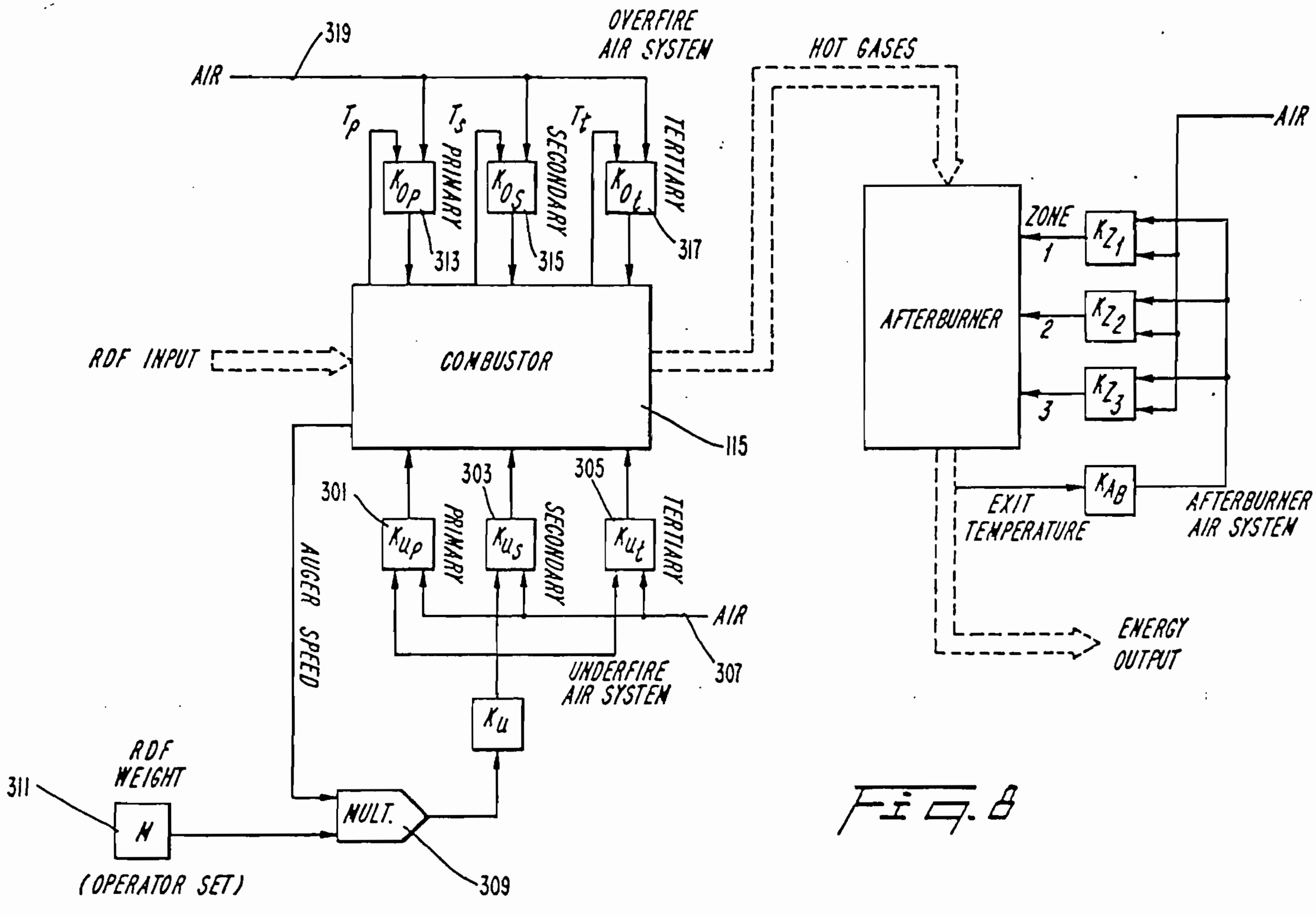

319
AIR
OVERFIRE
AIR SYSTEM
HOT GASES
Tp
Ts
Tt
PRIMARY
SECONDARY
TERTIARY
K0p
K0s
K0t
313
315
317
RDF INPUT
COMBUSTOR
115
AFTERBURNER
ZONE
1
2
3
KZ1
KZ2
KZ3
AIR
KAB
EXIT
TEMPERATURE
AFTERBURNER
AIR SYSTEM
ENERGY
OUTPUT
301
303
305
Kup
Kus
Kut
PRIMARY
SECONDARY
TERTIARY
AUGER SPEED
AIR
307
UNDERFIRE
AIR SYSTEM
Ku
RDF
WEIGHT
311
W
(OPERATOR SET)
MULT.
309

Fig. 8

FIG. 9

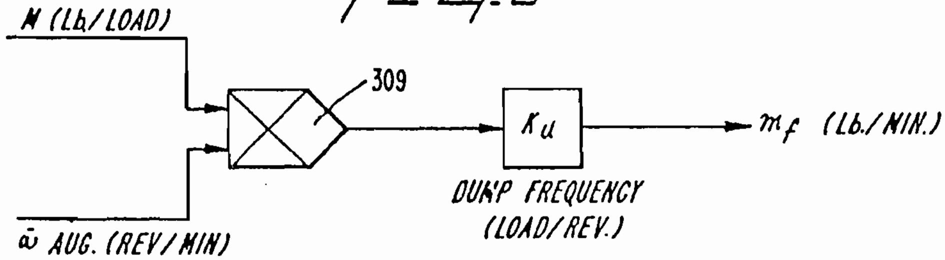


FIG. 10

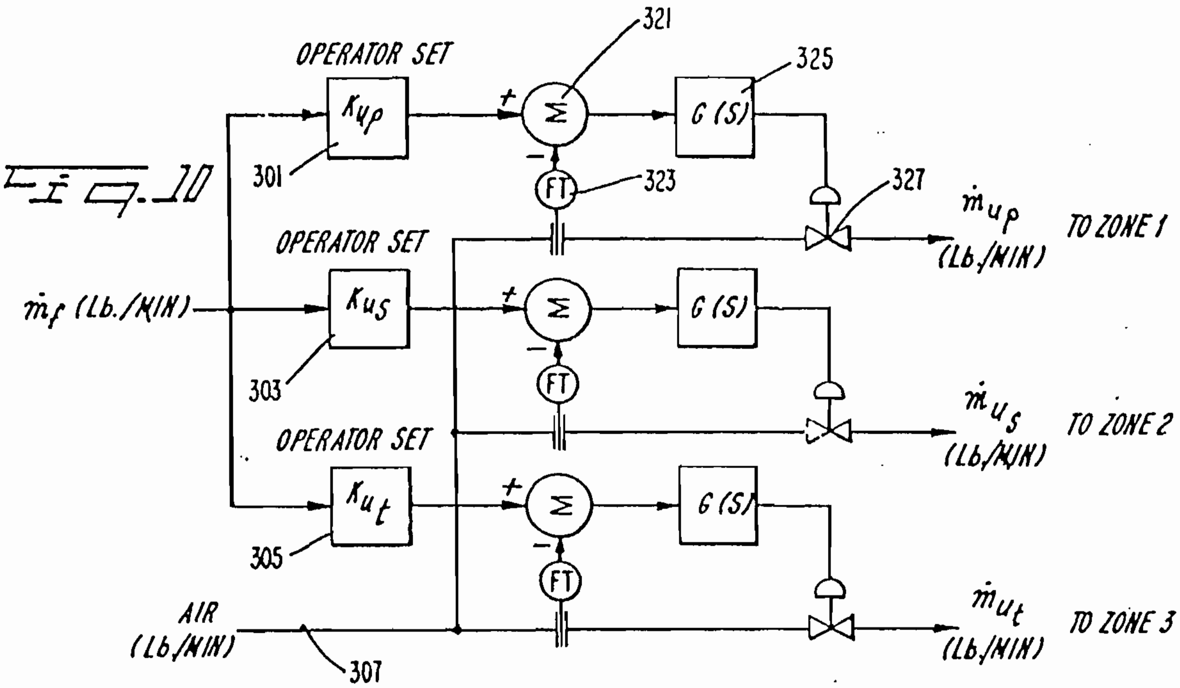
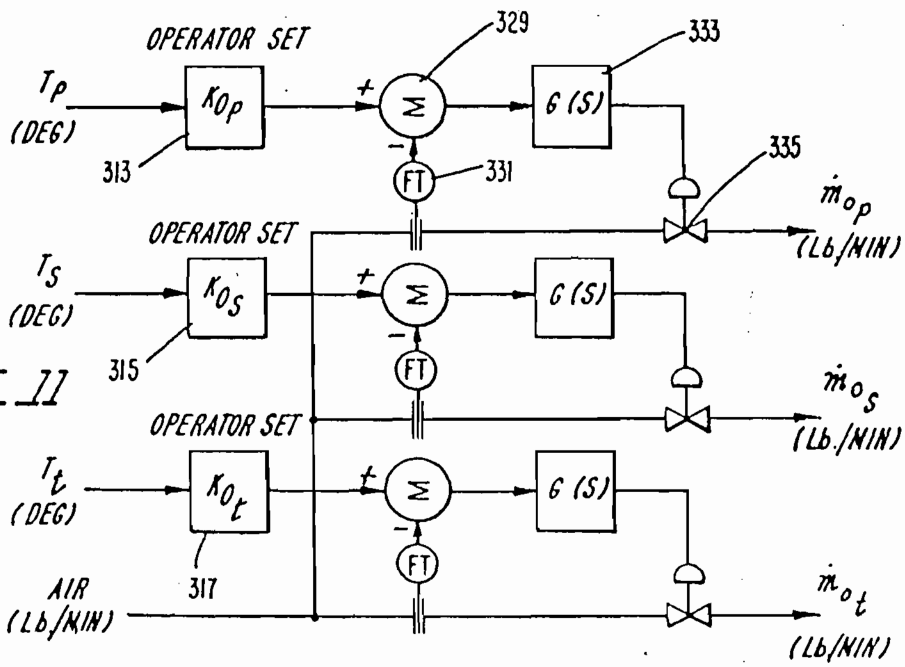


FIG. 11



CONTROL SYSTEM FOR A SINGLE AUGER STARVED-AIR COMBUSTOR

BACKGROUND OF THE INVENTION

In the last century, much of the world's energy needs have been fulfilled by hydrocarbon fuels which provided a convenient, plentiful, and inexpensive energy source. The current rising costs of such fuels and concerns over the adequacy of their supply in the future has made them a less desirable energy source and has led to an intense investigation of alternative sources of energy. The ideal alternative energy source is a fuel which is renewable, inexpensive, and plentiful, with examples of such fuels being the byproducts of wood, pulp, and paper mills, and household and commercial refuse.

The use of alternative energy sources is not problem-free, however, since there is a concern over the contents of the emissions from the combustion of such fuels as well as the environmental ramifications of acquiring and transporting the fuel and disposing of the residue of combustion.

One promising prior art device for using such alternative energy sources while maintaining a high degree of environmental quality is the starved-air combustor wherein the air supplied for combustion is controlled in order to control temperature conditions and the rates of combustion are controlled to consume the fuel entirely. Such starved-air combustors are capable of burning various types of fuel and producing significant amounts of heat which can be employed for any number of purposes including the production of process steam for use in manufacturing and in the generation of electricity.

Starved-air combustors, as previously known and operated, have not been entirely satisfactory in both entirely consuming the combustible elements of the fuel at high throughput while not producing noxious emissions. This problem results, in part, from the use of such starved-air combustors to burn a wide variety of fuels some of which may be non-homogeneous, e.g, household or commercial refuse. It has not been possible in the previously known starved-air combustors to tailor in a real time manner the combustion processes to the type of fuel being combusted in order to maximize the efficiency of the combustor while minimizing the generation of air pollutants. While the pollution problem can be solved to a degree by the utilization of scrubbers and other antipollution devices, such mechanisims are very expensive and their cost may militate against the use of alternative energy sources.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a starved-air combustor capable of efficiently utilizing many different types and quantities of fuel.

Another object of this invention is to provide a starved-air combustor which does not release noxious pollutants into the atmosphere.

Yet another object of this invention is to provide a starved-air combustor which is capable of combusting to a very high degree the percentage of all combustible material provided to it as fuel.

Still another object of this invention is to provide a starved-air combustor including a control system for selectively controlling the quantity of hot combustion gases produced thereby in accordance with the demand for heat produced by the starved air-combustor.

Yet another object of this invention is to provide a starved-air combustor wherein the combustion chamber is divided into a plurality of combustion zones and includes a control system which controls independently the injection of air into each of the combustion zones.

Another object of this invention is to provide a starved-air combustor wherein the air supplied to each combustion zone includes overfire air supplied above the fuel in the combustion zone and underfire air supplied beneath the fuel in the combustion zone and wherein the amount of overfire air supplied is dependent upon the temperature in the combustion zone and the amount of underfire air supplied is dependent upon the rate that fuel is being conveyed through the combustion chamber.

To achieve these objects, and in accordance with the purpose of the invention, as embodied and broadly described herein, the starved-air combustor comprises: a combustion chamber having an inlet end for receiving fuel, the combustion chamber for combusting the fuel to produce a quantity of heat (hot combustion gases) related to the rate of combustion; means for conveying the fuel through the combustion chamber at a variable rate; means for supplying a variable airflow to the combustion chamber; and means for controlling the rate of the conveying means and the quantity of air supplied by the supplying means to increase the quantity of hot combustion gases produced by the system responsive to an increase in the heat demand and to decrease the quantity of hot combustion gases produced by the system responsive to a decrease in the heat demand.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the starved-air combustor system of the instant invention connected between a fuel supply system and a system which produces process steam from the heat produced by the starved-air combustor system.

FIG. 2 is a graph illustrating the relationship between temperature in the combustion chamber and the afterburner of the starved-air combustor system as related to the amount of air supplied to the combustion chamber and to the afterburner.

FIG. 3 is a graph illustrating the control of the fuel flow for three given weights of fuel and a range of auger rotation rate.

FIG. 4 is a cross-sectional view taken along lines 4—4 of a means for feeding variable quantities of fuel to the combustion chamber in a batch mode illustrated in FIG. 1.

FIG. 5 is a timing diagram explaining the operation of the feeding means of FIG. 4.

FIG. 6 is a longitudinal cross-sectional view of the combustion chamber of the starved-air combustor system of FIG. 1 taken along the line 6—6.

FIG. 7 is a transverse cross-sectional view of the combustion chamber of the starved-air combustor system of FIG. 1 taken along the lines 7—7.

FIG. 8 is a schematic logic circuit diagram illustrating the control system for supplying overfire air and underfire air to the combustion chamber and air to the afterburner of the starved-air combustor system.

FIG. 9 schematically illustrates the logic of the control circuit for relating the angular rate of the auger to the quantity of fuel conveyed through the combustion chamber of the starved-air combustor system.

FIG. 10 schematically illustrates the control circuit for controlling the quantity of underfire air supplied to the combustion chamber of the starved-air combustor system.

FIG. 11 schematically illustrates the control circuit for controlling the overfire air supply to the combustion zones in the combustion chamber of the starved-air combustor system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an embodiment of a starved-air combustor according to the present invention coupled between a refuse feeder system and a steam generation system. As embodied herein, the refuse supply comprises a supply conveyor 101 for conveying fuel, in this instance refuse, from a receiving building (not shown) and one or more storage silos (not shown). The receiving building and storage silos are to insure that an adequate supply of fuel can be supplied to the combustor in order to permit the combustor to run at peak efficiency. In the illustrated embodiment, it is contemplated that the supply conveyor 101 would supply fuel to the fuel surge and recirculation bin 103 at a rate of at least fifteen tons per hour and that the capacity of the combustor system would range from 150 to 500 pounds per minute.

The fuel surge and recirculation bin 103 comprises an additional means for insuring that a constant and adequate supply of fuel is available to the combustor. The bin 103 could, for example, contain at least 10 minutes capacity of fuel, i.e., approximately 25 tons, which is received at the top of the bin 103 and supplied through the bottom of the bin 103 to the feed conveyor 105. Feed conveyor 105 supplies the fuel to a splitter valve 107 which may either direct the fuel into the feed and weigh bin 109 or, when the feed and weigh bin 109 is filled to capacity, to the return conveyor 111 for return to the fuel surge and recirculation bin 103. The feed and weigh bin 109 is calibrated to supply a constant weight of fuel at the inlet end 113 of a refractory lined combustor 115 at such time that the first flight of an auger 121 within the chamber 115 has been rotated into a fuel-receiving position. Within the starved-air combustor 115 there is provided a well-known oil igniter (not shown) in the input end 113 of the combustion chamber 115 to serve as a means for initially igniting the fuel upon start up of the starved-air combustor.

U.S. Pat. No. 4,009,667 issued to Robert C. Tyer et al on Mar. 1, 1977, illustrates an appropriate embodiment for a rotatably-driven auger comprised of a rotatable, water-cooled horizontal shaft supporting a spiral flight of decreasing pitch from the input end of the auger to the output end. It is contemplated in the instant system that the speed of the auger would range from 0.3 to 1 rpm. An appropriate oil igniter would comprise an oil burner having its flame extending into the input end of the combustor 115 to heat and to ignite the initial load of fuel supplied by the feed and weigh bin 109. It is contemplated that such an oil igniter would be capable of burning oil fuel at a rate of approximately six gallons per hour at two pounds per square inch pressure.

The combustor 115 has an output end 117 connected to a conduit 119 which feeds the top of an afterburner 129. The combustor 115 also includes air supply means 123 for supplying underfire air and conduits 125 for supplying overfire air. This air is provided by a fan 126 (shown in phantom) which also supplies air through conduits 127 to the afterburner 129. Alternatively, a separate fan or fans may be provided to supply underfire, overfire air, and air to the afterburner 129. A small air distributor 130 is connected to the upper conduit 127 to supply air into the afterburner 129 through special injectors located both at and below the midpoint of the afterburner 129.

Afterburner 129 is provided, in part, as a secondary combustor chamber which mixes the air supplied by the conduits 127 with the gaseous and entrained solid particle output of the combustor from the outlet end 117 to combust all combustible material in the gaseous output and, in part, to separate suspended ash and non-combustible solids from the hot non-combustible gas. Both the non-combustible material from the afterburner 129 and the combustion residue from the combustor 115 are fed through conduit 131 to an ash collector 135. The hot non-combustible gas is discharged into a superheater 137 from which it is supplied to a waste heat boiler 139 to produce, in this case, process steam. An electrostatic precipitator 141 removes any additional solids from the now cooler non-combustible gas exiting from the waste heat boiler 139 through an economizer 140 and the solid material is conveyed to an ash cart 135. From the precipitator 141, the non-combustible gas is drawn by a fan 143 and expelled from stack 145. Upon entering into the fan the temperature of the gas is approximately 300 to 400 degrees Fahrenheit and the fan 143 is of sufficient strength to exert a negative pressure in the system within the combustor 115, the afterburner 129, superheater 137, waste heat boiler 139, economizer 140, and precipitator 141.

One of the principal advantages of a starved-air combustion system is that gasification or partial oxidation of solid fuels can be made to occur at moderate temperatures (1300°–1800° F.). The significant beneficial effects of this include elimination of slagging or fusing of the fuel and ash particles, exposing the combustor structure to only moderate temperature in non-oxidizing conditions, and reducing the formation of nitrogen oxides.

The principal control difficulty in the prior art starved-air combustor systems lies in maintaining temperature levels throughout the combustor, i.e., within the pile of fuel material and the gas space above it in the combustion chamber, while also optimizing the performance of the combustor system, i.e., mass of solid material gasified per unit of time and unit of area of grate surface. Temperature control is achieved by regulating the airflow into the combustion chamber to achieve the proper air/fuel ratio.

FIG. 2 is a plot of temperature after reaction of fuel and air at different proportions and, as the terminology suggests, a starved-air combustor chamber operates at a negative percentage of excess air compared to the chemically correct amount in the temperature region indicated in FIG. 2. Thus, to increase the operating temperature within the combustion chamber of a starved-air combustor, it is necessary to increase the airflow into the combustion chamber.

Also evident from FIG. 2 is that the temperature within the afterburner responds to an increased airflow in the opposite manner as does the combustion chamber. Thus, to increase the temperature in the afterburner it is necessary to reduce the air supply thereto.

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One problem in regulating the temperature within the combustion chamber is that the fuel bed and the injection of air into it are not necessarily homogeneous and the schedule of events leading to complete gasification or oxidation is not uniformly identical for all particles of the fuel. Local air/fuel ratio increases from average can cause radical temperature increases within the combustion chambers. Some of these pertubations in temperature are unavoidable because, as will hereinafter be explained, the air is injected into the combustion chamber from discrete parts through the refractory lining of the chamber and the fuel particles are obviously discrete solid particles thereby causing non-homogeneous air/fuel mixtures where the injected air directly impacts upon the fuel particles. These conditions are only temporary, however, because the auger within the combustion chamber removes and tumbles fuel so that the non-homogeneous conditions do not last long enough to cause slagging of the non-combustible material. The major difficulty arises in correctly relating the volumes the underfire air (the air supplied beneath the fuel in the combustion chamber) and the overfire air, (air supplied above the fuel in the combustion chamber) used in partially combusting or gasifying the solid fuel and the fuel gas to the rate of fuel flow within the combustion chamber.

The prior art attempted to solve the slagging and temperature control problems by different types of control systems. One type of control system is illustrated in the above-mentioned Tyer et al patent wherein the underfire air was uniformly supplied beneath the bed of fuel in the combustion chamber and the overfire air was supplied in multiple zones above the fuel bed. No means was provided for regulating the amount of fuel fed to the combustion chamber and all of the controls of the underfire air and the overfire air were manual. Some of the drawbacks of this arrangement were that it did not provide for altered zoning of the underfire air to accommodate changes in fuel moisture content and reactivity, and the possibility that uncontrolled variable fuel feed could lead to undesired oscillations in the operating properties in the combustion chamber.

It has also been attempted, in the prior art, to provide a combustion chamber wherein no overfire air is provided but where the underfire air was separated into three different zones with independent control of the airflow into each zone. This approach suffers from the inability to balance properly the reaction sequence in the fuel bed and the reaction sequence in the evolved combustion gases especially during changes of fuel feed rate. When the fuel feed was interrupted temporarily or when the rate of fuel feed was decreased because of a reduction of fuel density, the severe local temperature aberrations occurred because of an increase in the air/fuel ratio. When the airflow rate was decreased, the gasification rate and efficiency of the starved-air combustor decreased.

The present invention, as will hereinafter be described, avoids the problems of the prior art starved-air combustor systems and provides a starved-air combustor of greater efficiency by providing a feed system for feeding fuel into the combustion chamber in constant weight batches, an air supply system for feeding both underfire and overfire air in a zoned manner, and a control system for regulating underfire airflow in accordance with the rate of fuel flow through the combustion chamber and overfire airflow in accordance with the temperatures in the combustion zones. The feed system charges a fixed (operator-set) weight of fuel (M) for each rotation or partial rotation of the auger within the combustion chamber. This means that the fuel weight flow rate (m_f) is adjusted by changing the auger rotation rate (W_{aug}). The proportion of underfire air (m_u) to fuel weight flow rate is operator-set, as a function of auger rotation rate W_{aug}, while overfire flow rates (m_o) are controlled according to the gas temperature of the combustion zones T_i. Thus, fuel flow and underfire air are keyed to the auger's speed by $m_u = K \cdot M \cdot W_{aug}$ so that after M and the constants for each zone K_i are set, then underfire air/fuel flow ratios are constant. If auger speed drops, m_u is automatically decreased in proportion. Similarly, if M is decreased, m_u is also decreased. Thus, the response of the starved-air combustor system to changes in heat demand is through auger speed.

This approach insures that the flow of fuel through the fuel bed in the combustion chamber is of uniform size and is provided with the same air/fuel ratio for each batch of fuel that is fed into the combustion chamber.

FIG. 3 is a graph relating fuel feed rates to auger speed. If, for example, the nominal maximum fuel feed rate and auger speed is 15 tons of fuel per minute and 0.9 revolutions of the auger per minute, then the line A relates decreases in the fuel feed rate to decreases in the auger speed for a constant fuel batch weight M1. It has been determined that if the auger is rotated at too slow a rate, e.g., less than 0.4 rpm, clinkering and slagging may occur within the combustion chamber. Thus, as the auger speed approaches 0.4 rpm with the fuel batch weight of M1, or the fuel feed rate is 8 tons per hour or less, then it is more efficient to operate along performance curve B with a fuel batch weight of M2 less than M1 than performance curve A. Similarly, a change to operating curve C with a fuel batch weight of M3 less than M2 should be effected when fuel is being fed at a rate of 5 or fewer tons per hour or auger speed approaches 0.4 rpm.

As stated above, the starved-air combustor system of the instant invention includes means for feeding selectable weights of fuel into the inlet end 113 of the combustion chamber 115 in a batch mode. Such a feeding means is illustrated in FIG. 4. The feeding means comprises a chute 201 positioned beneath the fuel feed conveyor 105 such that fuel conveyed by the conveyor 105 drops off into the chute 201. From the chute 201, the fuel can either pass into a combustor feed path 203 of the feeding means or a return path 205 to the return conveyor 111 for return to the surge an recirculation bin 103 as previously explained. A splitter valve 207 is rotatable in the neck of the chute 201 to guide the received fuel to the combustor feed path 203 or to the return path 205.

The combustor feed path 205 leads to a chute 209 for guiding the fuel directed to the combustion chamber 115 into a weigh bin 211. A cover valve 213 is provided at the inlet of the chute 209 and is rotatable to either permit the fuel to pass from the chute 209 and into weigh bin 211 when the cover valve is in an open or downward position or to prevent additional fuel from entering chute 209 and weigh bin 211 when the cover valve 213 is in a closed or, as illustrated in FIG. 4, a horizontal position. The cover valve 213 provides an airtight seal with the sides of the chute 209 such that when the cover valve 213 is closed, outside air is prevented from entering chute 209 and weigh bin 211. The cover valve 213 could alternatively be a slidable valve having an inward (closed) position and an outward (open) position.

The weigh bin 211 is connected to the chute 209 via a flexible coupling 215 so that the weight of the weigh bin 211 and any fuel contained therein is not supported by the chute 209 but, as will hereinafter be explained, is supported by means of one or more weigh cells 223 connected between a stationary support member 221 and support arms 225 extending from the exterior of the weigh bin 211.

Release valve 217 is not opened, i.e. rotated to extend into the lower chute portion 219 of the feeding means, until the weigh cells 223 indicate that a predetermined weight of fuel has been accumulated in weigh bin 211 and an auger position sensor 227 has determined that the auger 221 has been rotated into the proper feed orientation. The lower chute portion 229 is coupled to the weigh bin 211 by means of a flexible, airtight seal 218 so as not to support the weigh bin 211 but merely to guide the fuel into the inlet end 113 of the combustion chamber 115 while simultaneously preventing ambient air from entering the combustion chamber 115. As stated above, the feeding means includes weighing means which, as embodied herein, comprise one or more weigh cells 223 coupled, as above-described, between stationary support members 221 and support arms 225 connected to the weigh bin 211.

One skilled in the art will readily recognize that each weigh cell 223 comprises any one of a number of means whereby a particular weight can be selected, the weight of the weigh bin including fuel received and contained therein determined, and an output signal generated when the measured weight of the weigh bin exceeds a selected weight. As an example, the weigh cell 223 could comprise a variable resistor for generating a voltage signal with a level proportional to the weight of the fuel in the bin 211. A voltage threshold detector senses the voltage levels and actuates a microswitch when the sensed voltage exceeds a threshold voltage corresponding to a selected weight. The output of the microswitch is employed within suitable logic circuitry, as will be hereinafter explained, to actuate splitter valve 207, cover valve 213, and release valve 217 to feed the conveyor with fuel in a proper manner.

FIG. 4 also illustrates, in block diagram form, functional logic circuits that are needed to control the feeding means to feed fuel either into the combustor 115 or to the return conveyor 111. FIG. 5 is a timing diagram to be read in conjunction with the block diagram of FIG. 4 for complete understanding of the operation of the logic circuits.

In normal operation, during the combustion chamber feed mode, the splitter valve 207 will be positioned as indicated by the solid lines in FIG. 4. The cover valve 213 will be in its open, or downward position, and the release valve 217 will be in the closed position as shown in FIG. 4. Fuel will be dropping from feed conveyor 105 through the feed path 203 and the upper chute 209 into the weigh bin 211. This will gradually cause an increase in the weight of the fuel in the weigh bin 211 and, when the preselected weight of a batch or charge of fuel has been accumulated in the weigh bin 211, then the weigh cells 223 will cause bin full signals to be supplied to the feed control circuit 231. This is illustrated in FIG. 5 as a change of the bin full signal from a low value to a high value.

When the preselected weight has been accumulated in the weigh bin 211, it is necessary to rotate the splitter valve 207 into the orientation shown by the dotted lines in FIG. 4 and to close the cover valve 213. This is performed under the control feed control circuit 231 by supplying an appropriate output to cover valve control 223 and to splitter valve control 235. Once the splitter valve 207 has been rotated into its recirculation position and the cover valve 213 rotated into its air-sealing position, then the feeding means will not change state until the auger position sensor 227 determines that the auger 121 has been rotated into an orientation such that the area 151 is of its proper feed volume. When this orientation of the auger 121 is reached, the auger position sensor 227 supplies a pulse as shown in FIG. 5, to the feed control circuit 231.

There are many ways of implementing the auger position sensor 227, for example, a small magnetic flux producing element could be attached to the auger such that it would be rotated into alignment with a flux sensor when the auger has been rotated into the feed orientation. When the feed control circuit has received the auger position pulse and is also still receiving the bin full signal at a high level, the feed control circuit 231 will signal the release valve control 227 to rotate the release valve 217 to its downward orientation in order to permit the fuel contained within the weigh bin 211 to pass through lower chute 219 into the first area 151 of combustion chamber 115.

The feed control circuit 231 will produce a restore pulse, after a suitable delay to provide time for the fuel to be discharged from the weigh bin 211, that is supplied to the auger position sensor 227, release valve control 229, cover valve control 233, and splitter valve control 235 to control the feeding means in a manner to permit the accumulation of a subsequent charge or batch of fuel in the weigh bin 211. As explained above, this feeding orientation comprises: first, closing release valve 217; second, opening the cover valve 213; and third, rotating splitter valve 207 into the orientation illustrated by the solid lines in FIG. 4. The weigh cells 223 will automatically reset the microswitch because after the discharge of the fuel from weigh bin 211 the weigh cells 223 will no longer indicate that a preselected fuel weight has been accumulated in weigh bin 211.

FIG. 6 illustrates an embodiment of the combustion chamber 115 of the starved-air combustor system. As shown in FIG. 6, the starved-air combustor system includes means for conveying the fuel through a combustion chamber at a variable rate. As embodied herein, the conveying means comprises screw conveyor or auger 121 extending the length of the combustion chamber and being rotated by the auger motor and speed control 251. The auger motor and speed control 251 is capable of rotating the auger at rates of, for example, from 0.3 to 1.0 rpm under manual control.

The fuel bed 253 is of its greatest depth at the inlet end 113 of the combustion chamber and is conveyed from the inlet end 113 to the outlet end 117. During its travel through the combustion chamber, the fuel bed 253 gradually decreases in size as its contents are combusted and combustion gases evolved. The auger 121 is positioned off-center within the combustion chamber 115 in order to provide a gas mixing zone above the fuel bed 253. In the mixing zone, the evolved gases are mixed with overfire air supplied by air supply means 125 (FIG. 1) for further combustion. Conduits 123 supply underfire air to the combustion chamber beneath the bed of fuel 253 such that the underfire air, when at an elevated temperature, contributes to the ignition of the fuel in the fuel bed 253 by heating and drying the fuel.

The starved-air combustor system further comprises means for supplying a variable airflow to the combustion chamber 115. The physical structure for accomplishing this is illustrated in FIG. 6 and, as embodied therein, the walls of the combustion chamber 115 include underfire air plenums 255 each coupled to one of the air supply conduits 123. Air passes from the plenums 255 through pipes 256 (FIG. 7) embedded in a refractory layer 257 and terminating in a plurality of ports or injectors 259 communicating with the combustion chamber 115 beneath the bed of fuel 253. The plenums 255 are separated from each other by stops or gaskets 261 to define multiple underfire combustion zones Z1, Z2, and Z3.

Similarly, overfire air is supplied to the combustion chamber 115 by means of plenums 263 (FIG. 7) communicating with the overfire air supply means 125. The plenums are divided into a plurality of zones (in this case, three) and the air within each zone is injected into the combustion chamber 115 through ports or injectors 267 which extend through the layer of refractory material 257 lining the interior surface of the combustion chamber 115. As illustrated in FIG. 6, the zones of the overfire air and the zones of the underfire air may coincide and form combustion zones Z1, Z2, and Z3. A temperature sensor 271 (FIG. 7) is inserted through the refractory material 257 into the gas phase flame areas of each of the temperature zones to sense the temperature in the overfire area of the zone.

With reference to FIG. 7, the rotation of the auger (not shown) within combustion chamber 115 results in the fuel bed 253 being oriented as shown. Underfire air from supply 123 is supplied to plenum 255 from which it is injected beneath the fuel bed 253 by means of pipes 256 terminating in injectors 259. The pipes 256 are embedded in the refractory lining 257 of the combustion chamber 115.

Underfire air received by one of the plenums 263 from supply 125 is injected above the fuel bed 253 through ports 267. The temperature sensor 271 for one of the overfire air zones is provided above the fuel bed 253 and it is contemplated that a thermocouple capable of withstanding the high combustion chamber temperatures could be employed as sensor 271.

The starved-air combustor of the instant invention further comprises means for controlling the rate of the fuel conveying means or auger 121 and the volume of the airflow supplied into the zones Z1, Z2, and Z3 to increase or to decrease the quantity of heat produced in the form of hot combustion gases. The means for controlling the rate of the conveying means and the airflow supplied by the supplying means to increase the quantity of hot, combustion gases (heat) produced by the system responsive to an increase in the heat demand and to decrease the quantity of hot, combustion gases (heat) produced by the system responsive to a decrease in the heat demand, as embodied herein, is illustrated in FIG. 8 as comprising an underfire air system, an overfire air system, and an afterburner air system. The afterburner air system is not a feature of the present invention and will not be discussed in detail.

As illustrated in FIG. 8, the combustor 115 receives underfire air in three zones: primary (p) corresponding to Zone 1, secondary (s) corresponding to Zone 2, and tertiary (t) corresponding to Zone 3. Controllers 301, 303, and 305 control the injection of underfire air from air supply line 307 into the p, s, and t zones. These three zones are set to initial values to apportion the air supplied by the air supply line 307 to the previously discussed supplier 123 but, as explained above, if there is a change in heat demand then the speed of the auger will be changed necessitating corresponding changes in the supply of air to the p, s, and t zones by the controllers 301, 303, and 305, respectively. The change in auger speed as determined by the auger motor and speed control 251 (FIG. 6) are supplied to multiplier 309 along with a signal indicating the weight of each batch of fuel supplied to the combustion chamber. This weight is represented by the quantity M and could, for example, be an output of the previously explained weigh cells 223. The output of multiplier 309 is a signal K_u which is supplied as an input to each of the controllers 301, 303, and 305 to alter the airflow into their associated underfire zones.

The overfire air system is, as previously explained, temperature dependent and thus the signal T_p is an output of temperature sensor 271 (FIG. 7) which monitors the temperature in combustion zone Z1 or the primary zone. The controller 313 compares the instantaneous temperature within the primary zone to a desired temperature and properly alters the airflow from air supply line 319 to the primary zone in the combustion chamber. Similarly, controllers 315, and 317 receive the temperature indications T_s and T_t, respectively, from the temperature sensors to 271 in their associated combustion zones. Any change in the temperatures in their associated zone from the desired temperature will cause the controllers 315 and 317 to alter the airflow from air supply line 319 into the secondary and tertiary zones in the manner illustrated in FIG. 2.

FIG. 9 illustrates, in greater detail, the circuit for controlling the flow of fuel into the combustor 115. The mass of each fuel batch or charge is supplied to the multiplier 309 where it is multiplied by the change in auger rotation rate W_{aug}. The output of the multiplier 309 is the change in fuel feed m_f which must be accommodated by the underfire air control system.

FIG. 9 illustrates, in greater detail, the underfire air control system. The controllers 301, 303, and 305 are initially set with a constant indicating the air distribution into the primary, secondary, and tertiary zones. The controllers 301, 303, and 305 each receive, as an input, the change in fuel flow through the combustion chamber and each generate output signals to adjust accordingly the airflow into the primary, secondary, and tertiary zones. As an example, the output of controller 301 is a signal corresponding to the new airflow into the primary zone of the combustion chamber. This is supplied to an adder 321 which receives as its other input the output of flow transmitter 323 indicating the amount of air currently flowing into the primary zone from the air supply line 307. If there is a difference between the newly determined amount and the current airflow into the primary zone then a signal representing that difference is supplied to valve control circuit 325 to open or close a flow control device 327, e.g., a valve. The output of the flow control device 327 is the air supplied to the primary zone (Z1 in FIG. 6) through the appropriate air conduit 123 (FIG. 6). If the heat demand is increased, then the flow control device 327 will cause a greater airflow into the primary zone of the combustion chamber. Conversely, if the heat demand is decreased, the output of the adder 321 will be a negative difference and will cause valve control circuit 325 to control the flow control device 327 in a manner to restrict airflow into the primary zone of the combustion chamber. FIG. 10 also illustrates the circuits required to control airflow into the secondary and tertiary zones in the combustion chamber but these will not be explained since they operate in the same manner as the circuit for controlling airflow into the primary zone.

FIG. 11 illustrates an embodiment of a circuit for controlling the flow of overfire air into the primary, secondary, and tertiary zones. Initially, the controllers 313, 315, and 317, are set to values corresponding to the desired temperature in the primary, secondary, and tertiary zones, respectively, within the combustion chamber. The controller 313, as explained above, receives a signal T_p corresponding to the actual temperature within the primary zone and will generate an appropriate output signal representing the difference between the desired primary zone temperature and the actual primary zone temperature. This is supplied to the adder circuit 329 which receives as another input a signal corresponding to the current flow of overfire air into the primary zone. The difference between the two signals is determined and passed to valve control circuit 333 which appropriately opens or closes the flow control device, such as a valve 335, to either increase or to decrease the temperature within the primary zone. This will cause a change in the temperature in the primary zone which will be supplied to the controller 313. When the proper temperature has been reached in the primary zone, then the adding circuit 329 will no longer signal the valve control circuit 333 to adjust the flow control device 335.

Any number of embodiments for flow transmitters, summation circuits, valve control devices and flow control devices are known in the art and, one of ordinary skill in that art may select such devices according to the above teachings.

It will be further apparent to those skilled in the art, that numerous modifications and variations can be made to the feeding means of the starved-air combustor without departing from the scope or spirit of the invention and it is intended that the present invention cover the modifications and variations of the system, provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A starved-air combustor system comprising:
 a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said fuel, said combustion chamber being divided into a plurality of combustion zones;
 means for conveying said fuel through said combustion to said combustion zones in said combustion chambers; and
 means responsive to the temperatures in said combustion zone for controlling said supply means to supply selected quantities of air to said combustion zones wherein said conveying means conveys said fuel through said combustion chamber at a selectively variable rate and wherein said controlling means controls said supplying means to increase the supply of said air to said combustion zones responsive to an increase in the rate of said conveying means and to decrease the supply of air to said combustion zones responsive to a decrease in said rate of said conveying means.

2. A starved-air combustor system for producing a variable quantity of heat responsive to a demand for said heat, said combustion system comprising:
 a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said fuel to produce a quantity of heat related to the rate of combustion, said combustion chamber being divided into a plurality of combustion zones;
 means for conveying fuel through said combustion chamber at a variable rate;
 means for supplying a variable quantity of air to said combustion chamber, said supplying means comprising:
  a set of overfire air injectors associated with each of said plurality of zones for injecting air above the fuel in said associated combustion chamber zone;
  a temperature sensor associated with each of said combustion chamber zones for determining the temperature in said associated combustion zone; and
  an overfire air controller for controlling the quantity of air injected into each of said combustion zones by said associated set of overfire air injectors in response to the temperature in said associated zone as determined by said associated temperature sensor; and
 means for controlling the rate of said conveying means and the quantity of fuel supplied by said supplying means to increase the quantity of heat produced by said system responsive to an increase in said heat demand and to decrease the quantity of heat produced by said system responsive to a decrease in said heat demand.

3. A starved-air combustor system according to claim 2 further including means for feeding selectable weights of fuel into said inlet end of said conveyor in a batch mode.

4. A starved-air combustor system according to claim 3 wherein said combustion chamber is cylindrical and includes an outlet end for discharging combustion residue produced by said combustion and wherein said conveying means comprises:
 a rotatable screw conveyor in said combustion chamber for conveying said constant weight batches of fuel from said inlet end of said combustion chamber to said outlet end of said combustion chamber and for conveying said combustion residue toward said outlet end of said combustion chamber; and
 means for rotating said rotatable screw conveyor at a variable rate directly proportional to said heat demand to control the flow of said fuel through said combustion chamber.

5. A starved-air combustor system according to claim 4 wherein said air supplying means further comprises:
 a set of underfire air injectors associated with each said combustion chamber zone for injecting air into said associated zone beneath said fuel in said associated zone; and
 an underfire air controller for controlling the quantity of air injected into each of said associated zones by said set of underfire air injectors in direct proportion to said flow of fuel through said combustion chamber.

6. A starved-air combustor system for producing a variable quantity of heat responsive to a demand for said heat, said combustor system comprising:
 a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said received fuel to produce hot combustion gases and combustion residue related to the rate of com-

bustion of said fuel, said combustion chamber further having an outlet end for discharging said hot combustion gases, said combustion chamber being divided into a plurality of combustion zones serially spaced from said inlet end to said outlet end;

means for conveying said fuel in said combustion chamber from said inlet end toward said outlet end at a variable rate;

means for feeding selectable weights of said fuel into said inlet end in a batch mode;

a plurality of air injector means singularly associated with each of said combustion zones for independently supplying to said associated combustion zone a variable airflow; and

means for controlling the rate of said conveying means and the airflow of each of said injector means to increase the quantity of heat produced by said system responsive to an increase in said heat demand and to decrease the quantity of heat produced by said system responsive to a decrease in said heat demand.

7. A starved-air combustor system according to claim 6 wherein each of said air injector means comprises:

a set of overfire air injectors for injecting air above the fuel in said associated combustion zone;

a temperature sensor associated with each of said combustion zones for determining the temperature in said associated combustion zone; and

an overfire air controller for controlling the airflow of said set of overfire air injectors in an inverse relationship to changes in the temperature of said associated combustion zone.

8. A starved-air combustor system according to claim 7 wherein each of said plurality of air injector means further includes:

a set of underfire air injectors for injecting air into said associated combustion zone beneath the fuel in said associated combustion zone; and

an underfire air controller for controlling the airflow of said set of underfire air injectors in direct proportion to the rate of conveyance of said fuel in said combustion chamber.

* * * * *

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United States Patent [19] [11] 4,331,084

Fitch et al. [45] May 25, 1982

[54] FUEL FEED TECHNIQUE FOR AUGER COMBUSTOR

[75] Inventors: Robert E. Fitch, Kent, Wash.; Robert C. Tyer, Baldwin, Fla.

[73] Assignee: The Boeing Company, Seattle, Wash.

[21] Appl. No.: 148,370

[22] Filed: May 9, 1980

[51] Int. Cl.[3] F23N 5/18

[52] U.S. Cl. 110/186; 110/187; 110/101 CC; 110/101 CF

[58] Field of Search 110/203-205, 110/210-212, 186, 187, 185, 267, 101 CC, 101 CF

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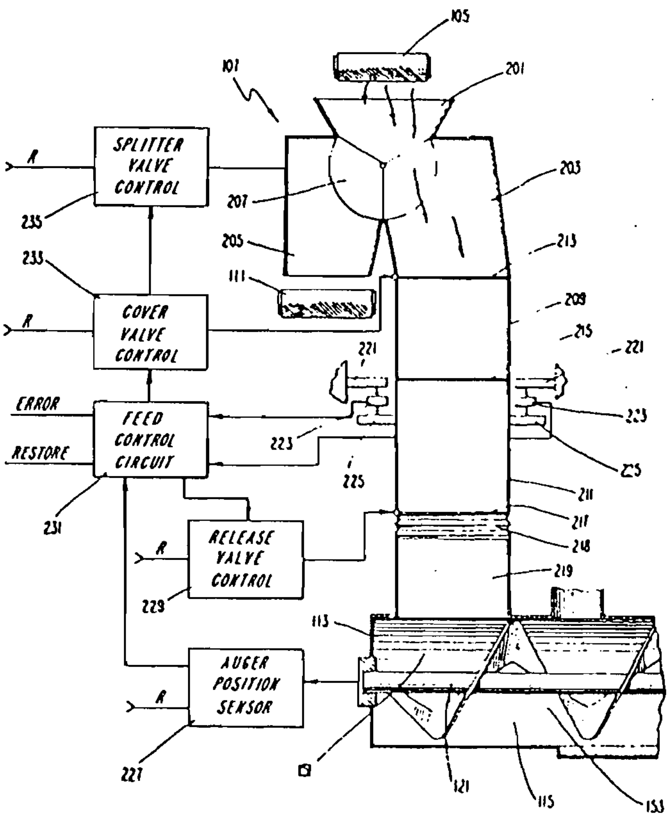
Primary Examiner—Henry C. Yuen

Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner

[57] ABSTRACT

A feeding system for a starved-air combustor which enables the batch feeding of preselected weights of fuel into a combustion chamber of the starved-air combustor. The feeding system also blocks the entry of ambient air into the combustion chamber during the feeding of fuel to the chamber and can control the feeding of fuel into the combustion chamber in response to the orientation of a fuel-conveying auger in the combustion chamber.

9 Claims, 3 Drawing Figures



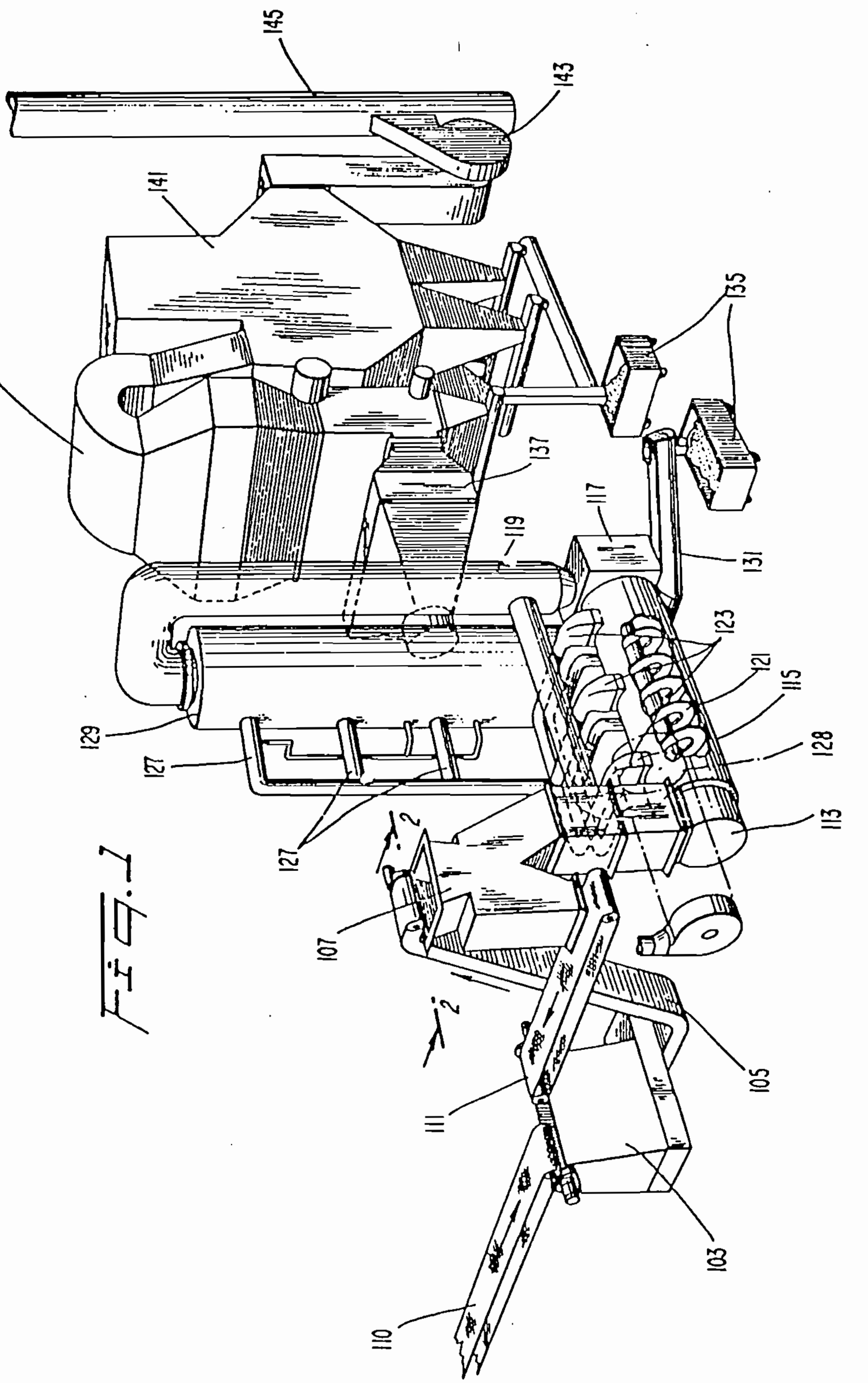

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Fig. 1

Fig. 2

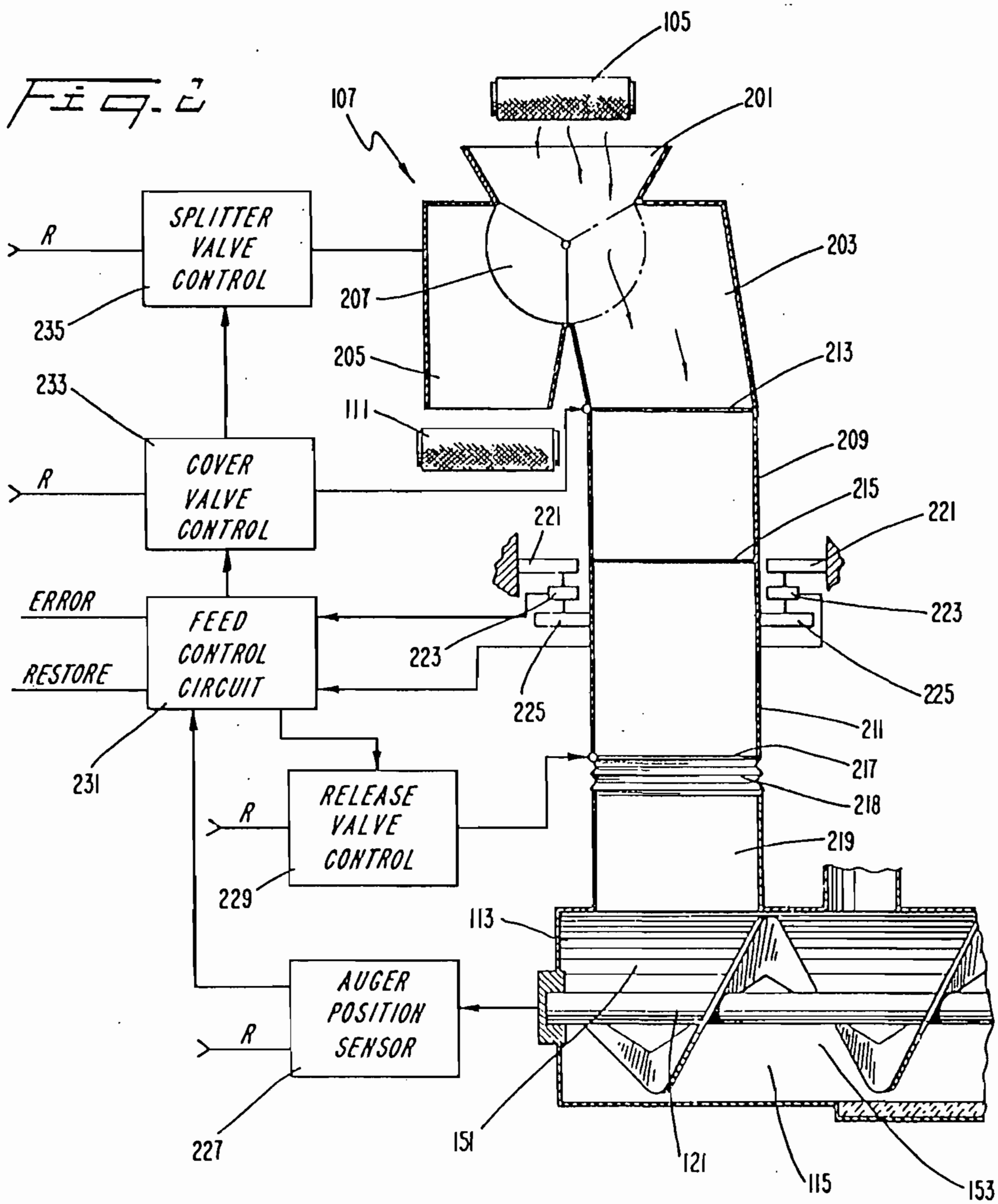
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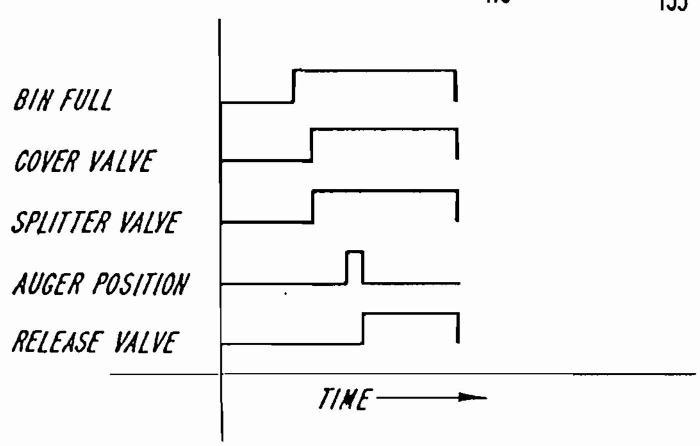
Fig. 3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RELEASE VALVE
TIME

FUEL FEED TECHNIQUE FOR AUGER COMBUSTOR

BACKGROUND OF THE INVENTION

In the last century, much of the world's energy needs have been fulfilled by hydrocarbon fuels which provided a convenient, plentiful, and inexpensive energy source. The current rising costs of such fuels and concerns over the adequacy of their supply in the future has made them a less desirable energy source and has led to an intense investigation of alternative sources of energy. The ideal alternative energy source is a fuel which is renewable, inexpensive, and plentiful, with examples of such fuels being the byproducts of wood, pulp, and paper mills, and household and commercial refuse.

The use of alternative energy sources is not problem-free, however, since there is a concern over the contents of the emissions from the combustion of such fuels as well as the environmental ramifications of acquiring and transporting the fuel and disposing of the residue of combustion.

One promising prior art device for using such alternative energy sources, while maintaining a high degree of enviromental quality, is the starved-air combustor wherein the air supplied for combustion is controlled in order to control temperature conditions and the rates of combustion are controlled to consume the fuel entirely. Such starved-air combustors are capable of burning various types of fuel and producing significant amounts of heat which can be employed for any number of purposes including the production of process steam for use in manufacturing and in the generation of electricity.

Starved-air combustors as previously known and operated, have not been entirely satisfactory in both entirely consuming the combustible elements of the fuel at high throughput while not producing noxious emissions. This problem results, in part, from the use of such starved-air combustors to burn a wide variety of fuels some of which may be non-homogeneous, e.g., household or commercial refuse. It has not been possible in the previously known starved-air combustors to tailor in a real time manner the combustion processes to the type of fuel being combusted in order to maximize the efficiency of the combustor while minimizing the generation of air pollutants. While the pollution problem can be solved to a degree by the utilization of scrubbers and other antipollution devices, such mechanisms are very expensive and their cost may militate against the use of alternative energy sources.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a starved-air combustor capable of efficiently utilizing many different types and quantities of fuel.

Another object of this invention is to provide a starved-air combustor which does not release noxious pollutants into the atmosphere.

Yet another object of this invention is to provide a starved-air combustor which is capable of combusting to a very high degree the percentage of all combustible materials provided to it as fuel.

Still another object of this invention is to provide a starved-air combustor including means for selectively feeding predetermined weights of fuel into the combustion chamber of the starved-air combustor.

To achieve these objects, and in accordance with the purpose of the invention, as embodied and broadly described herein, the starved-air combustor comprises combustion chamber means having an inlet end for receiving fuel, the combustion chamber means for combusting the received fuel to produce combustion gases and combustion residue, the combustion chamber means including an outlet end for discharging the combustion residue and an outlet port for discharging the combustion gases, means in the combustion chamber means for conveying the received fuel from the inlet end toward the outlet end, and means for selectively feeding predetermined weights of the fuel into the inlet end of the combustion chamber.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the starved-air combustor of the instant invention combined between a fuel supply system and a system which produces process steam from the heat produced by the starved-air combustor.

FIG. 2 is an enlarged cross-sectional view taken along lines 2—2 of FIG. 1 illustrating the fuel supply apparatus of the instant invention.

FIG. 3 is a timing diagram illustrating the sequence of operation of the fuel-feeding apparatus of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an embodiment of a starved-air combustor according to the present invention coupled between a refuse feeder system and a steam generation system. As embodied herein, the refuse supply comprises a supply conveyor 101 for conveying fuel, in this instance refuse, from a receiving building (not shown) and one or more storage silos (not shown). The receiving building and storage silos are to insure that an adequate supply of fuel can be supplied to the combustor in order to permit the combustor to run at peak efficiency. In the illustrated embodiment, it is contemplated that the supply conveyor 101 would supply fuel to the fuel surge and recirculation bin 103 at a rate of at least fifteen tons per hour and that the capacity of the combustor system would range from 150 to 500 pounds of fuel per minute.

The fuel surge and recirculation bin 103 comprises an additional means for insuring that a constant and adequate supply of fuel is available to the combustor. The bin 103 could, for example, contain at least 10 minutes capacity of fuel, i.e., approximately 2.5 tons, which is received at the top of the bin 103 and supplied through the bottom of the bin 103 to the feed conveyor 105. Feed conveyor 105 supplies the fuel to a splitter 107 which may either direct the fuel into the feed and weigh bin 109 or, when the feed and weigh bin 109 is filled to capacity, to the return conveyor 111 for return to the fuel surge and recirculation bin 103. The feed and weigh bin 109 is calibrated to supply a constant weight of fuel at the inlet end 113 of the combustor 115 at such time that the first flight of an auger 121 within the chamber 115 has been rotated into a fuel receiving position. Within the starved-air combustor 115 there is provided a well-known oil igniter (not shown) in the input end of the combustion chamber to serve as a means for initially igniting the fuel upon start-up of the starved air combustor.

U.S. Pat. No. 4,009,667 issued to Robert C. Tyer et al on Mar. 1, 1977, illustrates an appropriate embodiment for a rotatably-driven auger comprised of a rotatable, water-cooled horizontal shaft supporting a spiral flight of decreasing pitch from the input end of the auger to the output end. It is contemplated in the instant system that the speed of the auger would range from 0.3 to 1 rpm. An appropriate oil igniter would comprise an oil burner having its flame extending into the input end of the combustor 115 to heat and to ignite the initial load of fuel supplied by the feed and weigh bin 109. It is contemplated that such an oil ignitor would be capable of burning fuel at a rate of approximately six gallons per hour at two pounds per square inch pressure.

The combustor 115 has an output end 117 connected to a duct 119 which feeds the top of an afterburner 129. The combustor 115 also includes air supply means 123 for supplying underfire air and conduits 125 for supplying overfire air. This air is provided by a fan 126 (shown in phantom) which also supplies air through conduits 127 to the afterburner 129. Alternatively, a separate fan or fans may be provided to supply underfire air, overfire air, and air to the afterburner. A small air distributor 130 is connected to the upper conduit 127 to supply air into afterburner 129 through special injectors located both at and below the midpoint of the afterburner 129.

Afterburner 129 is provided, in part, as a secondary combustor chamber which mixes the air supplied by the conduits 127 with the gaseous and entrained solid particle output of the combustor from the outlet end 117 to combust all combustible material in the gaseous output and, in part, to separate suspended ash and non-combustible solids from the hot non-combustible gas. Both the non-combustible material from the afterburner 129 and the combustor residue from combustor 115 are fed through conduit 131 to an ash collector 135. The hot non-combustible gas exits into a superheater 137 from which it is supplied to a waste heat boiler 139 to produce, in this case, process steam. An electrostatic precipitator 141 removes any additional solids from the now cooler non-combustible gas exiting from the waste heat boiler 139 through the economizer 140 and the solid material is conveyed to an ash cart 135. From the precipitator 141, the non-combustible gas is drawn by a fan 143 and expelled from stack 145. Upon entering into the fan the temperature of the gas is approximately 300 to 400 degrees Fahrenheit and the fan 143 is of sufficient strength to exert a negative pressure in the system from the combustor 115, the afterburner 129, superheater 137, waste heat boiler 139, economizer 140, and precipitator 141.

The present invention is particularly concerned with an apparatus for selectively feeding predetermined weights of fuel into the inlet end of the combustion chamber of the starved-air combustor. By feeding only preselected weights of fuel, the present invention avoids a serious problem in the prior art starved-air combustors which greatly reduced the efficiency of such combustors. This inefficiency resulted from a varying fuel-to-air ratio in the combustion chamber 115. As discussed in the previously preferred patent to Tyer et al, the combustion chamber 115 is provided with underfire air which is air introduced through the walls of the combustion chamber 115 underneath the fuel in the chamber. Similarly, overfire air is injected through the walls of the combustion chamber above the fuel to aid combustion. Assuming that a constant volume of air is injected into the combustion chamber as underfire and overfire air, then the air-to-fuel ratio will be determined by the amount of fuel fed into the combustor. The prior art starved-air combustors did not regulate the amount of fuel fed thereto and could not establish proper air-to-fuel ratio. Also, it is advantageous to set different air-to-fuel ratios for different types of fuel consumed in the combustor in order to maximize the efficiency of combustion and to minimize the pollutants in the exhaust gas but if the quantity of fuel fed into the combustion chamber cannot be regulated, then no definite air-to-fuel ratio can be maintained.

The instant invention enables the air-to-fuel ratio to be selected by feeding predetermined weights of fuel into the inlet end of the combustion chamber in a batch mode. The weight of a particular fuel charge or batch could, for example, be selected to range from 150 to 500 pounds depending upon the combustability of the fuel currently being feed to the combustor. Thus, if a particular air-to-fuel ratio is desired then it can be accomplished merely by selecting a particular weight for each charge or batch of fuel and specific airflow for that feed rate.

Feeding fuel in a charge or a batch mode into the inlet of the combustion chamber provides a further advantage over the prior art starved-air combustors by enabling the combustor to achieve a maximum throughput. If, for example, unregulated amounts of fuel are supplied to the combustor as exhibited in U.S. Pat. No. 3,942,455 issued to Wallis on Mar. 9, 1976, then there exists the probability that the auger within the combustion chamber will be conveying either too little or too much fuel through the combustion chamber at any one time. Feeding the fuel in predetermined batch weights, as is done by the present invention, permits control over the combustion processes and a level of efficiency in the manner not previously attainable.

Referring to FIG. 2, the starved-air combustor comprises a combustion chamber 115 including an inlet end 113. As embodied herein, the combustion chamber comprises a refractory-lined horizontal cylinder chamber extending from the inlet end 113 to the outlet end 117. Within the chamber, there resides means for conveying fuel from the inlet end to the outlet end. As herein embodied, the conveying means comprises the screw conveyor or auger 121 formed with a rotatable cylindrical axis within the cylindrical combustion chamber with a spiral flight concentrically connected to the axis. As is well-known in the art, the spiral flight in cooperation with the axis forms an auger and provides a plurality of spaces 151 and 153 defined by the walls of the combustion chamber 115 and the spiral flight of the auger 121. As seen in FIG. 2, the orientation of the auger 121 within the combustion chamber 115 beneath the inlet end 113 illustrates the correct time for feeding fuel into the combustion chamber. This orientation causes area 151 to have its largest volume but, if desired, different orientations of the auger to present an area 151 of different volume could also be designated the feed position or positions.

The instant invention also includes means for selectively feeding predetermined weights of the fuel into the inlet end 113 of the combustion chamber 115. As embodied herein, the feeding means comprises means for receiving and containing the fuel, means for weighing the received and contained fuel, and means for selectively discharging the received and contained fuel responsive to the positioning of the auger 121 into the feeding orientation and to the accumulation of a preselected weight of fuel in the receiving and containing means.

A suitable embodiment for the receiving and containing means comprises a chute 201 positioned beneath the fuel feed conveyor 105 such that the fuel conveyed by the conveyor 105 drops off to the conveyor 105 into the chute 201. From the chute 201, the fuel can either pass into the combustor feed path 203 of the feeding and receiving means or through path 205 to the return conveyor 111 for return to the surge bin 103 as previously explained. A splitter 207 is rotatable in the neck of the chute 201 to guide the received fuel to the combustor feed path 203 or to the return path 205.

The receiving and containing means further includes a chute 209 for guiding the fuel directed to the combustor 115 into a weigh bin 211. A cover valve 213 is provided at the inlet of the chute 209 and is rotatable either to permit the fuel to pass into the chute 209 and the weigh bin 211 when the cover valve is in an open, or downward, position or to prevent additional fuel from entering chute 209 and weigh bin 211 when the cover valve 213 is in a closed, i.e., as illustrated in FIG. 2, a horizontal position. The cover valve 213 provides an airtight seal with the sides of the chute 209 such that when the cover valve 213 is closed, outside air is prevented from entering chute 209 and weigh bin 211. The cover valve 213 could alternatively be a slidable valve having an inward (closed) position and an outward (open) position.

The weigh bin 211 is connected to chute 209 via a flexible coupling 215 so that the weight of the weigh bin 211 and any fuel contained therein is not supported by the chute 209 but, as will be hereinafter explained, is supported by means of one or more weigh cells 223 connected to a stationary support member 221 and to support arms 225 on the exterior of the weigh bin 211.

As embodied herein, the discharging means comprises a release valve 217 shown in FIG. 2 in its closed position. As will also hereinafter be explained, the release valve 217 will not be opened, i.e., rotated to extend into the lower chute portion 219 of the feeding means, until the weighing means indicates that a predetermined weight of fuel has been accumulated in the weigh bin 211 and that an auger position sensor 227 has determined that the auger 122 has been rotated into the proper feed orientation. The lower chute portion 219 is coupled to the weigh bin 211 by means of a flexible, airtight seal 218 so as not to support the weigh bin 211 but only to guide the fuel into the inlet end 113 of the combustion chamber 115 while simultaneously preventing ambient air from entering the combustion chamber.

The weighing means, as embodied herein, comprises one or more weigh cells 223 coupled, as above-described, between stationary support members 221 and exterior arms 225 connected to the weigh bin 211. One skilled in the art will readily recognize that each weight cell 223 comprises any one of a number of means whereby a particular weight can be selected, the weight of the weigh bin including fuel received and contained therein determined, and an output signal generated when the measured weight of the weigh bin exceeds a selected weight. As one example, the weigh cell 223 could comprise a variable resistor providing a voltage output indicative of the weight of fuel in weigh bin 211. A voltage detector senses the voltage output of the variable resistor and actuates a microswitch when the sensed voltage exceeds a threshold voltage corresponding to a selected weight. The output of the microswitch is then employed within suitable logic circuitry, as will be hereinafter explained, to actuate the splitter 207, cover valve 213, and release valve 217 to feed the conveyor with fuel in a proper manner.

FIG. 2 also illustrates, in block diagram form, functional logic circuits that are needed to control the feeding means to feed fuel either into the combustor 115 or to the return conveyor 111. FIG. 3 is a timing diagram to be read in conjunction with the block diagram of FIG. 2 for a complete understanding of the operation of the logic circuits.

In normal operation, during the combustor feed mode, the splitter valve 207 will be positioned as indicated by the solid lines in FIG. 2. The cover valve 213 will be in its opened, or downward position, and the release valve 217 will be in the closed position as shown in FIG. 2. Fuel will drop from feed conveyor 105 through feed path 203 and upper chute 209 into the weigh bin 211. This will gradually increase the weight of fuel in the weigh bin 211 and when the preselected weight of a batch or charge of fuel has been accumulated in the weigh bin 211 then the weigh cells 223 will cause a bin full signal to be supplied from the weigh cells 223 to feed control circuit 231 to change from a low value to a high value as shown in FIG. 3.

After the preselected weight has been accumulated in the weigh bin 211, it is necessary to rotate the splitter valve 207 into the orientation shown by the dotted lines in FIG. 2 and to close the cover valve 213. This is performed under the control of feed control circuit 231 by supplying the appropriate output to cover valve control 233 and to splitter valve control 235. Once the cover valve 213 has been rotated into its closed and air-sealing position, then the feeding means will not change state until the auger position sensor 227 determines that the auger 121 has been rotated into an orientation such that the first area 151 is of its proper volume. When this orientation of the auger 121 is reached, the auger position sensor 227 supplies a pulse, as shown in FIG. 3, to the feed control circuit 231.

There are many ways of implementing the auger position sensor 227 but one would be to attach a small magnetic flux producing element to the auger such that it would be presented in alignment with a flux sensor when the auger has been rotated into the feed orientation.

After the feed control circuit has received the auger position pulse and is still receiving the bin full signal at a high level, it will signal the release valve control 229 to rotate the release valve 217 to its downward orientation in order to permit the fuel contained within the weigh bin 211 to pass through lower chute 219 and into the first area 151 of the combustion chamber 115. The feed control circuit 231 will produce, after a suitable delay to provide time for the fuel to be discharged from the weigh bin 211, a restore pulse that is supplied to the auger position sensor 227, release valve control 229, cover valve control 233, and splitter valve control 235 to control the feeding means in a manner to permit the accumulation of a subsequent charge or batch of fuel in the weigh bin 211. As explained above, this feeding orientation comprises: first, closing release valve 217; second, opening the cover valve 213; and third, rotating splitter valve 207 into the orientation illustrated by the solid lines in FIG. 2. The weigh cells 223 will automatically reset the microswitch because, after the discharge of the fuel from weigh bin 211, the weigh cells 223 will no longer indicate that the preselected fuel weight has been accumulated in weigh bin 211.

Since one of the purposes of this instant invention is to provide only preselected weights of fuel to the combustor 115, the feed control circuit 231 will generate an error signal if auger position sensor 227 determines that the auger 121 is in the feed orientation and provides a pulse to feed control circuit 231, while at the same time the weigh cells 223 have not supplied signals to feed control circuit 231 indicating that the predetermined weight of fuel had been accumulated in weigh bin 211. If such a situation occurs, the starved-air combustor could either be shut down temporarily, the feed conveyor means 105 accelerated to supply greater volumes of fuel per unit time, or an appropriate alarm actuated to indicate that the starved-air combustor is operating at less than optimum capacity because insufficient fuel is being provided or, alternatively, any combination of these actions could be taken.

It will be further apparent to those skilled in the art, that various modifications and variations can be made to the feeding means of the starved-air combustor without departing from the scope or spirit of the invention and it is intended that the present invention cover the modifications and variations of the system provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A starved-air combustor comprising:

a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said fuel to produce hot combustion gases and combustion residue, said combustion chamber also having an outlet end for discharging said combustion residue, and an outlet port for discharging said hot combustion gases;

means in said combustion chamber for conveying said received fuel from said inlet end toward said outlet end, said conveying means comprising a rotatable screw conveyor extending along the length of said chamber, said screw conveyor including a spiral flight defining a plurality of spaces within said combustion chamber, a first of said spaces located adjacent said inlet end of said combustion chamber; and

means for selectively and intermittently feeding predetermined weights of said fuel in a batch mode into said inlet end of said combustion chamber, said feeding means including means for receiving and containing said fuel, means for weighing said received and contained fuel, and means for selectively discharging said received and contained fuel responsive to the positioning of said screw conveyor into a predetermined orientation and to the accumulation of a preselected weight of said fuel in said receiving and containing means, said discharging means including a release valve connected to one end of said fuel receiving and containing means to enable in a first valve position the discharging of said fuel from said fuel receptacle into said inlet end of said combustion chamber and to enable in a second valve position the accumulation of said fuel in said fuel receptacle; and a cover valve connected to the other end of said fuel receiving and containing means to enable in a first valve position the hermetic sealing of said receiving and containing means from ambient air and to prevent the accumulation of fuel in said receiving and containing means, and to enable in a second valve position said fuel to pass into said receiving and containing means.

2. A starved-air combustor according to claim 1 wherein said conveying means further includes a cylindrical axle extending along the length of said combustion chamber, said spiral flight being concentrically connected to said axle.

3. A starved-air combustor comprising:

a cylindrical combustion chamber having an inlet end for receiving fuel and an outlet end for discharging combustion gases and combustion residue, said combustion chamber for combusting said received fuel to produce said combustion gases and combustion residue;

a rotatable screw conveyor in said combustion chamber for conveying said fuel from said inlet end toward said outlet end, said screw conveyor comprising a cylindrical axle extending along the length of said chamber and a spiral flight concentrically connected to said axle, said spiral flight and said cylindrical axle defining in said combustion chamber a plurality of spaces around said cylindrical axle, a first of said spaces being located beneath said inlet end of said cylindrical combustion chamber;

means for sensing the orientation of said screw conveyor in said cylindrical combustion chamber; and

means for selectively and intermittently feeding predetermined weights of said fuel in a batch mode into said first space through said inlet end, said feeding means including a fuel receptacle for receiving and for containing said fuel, means for weighing said received and contained fuel, and means responsive to the sensing of a predetermined orientation of said screw conveyor in said cylindrical combustion chamber by said sensing means and to the accumulation of a selected weight of said fuel in said fuel receptacle for discharging said fuel in said fuel receptacle into said first space, said discharging means including a release valve connected to one end of said fuel receptacle to enable in a first valve position the discharging of said fuel from said fuel receptacle into said inlet end of said combustion chamber and to enable in a second valve position the accumulation of said fuel in said fuel receptacle; and a cover valve connected to the other end of said fuel receptacle to enable in a first valve position the hermetic sealing of said fuel receptacle from ambient air and to prevent the accumulation of fuel in said fuel receptacle, and to enable in a second valve position said fuel to pass into said fuel receptacle.

4. A starved-air combustor according to claim 1, 2, or 3 wherein a plurality of said predetermined orientations are included in a single complete revolution of said screw conveyor.

5. A starved-air combustor according to claim 1 or 3 further including:

a storage bin for storing said fuel;

a first fuel feed conveyor for supplying fuel from said storage bin;

a second fuel feed conveyor for supplying fuel to said storage bin; and

a fuel path controller for receiving said fuel supplied by said first fuel feed conveyor and in a first mode for supplying the received fuel to said fuel receptacle and in a second mode responsive to a predetermined amount of fuel being accumulated in said fuel receptacle for supplying said fuel received from said first fuel feed conveyor to said second fuel feed conveyor.

6. A starved-air combustor according to claim 5 wherein said fuel path controller comprises a rotatable fuel feed valve having a first position associated with said first mode and a second position associated with said second mode.

7. A starved-air combustor comprising:

a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said fuel to produce hot combustion gases and combustion residue, said combustion chamber also having an outlet end for discharging said combustion residue, and an outlet port for discharging said hot combustion gases;

means in said combustion chamber for conveying said received fuel from said inlet end toward said outlet end; and

means for selectively feeding predetermined weights of said fuel into said inlet end of said combustion chamber, said feeding means comprising:

a fuel receptacle for receiving said fuel;

means for weighing the amount of fuel accumulated in said fuel receptacle; and

means for discharging all of said fuel in said fuel receptacle in a single batch into said inlet end of said combustion chamber responsive to said weighing means determining that a preselected weight of said fuel has been accumulated in said fuel receptacle, said discharging means including a cover valve connected to one end of said fuel receptacle to enable in a first valve position the hermetic sealing of said fuel receptacle from ambient air and to prevent the accumulation of fuel in said fuel receptacle and to enable in a second valve position said fuel to pass into said fuel receptacle, and a release valve connected to the other end of said fuel receptacle to enable in a first valve position the discharging of said fuel from said fuel receptacle into said inlet end of said combustion chamber and to enable in a second valve position the accumulation of said fuel in said fuel receptacle.

8. A starved-air combustor according to claim 7 further including a stationary support, wherein said weighing means comprises at least one weigh cell and wherein said fuel receptacle is connected to said support by said weigh cell such that said weigh cell determines and indicates the weight of said fuel accumulated in said fuel receptacle.

9. A starved-air combustor according to claim 7 further including a release valve connected to the other end of said fuel receptacle to enable in a first valve position the discharging of said fuel from said fuel receptacle into said inlet end of said combustion chamber and to enable in a second valve position the accumulation of said fuel in said fuel receptacle.

* * * * *

United States Patent [19]
Tyer et al.
[11] 4,331,085
[45] May 25, 1982

[54] EXIT GAS CONTROL FOR FLAME STABILIZATION AND PERFORMANCE TUNING OF STARVED-AIR AUGER COMBUSTOR

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[22] Filed: May 9, 1980

[51] Int. Cl.³ F23J 15/00

[52] U.S. Cl. 110/203; 110/210; 110/214; 432/59; 34/182

[58] Field of Search 34/182; 110/203-205, 110/210-212, 214, 224, 227; 432/59

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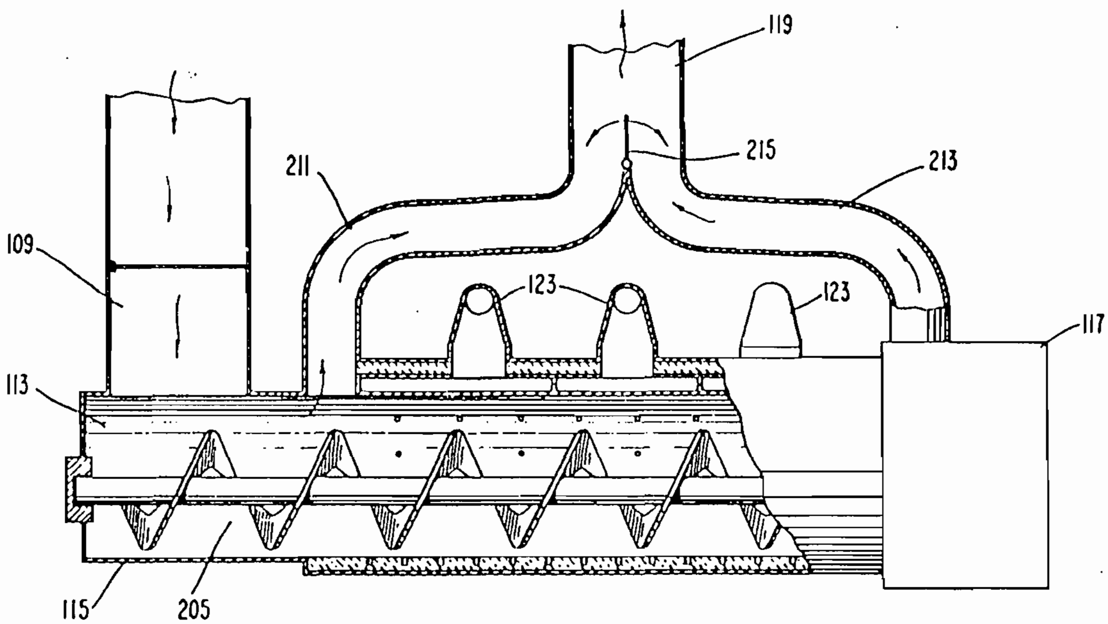
Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner

[57] ABSTRACT

An exit gas control apparatus for flame stabilization and performance tuning of a starved-air combustor includes a first air conduit communicating with the combustion chamber near the fuel inlet and a second conduit communicating with the combustion chamber near the residue outlet. A damper is provided to proportion the discharge of combustion gases entirely through the first conduit, entirely through the second conduit, or proportionately through the first conduit and the second conduit to enable the starved-air combustor to operate in full countercurrent, full co-current, or partial co-current and countercurrent modes, respectively.

2 Claims, 3 Drawing Figures



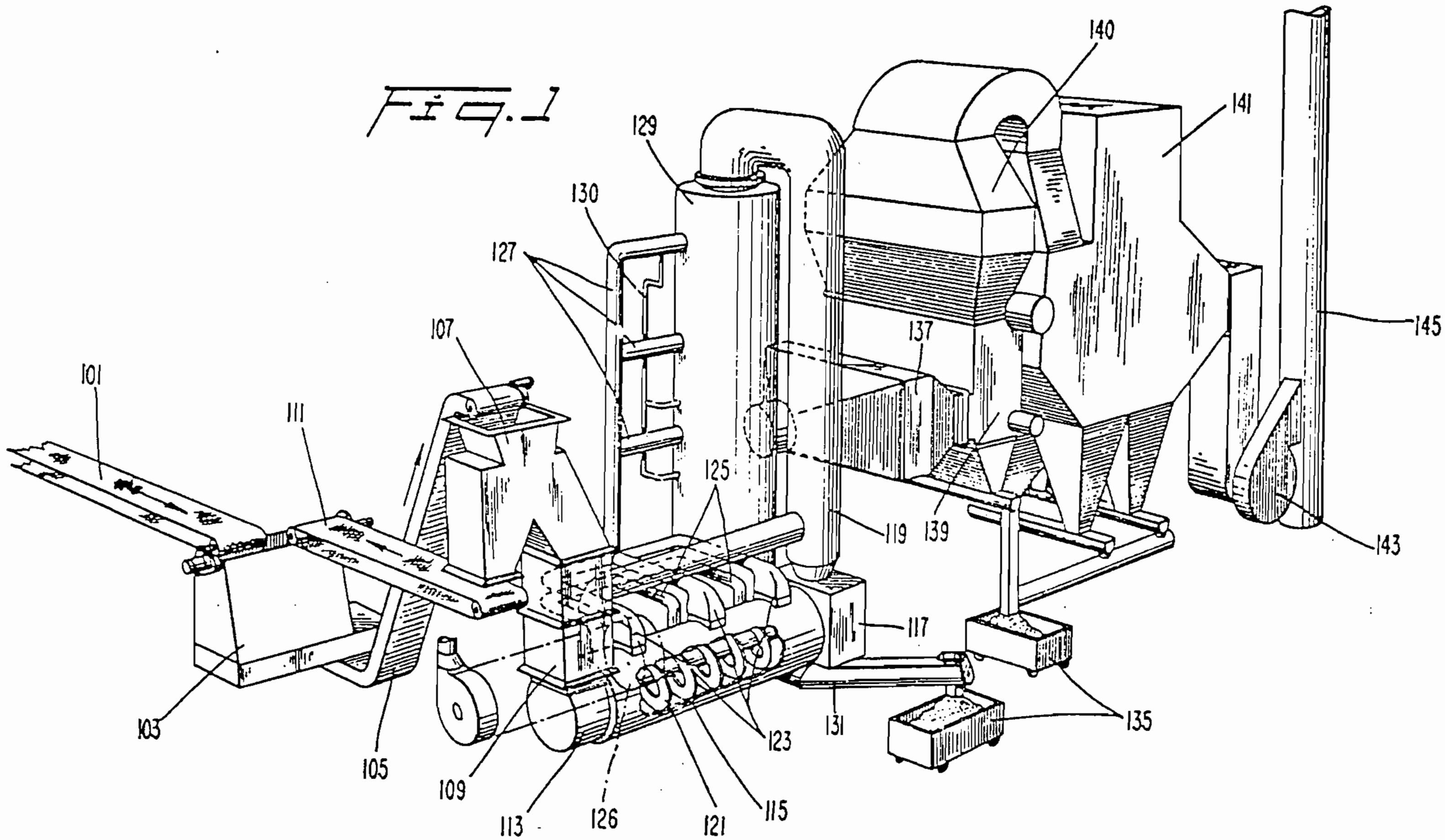

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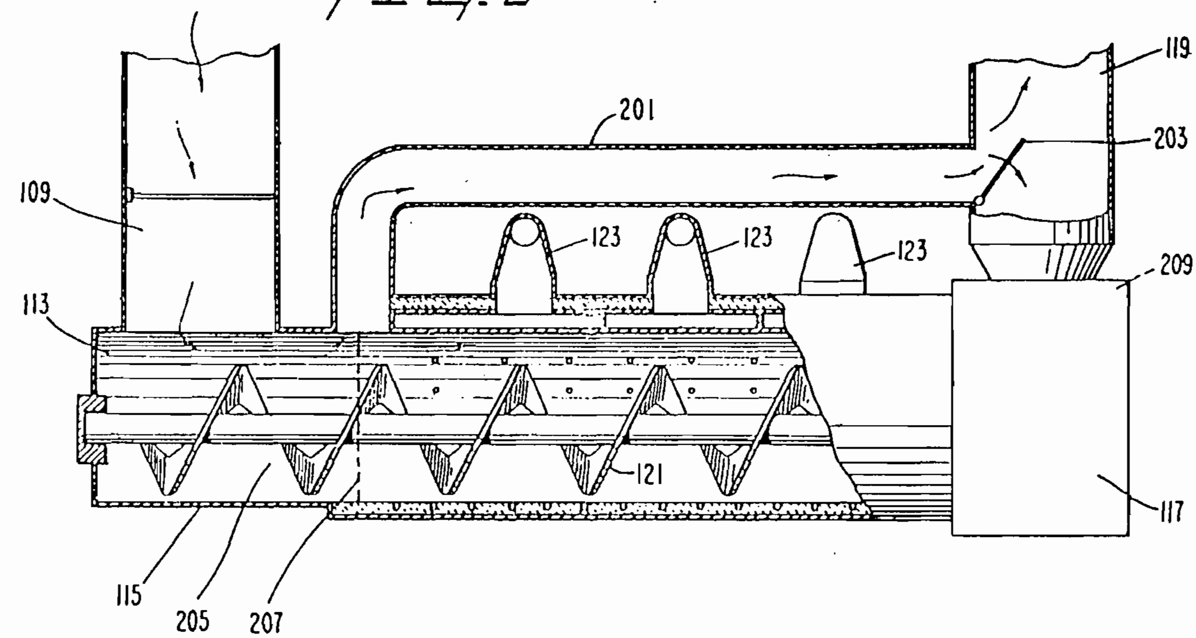
Fig. 1

Fig. 2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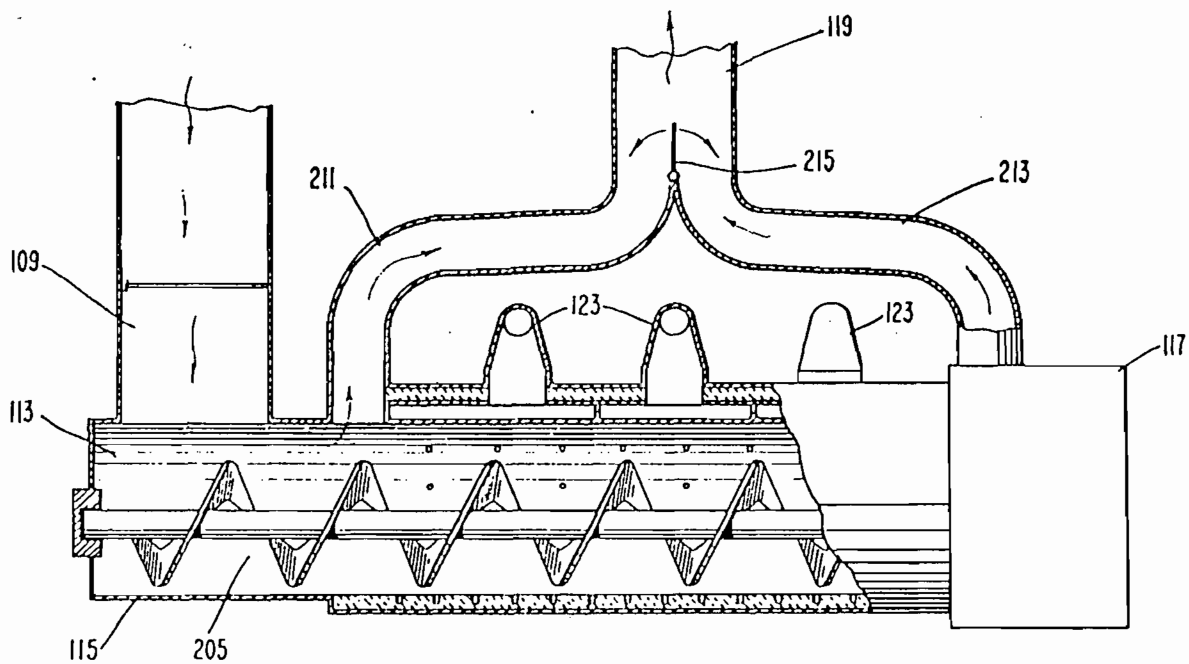
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Fig. 3

EXIT GAS CONTROL FOR FLAME STABILIZATION AND PERFORMANCE TUNING OF STARVED-AIR AUGER COMBUSTOR

BACKGROUND OF THE INVENTION

In the last century, much of the world's energy needs have been fulfilled by hydrocarbon fuels which provided a convenient, plentiful, and inexpensive energy source. The current rising costs of such fuels and concerns over the adequacy of their supply in the future has made them a less desirable energy source and has led to an intense investigation of alternative sources of energy. The ideal alternative energy source is a fuel which is renewable, inexpensive, and plentiful, with examples of such fuels being the byproducts of wood, pulp, and paper mills, and household and commercial refuse.

The use of alternative energy sources is not problem-free, however, since there is a concern over the contents of the emissions from the combustion of such fuels as well as the environmental ramifications of acquiring and transporting the fuel and disposing of the residue of combustion.

One promising prior art device for using such alternative energy sources, while maintaining a high degree of environmental quality, is the starved-air combustor wherein the air supplied for combustion is controlled in order to control temperature conditions and the rates of combustion are controlled to consume the fuel entirely. Such starved-air combustors are capable of burning various types of fuel and producing significant amounts of heat which can be employed for any number of purposes including the production of process steam for use in manufacturing and in the generation of electricity.

Starved-air combustors, as previously known and operated, have not been entirely satisfactory in both entirely consuming the combustible elements of the fuel at high throughput while not producing noxious emissions. This problem results, in part, from the use of such starved-air combustors to burn a wide variety of fuels some of which may be non-homogeneous, e.g., household or commercial refuse. It has not been possible in the previously known starved-air combustors to tailor in a real time manner the combustion processes to the type of fuel being combusted in order to maximize the efficiency of the combustor while minimizing the generation of air pollutants. While the pollution problem can be solved to a degree by the utilization of scrubbers and other antipollution devices, such mechanisms are very expensive and their cost may militate against the use of alternative energy sources.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a starved-air combustor capable of efficiently utilizing many different types and quantities of fuel.

Another object of this invention is to provide a starved-air combustor which does not release noxious pollutants into the atmosphere.

Yet another object of this invention is to provide a starved-air combustor which is capable of combusting to a very high degree the percentage of all combustible materials provided to it as fuel.

Still another object of this invention is to provide a starved-air combustor including means for selectively exhausting combustion gases from the combustion chamber in a direction co-current with the flow of fuel through the combustion chamber or countercurrent to the flow of fuel through the combustion chamber.

To achieve these objects, and in accordance with the purpose of the invention, as embodied and broadly described herein, the starved-air combustor comprises a combustion chamber having an inlet end for receiving fuel, the combustion chamber for combusting the received fuel to produce hot, combustion gases and combustion residue, the combustion chamber including an outlet end for discharging the combustion residue, means for conveying the fuel through the combustion chamber means from the inlet end toward the outlet end, first means for communicating with the combustion chamber proximate the inlet end of the combustion chamber for exhausting hot, evolved gases from the combustion chamber, second means communicating with the combustion chamber means proximate the outlet end of the combustion chamber means for exhausting hot, evolved combustion gases from the combustion chamber and means for controlling the exhausting of the combustion gases from the combustion chamber to exhaust selectively the evolved gases entirely through the second means or proportionately through the first means and the second means.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the starved-air combustor of the instant invention coupled, for illustration, between a fuel supply system and a system which produces process steam from the heat produced by the starved-air combustor.

FIG. 2 is an enlarged cross-sectional, schematic view taken along lines 2—2 of FIG. 1 illustrating the means for exhausting combustion gases from the combustion chamber.

FIG. 3 is a schematic view of an alternate embodiment of the means for exhausting combustion gases from the combustion chamber.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an embodiment of a starved-air combustor, according to the present invention, coupled between a refuse feeder system and a steam generation system. As embodied herein, the refuse supply system comprises a supply conveyor 101 for conveying fuel, in this instance refuse, from a receiving building (not shown) and one or more storage silos (not shown). The receiving building and storage silos are to insure that an adequate supply of fuel can be supplied to the combustor in order to permit the combustor to run at peak efficiency. In the illustrated embodiment, it is contemplated that the supply conveyor 101 would supply fuel to the fuel surge and recirculation bin 103 at a rate of at least fifteen tons per hour and that the capacity of the combustor system would range from 150 to 500 pounds per minute.

The fuel surge and recirculation bin 103 comprises an additional means for insuring that a constant and adequate supply of fuel is available to the combustor. The bin 103 could, for example, contain at least 10 minutes capacity of fuel, i.e., approximately 2.5 tons, which is received at the top of the bin 103 and supplied through the bottom of the bin 103 to the feed conveyor 105. Feed conveyor 105 supplies the fuel to a splitter valve 107 which may either direct the fuel into the feed and weigh bin 109 or, when the feed and weigh bin 109 is filled to capacity, to the return conveyor 111 for return to the fuel surge and recirculation bin 103. The feed and weigh bin 109 is calibrated to supply a preset weight of fuel at the inlet end 113 of a refractory-lined combustor 115 at such time that the first flight of an auger or screw-conveyor 121 within the chamber 115 has been rotated into a fuel receiving position. Within the starved-air combustor 115 there is provided a well-known oil igniter (not shown) in the input end of the combustion chamber 115 which serves as a means for initially igniting the fuel upon start up of the starved air combustor.

U.S. Pat. No. 4,009,667 issued to Robert C. Tyer et al on Mar. 1, 1977, illustrates an appropriate embodiment for a rotatably-driven auger comprised of a rotatable, water-cooled horizontal shaft supporting a spiral flight of decreasing pitch from the input end of the auger to the output end. It is contemplated in the instant system that the speed of the auger would range from 0.3 to 1 rpm. An appropriate oil igniter would comprise an oil burner having its flame extending into the input end of the combustor 115 to heat and to ignite the initial load of fuel supplied by the feed and weigh bin 109. It is contemplated that such an oil igniter would be capable of burning oil fuel at a rate of approximately six gallons per hour at two pounds per square inch pressure.

The combustor 115 has an output end 117 connected to a conduit 119 which feeds the top of an afterburner 129. The combustor 115 also includes air supply means 123 for supplying underfire air and conduits 125 for supplying overfire air. This air is provided by a fan 126 (shown in phantom) which also supplies air through conduits 127 to the afterburner 129. Alternatively, a separate fan or fans may be provided to supply underfire air, overfire air, and air to the afterburner 129. A small air distributor 130 is connected to the upper conduit 127 to supply air into the afterburner 129 through special injectors located both at and below the midpoint of the afterburner 129.

Afterburner 129 is provided, in part, as a secondary combustor chamber which mixes the air supplied by the conduits 127 with the gaseous and entrained solid particle output of the combustor from the outlet end 117 to combust all combustible material in the gaseous output and, in part, to separate suspended ash and non-combustible solids from the hot non-combustible gas. Both the non-combustible material from the afterburner 129 and the combustion residue from combustor 115 are fed through conduit 131 to an ash collector 135. The hot non-combustible gas exits into a super-heater 137 from which it is supplied to a waste heat boiler 139 and economizer 140 to produce, in this case, process steam. An electrostatic precipitator 141 removes any additional solids from the now cooler non-combustible gas exiting from the waste heat boiler 139 through the economizer 140 and the solid material is conveyed to an ash cart 135. From the precipitator 141, the non-combustible gas is drawn by a fan 143 and expelled from stack 145. Upon entering into the fan 143 the temperature of the gas is approximately 300 to 400 degrees Fahrenheit and the fan 143 is of sufficient strength to exert a negative pressure in the system from the combustor 115, the afterburner 129, superheater 137, waste heat boiler 139, and precipitator 141.

The present invention is particularly concerned with an apparatus for selectively exhausting combustion gases from the combustion chamber through a first exhaust port located proximate the inlet end of the combustion chamber and a second exhaust port located proximate the outlet end of the combustion chamber. When the combustion gases are exhausted from the port located near the outlet end of the combustion chamber, the starved-air combustor is said to be operating in the co-current mode meaning that the exhaust gases are traveling in the same direction as the fuel within the combustion chamber. Conversely, when the combustion gases are exhausted through the exhaust port located near the inlet end of the combustion chamber, the starved-air combustor is said to be operating in the countercurrent mode meaning that the exhaust gases are traveling against the direction of flow of fuel through the combustion chamber.

It is possible, by controlling the co-current and countercurrent exhaustion rates to both position and stabilize the flame front in the fuel bed within the combustion chamber 115. Full co-current exhaustion tends to establish the flame front closer to the outlet end 117 of the combustor 115 whereas full countercurrent exhaustion tends to establish the flame front proximate the inlet end 113. The ability to establish and stabilize the flame front is an important feature of the present invention because it is desirable to tailor the length of the flame bed to the type and condition of the fuel being combusted. For example, if the fuel is quite wet, it may be desirable to permit a lesser drying and heating distance for the fuel to travel before reaching the flame front.

As illustrated in the previously cited Tyer et al patent, the combustion chamber is supplied with overfire air, i.e., air injected into the combustion chamber above the fuel, and underfire air which is air injected into the combustion chamber from beneath the fuel bed in the combustion chamber. The progression of events transpiring between the entry of the fuel at the inlet end of the combustion chamber, the travel of the fuel through the combustion chamber while it is being combusted, and the evolution of combustion gases and combustion residue is well-known in the art of starved-air combustors. Generally, the water and the fuel are first evaporated and then, before the fuel reaches the ignition point, the cellulosic, plastic, and rubber materials begin to decompose as their temperatures increase and evolve volatile gases including heavy tars and acids. After the volatile gases are evolved, carbon particles begin to be produced and the presence of the overfire air causes the carbon particles and the tars to be combusted in the combustion chamber.

These processes all occur as the fuel travels from the inlet end of the combustion chamber toward the outlet end of the combustion chamber and, therefore, the gases near the inlet end of the combustion chamber contain a higher concentration of water, tars, and acids since they have not yet passed over the entire flame bed within the combustion chamber. Conversely, the gases present near the outlet end of the combustion chamber had a longer period of time to be mixed with the overfire air to combust further any combustible materials therein. As a result, the combustion gases near the outlet end of the combustion chamber include an increased concentration of carbon monoxide, carbon dioxide, and hydrogen and a decreased concentration of unreacted fuel chemical fragments.

Similarly, combustion gases exhausted near the inlet end of the combustion chamber will be at a lower temperature than combustion gases exhausted near the outlet end of the combustion chamber. This is because much of the heat in the combustion gases is absorbed by the commonly cool and wet fuel which is received at the inlet end. The passage of the hot exhaust gases through the fuel bed causes the fuel to evolve tars, acids, and water vapor and thus contain a higher concentration of combustible materials and other pollutants.

Gases that are exhausted near the outlet end of the combustion chamber will be significantly higher in temperature since the last process to which they are subject is mixture with over-fire air and further combustion of the combustible materials.

The present invention is directed to a means for selectively enabling the starved-air combustor to operate in a full co-current mode, a full countercurrent mode, or proportionally in both a co-current and countercurrent mode.

As illustrated in FIG. 2, the starved-air combustor comprises a combustion chamber formed, for example, from a cylindrical combustion chamber 115 having an inlet end 113 and an outlet end 117. Within the combustion chamber 115, a bed of fuel 205 is conveyed by a conveying means from the inlet end toward the outlet end. As embodied herein, the conveying means comprises a rotatable auger 121 extending eccentrically through the cylindrical combustion chamber 115 to provide a space at the top for the mixing of overfire air 123 and combination gases. A flame front 207 illustrates an example of where the ignition point of the fuel bed 205 is within the combustion chamber 115. The fuel from the flame front 207 toward the outlet end 117 is at a temperature at or above the ignition point of the fuel in the bed 205.

The starved-air combustor further includes first means communicating with the combustion chamber proximate to the inlet end 113 for exhausting hot, combustion gases evolved from the combustion of the fuel within the combustion chamber 115. The starved-air combustor further includes second means communicating with the combustion chamber 115 proximate to the outlet end 117 for also exhausting hot combustion gases evolved from the combustion of the fuel in the combustion chamber 115.

As embodied herein, the first means comprises a first conduit 201 coupled at one end to the interior of the combustion chamber 115 and coupled at its other end to the duct 119 which leads to the afterburner 129. The second means comprises a second conduit 209 constituting the lower portion of the duct 119 which communicates with the interior of the combustion chamber 115 near the outlet end 117.

The starved-air combustor further includes means for controlling the exhausting of the evolved gases from the combustion chamber to exhaust selectively the evolved gases entirely through the conduit 209 or proportionally through the conduit 201 and the conduit 209. As embodied herein, the controlling means comprises a manually-positionable damper 203 located at the intersection of the conduit 201 and the duct 119 and having a length sufficient to seal completely the intersection of the conduit 201 and the duct 119 when the damper 203 is positioned in a vertical position and to restrict partially the communication of conduit 209 with the duct 119 when the damper is rotated into the horizontal position. As illustrated in FIG. 2, the damper has been positioned to permit exhaustion of the gases through both the conduit 201 and the conduit 209 to enable the selective balancing of co-current and countercurrent flow of combustion gases in the combustion chamber 115.

FIG. 3 illustrates an alternate embodiment of the first and second exhausting means and the controlling means. As illustrated in FIG. 3, the first means and the second means comprise first and second conduits 211 and 213, respectively, which intersect at the location of the damper 215. The damper is selectively positionable to control the flow of exhaust gases through the conduit 211 or the conduit 213 into the exhaust gas collector or duct 119. As was the case with the embodiment illustrated in FIG. 2, the overfire air and underfire air supplied to the combustion chamber together with the draft of the fan 143 (FIG. 1) causes an inherent flow of combustion gases from the combusting fuel in the fuel bed 205 out of the combustion chamber 115.

It will be further apparent to those skilled in the art, that various modifications and variations can be made to the exhaust gas flow control means of the starved-air combustor without departing from the scope or spirit of the invention and it is intended that the present invention cover the modifications and variations of the system provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A starved-air combustor comprising:

a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said received fuel to produce hot, combustion gases and combustion residue, said combustion chamber including an outlet end for discharging said combustion residues;

means for conveying said fuel through said combustion chamber from said inlet end towards said outlet end;

an exhaust gas collector;

a first conduit communicating with said combustion chamber proximate said inlet end of said combustion chamber and with said exhaust gas collector for exhausting said hot, combustion gases from said combustion chamber to said exhaust gas collector;

a second conduit communicating with said combustion chamber proximate said outlet end of said combustion chamber and with said exhaust gas collector for exhausting said hot, combustion gases from said combustion chamber to said exhaust gas collector; and

means for controlling the exhausting of said combustion gases from said combustion chamber to exhaust selectively said evolved gases entirely through said second means or proportionately through said first means and said second means, said controlling means comprising a rotatable damper in said exhaust gas collector positionable in a first orientation to completely block the exhaustion of said combustion gases through said first conduit and to permit the complete exhaustion of said combustion gases through said second conduit, a second orientation to partially block the exhaustion of said combustion gases through said second conduit and to permit the partial exhaustion of said combustion gases through said first conduit, and a plurality of third orientations intermediate said first orientation and said second orientation, each of said third orientations for permitting the proportional exhaustion of said combustion gases from said combustion chamber through said first conduit and said second conduit.

2. A starved-air combustor according to claim 1 wherein said damper is manually positionable.

* * * * *

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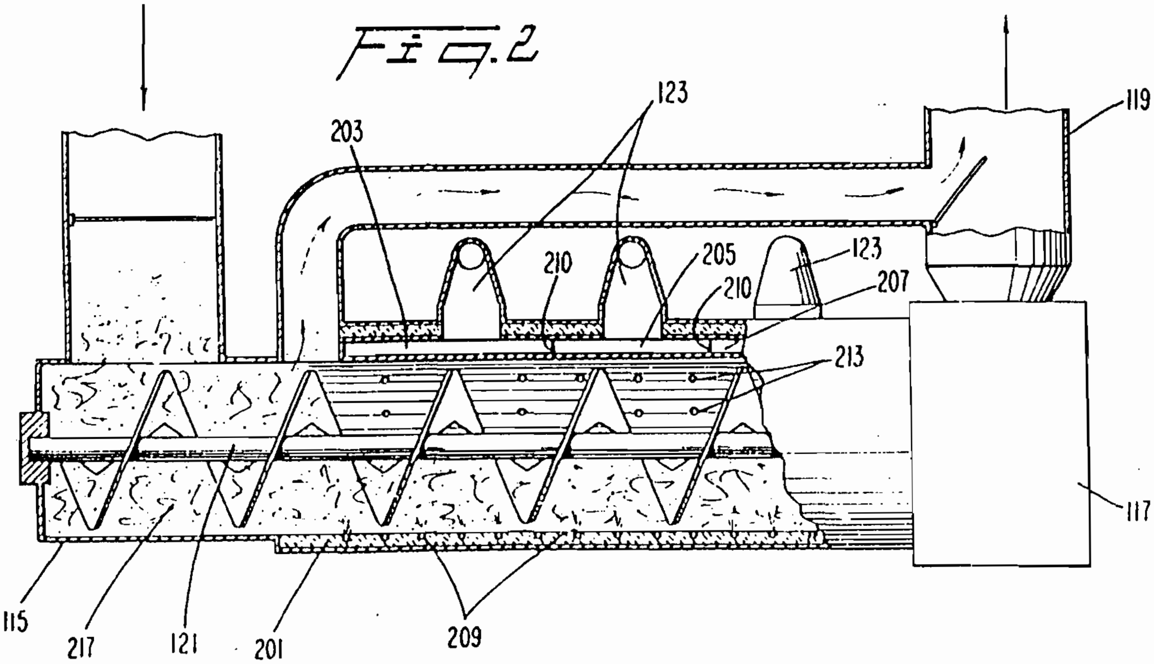
Fig. 2



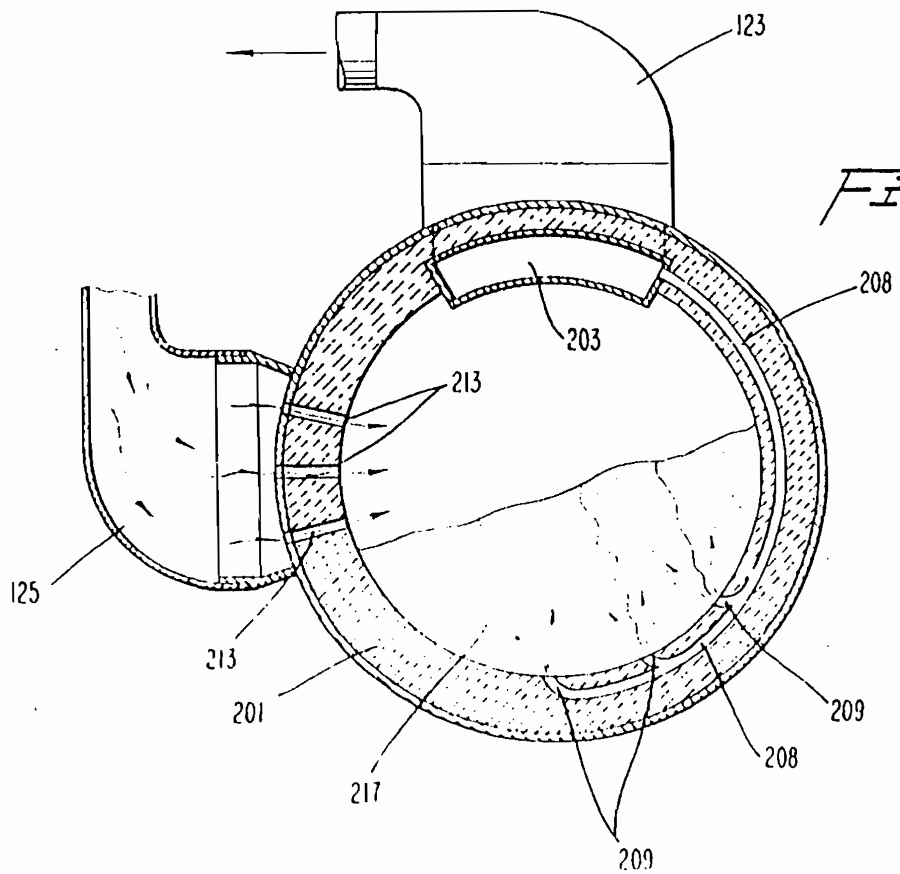


Fig. 3

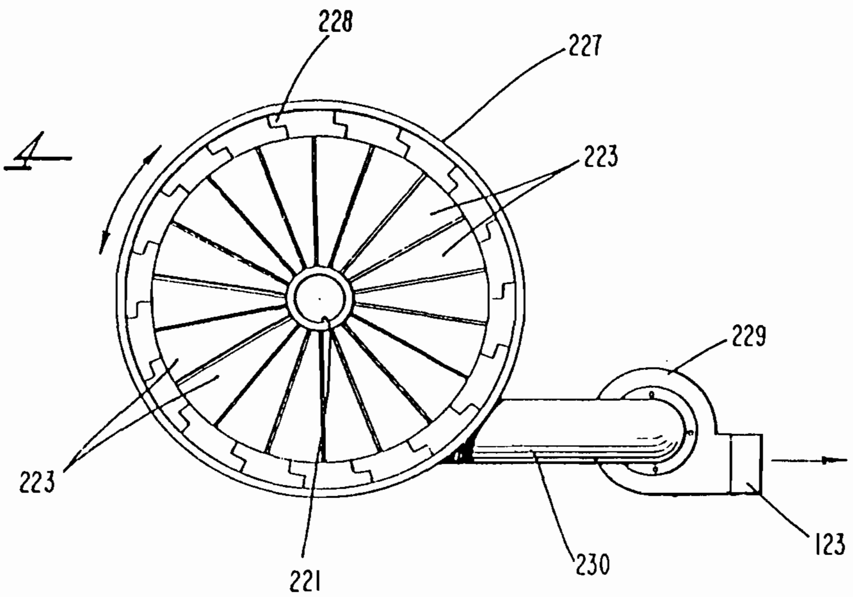

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Fig. 4

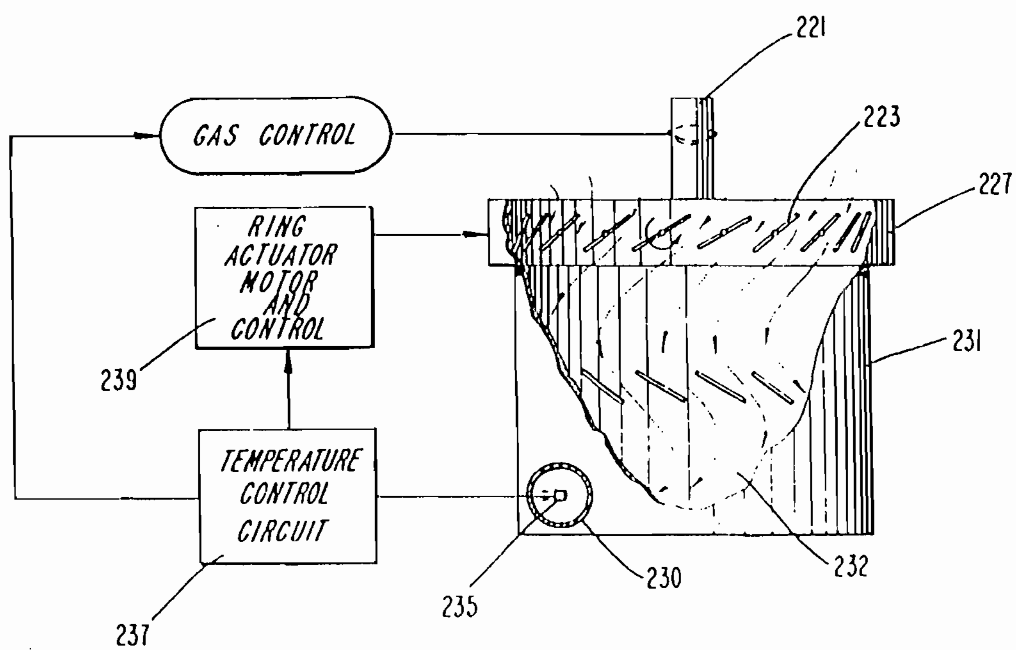
221
GAS CONTROL
223
227
RING ACTUATOR MOTOR AND CONTROL
239
231
TEMPERATURE CONTROL CIRCUIT
232
230
235
237

Fig. 5

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HOT GAS RECYCLE FOR STARVED-AIR COMBUSTOR

BACKGROUND OF THE INVENTION

In the last century, much of the world's energy needs have been fulfilled by hydrocarbon fuels which provided a convenient, plentiful, and inexpensive energy source. The current rising costs of such fuels and concerns over the adequacy of their supply in the future has made them a less desirable energy source and has led to an intense investigation of alternative sources of energy. The ideal alternative energy source is a fuel which is renewable, inexpensive, and plentiful, with examples of such fuels being the byproducts of wood, pulp, and paper mills, and household and commercial refuse.

The use of alternative energy sources is not problem-free, however, since there is a concern over the contents of the emissions from the combustion of such fuels as well as the environmental ramifications of acquiring and transporting the fuel and disposing of the residue of combustion.

One promising prior art device for using such alternative energy sources, while maintaining a high degree of environmental quality, is the starved-air combustor wherein the air supplied for combustion is controlled in order to control temperature conditions and the rates of combustion are controlled to consume the fuel entirely. Such starved-air combustors are capable of burning various types of fuel and producing significant amounts of heat which can be employed for any number of purposes including the production of process steam for use in manufacturing and in the generation of electricity.

Starved-air combustors, as previously known and operated, have not been entirely satisfactory in both entirely consuming the combustible elements of the fuel at high throughput while not producing noxious emissions. This problem results, in part, from the use of such starved-air combustors to burn a wide variety of fuels some of which may be non-homogeneous, e.g., household or commercial refuse. It has not been possible in the previously known starved-air combustors to tailor in a real time manner the combustion processes to the type of fuel being combusted in order to maximize the efficiency of the combustor while minimizing the generation of air pollutants. While the pollution problem can be solved to a degree by the utilization of scrubbers and other antipollution devices, such mechanisms are very expensive and their cost may militate against the use of alternative energy sources.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a starved-air combustor capable of efficiently utilizing many different types and quantities of fuel.

Another object of this invention is to provide a starved-air combustor which does not release noxious pollutants into the atmosphere.

Yet another object of this invention is to provide a starved-air combustor which is capable of combusting to a very high degree the percentage of all combustible materials provided to it as fuel.

Still another object of this invention is to provide a starved-air combustor with the ability to recycle hot combustion gases produced by the combustor in a mixture of air to the first combustion zone of the combustor to heat and to dry the fuel in the combustor

To achieve these objects, and in accordance with the purpose of the invention, as embodied and broadly described herein, the starved-air combustor comprises a combustion chamber having an inlet end for receiving fuel, the combustion chamber for combusting the received fuel to produce hot combustion gases and combustion residue, the combustion chamber further including an outlet end for discharging the combustion gases, means in the combustion chamber for conveying received fuel from the inlet end towards the outlet end, a plenum adjacent to the combustion chamber and communicating with the chamber through at least one aperture located beneath the fuel in the combustion chamber, means for the receiving hot combustion gases produced by the combustion chamber and for further combusting any combustible material entrained in the combustion gases to produce a hot non-combustible gas, means for selectively mixing a portion of the non-combustible gas with selected amounts of air to heat the air and for supplying the mixture to the combustion chamber through the aperture to heat and to dry the fuel in the chamber, and means for sensing the temperature of the mixture of air and non-combustible gases and for controlling the amount of air mixed with the non-combustible gas to maintain preselected temperature range for the mixture.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the starved-air combustor of the instant invention coupled between a fuel supply system and a system which produces process steam from the heat produced by the starved-air combustor.

FIG. 2 is an enlarged cross-sectional view of the combustor of FIG. 1 taken along lines 2—2 and illustrating the combustion chamber of the starved-air combustor system.

FIG. 3 is an enlarged cross-sectional view of the combustor of FIG. 1 taken along the lines 3—3.

FIG. 4 is a top view of the hot gas recycle apparatus of the instant invention.

FIG. 5 is a side view of the hot gas recycle apparatus of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an embodiment of a starved-air combustor according to the present invention coupled between a refuse feeder system and a steam generation system. As embodied herein, the refuse supply comprises a supply conveyor 101 for conveying fuel, in this instance refuse, from a receiving building (not shown) and one or more storage silos (not shown). The receiving building and storage silos are to insure that an adequate supply of fuel can be supplied to the combustor in order to permit the combustor to run at peak efficiency. In the illustrated embodiment, it is contemplated that the supply conveyor 101 would supply fuel to the fuel surge and recirculation bin 103 at a rate of at least fifteen tons per hour and that the capacity of the combustor system would range from 150 to 500 pounds per minute.

The fuel surge and recirculation bin 103 comprises an additional means for insuring that a constant and adequate supply of fuel is available to the combustor. The

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bin 103 could, for example, contain at least 10 minutes capacity of fuel, i.e., approximately 2.5 tons, which is received at the top of the bin 103 and supplied through the bottom of the bin 103 to the feed conveyor 105. Feed conveyor 105 supplies the fuel to a splitter 107 which may either direct the fuel into the feed and weigh bin 109 or, when the feed and weigh bin 109 is filled to capacity, to the return conveyor 111 for return to the fuel surge and recirculation bin 103. The feed and weigh bin 109 is calibrated to supply a constant weight of fuel at the inlet end 113 of a refractory-lined combustor 115 at such time that the first flight of an auger 121 within the chamber 115 has been rotated into a fuel receiving position. Within the starved-air combustor 115 there is provided a well-known oil igniter (not shown) in the input end of the combustion chamber 115 serve as a means for initially igniting the fuel upon start up of the starved-air combustor.

U.S. Pat. No. 4,009,667 issued to *Robert C. Tyer et al* on Mar. 1, 1977, illustrates an appropriate embodiment for a rotatably-driven auger comprised of a rotatable, water-cooled horizontal shaft supporting a spiral flight of decreasing pitch from the input end of the auger to the output end. It is contemplated in the instant system that the speed of the auger would range from 0.3 to 1 rpm. An appropriate oil igniter would comprise an oil burner having its flame extending into the input end of the combustor 115 to heat and to ignite the initial load of fuel supplied by the feed and weigh bin 109. It is contemplated that such an oil igniter would be capable of burning oil fuel at a rate of approximately six gallons per hour at two pounds per square inch pressure.

The combustor 115 has an output end 117 connected to a duct 119 which feeds the top of an afterburner 129. The combustor 115 also includes air supply means 123 for supplying underfire air and conduits 125 for supplying overfire air. This air is provided by a fan 126 (shown in phantom) which also supplies air through conduits 127 to the afterburner 129. Alternatively, a separate fan or fans may be provided to supply underfire air, overfire air, and air to the afterburner 129. A small air distributor 130 is connected to the upper conduit 127 to supply air into the afterburner 129 both at and below its midpoint.

Afterburner 129 is provided, in part, as a secondary combustor chamber which mixes the air supplied by the conduits 127 with the [illegible] and entrained solid particle output of the combustor from the outlet end 117 to combust all combustible material in the gaseous output and, in part, to separate suspended ash and non-combustible solids from the hot non-combustible gas. Both the non-combustible material from the afterburner 129 and the combination residue from combustor 115 are fed through conduit 131 to an ash collector 135. The hot non-combustible gas exits into a superheater 137 from which it is supplied to a waste heat boiler 139 and economizer 140 to produce, in this case, process steam. An electrostatic precipitator 141 removes any additional solids from the now cooler non-combustible gas exiting from the waste heat boiler 139 through an economizer 140 and the solid material is conveyed to an ash cart 135. From the precipitator 141, the non-combustible gas is drawn by a fan 143 and expelled from stack 145. Upon entering into the fan 143 the temperature of the gas is approximately 300 to 400 degrees Fahrenheit and the fan 143 is of sufficient strength to exert a negative pressure in the system from the combustor 115, the afterburner 129, superheater 137, waste heat boiler 139, economizer 140 and precipitator 141.

A starved-air combustor is specifically designed to operate at low temperatures under air-deficient conditions. When the starved-air combustor, however, receives very wet fuel, the temperature within the combustor is insufficient to provide additional energy which can be used to evaporate moisture quickly from the received wet fuel and to heat and to dry the fuel and to provide for its rapid ignition and efficient combustion. In such an instance, more of the residence time of the fuel in the combustion chamber is devoted to drying and less to combustion with the result that the capacity and efficiency of the machine are decreased.

There have been many attempts in the prior art to effect a partial solution of this problem by passing air through tubes embedded in the refractory lining of the combustion chamber or to heat the air in a separate heat exchanger with flue gas produced by the combustor. The heated air is injected into the fuel bed in the combustion chamber in an attempt to dry the fuel. The result of such devices has been to heat the air to limited degree at the expense of additional equipment including a fan with extreme temperature capabilities. These approaches have not proved completely satisfactory.

The hot gas recycle apparatus of the instant invention consists of a device for withdrawing hot combustion gas discharged from the afterburner and blending the gas with air in the proportion necessary to provide a mixture with a temperature of at least 500° F. and to inject the mixture as underfire air into the first zone of the combustion chamber. This approach provides air at approximately 500° F. only slightly vitiated (O_2 concentration of 15-18%) which has a strong capacity to heat and to dry the fuel in the combustion chamber by both heating the refractory on which the fuel lies and by injecting the hot air directly into the fuel.

As illustrated in FIG. 2, the starved-air combustor of the instant invention comprises a combustion chamber 115 having an inlet end 113 for receiving fuel and an outlet end 117 for discharging combustion gases produced by the combustion of the received fuel in the combustion chamber 115. Within the combustion chamber 115 there resides means for conveying the received fuel from the inlet end 113 towards the outlet end 117. As embodied herein, this means comprises an auger 121 eccentrically positioned within the combustion chamber 115. As explained in the above-referenced Tyer et al patent, rotation of auger 121 moves the fuel from the inlet end 113 toward the outlet end 117. The fuel bed 217 resides within the combustion chamber 115 and decreases in bulk as it extends towards the outlet end 117 due to the combustion of the combustible material within the fuel and the production of the combustion residue and combustion gases.

The combustion chamber 115 is lined with a layer of refractory material 201. The combustion chamber 115 receives underfire air injected into the fuel bed 217 from plenums 203, 205, and 207 located contiguous with one wall of the combustion chamber 115. A series of tubes 2°3 (FIG. 3) terminating in injectors 209 permit air introduced into the plenums 203, 205, or 207 to pass into the combustion chamber 115. As shown in FIG. 2, the plenums 203, 205, and 207 are separated by sealing stops or gaskets 210.

The combustion chamber 115 receives overfire air from air supplies 125 which communicate with associated plenums such as plenum 211 in FIG. 3. The overfire air is supplied from the plenums into the combustion chamber through ports 213 extending through the layer of refractory material 201. The injection of overfire air into the combustion chamber 115 does not, however, comprise a feature of the instant invention.

FIG. 3 shows combustion chamber 115 in cross-section with auger 121 removed. Plenum 203 receives its air from underfire source 123 and the received air is transferred to injectors 209 through refractory-embedded tubes 208 for discharge into fuel bed 217.

The instant starved-air combustor further comprises means for receiving the hot, combustion gases from the combustion chamber and for further combusting any combustible material entrained in the combustion gases to produce hot, non-combustible gases. As embodied herein, this receiving and combusting means comprises afterburner 129 (FIG. 1) connected to the outlet end 117 of the combustion chamber 115 by means of duct 119. The instant exhaust gas recycle device is operable with many different types of afterburners but reference can be made to U.S. Patent Application Ser. No. 148,361, filed on even date herewith in the name of Gordon H. Tucker and entitled "After Burner for Combustion Starved-air Combustor Fuel Gas Containing Suspended Solid Fuel and Fly Ash." This patent application is assigned to the assignee of the present invention.

The output of the afterburner 129 is a gas having a temperature between 1500°-2000° F. This gas is supplied, as previously explained, to superheater 137 but, as contemplated in the instant invention, a portion of this gas is also supplied to a means for selectively mixing the gas with selected amounts of air to heat the air and for supplying the mixture to the underfire air inlet 123 of plenum 203 for injection into the combustion chamber through the injectors 209 embedded the layer of refractory material 201.

This mixing and supplying means is illustrated in FIGS. 4 and 5 and, as embodied herein, comprises a mixing chamber having a central inlet 221 for receiving the hot gases from the discharge of the afterburner 129. Surrounding the inlet 221 are radial vanes 223 rotatable around axes 225 to permit selected amounts of air to enter the mixing chamber. As shown in FIG. 4, the vanes 223 are in their fully closed position and, therefore, would not permit the entry of air into the mixing chamber.

Surrounding the ends of the radial vanes 123 is a ring actuator 227 concentrically rotatable about the inlet 221. Rotation of the ring actuator 227 controls the opening and closing of the radial vanes 223 by appropriate links 228 which cause the vanes 223 to rotate upon rotary displacement of the actuator 227 to control the entry of air into the mixing chamber. The mixing chamber further includes an outlet 230 for discharging the mixed combustion gases received through inlet 221 and air received through the openings through the vanes 223. A fan 229 provides the appropriate negative pressure to pull air into the mixing chamber. The inlet 123 into the first plenum 203 is connected to the output side of fan 229 such that the mixture of air and combustion gases is supplied to the plenum 203.

FIG. 5 is a side view of the mixing chamber broken-away along line 232. The side view of the vanes 223 illustrates them in a partially open position to permit air to enter the mixing chamber 231. A fixed set of radial vanes 233 is provided within the mixing chamber 231 to reverse the flow of the air and combustion gas in the chamber 231 to insure a complete mixture of the air and the gas.

The starved-air combustor further includes means for sensing the temperature of the mixture of air and non-combustible gas and for controlling the amount of air mixed with the non-combustible gas to maintain a preselected temperature range for the mixture. As embodied herein, the sensing and controlling means comprises a sensor unit 235, for example, a thermocouple, connected to temperature control circuit 237. The temperature sensor 235 produces an output signal having a magnitude reflecting the temperature of the gas exhausted from the outlet 230 of the mixing chamber 231. If the magnitude of the output signal is within the range of magnitudes corresponding to a range of acceptable temperatures for the mixture of air and gas, then temperature control circuit 237 will permit the status of the mixing chamber 231 to remain unchanged. If, however, the magnitude of the output signal of temperature sensor 235 indicates that the temperature of the mixture discharged through outlet 230 is not within the preselected range, temperature control circuit 237 supplies an appropriate outlet signal to ring actuator control 239 to control the rotation of ring actuator 227 to either further open or further close the vanes 223. If the temperature of the discharged mixture is too low, then too much air is entering the mixing chamber 231 and the ring actuator control will cause the ring actuator 227 to rotate in the direction to cause the vanes 223 to close and permit less air to enter the mixing chamber 231. If, however, the temperature of the mixture discharged through outlet 230 is too high, as sensed by temperature sensor 235, then the ring actuator control 239 will cause the ring actuator 227 to rotate in the direction to open the vanes 223 of the mixing chamber 231 to permit more air to enter the mixing chamber 231. If the temperature of the discharged mixture exceeds a certain boundary temperature, then temperature control circuit 237 will signal gas control 241 to rotate valve 243 within the gas inlet 221 to block the entry of gas into the mixing chamber 231.

In summary, the instant combustion gas recycle apparatus receives hot gases (1500°-2400° F.) from the afterburner in the starved-air combustor system of the instant invention. The top of the mixing chamber 231 has automatically controlled radial vanes 223 which open and close to modulate the amount of air drawn into the mixing chamber 231 to maintain a preset mixed gas temperature upon discharge from outlet 230 of the mixing chamber 231. The orientation of the vanes 223 is such as to impact a strong swirl to the air as it enters the box whereby the combustion gas and the air mix by sheer-generated turbulence with the inner core of air being hotter and the areas surrounding the walls of the mixing chamber 231 being cooler. With this flow pattern, a refractory lining of the mixing chamber is not required although such a refractory lining could be provided. A plurality of fixed, radial vanes 233 within the mixing chamber 231 reverses the direction of flow to further enhance mixing. The mixed gas and air exits through outlet 230 of the mixing chamber 231.

From outlet 123, the mixture is supplied as underfire air to the first plenum 203 of the combustion chamber 115 to be injected into the fuel duct 123 connected to plenum 203 to heat and to dry the fuel in the bed 217 as an aid to combustion.

It will be further apparent to those skilled in the art, that numerous modifications and variations can be made

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to the combustion gas recycle device of the starved-air combustor without departing from the scope or spirit of the invention and it is intended that the present invention cover the modifications and variations of the system provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A starved-air combustor comprising:

a combustion chamber having an inlet end for receiving fuel, said combustion chamber for combusting said received fuel to produce hot combustion gases and combustion residue, said combustion chamber further including an outlet end for discharging said combustion gases;

means in said combustion chamber for conveying received fuel from said inlet end toward said outlet end;

a plenum adjacent to said combustion chamber and communicating with said chamber through at least one aperture located beneath said fuel in said combustion chamber;

means for receiving said hot combustion gases from said combustion chamber and for further combusting any combustible material entrained in said combustion gases to produce a hot non-combustible gas;

means for selectively mixing a portion of said non-combustible gas with selected amounts of air to heat said air and for supplying said mixture to said plenum for injection into said combustion chamber through said aperture to heat and to dry said fuel in said chamber, said mixing means comprising:

a mixing chamber having an inlet end for receiving said hot non-combustible gas and an outlet end;

a ring actuator at said inlet end of said mixing chamber, said ring actuator including a plurality of rotatable vanes positionable to permit selected amounts of air into said chamber and to impart a swirling motion to said admitted air;

means for supplying said hot non-combustible gases to the center of said ring actuator to enable the mixing of said gases with said swirling air; and

a plurality of fixed vanes in said mixing chamber downstream of said ring actuator, said fixed vanes for imparting a swirling motion to said mixture of gases and said swirling air to prevent the formation of hot spots along the surface of said mixing chamber; and

a conduit for applying said mixture of air and non-combustible gases to said plenum; and

means for sensing the temperature of said swirling mixture of air and non-combustible gases to be supplied to said plenum and for controlling the amount of air mixed with said non-combustible gas to maintain a preselected temperature range for said mixture, said sensing means for controlling said ring actuator to rotate said rotatable vanes in a closing direction to decrease the amount of air admitted into said chamber responsive to the sensed temperature of said mixture of air and non-combustible gases being below said preselected temperature range and to rotate said rotatable vanes in an opening direction responsive to said sensed temperature of said mixture of air and non-combustible gases being above said preselected temperature range.

2. A starved-air combustor according to claim 1 wherein said temperature sensing and controlling means comprises a thermocouple for sensing the temperature of said mixture of air and non-combustible gases supplied to said plenum through said conduit, and a valve in said supplying means for regulating the quantity of hot non-combustible gas supplied to said mixing chamber responsive to said sensed temperature of said mixture to maintain the temperature of said mixture within a preselected temperature range.

* * * * *

United States Patent [19]

Tucker et al.

[11] **4,332,206**

[45] **Jun. 1, 1982**

[54] **AFTERBURNER FOR COMBUSTION OF STARVED-AIR COMBUSTOR FUEL GAS CONTAINING SUSPENDED SOLID FUEL AND FLY ASH**

[75] Inventors: Gordon H. Tucker, Enumclaw; Robert E. Fitch, Kent, both of Wash.

[73] Assignee: The Boeing Company, Seattle, Wash.

[21] Appl. No.: 148,361

[22] Filed: May 9, 1980

[51] Int. Cl.[3] F23J 15/00

[52] U.S. Cl. .... 110/203; 110/205; 110/212; 236/15 E

[58] Field of Search .... 110/203, 204, 205, 210-212, 110/214; 236/15 E

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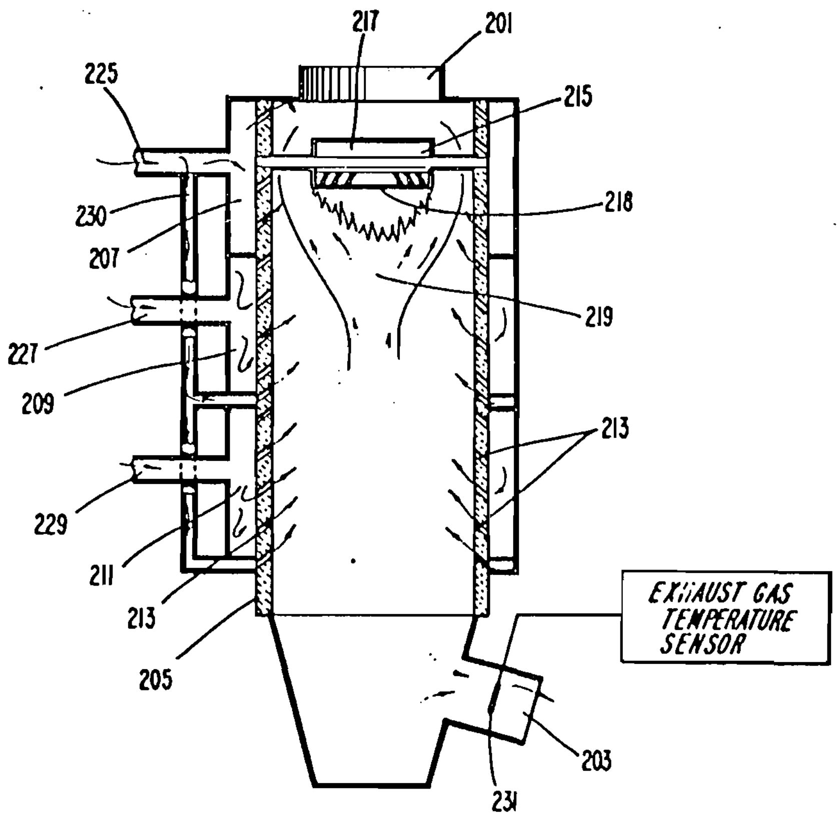
Primary Examiner—Henry C. Yuen
Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner

[57] **ABSTRACT**

An afterburner for use as a secondary combustion chamber in a starved-air combustor system to further combust any combustible material in the combustion gas and entrained solid particle material discharge from the combustion chamber of the starved-air combustor system. The afterburner is lined with refractory and includes a diverter plate positioned transversely to the incoming flow of combustion gases. The afterburner is divided into a plurality of reaction zones, each of which has an associated reaction air supply. The diverter plate imparts a cyclonic flow to the combustion gas which is enhanced by air injected in the combustion zones. The temperature of the gas discharged from the afterburner is monitored and the flow of reaction air controlled responsive to changes in discharge gas temperature from a predetermined temperature.

9 Claims, 5 Drawing Figures



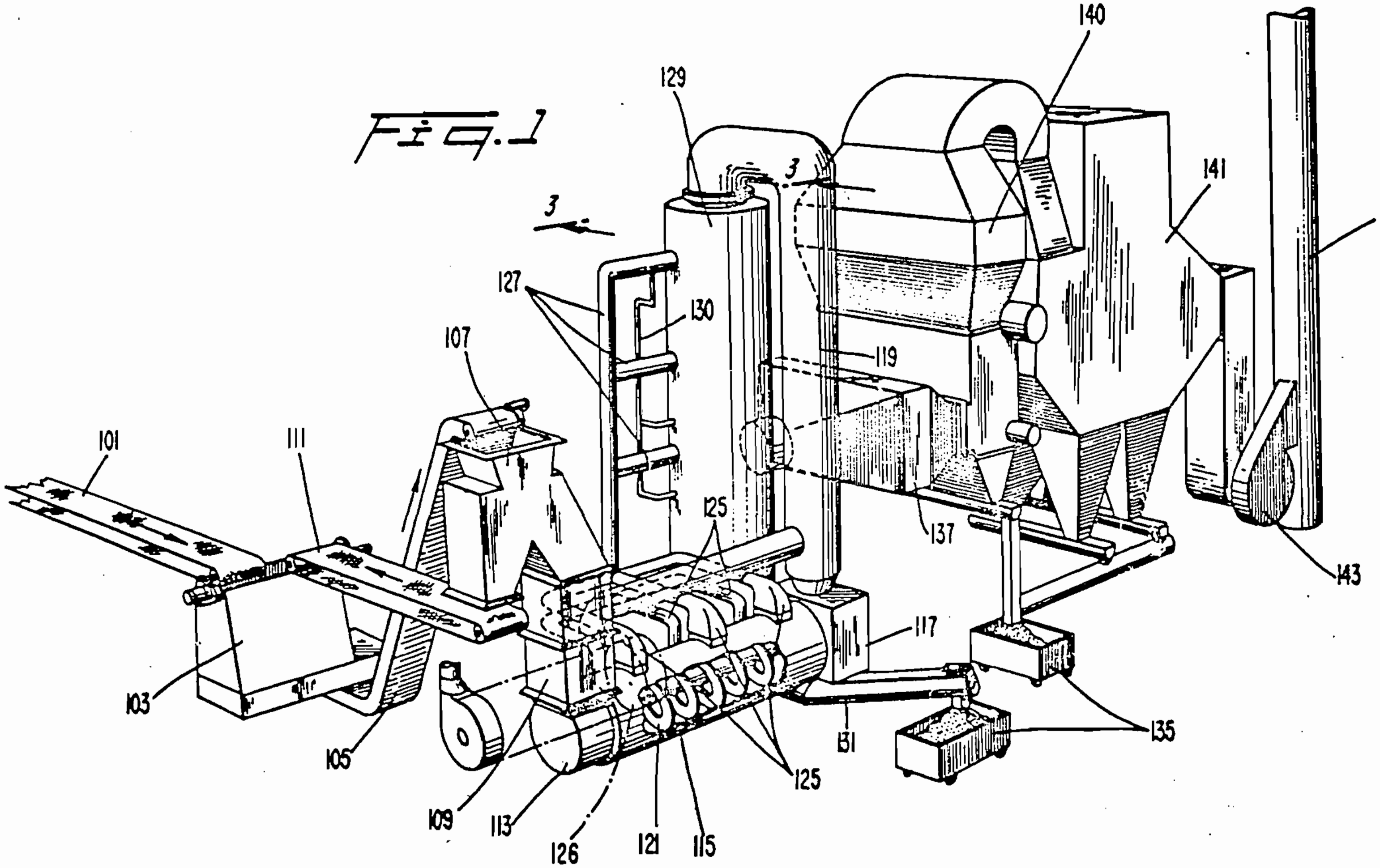


Fig. 1
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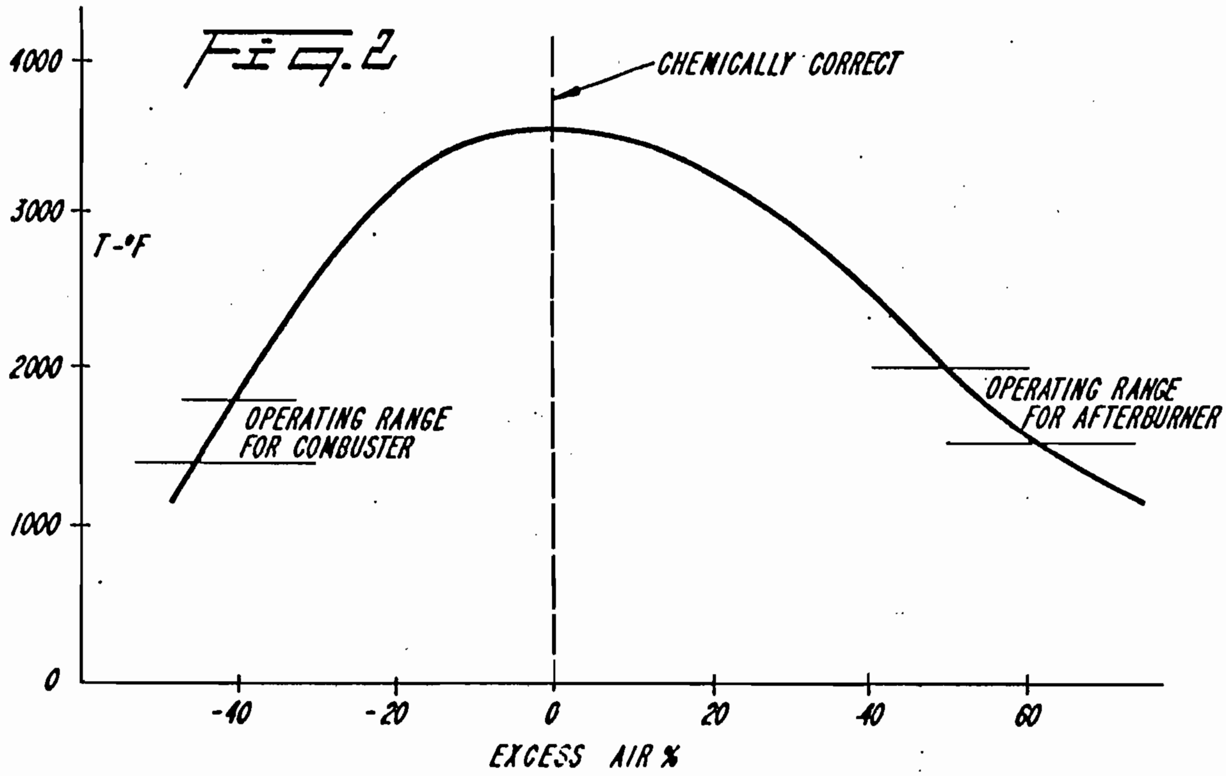
Fig. 2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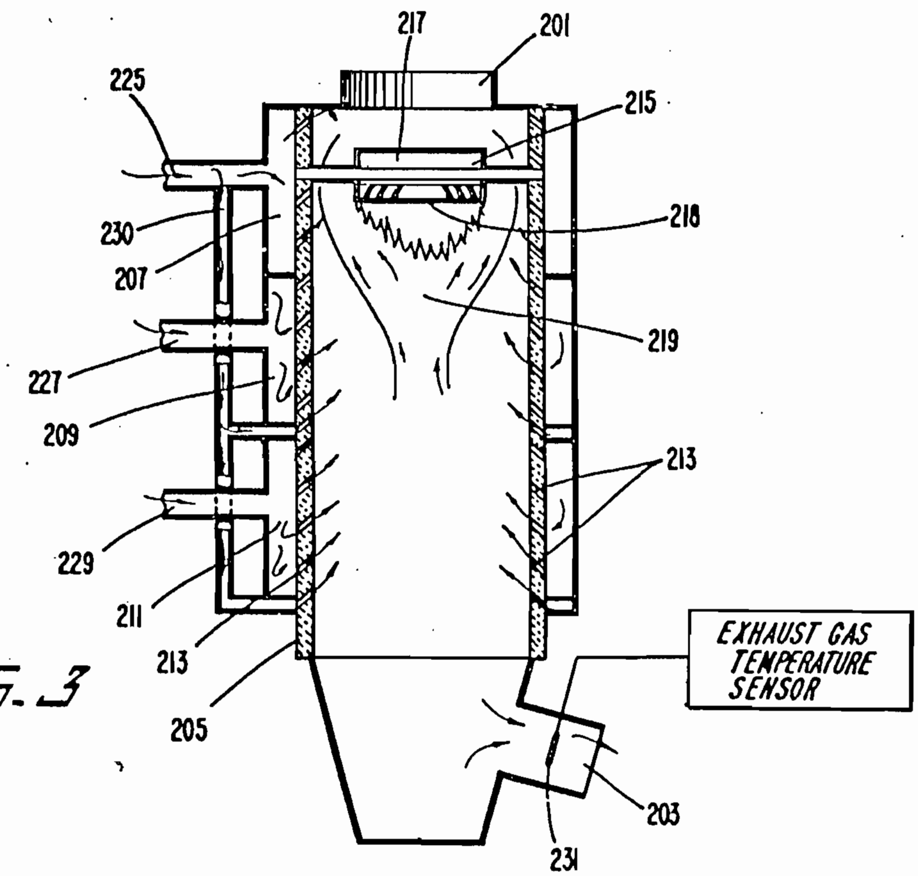
EXCESS AIR %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EXHAUST GAS TEMPERATURE SENSOR
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Fig. 3

FIG. 4

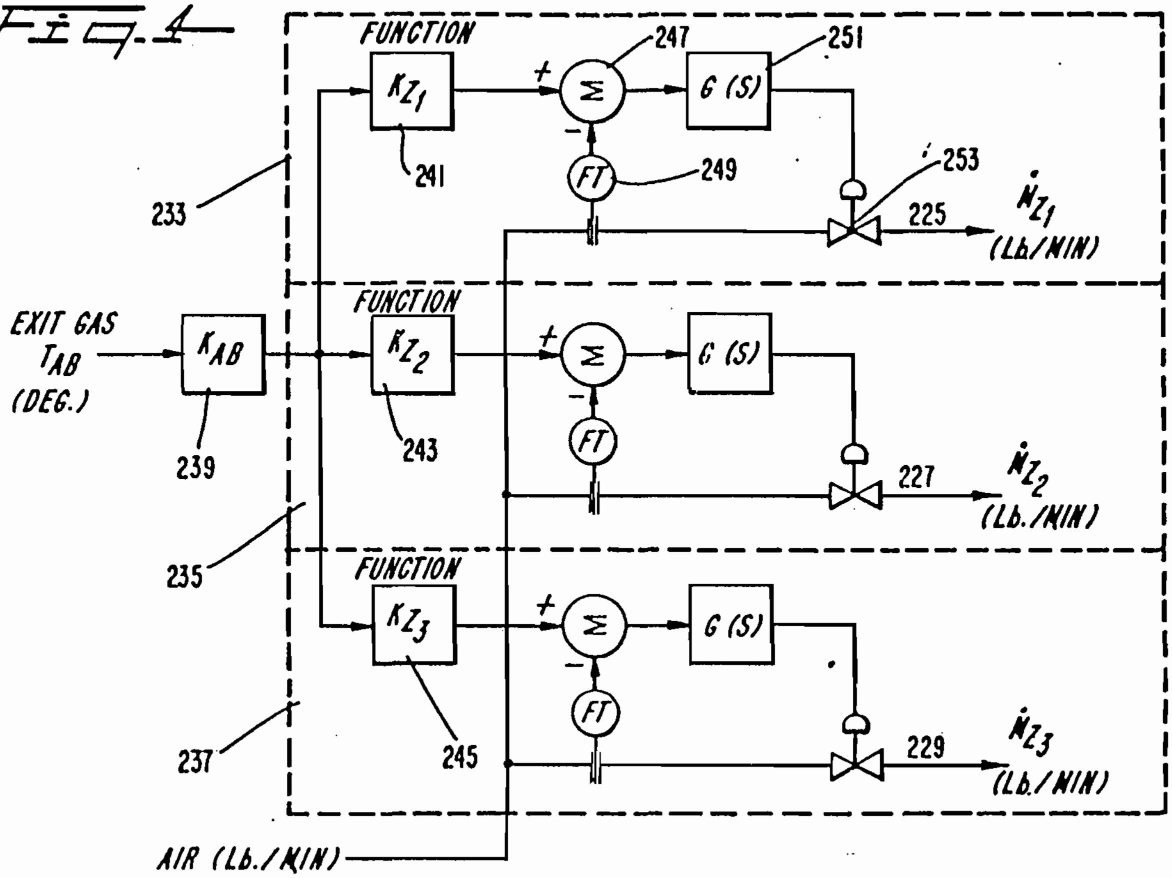
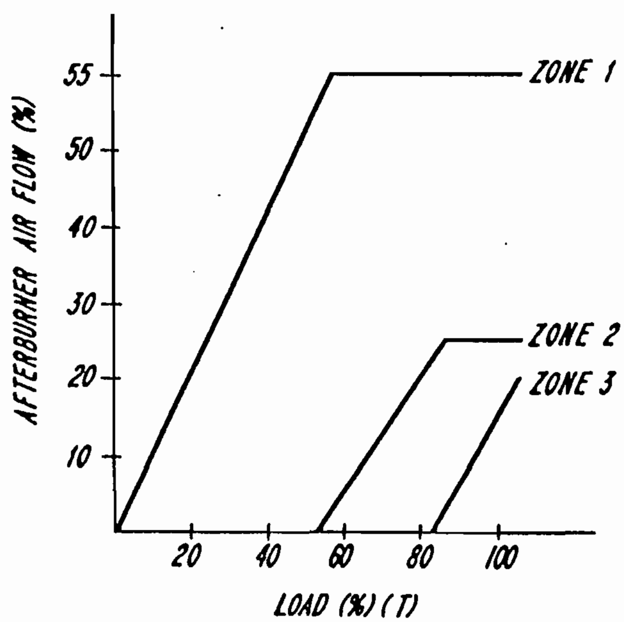

FUNCTION
K_{Z_1}
247
G (S)
251
241
FT
249
253
233
225
$\dot{N}_{Z_1}$
(Lb./MIN)
EXIT GAS
T_{AB}
(DEG.)
K_{AB}
FUNCTION
K_{Z_2}
G (S)
FT
239
243
227
$\dot{N}_{Z_2}$
(Lb./MIN)
235
FUNCTION
K_{Z_3}
G (S)
FT
237
245
229
$\dot{N}_{Z_3}$
(Lb./MIN)
AIR (Lb./MIN)

FIG. 5


AFTERBURNER AIR FLOW (%)
55
50
40
30
20
10
ZONE 1
ZONE 2
ZONE 3
20
40
60
80
100
LOAD (%) (T)

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,332,206

DATED : June 1, 1982

INVENTOR(S) : Gordon H. Tucker and Robert E. Fitch

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

In the drawings, Sheet 2, Fig. 3, the arrows within the area indicated by reference numeral 219 should point in a downward direction and not an upward direction.

Signed and Sealed this

Twenty-second Day of *March 1983*

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer *Commissioner of Patents and Trademarks*

AFTERBURNER FOR COMBUSTION OF STARVED-AIR COMBUSTOR FUEL GAS CONTAINING SUSPENDED SOLID FUEL AND FLY ASH

BACKGROUND OF THE INVENTION

In the last century, much of the world's energy needs have been fulfilled by hydrocarbon fuels which provided a convenient, plentiful, and inexpensive energy source. The current rising costs of such fuels and concerns over the adequacy of their supply in the future has made them a less desirable energy source and has led to an intense investigation of alternative sources of energy. The ideal alternative energy source is a fuel which is renewable, inexpensive, and plentiful, with examples of such fuels being the byproducts of wood, pulp, and paper mills, and household and commercial refuse.

The use of alternative energy sources is not problem-free, however, since there is a concern over the contents of the emissions from the combustion of such fuels as well as the environmental ramifications of acquiring and transporting the fuel and disposing of the residue of combustion.

One promising prior art device for using such alternative energy sources, while maintaining a high degree of environmental quality, is the starved-air combustor wherein the air supplied for combustion is controlled in order to control temperature conditions and the rates of combustion are controlled to consume the fuel entirely. Such starved-air combustors are capable of burning various types of fuel and producing significant amounts of heat which can be employed for any number of purposes including the production of process steam for use in manufacturing and in the generation of electricity.

Starved-air combustors, as previously known and operated, have not been entirely satisfactory in both entirely consuming the combustible elements of the fuel at high throughput while not producing noxious emissions. This problem results, in part, from the use of such starved-air combustors to burn a wide variety of fuels some of which may be non-homogeneous, e.g., household or commercial refuse. It has not been possible in the previously known starved-air combustors to tailor in a real time manner the combustion processes to the type of fuel being combusted in order to maximize the efficiency of the combustor while minimizing the generation of air pollutants. While the pollution problem can be solved to a degree by the utilization of scrubbers and other antipollution devices, such mechanisms are very expensive and their cost may militate against the use of alternative energy sources.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a starved-air combustor capable of efficiently utilizing many different types and quantities of fuel.

Another object of this invention is to provide a starved-air combustor which does not release noxious pollutants into the atmosphere.

Yet another object of this invention is to provide a starved-air combustor which is capable of combusting to a very high degree the percentage of all combustible materials provided to it as fuel.

Still another object of this invention is to provide a starved-air combustor including an afterburner receiving the hot combustion gases from the combustion chamber, for reacting the combustion gases with air, and for combusting any combustible materials entrained in the received combustion gases.

Another object of this invention is to provide a starved-air combustor including an afterburner having a plurality of combustion zones and an air supply controller for controlling the supply of reaction air to the combustion zones in accordance with the temperature of the gases discharged from the afterburner.

To achieve these objects, and in accordance with the purpose of the invention, as embodied and broadly described herein, the starved-air combustor comprises a primary combustion chamber having an inlet end for receiving fuel, the primary combustion chamber for combusting the received fuel to produce hot, combustion gases and combustion residue, the primary combustion chamber further including an outlet end for discharging the hot, combustion gases; a secondary combustion chamber having an inlet end for receiving the hot, combustion gases and an outlet end; the secondary combustion chamber for reacting the hot, combustion gases with selective amounts of air at a significant velocity to combust further any combustible materials entrained in the received hot, combustion gases to produce hot secondary combustion gases and for discharging the hot secondary combustion gases through the outlet end of the secondary combustion chamber; and means for controlling the supply of the reaction air to the secondary combustion chamber according to the temperature of the secondary combustion gases discharged from the outlet end of the secondary combustion chamber.

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the starved-air combustor system of the instant invention connected, for purposes of example, between a fuel supply system and a system which produces process steam from the heat produced by the starved-air combustor system.

FIG. 2 is a graph illustrating the relationship between temperature in the combustion chamber and the afterburner of the starved-air combustor system as related to the amount of air supplied to the combustion chamber and to the afterburner.

FIG. 3 is a cross-sectional view of FIG. 1 the afterburner taken along the lines 3—3.

FIG. 4 is a schematic diagram of a circuit for controlling the supply of air to the afterburner of the instant invention.

FIG. 5 is a graph illustrating the relationship between the supply of air to the zones in the afterburner to the temperature of the gases discharged from the afterburner.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an embodiment of a starved-air combustor according to the present invention coupled between a refuse feeder system and a steam generation system. As embodied herein, the refuse supply comprises a supply conveyor 101 for conveying fuel, in this instance refuse, from a receiving building (not shown) and one or more storage silos (not shown). The receiving building and storage silos are to insure that an adequate supply of fuel can be supplied to the combustor in order to permit the combustor to run at peak efficiency. In the illustrated embodiment, it is contemplated that the supply conveyor 101 would supply fuel to the fuel surge and recirculation bin 103 at a rate of at least fifteen tons per hour and that the capacity of the combustor system would range from 150 to 500 pounds of fuel per minute.

The fuel surge and recirculation bin 103 comprises an additional means for insuring that a constant and adequate supply of fuel is available to the combustor. The bin 103 could, for example, contain at least 10 minutes capacity of fuel, i.e., approximately 2.5 tons, which is received at the top of the bin 103 and supplied through the bottom of the bin 103 to the feed conveyor 105. Feed conveyor 105 supplies the fuel to a splitter 107 which may either direct the fuel into the feed and weigh bin 109 or, when the feed and weigh bin 109 is filled to capacity, to the return conveyor 111 for return to the fuel surge and recirculation bin 103. The feed and weigh bin 109 is calibrated to supply a constant weight of fuel at the inlet end 113 of a refractory-lined combustor 115 at such time that the first flight of an auger 121 within the chamber 115 has been rotated into a fuel receiving position. Within the starved-air combustor 115 there is provided a well-known oil igniter (not shown) in the input end of the combustion chamber 115 to serve as a means for initially igniting the fuel upon start up of the starved-air combustor.

U.S. Pat. No. 4,009,667 issued to Robert C. Tyer et al on Mar. 1, 1977, illustrates an appropriate embodiment for a rotatably-driven auger comprised of a rotatable, water-cooled horizontal shaft supporting a spiral flight of decreasing pitch from the input end of the auger to the output end. It is contemplated in the instant system that the speed of the auger would range from 0.3 to 1 rpm. An appropriate oil igniter would comprise an oil burner having its flame extending into the input end of the combustor 115 to heat and to ignite the initial load of fuel supplied by the feed and weigh bin 109. It is contemplated that such an oil igniter would be capable of burning oil fuel at a rate of approximately six gallons per hour at two pounds per square inch pressure.

The combustor 115 has an output end 117 connected to a duct 119 which feeds the top of an afterburner 129. The combustor 115 also includes air supply means 123 for supplying underfire air and conduits 125 for supplying overfire air. This air is provided by a fan 126 (shown in phantom) which also supplies air through conduits 127 to the afterburner 129. Alternatively, a separate fan or fans may be provided to supply underfire air, overfire air, and air to afterburner 129. A small air distributor 130 is connected to the upper conduit 127 to supply air into the afterburner 129 through special injectors located both at and below the midpoint of the afterburner 129.

Afterburner 129 is provided, in part, as a secondary combustor chamber which mixes the air supplied by the conduits 127 with the gaseous and entrained solid particle output of the combustor from the outlet end 117 to combust all combustible material in the gaseous output and, in part, to separate suspended ash and non-combustible solids from the hot non-combustible gas. Both the non-combustible material from the afterburner 129 and the combustion residue from combustor 115 are fed through conduit 131 to an ash collector 135. The hot non-combustible gas exits into a superheater 137 from which it is supplied to a waste heat boiler 139 to produce, in this case, process steam. An electrostatic precipitator 141 removes any additional solids from the now cooler non-combustible gas exiting from the waste heat boiler 139 through a economizer 140 and the solid material is conveyed to an ash cart 135. From the precipitator 141, the non-combustible gas is drawn by a fan 143 and expelled from stack 145. Upon entering into the fan the temperature of the gas is approximately 300 to 400 degrees Fahrenheit and the fan 143 is of sufficient strength to exert a negative pressure in the system from the combustor 115, the afterburner 129, superheater 137, waste heat boiler 139, the economizer 140, and precipitator 141.

The starved-air combustion of cellulosic and carbonaceous fuel produces an off-gas which is rich in unburned gases, and in most cases, carries a substantial amount of suspended solid fuel and ash particles. The gases are typically at 1500°-2000° F. and typically have a flame temperature at complete combustion with air of 3000°-4000° F., depending upon fuel composition and mositure content. The problem arises from mixing these hot combustible gases with air and completing combustion while providing for low cost, confinement of air-fuel gas mixing and high temperature flame into a zone detached from physical surfaces of the afterburner, protection of refractory surfaces and metal surfaces from thermal loads by active air cooling, completion of combustion of solid fuel particles, and coalescence and cooling of ash to temperatures below the softening temperature before impingement on the afterburner walls, collection and removal of the ash particles which are large enough to be influenced by cyclonic flow field, mixing of air and combustion products to avoid cold/hot regions in the existing flow of combustible gases, and flame stability and control of exit temperature at variable throughput.

The prior art afterburners have not utilized advantageous gas dynamic practices to the fullest extent possible in the fact that most do not produce highly rotational flow (cyclonic) to separate the solid non-combustible particles, and do not provide for capture and removal of ash particles without operation in the ash slagging mode, thus causing build up of slag and clinkers on the afterburner surface. Also, they do not insure detachment of the flame zone from the walls of the afterburner with active air cooling of the structure.

The afterburner of the instant invention provides for an upstream component of air injection to increase the confinement of the flame zone, injection of air from the base of a diverter plate located transverse to the flow of combustion gases in the afterburner to provide for combustion on the inner surface of the flame zone, introduction of the combustion gas into the afterburner with a radial component to direct entrained particles of combustible material outward toward the combustion air, and the provision of a plurality of combustion zones in the afterburner with each zone having an independently controlled air supply.

The principal control difficulty in the prior art starved-air combustor systems lies in maintaining temperature levels throughout the combustor, i.e., in the combustion chamber and the afterburner, at acceptable levels while also optimizing the performance of the system. Temperature control is achieved by regulating the airflow into the combustion chamber and the afterburner to achieve the proper air/fuel ratios. FIG. 2 is a plot of temperature after reaction of fuel and air at different proportions and, as the terminology suggests, the combustion chamber of a starved-air combustor operates at a negative percentage of excess air compared to the chemically correct amount in the temperature region indicated in FIG. 2. Thus, to increase the operating temperature within the combustion chamber of a starved-air combustor, it is necessary to increase the airflow into the combustion chamber.

Also evident from FIG. 2 is that the temperature within the afterburner responds to an increase in airflow in a manner opposite to that of the combustion chamber. Thus, to increase the temperature of the combustion gases discharged from the afterburner, it is necessary to reduce the air supplied thereto.

As illustrated in FIG. 3, the afterburner of the starved-air combustor system includes an inlet end 201 for receiving the hot, combustion gases from the combustion chamber 115 and an outlet end 203 for discharging hot, secondary combustion gases from the afterburner. As stated above, it is the purpose of the afterburner to mix the hot combustion gases from the combustion chamber with air in order to combust any combustible material entrained in the combustion gases received from the combustion chamber.

The walls of the afterburner are lined with a refractory material 205 and spaced along the outside of the afterburner are air supply zones 207, 209, and 211. These zones are separate from each other and wrap completely or substantially completely around the entire external surface of the afterburner. A series of apertures or tuyures 213 are provided to enable air to be injected from the air supply zones 207, 209, and 211 into the interior of the afterburner. The tuyures 211 are directed upwardly toward the inlet end 201 of the afterburner and tangentially with respect to the inner surface of the refractory lining 205 of the afterburner. It is the purpose of the air injected by the tuyures to mix with the combustion gases received through the inlet end 201 and to facilitate a swirling pattern of the mixture while maintaining a layer of cooling air between the flame zone 219 in the afterburner and the refractory lining 205.

A diverter plate 217 is provided transverse to the flow of combustion gases into the afterburner through the inlet end 201. The diverter plate 217 receives air from the first zone 207 and includes tuyures 218 in its bottom surface to establish a flame zone in the afterburner and to initiate combustion at the underside of the flame zone 219. The hot combustion gases entering the afterburner through inlet 201 are diverted by diverter plate 215 and a swirling or cyclonic pattern is imparted to the incoming combustion gases. As mentioned above, this cyclonic or swirling action is enhanced by the flow of air from the zones 207, 209, and 211.

A conduit 230 extends from the air inlet 225 for the first zone 207 to the other zones 209 and 211 to inject air supplied to the first zone 207 through appropriate tuyures into the afterburner in zones 209 and 211. The zones 209 and 211 include their own air supply conduits 227 and 229.

The starved-air combustor also includes means for controlling the supply of reaction air to the secondary combustion chamber according to the temperature of the secondary combustion gases discharged from the outlet end 203 of the secondary combustion chamber, i.e., the afterburner. As embodied herein, part of the controlling means comprises a thermacouple 223 located in the outlet end 203 of the afterburner which provide a temperature sensor 231 with the instantaneous temperature of the secondary combustion gas exhausted through the outlet end 203 of the afterburner.

The controlling means further comprises an air supply controller associated with each zone for adjusting the supply of air to the associated zone to increase the supply of air into the plenum of the associated zone if the sensed temperature of the discharged secondary combustion gas is higher than a predetermined temperature and to decrease the supply of air into the plenum of the associated zone if the sensed temperature of the discharged secondary combustion gas is lower than a predetermined temperature.

FIG. 4 illustrates the air supply controller as comprising controller circuits 233, 235, and 237 corresponding to zones 207, 209, and 211. As embodied herein, the temperature from temperature sensor 231 is supplied to temperature comparater 239 wherein it is determined whether the temperature of the secondary combustion gas discharged from the secondary combustion chamber is within a predetermined temperature range. If it is not within the temperature range, then the comparator circuit 239 generates an output indicating the variance of the actual temperature from the desired temperature and this output is supplied to the function circuits 241, 243, and 245. The function circuits are initially set to apportion the airflow into the afterburner by assigning to each of the zones a percentage of the 100% of air supplied to the afterburner. As an example, it may be desired to supply 55% of the air to zone 1 of the afterburner in which case K_{z1} would be equal to 55%. Similarly, K_{z2} and K_{z3} could be 25% and 20%, respectively.

The function circuit 241 generates an output signal corresponding to the amount of change necessary in the airflow from zone 1 in order to cause a temperature of the secondary combustion gas to be within the range of desired temperatures. This output is supplied to a summation circuit 247. The other input to summation circuit 247 is the output of flow transmitter 249 which senses the volume of air supplied to conduit 225. The summation circuit generates a signal corresponding to the difference between the desired airflow and the actual airflow and supplies that signal to the flow control circuit 251 which controls a flow control device 253, e.g., a valve, to either increase or to decrease the flow of air into the conduit 225. When a desired airflow has been reached, the output of the summation circuit 247 will be equal to zero and the flow circuit 251 will cease to adjust the flow control device 253. The operation of the circuits 235 and 237 are the same as the operation of circuit 233.

FIG. 5 illustrates the manner in which the air supplies to zones 1, 2, and 3 are controlled in accordance with the load on the afterburner, i.e., the desired temperature of the secondary combustion gases discharged from the outlet 203 of the afterburner. As seen from FIG. 5, when the load is 100% of the capacity of the afterburner, 55% of the air supplied to the afterburner is provided by zone 1, 25% is provided by zone 2, and 20% is provided by zone 3. As the load decreases from 100% to just over 80%, the amount of air supplied to zone 3 is decreased from 20% down to zero percent. If the load should decrease further, then the quantity of air supplied by zone 2 is decreased from as maximum of 25% to 0% when the load is approximately 50%. Finally, the air supplied by zone 1 will be reduced from its maximum of 55% when the load drops to approximately 50%. It should be noted, that the provision of conduit 221 communicating with tuyures in the secondary and tertiary zones 209 and 211 of the afterburner causes some air to be provided to zones 2 and 3 even after the air supplied to conduits 227 and 229 has been completely cut off. This insures that there will always be a layer of high-velocity cooling air along the refractory lining 205 of the afterburner.

It will be further apparent to those skilled in the art, that various modifications and variations can be made to the afterburner to the starved-air combustor without departing from the scope or spirit of the invention and it is intended that the present invention cover the modifications and variations of the system, provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A starved-air combustor comprising:

a primary combustion chamber having an inlet end for receiving fuel, said primary combustion chamber for combusting said received fuel to produce hot, combustion gases and combustion residue, said primary combustion chamber further including an outlet end for discharging said hot, combustion gases;

a secondary combustion chamber having an inlet end for receiving said hot, combustion gases and an outlet end, said secondary combustion chamber for reacting said hot, combustion gases with selective amounts of air at a significant velocity to combust further any combustible material suspended in said received hot combustion gases to produce secondary hot combustion gases and for discharging said secondary hot combustion gases through said outlet end of said secondary combustion chamber, said secondary combustion chamber including at least first and second air supply zones, each said air supply zone comprising a plenum located adjacent to said secondary combustion chamber, an air supply into said plenum, and at least one air passageway for enabling the flow of air from said plenum into said secondary combustion chamber; and

means for controlling the supply of said reaction air to said secondary combustion chamber according to the temperature of said secondary combustion gases discharged from said outlet end of said secondary combustion chamber.

2. A starved-air combustor according to claim 1 wherein said secondary combustion chamber includes a deflection plate located transverse to the flow of said received hot combustion gases to impart a swirling motion to said received hot combustion gases and to establish a flame zone in said secondary combustion chamber.

3. A starved-air combustor according to claim 1 or 2 wherein said passageway directs the flow of air to increase the swirling of said received hot combustion gases and to increase the period of time said hot combustion gases are in said flame zone.

4. A starved-air combustor according to claim 3 wherein said controlling means comprises:

a temperature sensor for sensing the temperature of said discharged secondary combustion gases; and

an air supply controller associated with each zone for adjusting the supply of air to said associated zone to increase the supply of air into said plenum of said associated zone if said sensed temperature of said discharged secondary combustion gas is higher than a predetermined temperature and to decrease the supply of air into said plenum of said associated zone if said sensed temperature of said discharged secondary combustion gas is lower than a predetermined temperature.

5. A starved-air combustor according to claim 4 wherein said first zone is positioned closer to said inlet end of said secondary combustion chamber than said second zone and wherein said first zone further includes a conduit for supplying a portion of the air supplied to said first zone to said second zone for injection into said secondary combustion chamber.

6. A starved-air combustor according to claim 5 wherein said air supply controller associated with said second zone adjusts the air supplied thereto in priority to said air supply controller associated with said first zone adjusting the air supplied thereto.

7. A starved-air combustor comprising:

a primary combustion chamber having an inlet end for receiving fuel, said primary combustion chamber for combusting said received fuel to produce hot, combustion gases and combustion residue, said primary combustion chamber further including an outlet end for discharging said hot, combustion gases;

a secondary combustion chamber having an inlet end for receiving said hot combustion gases and an outlet end, said secondary combustion chamber for reacting said received hot combustion gases with selective amounts of air at a significant velocity to combust further any combustible material entrained in said received hot combustion gases to produce hot secondary combustion gases and for discharging said secondary combustion gases through said outlet of said secondary combustion chamber;

a deflection plate located in said secondary combustion chamber transverse to the flow of said received combustion gases for imparting a swirling motion to said received combustion gases and to establish a flame zone in said secondary combustion chamber;

a first air supply zone located adjacent to said secondary combustion chamber proximate to said inlet end of said secondary combustion chamber, said first air supply zone including a first plenum, a first air supply to said first plenum, and a first aperture for supplying air from said first plenum to said secondary combustion chamber;

a second air supply zone located adjacent said first air supply zone, said second air supply zone including a second plenum, a second air supply to said second plenum, and a second aperture for supplying air from said second plenum to said secondary combustion chamber; and

an air supply controller for sensing the temperature of said secondary combustion gases discharged from said secondary combustion chamber and for controlling the air supplied to said first plenum by said first air supply and the air supplied to said second plenum by said second air supply in a manner inversely related to the variance of said sensed temperature of said discharged secondary combustion gases from a predetermined temperature.

8. A starved-air combustor according to claim 7 wherein said first air supply zone further includes a conduit connecting said first plenum with the interior of said second air supply zone in said second combustion chamber to inject into said secondary combustion

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chamber through said second air supply zone a portion of the air supplied to said first air supply zone.

9. A starved-air combustor according to claim 8 wherein said air supply controller adjusts the air supplied by said second air supply zone in response to said variance of said sensed temperature of said discharged secondary combustion gases from said predetermined temperature before adjusting the air supplied by said first air supply zone.

* * * * *

THE ISSUE OF DIOXINS

PROPRIETARY
E.I.S., INC.

R. E. Fitch

I. Background

The recent furor over dioxins and energy recovery has its origins in the Vietnam war use of the herbicide 2,4,5-T, which resulted in widespread and serious health effects at least partly via its contaminant, the dioxin 2,3,7,8,-TCDD. TCDD stands for tetrachlorodibenzo-para-dioxin, describing one of the eight classes of chlorinated hydrocarbons. (1) The TCDD class contains 22 varieties of which the most studied, and the most toxic of those studied, is the 2,3,7,8 isomer. The eight classes of dioxins are those ranging from mono- to octa-chlorine substitution and contain a total of 75 separate compounds. Only the TCDDs have been examined extensively for their toxicological effects.

Dow Chemical, USA has studied dioxins for several years and has reported its findings in a survey article in a recent technical magazine. (1) This appears to be the most comprehensive report yet published. Duckett (2) also addressed the issues in a recent NCRR symposium.

The present concern over dioxins from waste burning stems from the discovery of a dioxin (not necessarily a TCDD) in an ash deposit in the stack of the new energy recovery system at Hempstead, NY during an investigation of an odor problem at that facility. The subsequent hue and cry of local residents, coupled with other business and systems performance factors, caused the closing of that facility.

Subsequently, EPA has launched a program to identify and resolve the dioxin issues, including:

1. Development of a test protocol accepted by the appropriate scientific, environmental, governmental and industrial communities;

2. Determination and characterization of the mechanisms of dioxin formation and destruction in the waste combustion processes;

3. Characterization of background levels and other sources of dioxin emissions.

DOE has apparently taken the position that dioxins are ubiquitous, on the basis of existing evidence, and is trying to head off EPA from legislating emissions requirements that would hinder or delay waste-to-energy implementation. DOE is conducting a stack sampling and analysis program at Ames, Iowa, where coal and RDF are co-fired, to determine whether TCDD and other emissions are present in those stack exhausts.

ASME has commissioned a review paper on dioxins as potential emissions sources.

II. Present Status

The dioxin issue is confusing, especially to a prospective purchaser of an energy recovery system. Much is not known about all phases of the issue. However, some is known about some of the significant aspects.

A. Toxicity - The toxicity of the 2,3,7,8 - TCDD isomer is greater than most common toxins, but less than some. The NAS has reported a dosage which has produced no observed acute effect (on laboratory animals). This does not address the potential carcinogenic or mutagenic effects. There is currently no basis for establishing a health-related safe level of exposure to airborne concentrations of 2,3,7,8 - TCDD.

B. Ubiquity - The claim by DOE and others that dioxins are widely prevalent in our environment appears to be amply supported by evidence. Dow has found chlorinated dioxins in a variety of locations and substances, both related and nonrelated to the chemical industry (i.e. engine exhausts, soil, dusts, cigarette smoke, food waste incinerators, etc.) (1) Others have chlorinated dioxins in waste combustion and in industrial heating facilities.

C. Formation and Destruction - The predominant source of environmental dioxins appears to be combustion processes of various sorts through trace chemistries of fire consisting of numerous chemical reactions occurring at low concentrations (e.g. 10 -10 percent). Existing evidence suggests that chlorinated dioxins are formed by interaction of inorganic chlorine with organic material, as well as by the reactions of pre-existing polychlorinated phenols, which are usually present in wastes.

Polychlorinated dioxins have been destroyed by oxidation at high temperature, or by exposure to elevated temperatures above 800°C (1472°F). The characteristics of decomposition are not understood, nor are the time, temperature, and composition conditions which produce decomposition in varying degrees. Bumb (1) states that 99.9% combustion efficiency is required to achieve a thousandfold reduction in dioxin level, and that common combustion practices are not adequate for this.

III. Auger Combustor System

The auger combustor/afterburner system has operating features which should aid in suppressing the emissions of dioxins from waste combustion:

1. Long residence time at elevated temperatures;
2. Combustion completeness exceeding 99.9%;

3. All gaseous products reaching stoichiometric adiabatic flame temperature.

A. Process Description

Figure 1 is a plot of the calculated temperature and products of combustion produced by gasification and/or combustion, in air, of a composite waste composition (encountered during the prototype tests in Jacksonville). These are shown as a function of air/fuel ratio, and represent conditions which would occur if 90% of the combustibles in the waste stream were gasified completely and reacted to chemical equilibrium with the air. Account was taken of the thermal losses of the ash and combustible residue, as well as heat transfer from the system. That portion of the curves to the left of the chemically correct mixture (stoichiometric) represents incomplete oxidation, (referred to generically as partial oxidation, starved-air combustion, substoichiometric, etc.). The right of the curves represents complete combustion with excess air, as indicated by the presence of free oxygen.

Consider the example illustrated by conditions (1) and (2) on the figure. Condition (1) is for the primary combustor operating at a gas phase equilibrium temperature of 1500°F. Condition (2) is the afterburner exit at a temperature of 2000°F. It will be shown later that the combustion products pass from (1) to (2) without significant loss of heat (as is encountered with a radiant heat boiler) and that the path from (1) to (2) is along the curves. This means that each element of the gas phase passes through the maximum possible temperature which combustion of the waste material can produce (adiabatic flame temperature at stoichiometric air fuel ratio).

Figure 2 is a schematic of the process and shows the flow of the main material from feed through combustion and heat extraction.

Primary Combustor (0-1,2) - The waste is introduced to the combustor feed end. The auger moves it through the reactor with a residence time of 10 to 30 minutes. During its travel, it is stirred and tumbled by the action of the auger. The material is heated and ignited by radiation from the hot refractory, radiation and convection from the hot combustion gasses over the bed of material, and by conduction from the auger flight as it contacts the bed after having been heated by the gas during its rotation.

Several kinds of reactions take place in the combustor, the cumulative effect of which is to completely gasify (or nearly so) the combustible portion of the fuel without completely oxidizing the gasses produced, which maintaining close control on temperature. These reactions, in general order of their sequence, are 1) evaporation of moisture, 2) pyrolysis and evolution of volatiles, 3) partial oxidation and continued cracking of heavier volatiles, 4) hetrogeneous solid-gas phase reactions, partial oxidation of remaining fixed carbon, 5) suspension of light unburned paper and cardboard fragments. Within the bed of material, conditions are not uniform as the fuel moves and as the forced draft underfire air penetrates the bed in a nonuniform fashion. Local hot spots may produce all of the reactions listed above. However, after passing through the bed, the gases mix in the open volume of the reactor, and with sufficient dwell time, should approach chemical equilibrium. Although some particle reaction will proceed, reaction of the levitated particles with the gas phase will certainly be slower than gas phase reactions and probably will not be significant in the primary reactor.

Hot Ducting (1,2,-3-4) - The primary gases flow through the hot ducting to the afterburner, with no significant change, except that the long residence time at elevated temperatures provides for additional reaction to approach more closely to chemical equilibrium.

Afterburner (4-6) - The afterburner has been designed to combust completely the gaseous and solid combustor products, while protecting the surfaces and structure and minimizing thermal losses by active regenerative cooling and by carefully tailoring the flame zone.

The afterburner flow field sketched in Figure 3 produces several beneficial effects:

1. The blunt base of the diverter plate acts as a flame holder and provides a recirculation zone into which combustion air is introduced.

2. The annular injection of combustible gas thus produced provides for inner and outer diffusion flame zones which increase the rate at which the gases react with air.

3. The diverter aims the particles outward so that their radial momentum carries them to the outer stream lines of the flow field either into the air or at least into the outer edges of the mixing zone. This exposure to higher oxygen concentration increases the rate at which the particles can react, compared to their reaction rates if the particles followed the same stream lines as the gas phase which will consume oxygen nearly instantaneously, preferentially compared to the particles.

4. The outer air injectors, aimed upstream and tangentially, produce a cyclonic flow with a centrifugal effect which enhances migration of the fuel particles into oxygen-rich zones.

5. The ash or slag particles from the solid fuel

combustion continue their migration toward the outer wall into cooler air where they can coalesce and/or freeze and be removed in a dry, concentrated state.

Figure 4 shows a/f and temperature profiles at flow field stations (See Figure 3). At Section A, the mixing zones between heated fuel gas and air are thin, with strong a/f and temperature gradients. In Section B the mixing zones have widened so that the inner and outer zones are nearly touching. The points of maximum temperature in all cases is the adiabatic flame temperature (assuming no heat loss to surroundings) along the locus in the mixing zones where the a/f is stoichometric. As mixing continues, as at C, the zones have begun to merge and the profile tends to even, so that by Station D, the gradients have nearly dissipated and the profile approaches flatness.

From the dioxin standpoint, the point of most significance is that all gaseous fuel elements pass from the temperature at entry through the maximum possible temperature (subject to minimal radiative loss from the flame) before decaying to the bulk exit temperature associated with the mixed a/f ratio. Also, even though the interior refractory wall is hot (>1500°F in the prototype test) heat loss is minimized by regenerative cooling of the wall (injected air used to cool the structure before injection).

Steam Generator (6-10)

The steam generator shown includes a high temperature generator (6-7), superheater (8-9), and boiler (9-10) of conventional design and configuration.

B. Combustion Efficiency

In the prototype testing, the auger combustor was shown to be a highly efficient combustion machine. Hydrocarbon combustibles in the gas phase ranged from 5-29 ppm. CO concentrations at excess air conditions greater than 30% averaged 156 ppm with the lows in the 60-100 ppm range. At 35% excess air, CO_2 and CO concentrations were 14% and 100 ppm respectively, giving a combustion efficiency in excess of 99.95%. Combustibles in the fly ash (1.5-2 grains/dscf) were mostly in the range below 5% with a few runs exceeding 25%. This also indicated near completeness of combustion.

C. Temperature History

Figure 5 shows the theoretical average temperature-time history of the gasified material from the onset of combustion to exit from the boiler. In practice the peak may be reduced slightly owing to radiation from the flame, but other elements of the flow field will encounter a corresponding momentary increase in temperature. In any event, the combustor products are at 1500°F or greater for more than two seconds. The time at 1500°F is about equally divided between reducing and oxidizing conditions, while the higher temperature is nearly all oxidizing.

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REVIEW OF THE AUGER COMBUSTOR SYSTEM

by

Robert E. Fitch

for

Environmental Incineration Systems, Inc.
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ROBERT E. FITCH
13262 SE 261st St.
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REF-006
May 25, 1987

Ms Elizabeth D. Fletcher
Environmental Incineration Systems, Inc.
Suite 1113 Blackstone Building
Jacksonville, Florida 32202

Dear Ms Fletcher,

Transmitted herewith are the auger combustor process system description which you asked me to review, the "Review of the Auger Combustor System", modified as you suggested, and a recent resume which describes most of my activities in waste-to-energy.

I do not have the time to rewrite my resume, but I believe the following amplifying information will be of interest to anyone who is concerned with my expertise or judgment with respect to the waste-to-energy field:

HAVERHILL-LAWRENCE

As Risk Assessment Manager for this project, I was responsible for identifying and resolving all technical risks associated with the project. I was directly involved from the time of negotiation of the original design/construction contract with the customer to the completion of the acceptance tests and transferral of the plants to the owner. I evaluated many other waste processing systems in this country, personally visited and inspected them, interviewed the operators in detail, and established design criteria for the process facilities based upon my findings. These plants included:

Pompano Beach, Fl
Cockeysville, Md
Albany, NY
Rochester, NY
Niagara Falls, NY
Madison, Wi
Anchorage, Al
Dade County, Fl
Tacoma, Wa
Columbus, Oh

During design and construction of the Haverhill-Lawrence plants I supervised and participated in the development of several items of equipment by our major subcontractors, Heil and Babcock & Wilcox, including two-stage trommels and auger feed distributing conveyors, and boiler feeders, respectively. All of these items have worked well since they went into service in 1984.

After the plants were built I became Startup and Acceptance Test Manager for Boeing. The Haverhill facility was started up in early 1984 and passed its acceptance test in March, completing 21 days of successful 700-ton processing in 22 operating days, well within contract time. The Lawrence steam generating plant started up in mid-year and passed its tests in December, 1984. Except for serious boiler and superheater tube corrosion, the plants have operated successfully since then.

I feel fortunate to have participated in this project in such key roles, from start to finish. Having shared the responsibility for design of the plants and development of the sensitive pieces of equipment, and later been responsible for placing the plants in service and working out the "bugs", has given me a perspective of waste processing and energy recovery systems that few can match.

EVERETT

In 1981 and 1982, Boeing installed a small (50 tpd) modular incineration-energy recovery system at its Everett, Wa plant. The system did not perform to specification nor to expectation. I was charged with the technical evaluation of the system and later with technical oversight of the implementation of limited modifications. Subsequently Boeing gave up, appropriately, on this system and scrapped it. This plant was a lesson in "what not to do".

VICOM MASS BURNING ENERGY RECOVERY SYSTEM

In 1984, DE&C Engineers entered into an agreement with Vicom (corporate name uncertain) to design and build energy recovery plants using the Vicom two-stage mass burning system. I performed the technical evaluation of the sustem, including two in-depth inspections of a commercial facility at Pittsfield, Mass. -one during annual maintenance shutdown and one during full operation. In addition, I extensively interviewed the inventor-designers and the operators of the plant.

The system is unique among two stage burners in that the first stage operates in an excess air mode, rather than starved air. This was done to control, with diluent air, the slagging and caking of the fuel bed which is common in small modular incinerators such as the one at the Boeing, Everett plant. This fix worked well, but it did produce substantially lower energy recovery because excess air acted as a coolant.

In my opinion, the starved air auger combustor is still the safest, easiest to regulate, efficient, and environmentally cleanest energy recovery system in the size range up to 360 tons fuel per day per unit.

This sums up my recent experience in the processing of solid waste and its conversion to useful energy forms. I hope it will be helpful.

I believe that I have answered the questions of your letter dated May 20th. If you wish additional information, please let me know.

Sincerely,

ROBERT E. FITCH

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REF3
5/25/87

REVIEW OF THE AUGER COMBUSTOR SYSTEM

1. General Characteristics

The auger combustor is a starved-air incinerator, which means that not enough air is added in the combustor to burn all the gases which evolve, principally carbon monoxide. Thus the temperatures are moderate, because not all the heat of combustion is released in the primary combustion vessel. Because of this feature, in fact, the primary temperature is not only easily controlled by the amount of air introduced into the combustor, but also the introduction of highly flammable materials such as gasoline results in a benign reaction because of the scarcity of air. Therefore it is a very safe reactor.

Combustion is completed in a separate vessel, the afterburner, in which more air than is necessary to burn the off-gases is provided, to maintain temperature control and also to ensure completeness of combustion. The afterburner is likewise a safe reactor because the gases are fed into it in a controlled, even, flow, so that it is not subject to surge to the degree that mass burning or traveling grate RDF furnaces are, which combust completely in a single reactor.

Feed of the auger reactor can be relatively coarsely ground (8" minus), compared to other RDF furnaces which operate best with a smaller size feed, eg. 4" minus. The feed is batch weighed and fed to coincide with the rotation of the auger.

Steam is generated in a waste heat boiler after all combustion is completed and after most of the particulate matter (fly ash) has been removed in the afterburner. Conditions are stable, steady, and the gas is non-reactive, a significant benefit which is explained below.

2. Size

During the testing of the full-scale prototype in Jacksonville, the auger was operated at throughputs of from two (2) to fourteen (14) tons per hour of various materials, including pine bark, RDF, auto shredding waste (fluff), and coal. The capacity of the system was limited by the forced and induced draft fan capacity, not by any inherent limitation of the auger or afterburner. It is believed that the optimum feed rate for the auger is approximately fifteen (15) tons per hour, but it can operate well at much reduced rates, although the thermal losses from the system will be disproportionately greater for the lower throughput system. The 15 tph RDF rate translates to about 400 tons per day of refuse processed, depending upon the [illegible] front-end processing and resources such as glass, metals, paper and plastics recovered in the processing.

3. Feed System

One of the most serious problems in maintaining smooth operation of a conventional RDF travelling grate furnace is caused by variations in fuel properties, principally density. Conventional feeders are volume-measuring devices and as such, produce a varying fuel flow as density varies due to packing, wadding, voids, etc. Combustion behavior associated with a variable fuel flow is likewise variable, which makes regulating the furnace more difficult. In larger furnaces this is somewhat eased by feeding with a number of feeders, such thst the variations in each feeder are averaged to produce a more regular total flow, but the local variations still remain.

The auger combusteor is fed with a batch-weigh system, timed to synchronize with the turning of the auger. Thus, every charge, corresponding to one flight space of the auger, is of the correct mass, having been weighed instead of having been metered by volume. This is one of the most important features of the auger combustor, and helps to ensure that the proper and uniform mixture of air and fuel can be maintained. Thus the excursions of gas properties which are encountered in other systems and which account for serious tube corrosion simply do not exist. Travelling grate boilers which volumetrically meter the feed into a large, single combustion chamber have experienced such damaging and costly corrosion, to wit, Lawrence, Mass., Niagara Falls, NY; Albany, NY; and Dade Co., Fla. All of these furnaces have been retubed, at least partially if not totally. Superheater tubes, especially, have suffered premature failure. The corrosion has been caused by two principal factors: alternating periods of reducing and oxidizing atmospheres at elevated temperatures to which most metals are not resistant, and ash containing corrosive chemical species which deposits on the tubes providing a protected zone where the chemicals can do their dirty work. Neither of the conditions are present in the auger combustor sustem. The steam generating and superheating tubes are exposed to the gas stream only after all combustion has taken place, the composition of the exhaust gas is uniformly oxidizing, nearly all of the fly ash has been removed, and what has not has been cooled to the point where it is unlikely that it would stick to the tubes. All of these beneficial effects are possible because the feed is precisely controlled by weight, thereby allowing precise air/fuel mixture control, which provides for stable combustion, regulated temperatures, and uniform gas chemistry.

Another important feature of the auger caombustor is its ability to handle a coarsely shredded feed. In fact, coarseness is a benefit, to a degree, because it provides for a more porous fuel bed in the reactor, which also aids in stabilizing the combustion process. From a fuel processing standpoint, this means reduced costs of shredding. Other systems which use the volume metering technique (including those named above)require more finely shredded feed in order to keep from jamming the metering apparatus.

3. Afterburner

The afterburner is the second stage of the combustion process and completes the reaction of the fuel gases produced by the primary chamber, as well as any particulate fuel carried over from the auger chamber. In addition, being a cyclonic reactor in which the cool combustion air is introduced at the wall to produce the spinning effect, the particles are separated and cooled, so that by the time they reach the wall they have been quenched to the point of dryness and do not stick to the wall, but can be collected and bled off separately from the gas stream before it passes into the boiler section, or they can pass through the first bank of tubes with little fear of depositing.

The gases, being of relatively even fuel-rich composition, burn cleanly and evenly in the afterburner. Their temperature is around 1800 degrees F, well above their autoignition temperature. The combustion air is preheated, as well, and this combination insures instantaneous ignition and combustion during the mixing of the two streams. Thus, combustion is complete, provided that sufficient air has been added.

4. Control

All the foregoing advantages lead to one extremely significant feature: the auger combustor system is a beauty to control! Because one reactor is starved of air and the other is air-rich, the control of each is not complicated by the alternating from reducing to oxidizing conditions in the same furnace zones as is common with the aforementioned systems. The amount of air is very conveniently and safely regulated in each vessel using temperature as a control parameter, but in opposite effect: in the primary, increased air elevates the temperature by producing more combustion, but in the afterburner, added air acts as a cooling diluent. Thus, control of each is easy and precise, and tied directly into the speed of the auger and the weight of each fuel charge.

The regularity of the combustion process lends itself nicely to the use of "expert" systems, in that the control system can teach itself to recognize variations in fuel quality (such as would occur when switching to another fuel such as auto fluff) and make its own educated adjustments to combustion air flow, auger rotation speed, fuel charge weight, etc.

5. Emissions of NOX and Dioxins

NOX

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It is widely accepted that the production of NOX from combustion processes is, to a large degree, a function of the processes themselves. If the oxidizing reactions take place in a single vessel to which more oxygen is added than is necessary for complete combustion, as is typical in a travelling grate, water wall furnace with a highly agitated combustion zone, there are regions within the reactor which will alternate between under- and over-oxidized, before time and distance have allowed the reaction zones to become well mixed and homogeneous. This produces conditions in which incompletely gasified fuel particles are exposed to elevated oxygen concentrations in the presence of abundant nitrogen. The chain of chemical reactions in this circumstance favors the production of oxygen-nitrogen species, principally NO, because of the formation of atomic oxygen and nitrogen in these zones, and the opportunity for them to combine.

On the other hand, the first stage of a two stage reactor system such as the auger combustor, in which the primary reactor (auger vessel) is starved of enough oxygen to completely react the fuel, does not have the excess of oxygen to react with the nitrogen, nor is the temperature high enough to disassociate the nitogen, to make it in a state to react readily if there were available oxygen. Thus, little NO is produced in the primary. The main products of the starved-air combustion are carbon monoxide (CO), carbon dioxide (CO2), hydrogen (H2), and water (H2O).

In the afterburner the gases CO and H2 are reacted completely with additional oxygen. These reactants are much more reactive with oxygen than is the nitrogen and essentially deny the oxygen from the nitrogen. The reaction chain thus inhibits the production of NO species, in contrast to the favorable conditions which the single stage reactor produces.

DIOXINS

Dioxins are a small set of a large group of micro-pollutants which are produced in the combustion of many classes of waste materials. They are apparently ubiquitous,having been found in micro-levels in many types of incineration and other reaction systems. They are the result of failing to complete the combustion or decomposition processes in the reactors. The destruction of such micro-pollutants is encouraged by providing long (relatively) residence times in the reaction system at elevated temperatures, particularly in the presence of excess oxygen. This favorable set of conditions exists in the auger combustor system. The residence time in oxidizing conditions at elevated temperature can exceed one second. Contrast this to the conventional waterwall single stage furnace in which the flame zone radiates to the water tubes even before all the heat is released in the combustion process, and the residence time is very much less than one second before the gases pass into the superheater tube bank and are cooled further.

GENERAL

The two stage combustion process, being controllable in both stages to a degree not found in conventional water-wall

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travelling grate furnaces, is more environmentally sound than those types of combustors. In addition to the controllability, the residence time at elevated temperatures, in first reducing and then oxidizing conditions, induce more complete combustion of both particulate and micropolluting emissions.

6. Risk Assessment

There are believed to be no significant technical risks associated with the auger combustor. There are risks, of the kind to be found with any non-commercialized new system. The experience of the author, in personally operating the prototype system, led to the strong belief that the auger system is unique in its controllability and benign operating environment and conditions. Subsequent to that testing, the author participated directly in the operation of the combustors at Lawrence (travelling grate, water wall) and the modular mass-burning incinerator installed by The Boeing Company at its plant in Everett, Washington to burn plant waste. Both of those systems had serious control, slagging, and performance problems. The auger combustor was even more efficacious in contrast.

There will be start-up problems of the sort encountered in any process plant, especially those handling solid waste. One would expect that unforeseen difficulties may arise with the feed system and with the control system that will take time to resolve. However, these will require "tuning" fixes and not the major overhaul types of modifications which have been experienced by other operators.

The improvements which have been proposed for the system are based upon straightforward, state-of-th-art techniques which have been well demonstrated in other applications, although they have not, to the author's knowledge, been assembled into the system proposed for the auger combustor.

It is believed that this system is ready for commercial use, by virtue of the two-stage nature of the process, the full-scale prototype operation in a variety of conditions and with a variety of fuels, and the extensive experience of the contributors to the process design.

7. Summary

The major features of the auger combustor system are:

a. Safe, controlled temperature environment for all materials in the system.

b. Evenly controlled chemical compositions in each reactor.

c. Ability to handle a coarse feed.

d. Weighed batch feed rather than volume- metered feed.

e. Combustion complete and most fly ash removed before entering boiler.

f. Highly efficient combustion procces resulting from a. through e., above.

g. Two stage combustion inhibits the formation of nitrogen-oxygen species.

h. The long residence time at elevated temperature in oxidizing conditions which encourages the destruction of fuel residue micro-pollutants such as dioxins.

i. The auger combustor and afterburner have been demonstrated in full scale prototype, the other elements of the system are state of the art, and the system is ready for commercializing.

Assessment of Environmental Incineration Systems, Inc.
Auger Combustor Process System

Alex E. S. Green

This is an evaluation of the Environmental Incineration Systems, Inc. Auger Combustor Process System (EIS-ACPS) based upon the unassembled components of the 15 TPH incinerator as observed in Jacksonville on December 26, 1986, documents describing its construction and performance [1-5], a background in clean combustion technologies as reflected, for example, in service on the National Coal Council during the preparation of the report on Clean Coal Technologies [6], and research on clean coal and waste combustion technology [7-10]. The assessment also reflects a literature analysis of municipal waste incineration [11-12], reports at the Thirtienth Annual Research Symposium on Hazardous Waste [13] held in Cincinatti, Ohio on May 6-8, 1987, and a very recent critical review of hazardous waste incineration [14].

While urban wastes are far more benign than hazardous wastes and in some respects even more benign than coal, hazardous waste and coal combustion have had the benefit of much better research funding and far more intensive study than urban waste combustion. Accordingly, much of the current stratagy and understanding of clean solid combustion technology has developed from experience and studies of coal combustion and solid hazardous waste combustion. Table 1 is a listing of clean coal technologies which might be utilized in retrofitting an industrial oil boiler to coal. These technologies are grouped under the major headings (A) Precombustion, (B) Combustion/Conversion and (C) Post-Combustion Techniques. The table succinctly identifies most of the practical techniques which can minimize emissions of harmful pollutants in the combustion of coal in retrofitting an industrial oil boiler.

The literature on the incineration of hazardous waste, has developed even more rapidly in recent years largely under the stimulation of Superfund appropriations. The recent excellent critical review by Oppelt [14] contains 178 references to work on this topic. Here the major subsystems which may be incorporated into a hazardous waste incineration systems are listed as (A) waste preparation and feeding (B) combustion chambers (C) air pollution control and (D) residue/ash handling. The first three of these exactly parallel the subsystems used in categorizing clean coal technologies. Figure 1 gives a general orientation of hazardous waste incinerator subsystems.

Urban waste incineration has a number of aspects of hazardous waste incineration and of coal combustion. Indeed typically a fraction of urban waste input, for example the halogenated hydrocarbons in many plastics, and various pesticides may be classified as hazardous waste. The heavy metals in urban waste are comparable to the metals emitted from coal burning plants. Accordingly, urban or municipal waste incineration must incorporate the best approaches developed in the combustion of hazardous waste and of coal - the most difficult to burn cleanly and efficiently of the fossil fuels (coal, oil, and natural gas).

Let us examine the various approaches to hazardous waste combustion which lead to stack effluents which meet the very stringent requirements of the Resource Conservation and Recovery Act of 1976 (RCRA). These requirements include (1) 99.99 percent (the 4 nines rule) destruction and removal efficiency (DRE) for each principal organic hazardous component (POHC) in the waste, (2) 99% removal of hydrogen chloride from the exhaust gas if hydrogen chloride stack emissions are greater than 1.8 kg/h, and (3) particulate matter emissions no greater than 180mg/standard m^3 corrected to 7% oxygen in the stack gas.

Municipal or urban waste streams are far more benign than the typical hazardous waste streams and current municipal waste standards provide only limits on particulate emissions. However the EPA is required under the 1984 Hazardous and Solid Waste Acts Amendments (Section 102) to prepare a report to Congress on the extent of risks due to dioxin emissions from municipal waste incinerators and on appropriate methods for reducing those emissions. The report will include data on cancer risks and controls associated with additional pollutants emitted by the municipal incinerator. This makes the hazardous waste literature of particular relevence to the urban waste field.

Among the standard accepted incinerator designs of hazardous solid waste incinerators which can meet the requirements of the RCRA are the rotary kiln, the fixed hearth and the fluidized bed (see Fig. 1). The recent review of Oppelt [14] does not mention the Auger Combustor although a typical fixed hearth incinerator shares a number of features with the EIS-Auger Combustor Process System (ACPS). It does mention augers in connection with waste preparation. The fact that the ACPS is not yet listed among the major types of hazardous waste incinerator methods may simply be indicative of its conceptual newness and the tortuous path needed for advanced concepts to gain acceptance in the public health arena. While there is at this time great public confusion as to the best methods of waste disposal, nevertheless, it is becoming increasingly recognized that among the treatment technologies for disposing of hazardous waste, incineration provides the highest overall degree of destruction and control for the broadest range of waste streams. If one examines, in detail, the various subsystems that are incorporated in the EIS-ACPS (see Fig. 2) in relationship to hazardous waste incineration (see Fig. 1) one sees that the EIS-ACPS is a municipal waste incinerator with all the essential features of a hazardous waste incinerator.

The following features of the EIS-Auger Combustor Process System (see Fig. 2) give it a leading position among municipal waste incinerators:

(1) The use of the starved air regeneratively cooled primary chamber which in effect is a high temperature pyrolyzer or gasifier fired at substoichiometric conditions. This condition causes most of the volatile fraction of the waste to be destroyed pyrolytically with the fixed carbon fraction of the waste providing most of the heat needed for pyrolysis.

(2) The use of a unique water cooled auger system fed by a batch weighing system timed to synchronize with the turning of the auger. Ten of the auger's ribbon flights are made of temperature resistant metal to move and tumble the waste.

(3) A double walled afterburner cyclone completes the combustion of the pyrolytic products. Thus the smoke and products of pyrolysis along with the hot combustion products of the strarved air chamber pass to the secondary afterburning chamber. Additional air is here injected to assist the combustion in reaching high temperatures suitable for the destruction of all organic compounds. Air preheat is provided by regenerative cooling and turbulence inducing arrangements, which leads to an unusual completeness of combustion at low excess air. The cyclonic flow of the afterburner also serves to remove a significant proportion of the particles carried from the first stage which survive the secondary chamber.

(4) The EIS-ACPS has an energy recovery system, which consists of a conventional superheater, waste heat boiler and economizer. The energy recovery system will become increasingly valuable as oil prices return to higher levels.

(5) The proposed emissions clean-up system for the Auger Combustor Process System reflects a state of the art flue gas cleaning process - which incorporate the best of current thought and practice on removal of acid gases, of coarse and fine particles, and mist.

The recent study of Howes et. al. [12] provides a basis for estimating the emission levels of the EIS Auger Combustor Process System. They compared stack emissions from three municipal refuse to energy systems characterized by refuse derived fuel (RDF), mass burning (MASS) and modular (MOD). The EIS-ACPS can be regarded as an advanced version of modular incinerators since MOD also has the starved air primary chamber and an excess air afterburner chamber. These systems usually have stokers or transfer rams to move the pyrolyzing waste towards the ash discharge. While the comparisons of emissions from various municipal refuse-to-energy systems varied widely for the same unit as well as among the three units, the MOD emissions were lowest and the MASS were highest. Compounds present in emissions of all three units included: naphthalene, phenanthrene/anthracene, pyrene, and acenapthylene, although the higher molecular (PAH) compounds, such as benzopyrenes were detected only in the MASS emissions. The tetrachlorinated benzo-p dioxins (TCDD) and dibensofurans (TCDF) data also show considerable variation in levels among tests on the same unit and between units. The average total TCDD concentrations measured in the RDF, MASS, and MOD stack emissions were 174, 245, and 11 ng/dscm, respectively. The 2,3,7,8-TCDD isomer, the most hazardous of the dioxins constituted a significantly larger fraction of the total TCDD emission from MASS unit than from the other two incinerators. The average total TCDF emissions from the RDF, MASS and MOD units were 458, 385, and 73 ng/dscm, respectively. Large variations in aldehyde levels also occur both within and between incinerators but generally higher concentrations were observed in the MASS emissions.

The particulate emissions from the three types of refuse-to-energy units are similar in inorganic chemical composition. Inorganic compounds in the emissions are present primarily as chlorides and sulfates. The emissions from the municipal refuse-to-energy units varies greatly in organic chemical composition. This result is presumably due to design differences and variations in refuse feed composition and operating parameters of the units. The Howes et. al. study has yielded a comprehensive data base to support environmental assessment of municipal refuse-to-energy systems and to identify the many areas that require additional research. It concludes that improvements in design or operation of municipal refuse-to-energy systems can be made to reduce stack emissions and indicates the general nature of modifications which will lead to emission reduction.

The EIS-Auger Combustor Process System provides improvements in design which are expected to substantially reduce emissions even with respect to the MOD incinerator, the lowest emitting of the municipal waste to energy systems. In effect the EIS-ACPS is a municipal waste system which incorporates the main features of advanced hazardous waste incinerators. In particular there is a high degree of control afforded by (a) waste injection by weight, (b) uniform and controlled movement of the pyrolyzing waste in the first chamber by means of the auger, (c) precise temperature regulation provided by the air supply systems to the primary and secondary chambers, and (d) the use of an advanced state of the art stack emission acid neutralizing and particle removing system. These are all improvements of the nature of those recommended by Howes et. al. for municipal incinerators and of the nature of those cited by Oppelt for hazardous waste incinerators. Thus it is expected that emissions from the EIS-ACPS would be substantially lower than those quoted by Howes et. al. for MOD systems and much closer per unit mass injected to emissions expected from RCRA certified hazardous waste systems when more benign municipal wastes are injected. The EIS-ACPS also incorporates some of the most advanced clean up techniques developed in the international clean coal technology research and development effort.

In final summary, with its strong combination of features, the Environmental Incinerator Systems, Inc. Auger Combustor Process System constitutes a unique approach to urban incineration. There is little doubt that this high technology combustor system ranks among the most environmental advanced urban waste incinerators.

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TABLE 1
INDUSTRIAL OIL BOILER RETROFIT [21, 22]

A.	**PRE-COMBUSTION**		
	1. Coal Selection	C	1986
	2. Physical Cleaning	C	1986
	3. Chemical Cleaning	P	1995
	4. Biological Cleaning	P	1995
B.	**COMBUSTION/CONVERSION**		
	1. Micronized Coal	P	1990
	2. Coal-Water Slurry	P	1990
	3. Coal-Water-Gas	P	1987
	4. Two stage Slagging Combustion	P	1992
	5. Two stage dry Combustion	P	1988
	6. Sorbent Injection	P	1992
	7. Low NOx Combustion	D	1988
	8. Sel. Noncatalytic Red. of NOx	D	1990
	8. Atmospheric FBC	D	1990
	9. Pressurized FBC	P	1992
	10. Gasification Combined Cycle	D	1988
	11. Gasification Fuel Cell	L	1998
C.	**POST-COMBUSTION**		
	1. Conventional Wet FGD	C	1986
	2. Spray Dry FGD	C	1986
	3. Advanced Wet FGD	D	1990
	4. Dry Injection FGD	P	1990
	5. Combined SOx/NOx Removal	P	1995
	6. Sel. Catalytic Red. of NOx	D	1990
	7. Advanced Baghouse	P	1988
	8. Advanced Cyclones	L	1990
	9. Advanced Precipitators	L	1990
D.	**COMBINATIONS**		
	1. B5 + B6 + C4	I	1990
	2. B6 + C3	I	1990
	3. C3 + C6	I	1990
	4. A1 + A2 + B3 + C2 + C7	I	1989
	5. A1 + A2 + B3 + B5 + B6 + C2 + C7	I	1989

C Commercial, D demonstrated, P Pilot Plant

L Laboratory; I Idea/Concept.

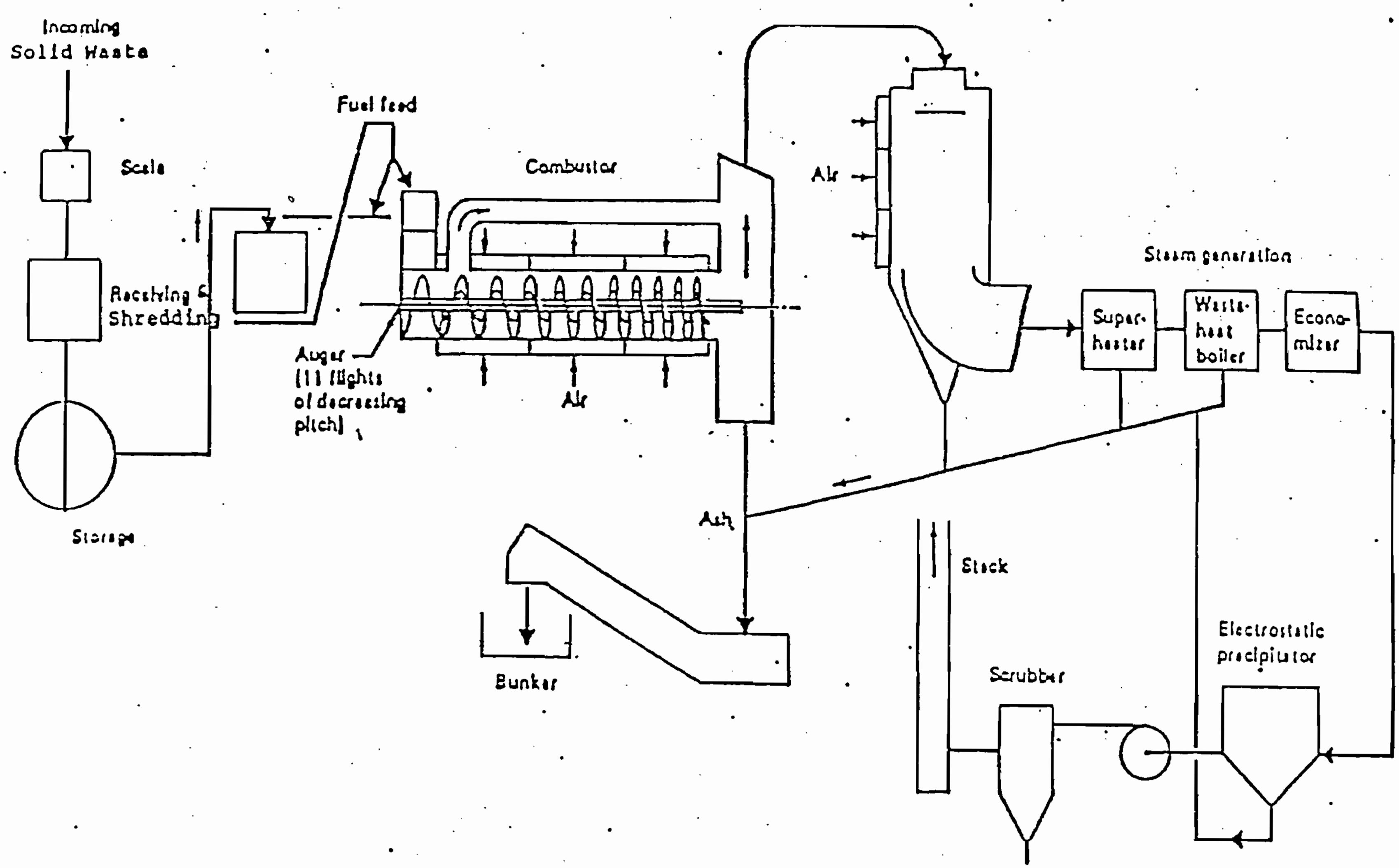

Figure 2. Plant Process Flow

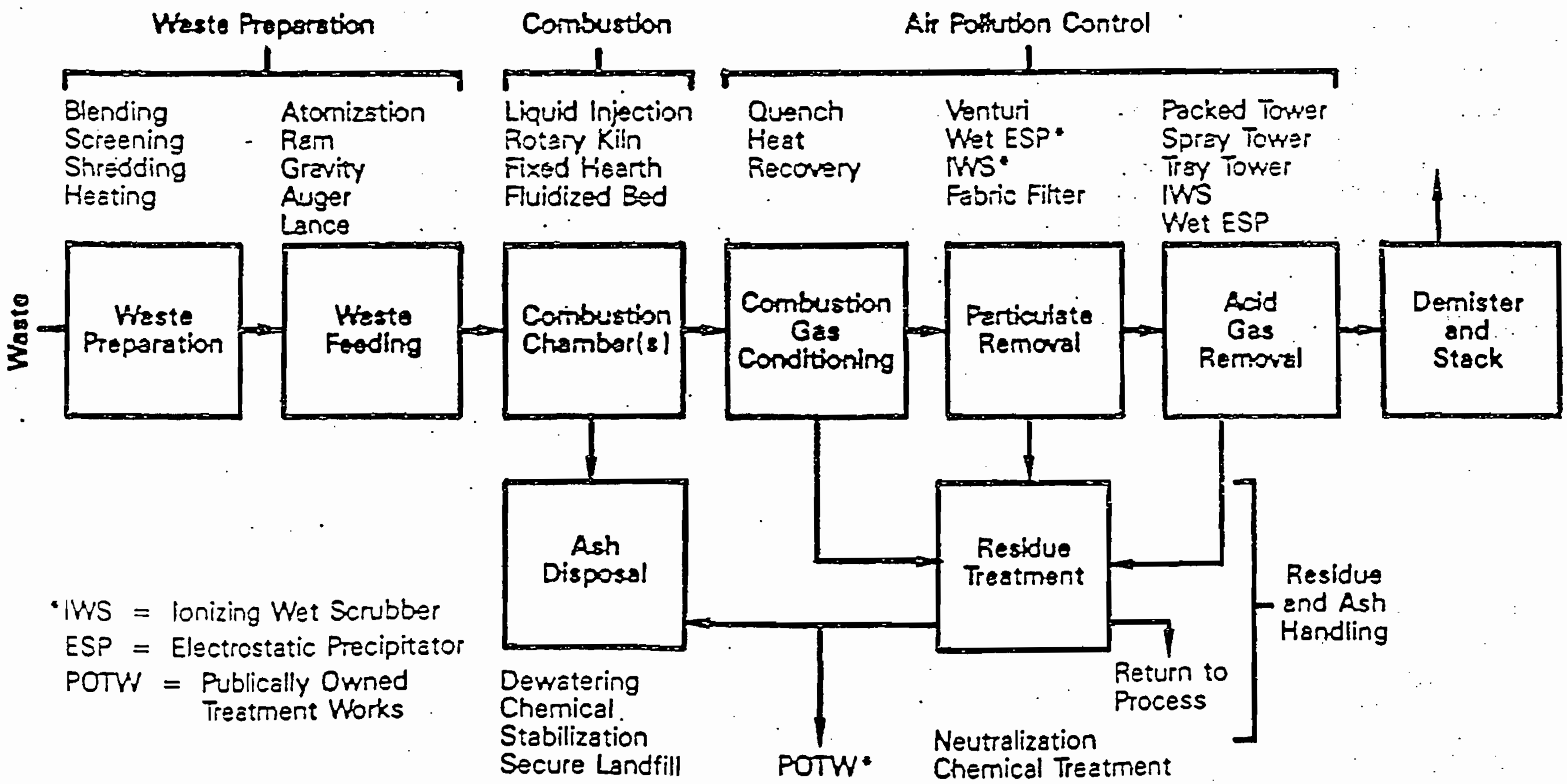

Figure 1. General orientation of incineration subsystems and typical process component options. (from Oppelt [14])

Personal	Name: Alex E.S. Green Birthdate: June 2, 1919	
Titles	Graduate Research Professor of Mechanical Engineering and Nuclear Engineering Sciences; Director: Interdisciplinary Center for Aeronomy and other Atmospheric Sciences (ICAAS) and the UF-STC Clean Combustion Technology Laboratory (CCTL)	
Education	BS Physics - City College of New York, 1940 MS Physics - California Institute of Technology, 1941 PhD Physics - University of Cincinnati, 1948	
Interests	Alternative fuels, and coburning of fuels at industrial and commercial combustors, spectroscopic diagnoses, atmospheric optics, radiological physics, atomic and nuclear physics	
Employment	1943-45: U.S. Air Force- R&D, Operations Analyst 20th AF 1946-53: University of Cincinnati- Assoc. Prof. of Physics 1953-59: Florida State University- Professor, Director Tandem Van de Graaff Program 1959-63: Convair- General Dynamics- Manager, Space Science Lab 1963-present: University of Florida- Graduate Research Professor, ICAAS and CCTL director	
Professional Activities	American Society of Mechanical Engineers-Committee on Alternative Fuels, Member National Coal Council, Fellow Optical Society, Phi Beta Kappa, Sigma Xi, Fellow American Physical Society	
Research	Received research grants from many sources such as AFOSR, AFCRL, NASA, DOE, NSF, DOT, EPA, Florida Energy Office and industrial organizations.	
Related Publication	Over 325 articles in journals and conference proceedings and 9 books on atmospheric physics, combustion, nuclear, atomic and radiological physics. Some pertinent articles are listed on attached sheet.	
Proposed Involvement	Capabilities: Facility Power Systems 1(a), 1(b), 1(c), 3(a). (See CCTL Announcement for relevance to these tasks)	

Pertinent Publications of A.E.S. Green (Author, Co-Author or Editor)

6. Eleven Operations Analysis Reports prepared overseas for the Twentieth Air Force on various technical problems of the B-29 campaign in WWII.

52. "Atmospheric Attenuation Over Finite Paths" BSD-63-174, USAFSC,(1963).

59. Book - Atomic and Space Physics, Addison-Wesley (1965).

60. Book - The Middle Ultraviolet: Its Science & Technology, Wiley (1966).

76. "Auroral Intensities", J. Geophys. Res., 72, 3967-3974 (1967).

89. "Energy Loss Functions", J. of Geophys. Res., 73, 233-241 (1968).

121. "Interpretation of the Sun's Aureole Based on Atmospheric Aerosol Models", Applied Optics, 10, #6, 1263-1279 (1971).

262. "Factor of Safety Method, Application to Air and Noise Pollution", Atmospheric Environment, 14, 327-338, (1980).

268. Book - Coal Burning Issues, University Presses of Florida, (1980).

272. "Analytic Extensions of the Gaussian Plume Model", Jour. of Air Pollution Control Assoc., 30, 7, 773 (1980).

288. Book - An Alternative to Oil: Burning Coal with Gas, University Presses of Florida, University of Florida, Gainesville, FL (1981).

--- Patents No. 4,561,364 (Dec, 1985), No. 4,572,084 (Feb. 1985) and No. 4,597,392 (July 1986) on Coal Gas Combustion.

296. "Remote Temperature Measurements in Gas and Gas-Coal Flames Using the OH(0,0) Middle UV-Band," Appl. Optics 21, 3357 (1982).

302. "Spectroscopic Observations of Methane-Pulverized Coal Flames," Journal of Quant. Spectros. & Rad. Trans. 31, 189 (1984).

307. Acid Deposition: Causes and Effects, Gov. Inst., Rockville, MD (1983).

308. "Synergistic Combustion of Coal and Natural Gas", Energy,9, 477(1984).

310. "A Molecular Model of Coal Pyrolysis", Int. Journal of Quantum Chemistry, 18, 589-599 (1984).

319. "Natural Gas Use to Facilitate Coal & Waste Combustion", Proc. Conf. Select Use of Natural Gas for Environmental Purposes, July 23, 1985.

320. "Coal-Water-Gas, An All American Fuel for Oil Boilers," Slurry Technology, 11th International Conf., Hilton Head, SC, March 1986.

327. "Clean Combustion Technology", Proceeding of Conference "There Is No Away," University of Florida Law School, Gainesville, FL, (1986).

330. "The Big Bands of H_2O", Radiation Research, in press.

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COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

ICAA

UNIVERSITY OF FLORIDA
SPACE SCIENCES RESEARCH B
GAINESVILLE, FLORIDA 32611
AREA CODE 904 PHONE 392-20

CLEAN COMBUSTION TECHNOLOGY LABORATORY

A Cooperative Laboratory of the University of Florida and the Sunland Training Center - based at the Central Steam Plant of the Sunland Training Center.

The University of Florida-Sunland Training Center Clean Combustion Technology Laboratory (CCTL) has evolved from joint programs of ICAAS, an Interdisciplinary Center of Aeronomy and other Atmospheric Sciences and combustion programs of the Department of Mechanical Engineering. The CCTL has been using boiler No. 3, a 535 HP watertube boiler, for experiments on the clean and efficient combustion of coal water slurries with natural gas assist (CWG) in an industrial boiler designed for oil. We have successfully demonstrated this minimal cost oil boiler retrofit which should be economically viable when oil is back in the $20 to $30 per barrel range. Since the oil price drop we have been examining the use of gas with coal slurry assist (GCS) in conversions of oil boiler to a domestic fuel. The radiation enhancement afforded by small proportions of a tailored coal slurry should lead to 2% to 5% increases in boiler efficiency.

The objectives of our clean combustion technology program have been expanded to also utilize boiler No. 4, a 450 HP watertube oil boiler, boiler No. 1, a 300 HP firetube gas boiler, and a 30 HP firetube gas boiler. Automobile Recycling of Gainesville has donated to CCTL a starved air two chamber incinerator (Environmental Control Products Model 500T, 1972) which is now installed in front of the steam plant. Gainesville Regional Utilities has recently donated a Dual Fuel System, Inc. Gas Compressor Model 55-22 and 10 dual fuel gas kits to convert standard automobile engines to operate on either gasoline or natural gas. The compressor-refill station is close to the CCTL.

The incinerator will serve (A) the needs of Sunland Training Center for waste reduction and energy recovery and (B) the needs of the CCTL for a research, development and demonstration (RD&D) incinerator to test advanced techniques in (1) source reduction, (2) recycling, (3) energy recovery, (4) hot gas clean up, (5) emission reduction and (6) combustion product disposal. Emerging clean coal technologies are used as models of techniques to minimize harmful emissions from solid waste, wood and sludge combustion. The compressor will permit gas atomization studies and also serve as a refill facility for campus vehicles using dual and blended fuels for emission reduction. The replication value of the boiler facilities now at STC steam plant which are now available to the CCTL program exceeds $1,000,000. The spectroscopic, scientific and computer instrumentation at the Space Sciences Laboratory which supports the UF-STC-CCTL program exceeds $250,000. With the help of other University of Florida and community resources the UF-STC-CCTL can serve as a leader in the RD&D of clean combustion technologies. For further information contact Alex Green, ICAAS-SSRB University of Florida, Gainesville, FL 32611 [904/392-2001].

ATTACHMENT C

POTENTIAL PURCHASERS OF RECYCLABLES

(CONFIDENTIAL INFORMATION)

EXECUTIVE OFFICES
P.O. BOX 1380
JACKSONVILLE, FLORIDA 32201
MILL
PORT ST. JOE, FLORIDA

St. Joe PAPER COMPANY

P. O. BOX 190 • PORT ST JOE, FLORIDA 32456-0190 • AREA CODE 904/227-1171

September 29, 1992

Mr. John L. Matthews
Florida Reduction Corporation
219 Camp Drive
Dunnellon, Florida 32360

Dear Mr. Matthews:

As indicated to you in our recent meeting in my office here in Port St. Joe, I confirm that the St. Joe Forest Products Company is vitally interested in a continuous supply of good quality, fair performance, recyclable fibre to meet its mill's increasing and continuing need. Waste meeting St. Joe's specifications on an uninterrupted supply schedule at competitive cost is sought for the St. Joe mill operation.

As you progress with plans to construct the Gretna, Florida, facility, St. Joe Forest Products would be pleased to receive from you a proposal for this supply.

Mr. Dave Bricker of this office in Port St. Joe is in charge of the procurement of recyclables and it would be advisable for you to contact him for a meeting.

St. Joe is hopeful that your product will meet all criteria for use here at the mill. We envision no reason why you will not be in a position to make a proposal for a portion of our requirements.

St. Joe Forest Products Company, a wholly-owned subsidiary of St. Joe Paper Company, is currently consuming approxiamtely 90,000 - 95,000 tons of waste paper annually in its pulping process at the Port St. Joe, Florida, paperboard mill. A greater amount may be consumed as facilities for additional waste are installed.

I have been away from my desk for a few days and have not had an opportunity to review this need with Mr. Bricker, although I am told you have spoken with him.

Sincerely,

ST. JOE PAPER COMPANY

J. C. Belin
Chairman
Executive Committee

JCB/11

cc: Mr. Dave Bricker

MINDIS METALS, INC.

246-2556

110 GRAY STREET
BAINBRIDGE, GA 31317

PHONE: (912) 246-2556
FAX: (912) 246-2732

FAX CONTROL SHEET

DATE: 9-16-92

TO: This is to inform you that Mindis Recycling of Bainbridge Ga. is prepared and willing to handle all of the Steel, Copper, Brass Aluminum and Stainless Steel recyclables generated by Florida selection

Regards
Larry Lively
General Manager Bainbridge

MINDIS RECYCLING
an Attwoods co.
LARRY LIVELY
General Manager

110 Gray Street
Bainbridge, GA 31717
Recycled Paper
(912) 246-2556
Fax (912) 246-2732

FROM:

NUMBER OF PAGES IN THIS TRANSMISSION
(including the control sheet)

ATTACHMENT D

FAN SPECIFICATIONS

FAN SPECIFICATIONS

Preliminary design has called for three sets of fans. The fan specifications are as follows:

1. 20,000-acfm forced-draft fan for the primary combustion chamber with up to 6 inches W.G. of static pressure.
2. 30,000-acfm forced-draft fan for the after-burner unit with up to 6 inches W.G. of static pressure.
3. 65,000-acfm induced-draft fan with up to 20 inches W.G. of static pressure to be installed between the baghouse and the stack outlet.

Specifications and fan curves for all three fans were obtained from Chicago Blower Corporation and are included in this Appendix D.

6N

CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:33pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS

Volume	20000	CFM
Static Pressure	6.00	in.WG
Density	0.075	lb/cu.ft
Temperature	70	deg F.
Altitude	Sea Level	
Rel Humidity	0.0	%
Spec gravity	1.000	

FAN SELECTIONS

				*	
Size	30	33	36.50	40.25	44.50
Type	D10A	D10A	D10A	D10A	D10A
RPM	1689+	1379	1095	950+	838+
BHP	27.2	24.6	23.7	23.7	24.4
OV	3795	3134	2564	2109	1727
SE %	69	76	79	79	77
Class 1	1647	1413	1344	903	817
Class 2	1807	1552	1497	1179	1066
Class 3	2166	1970	1700	1541	1394
Class NA					

* Most efficient + Class 2

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.

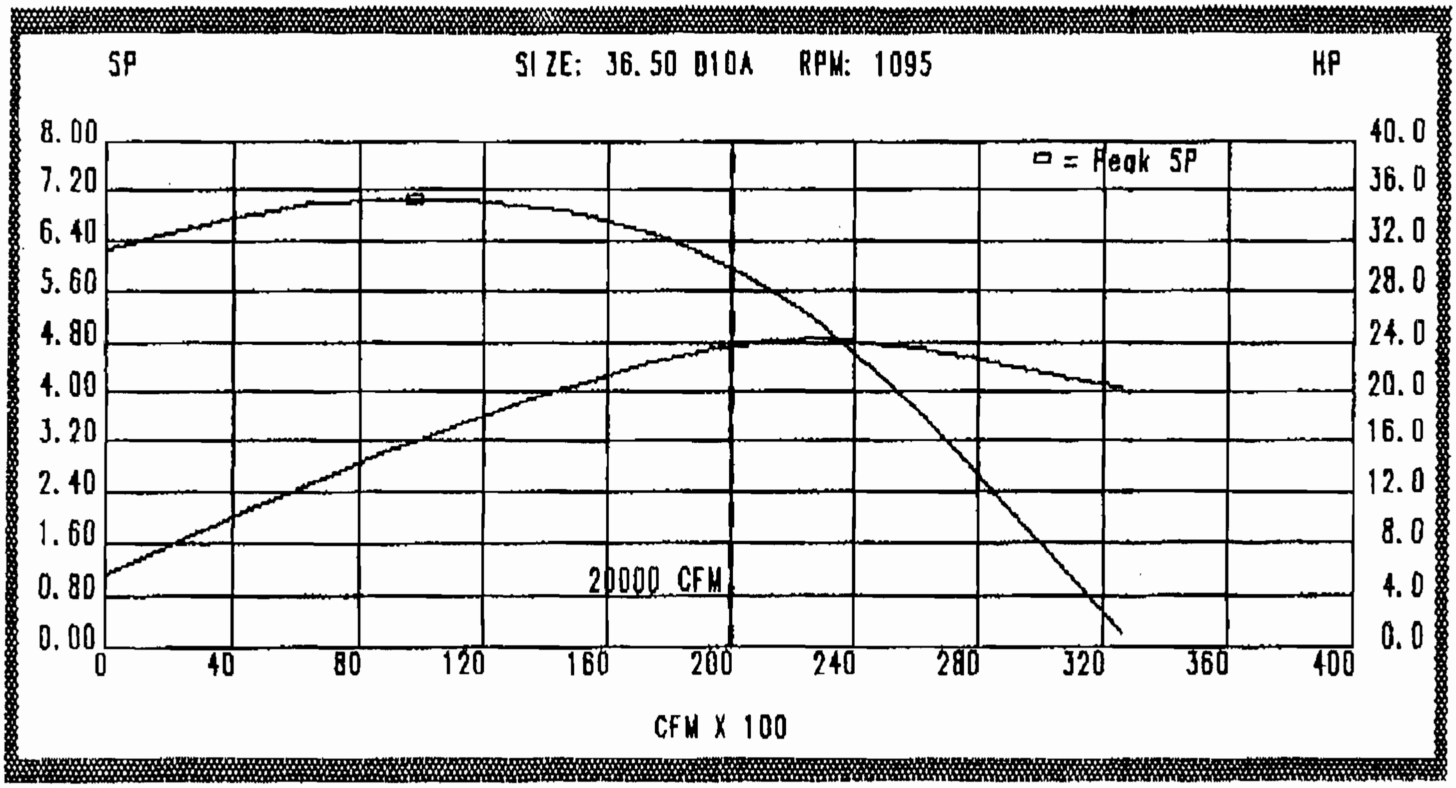
CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:36pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS			FAN SELECTIONS	
Volume	20000	CFM	Size	36.50
Static Pressure	6.00	in.WG	Type	D10A
Density	0.075	lb/cu.ft	RPM	1095
			BHP	23.7
Temperature	70	deg F.	OV	2564
Altitude	Sea Level		SE %	79
Rel Humidity	0.0	%	Class 1	1344
Spec gravity	1.000		Class 2	1497
			Class 3	1700
			Class NA	

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.



Same Fan can be Used For 30,000 CFM

CHICAGO BLOWER CORPORATION

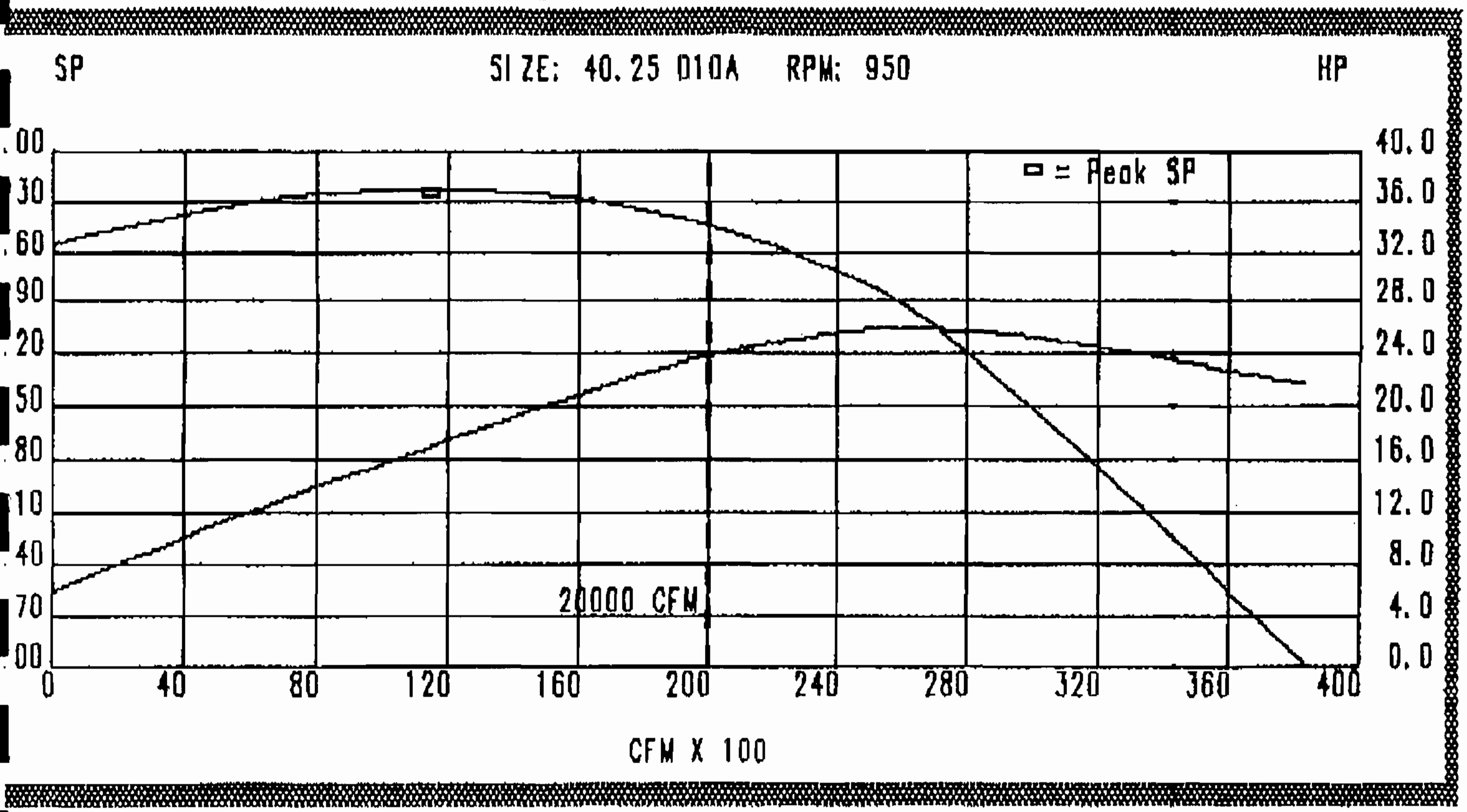
DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:34pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS			FAN SELECTIONS	
				*
Volume	20000	CFM	Size	40.25
Static Pressure	6.00	in.WG	Type	D10A
Density	0.075	lb/cu.ft	RPM	950+
			BHP	23.7
Temperature	70	deg F.	OV	2109
Altitude	Sea Level		SE %	79
Rel Humidity	0.0	%	Class 1	903
Spec gravity	1.000		Class 2	1179
			Class 3	1541
			Class NA	

* Most efficient + Class 2

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.



CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:38pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS			FAN SELECTIONS				*	
Volume	30000	CFM	Size	36.50	40.25	44.50	49	54.25
Static Pressure	6.00	in.WG	Type	D10A	D10A	D10A	D10A	D10A
Density	0.075	lb/cu.ft	RPM	1312	1072+	901+	782+	688+
			BHP	41.1	37.3	35.6	35.5	36.4
Temperature	70	deg F.	OV	3846	3164	2590	2135	1740
Altitude	Sea Level		SE %	68	75	79	79	77
Rel Humidity	0.0	%	Class 1	1344	903	817	742	670
Spec gravity	1.000		Class 2	1497	1179	1066	968	875
			Class 3	1700	1541	1394	1221	1103
			Class NA					

* Most efficient + Class 2

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.

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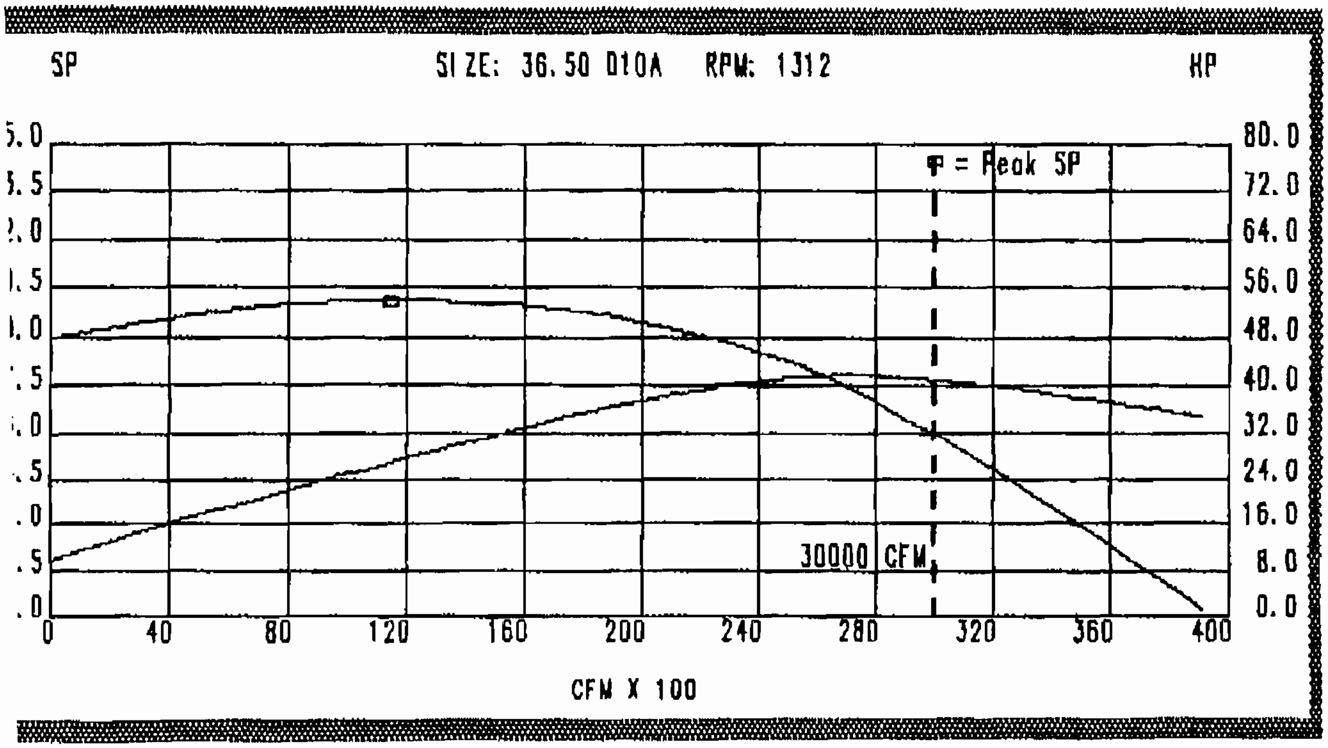
CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:39pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS		FAN SELECTIONS	
Volume	30000 CFM	Size	36.50
Static Pressure	6.00 in.WG	Type	D10A
Density	0.075 lb/cu.ft	RPM	1312
		BHP	41.1
Temperature	70 deg F.	OV	3846
Altitude	Sea Level	SE %	68
Rel Humidity	0.0 %	Class 1	1344
Spec gravity	1.000	Class 2	1497
		Class 3	1700
		Class NA	

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.



CHICAGO BLOWER CORPORATION

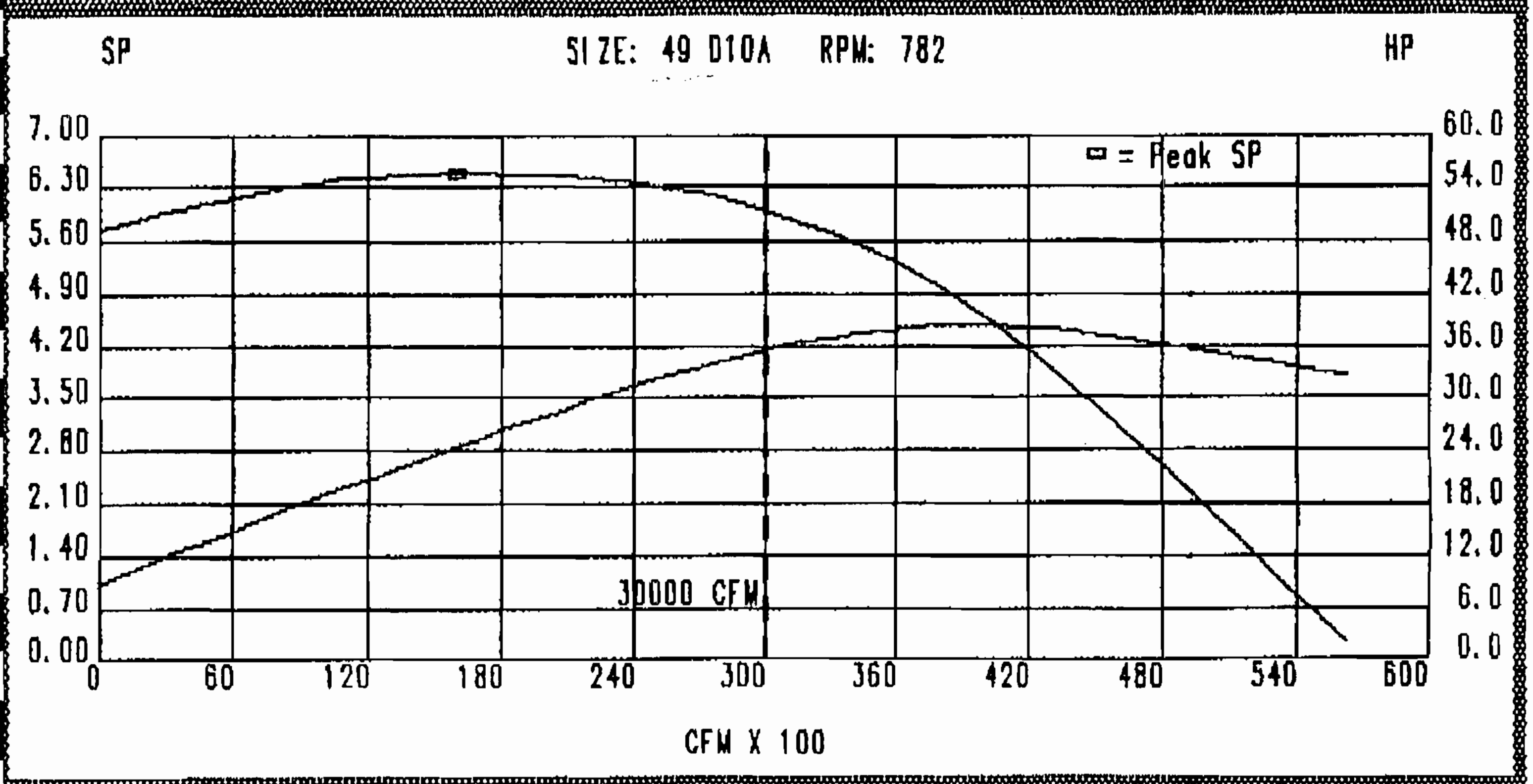
DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:40pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS			FAN SELECTIONS	
				*
Volume	30000	CFM	Size	49
Static Pressure	6.00	in.WG	Type	D10A
Density	0.075	lb/cu.ft	RPM	782+
			BHP	35.5
Temperature	70	deg F.	OV	2135
Altitude	Sea Level		SE %	79
Rel Humidity	0.0	%	Class 1	742
Spec gravity	1.000		Class 2	968
			Class 3	1221
			Class NA	

* Most efficient + Class 2

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.



CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:44pm 10/ 8/92

Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS			FAN SELECTIONS	*		
Volume	65000	CFM	Size	49	54.25	60
Static Pressure	20.00	in.WG	Type	D10A	D10A	D10A
Density	0.060	lb/cu.ft	RPM	1612=	1411=	1257=
			BHP	255.6	260.6	272.9
Temperature	200	deg F.	OV	4626	3770	3086
Altitude	Sea Level		SE %	80	78	74
Rel Humidity	0.0	%	Class 1	742	670	606
Spec gravity	1.000		Class 2	968	875	791
			Class 3	1221	1103	997
			Class NA			

* Most efficient = Class NA

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.

This will require a very large Motor 300 HP

CHICAGO BLOWER CORPORATION

DESIGN 10 SISW AIRFOIL CENTRIFUGAL FAN 7:44pm 10/ 8/92

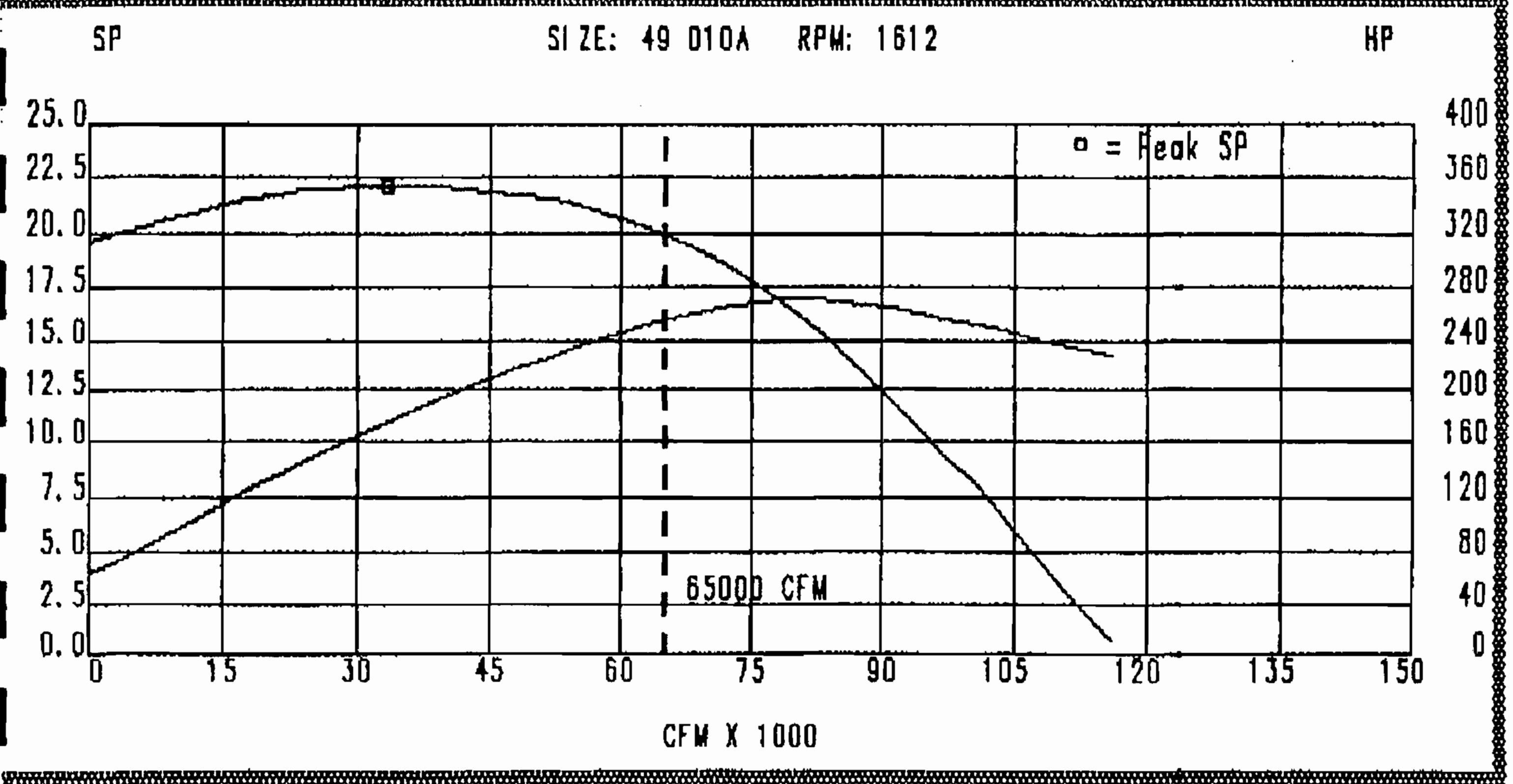
Job Name: KBN ENGINEERING
Reference: AIR FAN

SELECTION PARAMETERS		
Volume	65000	CFM
Static Pressure	20.00	in.WG
Density	0.060	lb/cu.ft
Temperature	200	deg F.
Altitude	Sea Level	
Rel Humidity	0.0	%
Spec gravity	1.000	

FAN SELECTIONS	*
Size	49
Type	D10A
RPM	1612=
BHP	255.6
OV	4626
SE %	80
Class 1	742
Class 2	968
Class 3	1221
Class NA	

* Most efficient = Class NA

All ratings are based on tests made in accordance with AMCA standard 210.
All selections are to the right of peak SP.



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CHICAGO

[illegible] Size 5718

Wheel Diameter: 57.125 inches
Outlet Area: 18.82 sq. ft.
Inlet Area: 15.68 sq. ft.

Maximum Motor Size: 300 HP
Maximum Allowable Speed @70° F: 1457 RPM

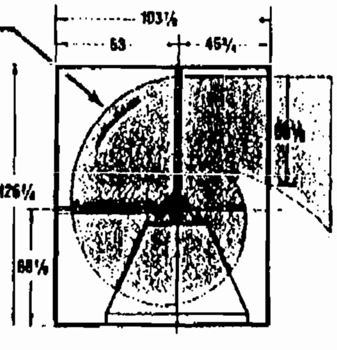
[illegible]	[illegible]	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP
30000	1594	712 50.8	789 64.8	862 79.7							
34000	1807	724 56.8	797 71.8	866 87.5	932 104.0	964 112.4					
38000	2019	740 63.4	810 79.4	875 96.0	938 113.3	968 122.3	998 131.3	1028 140.6	1056 150.0	1085 159.5	
42000	2232	759 70.7	826 87.6	888 105.2	948 125.5	977 132.9	1006 142.4	1034 152.0	1061 161.9	1089 171.8	1115 181.9
46000	2444	778 78.7	844 96.5	904 115.1	962 134.4	990 144.3	1017 154.2	1044 164.4	1070 174.6	1097 185.0	1122 195.6
50000	2657	798 87.5	863 106.2	972 125.8	978 146.0	1005 156.4	1031 166.9	1057 177.5	1083 188.3	1108 199.1	1133 210.1
54000	2869	818 97.1	883 116.9	942 137.3	996 158.5	1022 169.3	1048 180.3	1073 191.4	1098 202.7	1122 214.1	1146 225.6
58000	3082	837 106.8	903 128.5	962 149.8	1016 171.9	1041 183.1	1066 194.6	1091 206.2	1115 218.0	1138 229.8	1162 241.9
62000	3294	857 115.5	923 140.7	982 163.4	1035 186.3	1061 198.1	1086 210.0	1110 222.0	1133 234.2	1156 246.6	1179 259.1
66000	3507	874 126.2	942 152.5	1001 178.0	1055 202.0	1081 214.1	1106 226.5	1129 239.0	1153 251.6	1175 264.4	1198 277.4
70000	3719	891 139.5	961 163.4	1021 192.5	1075 218.7	1101 231.4	1126 244.2	1149 257.1	1173 270.2	1195 283.6	1217 296.8
74000	3932	915 154.9	978 177.7	1040 206.0	1095 235.8	1120 249.7	1145 263.2	1169 276.6	1193 290.1	1215 303.8	1237 317.6
78000	4145	947 174.1	995 193.8	1059 219.7	1114 252.2	1140 267.9	1165 282.8	1189 297.2	1212 311.3	1235 325.5	1257 339.8
83000	4410	992 202.3	1025 217.9	1080 242.4	1138 271.4	1164 288.9	1189 306.4	1213 323.0	1237 338.9	1260 354.3	1282 369.4
88000	4676	1041 234.5	1066 248.5	1104 268.6	1159 296.0	1187 311.8	1213 328.2	1237 346.9	1261 365.5	1284 383.1	1306 400.0

[illegible]	OUTLET VEL.	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP	[illegible] RPM BHP
41000	2179	1141 188.8	1167 199.1								
46000	2444	1148 206.3	1173 217.1	1197 228.0	1222 239.1	1246 250.4	1270 261.7	1294 273.2	1317 284.8		
51000	2710	1160 225.2	1184 236.6	1207 248.1	1231 259.7	1254 271.4	1277 283.3	1299 295.3	1322 307.6	1344 319.7	1366 332.1
56000	2976	1177 245.5	1200 257.6	1222 269.8	1245 281.8	1267 294.1	1288 306.8	1310 319.1	1332 331.8	1353 344.6	1374 357.5
61000	3241	1197 267.2	1219 279.8	1241 292.6	1262 305.4	1283 318.3	1304 331.4	1325 344.6	1346 357.9	1366 371.2	1386 384.7
66000	3507	1220 290.4	1241 303.7	1262 317.0	1283 330.5	1304 344.1	1324 357.8	1344 371.6	1364 385.5	1383 399.5	
71000	3773	1244 315.5	1265 329.3	1285 343.3	1306 357.3	1326 371.5	1346 385.8	1365 400.2	1385 414.7		
76000	4038	1269 342.7	1289 357.0	1310 371.5	1330 386.1	1350 400.8	1369 415.7				
81000	4304	1294 372.1	1314 386.9	1335 401.9	1355 417.1	1374 432.6					
86000	4570	1318 403.5	1339 419.1	1360 434.7	1380 450.4						
91000	4835	1342 435.6	1364 452.8	1384 469.6							
96000	5101	1367 466.1									

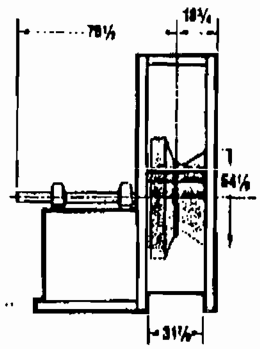
Performance shown is for inlet and outlet ducted with evase discharge.

Dimensions

All dimensions are in inches.

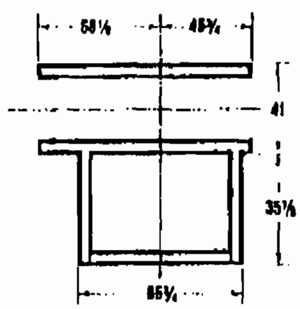


SIDE ELEVATION (Drive Side)

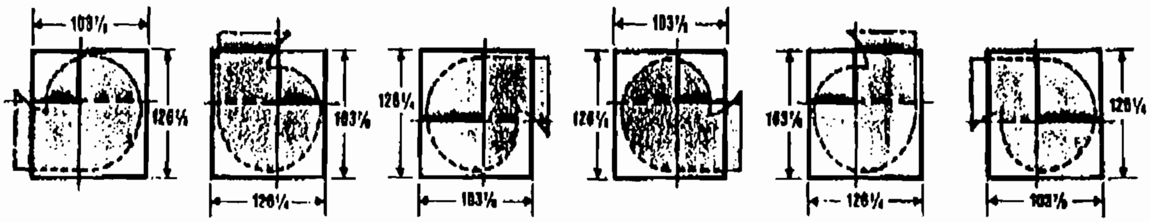


FRONT ELEVATION

TH-CW SHOWN. OTHER ROTATION & DISCHARGE SHOWN BELOW.



FOUNDATION (Plan)



BH-CW UB-CW TH-CW BH-CCW UB-CCW TH-CCW

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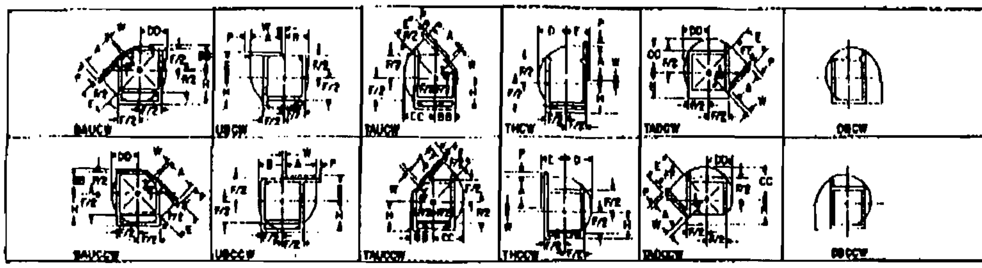
Arrangement 1 & 9 · Fixed Housing DIMENSIONS

Class III · SISW (D/10A)



SIZE 22¼ THROUGH 66

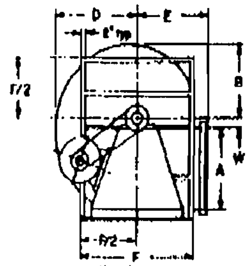
CHICAGO AIRFOIL CENTRIFUGAL FANS

POSITIONS OF DISCHARGE AND ROTATION AS VIEWED FROM DRIVE SIDE.

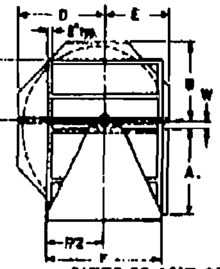
ARRANGEMENT 9 MEAN DRIVE CENTERS FOR FRAMES SHOWN

FAN SIZE	DISCH. POS.	CENTER DISTANCE 182-184	213-215	254-256	284-286	324-326	364-365	404	444
22½	ALL	[illegible]	[illegible]	[illegible]	[illegible]				
24½	ALL		[illegible]	[illegible]	[illegible]				
27	ALL		[illegible]	[illegible]	[illegible]	[illegible]			
30	ALL			[illegible]	[illegible]	[illegible]			
33	ALL			[illegible]	[illegible]	[illegible]	[illegible]		
36½	SH-BAU				[illegible]	[illegible]	[illegible]		
	UB				[illegible]	[illegible]	[illegible]		
	TAU				[illegible]	[illegible]	[illegible]		
	TH				[illegible]	[illegible]	[illegible]		
	TAD				[illegible]	[illegible]	[illegible]		
40½	SH-BAU				[illegible]	[illegible]	[illegible]	[illegible]	
	UB				[illegible]	[illegible]	[illegible]	[illegible]	
	TAU				[illegible]	[illegible]	[illegible]	[illegible]	
	TH				[illegible]	[illegible]	[illegible]	[illegible]	
	TAD				[illegible]	[illegible]	[illegible]	[illegible]	
44½	SH-BAU				[illegible]	[illegible]	[illegible]	[illegible]	
	UB				[illegible]	[illegible]	[illegible]	[illegible]	
	TAU				[illegible]	[illegible]	[illegible]	[illegible]	
	TH				[illegible]	[illegible]	[illegible]	[illegible]	
	TAD				[illegible]	[illegible]	[illegible]	[illegible]	
49	SH-BAU				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	UB				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TAU				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TH				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TAD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1. MIN. & MAX. CENTERS = MEAN ± 1-1/2".
2. SIZES 54½ - 66 AVAILABLE IN ARRANGEMENT 1 ONLY.

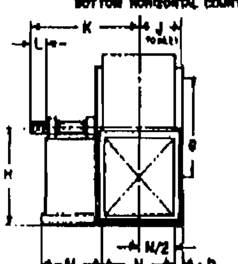


SIZES 22½ – 54½ ARRG'T. 9 SHOWN

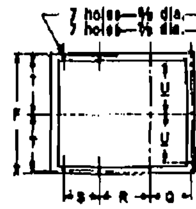


SIZES 60 AND 66 ARRG'T. 1 SHOWN

SIDE ELEVATION (drive side) BOTTOM HORIZONTAL COUNTER CLOCKWISE



FRONT ELEVATION



FOUNDATION (plan)

22½	24	2-11/16	5/8 x 5/16	21-7/8	18-1/2	22-3/16	19-1/4	25-5/8	33-1/4	28-1/8	28-5/8	28-5/8	28-5/8	28-5/8	28-5/8	28-5/8	11-13/16
24½	26-7/16	2-15/16	3/4 x 3/8	24	20-3/8	24-7/16	20-1/4	28-3/4	35-3/4	30-5/8	29	29	29	29	29	29	12-3/4
27	29-1/8	2-7/16	5/8 x 5/16	26-1/2	22-1/2	26-15/16	22-3/4	30-1/8	38-7/16	33-13/16	31-11/16	31-11/16	31-11/16	31-11/16	31-11/16	31-11/16	14-3/8
30	32-3/8	2-7/16	5/8 x 5/16	29-3/32	24-15/16	29-7/8	22-1/4	32-1/8	42-5/8	37	34-13/16	34-13/16	34-13/16	34-13/16	34-13/16	34-13/16	15-3/4
33	35-9/16	2-7/16	5/8 x 5/16	32	27-7/16	32-7/8	25-3/4	34	46	40-3/8	38	38	38	38	38	38	17-1/16
36½	39-3/8	2-11/16	5/8 x 5/16	35-5/8	30-1/4	36-1/4	28-1/4	36	50-1/4	–	42-5/8	40	37-15/16	34-1/2	31-9/16	28	–
40½	43-7/16	2-15/16	3/4 x 3/8	39-1/4	33-3/8	40	31	39-1/2	55-1/4	–	46-9/16	44	41-15/16	37-1/2	35	31-1/2	–
44½	48	3-3/16	3/4 x 3/8	43-3/8	36-7/8	44-3/16	33-3/4	43	61	–	51-1/16	48-1/2	45-15/16	41-1/2	38-7/16	35	–
49	52-7/8	3-7/16	7/8 x 7/16	47-7/8	40-5/8	48-1/16	37	47-1/4	67-1/4	–	56-7/8	53-1/2	50-3/4	45-1/2	42-5/8	38	–
54½	58-1/2	3-11/16	7/8 x 7/16	53	44-15/16	53-7/8	40-3/4	52-1/8	74-1/4	–	61-3/8	58	55-3/8	50-1/2	46-1/2	42	–
60	64-3/4	3-15/16	1 x 1/2	58-9/16	52-1/4	62	45	57-7/8	82	–	69-1/2	66-7/8	62-1/2	57	52-3/4	48	–
66	71-3/16	3-15/16	1 x 1/2	64-7/16	57-3/16	67-15/16	48	63	90-1/4	–	75-7/8	73-3/8	68-1/2	62-3/8	57-3/4	52-1/2	–

22½	40-3/4	5	28	18-5/8	3	11-9/16	14-9/16	22	15-3/8	11-1/2	1-3/4	18-25/32	23-5/8	20-3/32	23	5.8
24½	43-3/4	6	29	21-9/16	3	12-9/16	15-1/2	23	16-5/8	12-1/2	2	18-15/32	26-1/32	22-3/32	24-3/8	6.4
27	47-1/2	7	30-5/8	23-3/4	3	13-5/8	16-5/8	24-5/8	18-1/2	15	2-3/16	20-3/8	30-11/16	24-3/8	27-3/32	7.0
30	50-3/8	8	31-3/16	26-1/2	3	15	18	25-3/16	20-1/16	16-1/2	2-23/32	22-5/8	31-27/32	27-1/16	28-3/16	7.8
33	52-1/2	8	31-15/16	29-1/8	3	16-5/16	19-5/16	25-15/16	21-3/4	18	3-1/64	24-27/32	35	29-3/4	31-1/4	8.4
36½	58-1/2	8	38-1/4	32-1/8	4	18-9/16	22-9/16	28-1/4	23-5/8	21-5/8	3	27-7/16	38-5/8	32-13/16	32-1/2	9.8
40½	59-1/4	9	35-9/16	35-3/8	4	20-3/16	24-3/16	27-9/16	26-1/8	24-3/16	3-5/16	30-1/4	42-5/8	36-3/16	35-3/4	10.8
44½	60-1/4	9	34-11/16	38-1/16	4	22-1/16	26	28-11/16	29	26-5/8	3-11/16	33-1/2	47-1/8	40	38-7/16	11.8
49	64-1/4	9	38-3/4	43	4	24	28	28-3/4	32-1/8	30-1/8	4	36-7/8	51-15/16	44-1/8	43-9/16	13.1
54½	66-3/4	9	36-7/8	47-9/16	4	26-5/16	30-1/4	28-7/8	35-5/8	33-3/4	4-3/8	40-3/4	57-7/16	49-3/4	48-1/8	14.5
60	74-1/2	9	42-7/8	52-9/16	6	28-25/32	39	27-5/8	38-1/2	38-1/2	4-15/16	47-7/16	66-5/16	56-3/8	53-5/8	16.5
66	81	10	44-3/8	57-3/4	6	32-3/8	42	28-3/4	42-5/8	40-5/8	5-7/16	51-15/16	72-11/16	61-3/4	56-7/8	18.2

DO NOT USE FOR CONSTRUCTION UNLESS CERTIFIED

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CHICAGO AIRFOIL CENTRIFUGAL FANS CLASS I - II - III

33 SISW

35-9/16 in. diameter | 32-1/16x28-3/4 in. inside | 6.38 sq. ft. inside area | MAXIMUM BHP = 9.68 $(\frac{RPM}{1000})^3$

CLASS I RPM 1413 | CLASS II RPM 1552 | CLASS III [illegible] | TIP SPEED, fpm = 9.31 x RPM

CFM	OV FPM	1/2" SP RPM	1/2" SP BHP	3/4" SP RPM	3/4" SP BHP	1" SP RPM	1" SP BHP	1-1/2" SP RPM	1-1/2" SP BHP	2" SP RPM	2" SP BHP	2-1/2" SP RPM	2-1/2" SP BHP	3" SP RPM	3" SP BHP	3-1/2" SP RPM	3-1/2" SP BHP	4" SP RPM	4" SP BHP	4-1/2" SP RPM	4-1/2" SP BHP
6380	1000	417	.71	463	.87	501	1.13	588	1.71	635	2.37	688	3.05								
7018	1100	438	.82	485	1.10	523	1.39	588	1.97	648	2.58	708	3.77	765	4.01						
7656	1200	461	.84	505	1.25	545	1.57	609	2.19	665	2.83	721	3.63	775	4.28	829	5.08				
8294	1300	488	1.09	528	1.42	566	1.76	631	2.43	685	3.11	737	3.82	787	4.59	838	5.41	887	6.28		
8932	1400	512	1.25	548	1.58	588	1.98	657	2.89	707	3.42	755	4.15	803	4.83	858	5.70	887	6.65	843	7.58
9570	1500	539	1.43	577	1.79	607	2.17	674	2.88	728	3.74	778	4.57	821	5.32	865	6.16	909	7.06	953	8.00
10208	1600	566	1.63	597	2.01	630	2.41	695	3.24	750	4.08	797	4.91	841	5.74	883	6.60	924	7.51	965	8.48
10846	1700	594	1.85	623	2.25	653	2.67	715	3.55	771	4.43	818	5.32	862	6.20	903	7.09	942	8.01	981	8.96
11484	1800	622	2.09	650	2.51	678	2.95	738	3.87	792	4.81	841	5.74	884	6.68	923	7.62	961	8.57	998	9.54
12122	1900	651	2.36	677	2.80	703	3.25	758	4.21	813	5.20	862	6.19	905	7.18	945	8.17	982	9.18	1018	10.18
12760	2000	680	2.66	704	3.11	729	3.58	780	4.57	833	5.61	883	6.66	927	7.70	967	8.74	1003	9.78	1038	10.82
14036	2200	738	3.33	761	3.82	783	4.33	829	5.39	878	6.50	924	7.65	969	8.80	1010	9.96	1047	11.09	1081	12.23
15312	2400	798	4.17	818	4.65	839	5.20	880	6.33	922	7.51	966	8.74	1010	9.98	1052	11.26	1090	12.50	1125	13.75
16588	2600	857	5.04	876	5.61	895	6.19	933	7.40	972	8.65	1012	9.95	1057	11.70	1083	12.66	1131	14.01	1167	15.37
17864	2800	918	6.10	935	6.71	953	7.33	988	8.61	1024	9.94	1066	11.30	1097	12.71	1138	14.10	1173	15.62	1208	17.09
19140	3000	978	7.31	995	7.96	1011	8.67	1044	9.97	1077	11.37	1118	12.81	1144	14.29	1179	15.91	1215	17.36	1250	18.93
20416	3200	1040	8.78	1055	9.37	1070	10.07	1101	11.59	1132	12.97	1163	14.48	1194	16.03	1220	17.92	1259	19.24	1292	20.90
21692	3400	1101	10.24	1115	10.99	1130	11.70	1159	13.20	1188	14.75	1217	16.33	1240	17.95	1278	18.81	1308	21.30	1337	23.02
22968	3600	1162	11.97	1176	12.73	1190	13.50	1217	15.08	1244	16.70	1272	18.36	1298	20.06	1327	21.76	1358	23.64	1384	25.34
24244	3800	1224	13.88	1237	14.70	1250	15.50	1276	17.16	1302	18.88	1327	20.59	1353	22.36	1380	24.18	1406	25.99	1433	27.85

CFM	OV FPM	5" SP RPM	5" SP BHP	5-1/2" SP RPM	5-1/2" SP BHP	6" SP RPM	6" SP BHP	7" SP RPM	7" SP BHP	8" SP RPM	8" SP BHP	9" SP RPM	9" SP BHP	10" SP RPM	10" SP BHP	11" SP RPM	11" SP BHP	12" SP RPM	12" SP BHP	13" SP RPM	13" SP BHP
10846	1700	1020	9.80	1058	11.03	1097	12.12	1172	14.41												
11484	1800	1035	10.50	1072	11.62	1108	12.72	1181	15.04	1252	17.48										
12122	1900	1053	11.19	1088	12.26	1122	13.37	1192	15.71	1260	18.19	1327	20.80								
12760	2000	1072	11.88	1105	12.90	1139	14.09	1205	16.44	1270	18.85	1335	21.58	1398	24.33						
14036	2200	1114	13.38	1146	14.53	1176	15.68	1237	18.09	1297	20.64	1357	23.32	1418	26.13	1475	28.86	1532	31.88		
15312	2400	1162	14.99	1188	16.24	1218	17.45	1276	20.01	1331	22.81	1386	25.33	1441	28.18	1490	31.10	[illegible]	[illegible]	[illegible]	[illegible]
16588	2600	1201	16.72	1232	18.07	1262	19.42	1318	22.12	1371	24.86	1422	27.84	1473	30.63	1524	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17864	2800	1243	18.55	1275	20.01	1305	21.46	1361	24.37	1413	27.20	1463	30.21	1511	33.19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19140	3000	1284	20.50	1317	22.07	1347	23.83	1404	26.75	1456	29.88	1505	32.99	1561	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20416	3200	1325	22.67	1358	24.74	1388	25.82	1447	28.78	1500	32.08	1548	35.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21692	3400	1368	24.78	1399	26.65	1430	28.33	1488	31.80	1542	35.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22968	3600	1413	27.16	1442	28.82	1472	30.89	1530	34.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24244	3800	1460	29.75	1487	31.07	1515	33.63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25520	4000	1509	32.64	1535	34.63	[illegible]	[illegible]	1614	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26796	4200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38.70	1658	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The BHP shown does not include belt drive loss. The performance shown is for fan with outlet duct.

36½ SISW

39-3/8 in. diameter | 35-7/16x31-3/4 in. inside | 7.80 sq. ft. inside area | MAXIMUM BHP = 18.9 $(\frac{RPM}{1000})^3$

CLASS I RPM 1344 | CLASS II RPM 1497 | CLASS III [illegible] | TIP SPEED, fpm = 10.3 x RPM

CFM	OV FPM	1/2" SP RPM	1/2" SP BHP	3/4" SP RPM	3/4" SP BHP	1" SP RPM	1" SP BHP	1-1/2" SP RPM	1-1/2" SP BHP	2" SP RPM	2" SP BHP	2-1/2" SP RPM	2-1/2" SP BHP	3" SP RPM	3" SP BHP	3-1/2" SP RPM	3-1/2" SP BHP	4" SP RPM	4" SP BHP	4-1/2" SP RPM	4-1/2" SP BHP
7800	1000	356	.86	387	1.17	434	1.48														
8580	1100	375	1.00	414	1.35	450	1.67	518	2.45												
9360	1200	395	1.18	432	1.53	467	1.90	528	2.65												
10140	1300	417	1.34	450	1.73	484	2.14	543	2.82	600	3.84										
10920	1400	438	1.54	470	1.95	501	2.39	560	3.24	612	4.12	660	5.20								
11700	1500	462	1.77	490	2.20	520	2.66	577	3.60	627	4.48	678	5.52	730	6.73						
12480	1600	484	2.02	517	2.48	539	2.95	594	3.98	643	4.81	690	5.90	736	7.08	788	8.41				
13260	1700	507	2.29	534	2.79	560	3.28	611	4.33	660	5.38	704	6.38	747	7.50	793	8.80	843	10.23		
14040	1800	530	2.59	567	3.12	581	3.63	628	4.73	677	5.88	721	6.93	762	8.01	803	9.28	848	10.66		
14820	1900	553	2.91	580	3.48	603	4.02	648	5.15	695	6.36	738	7.51	778	8.82	818	9.82	855	11.18	897	12.67
15600	2000	576	3.26	602	3.87	625	4.45	668	5.61	712	6.88	755	8.11	795	9.30	832	10.48	888	11.78	905	13.24
17160	2200	623	4.08	648	4.73	671	5.39	711	6.65	750	7.96	790	9.35	879	10.73	865	12.04	899	13.32	932	14.88
18720	2400	670	5.00	694	5.77	716	6.65	755	7.85	788	9.23	877	10.70	884	12.21	899	13.72	933	15.17	965	16.88
20280	2600	718	6.06	740	6.86	762	7.65	800	9.20	834	10.68	868	12.21	900	13.81	934	15.46	967	17.10	998	18.88
21840	2800	767	7.35	787	8.16	808	9.01	845	10.70	878	12.32	909	13.83	939	15.59	971	17.32	1002	19.10	1033	20.88
23400	3000	818	8.79	835	9.65	854	10.54	891	12.37	923	14.14	953	15.85	981	17.58	1010	19.38	1038	21.24	1068	23.14
24960	3200	865	10.43	883	11.32	901	12.28	937	14.21	969	16.13	997	17.88	1024	19.81	1051	21.88	1070	23.59	1105	25.57
26520	3400	915	12.27	932	13.71	949	14.19	983	16.24	1014	18.30	1043	20.31	1068	22.20	1094	24.28	1118	26.18	1146	28.22
28080	3600	965	14.32	981	15.31	997	16.33	1029	18.47	1060	20.67	1088	22.83	1114	24.92	1138	26.88	1162	29.04	1188	31.16
29640	3800	1015	16.61	1030	17.64	1045	18.71	1076	20.94	1108	23.26	1134	25.68	1159	27.81	1183	30.08	1206	32.16	1228	34.35

CFM	OV FPM	5" SP RPM	5" SP BHP	5-1/2" SP RPM	5-1/2" SP BHP	6" SP RPM	6" SP BHP	7" SP RPM	7" SP BHP	8" SP RPM	8" SP BHP	9" SP RPM	9" SP BHP	10" SP RPM	10" SP BHP	11" SP RPM	11" SP BHP	12" SP RPM	12" SP BHP	13" SP RPM	13" SP BHP
15600	2000	845	14.83	980	16.53																
17160	2200	966	16.19	1000	17.81	1036	19.65														
18720	2400	996	17.96	1026	19.51	1057	21.17	1121	24.84												
20280	2600	1029	20.21	1058	21.72	1088	23.29	1142	26.76	1201	30.68	1265	34.98								
21840	2800	1063	22.60	1092	24.27	1119	25.89	1172	29.23	1224	32.85	1270	37.10	1335	41.60						
23400	3000	1098	25.04	1126	26.91	1153	28.73	1205	32.74	1254	36.81	1302	39.75	1352	44.10	1404	48.81	1468	53.82	[illegible]	[illegible]
24960	3200	1133	27.50	1161	29.62	1187	31.63	1239	35.63	1287	39.16	1332	43.08	1378	47.18	1424	51.78	1472	56.80	[illegible]	[illegible]
26520	3400	1170	30.33	1198	32.47	1222	34.63	1273	38.90	1321	43.01	1368	46.88	1409	50.88	1462	55.28	1495	59.97	[illegible]	[illegible]
28080	3600	1210	33.30	1234	35.52	1259	37.79	1308	42.35	1356	46.85	1400	51.10	1442	56.37	1483	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29640	3800	1251	36.58	1274	38.84	1297	41.17	1343	45.95	1388	50.77	1434	55.50	1476	60.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31200	4000	1294	40.12	1315	42.46	1330	44.83	1380	48.70	1428	54.03	1468	58.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32760	4200	1338	43.97	1358	46.39	1378	48.83	1418	53.88	1461	59.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34320	4400	1382	48.11	1402	50.67	1421	53.15	1460	58.31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35880	4600	1427	52.53	1447	55.15	1465	57.78	1502	63.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37440	4800	1473	57.23	1492	59.98	1510	62.73	1546	68.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The BHP shown does not include belt drive loss. The performance shown is for fan with outlet duct.

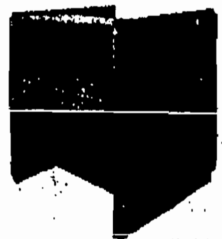
BEST AVAILABLE COPY

ARRANGEMENTS

SQUARE HOUSING—SQA

ARRANGEMENT 1, SISW
For belt drive, open inlet. Wheel overhung. For elevated temperatures, corrosive fumes or ventilation and air conditioning applications.

ARRANGEMENT 9, SISW
For belt drive similar to Arrangement 1 except for provision to mount motor on top or side of fan.



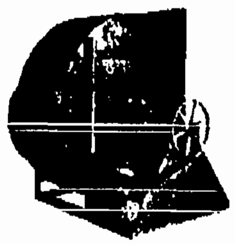
ARRANGEMENT 3, DIDW
For belt drive. Wheel center hung between bearings. For industrial applications, ventilation and air conditioning.

GENERAL NOTE: All Arrangement 1 and 9 Centrifugal Fans offered by Chicago Blower in this catalogue, whether they be designed with a square or scroll type housing, are constructed to accept a shaft cooler and shaft cooler guard as well as a shaft seal.

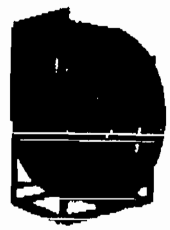
SQUARE HOUSING FAN BELT DRIVE NOMENCLATURE: Both Arrangements 3 and 9 may use a top or side mounted motor. "T" for Top; "SR" for right side; "SL" for left side. Right or Left is determined by looking at the fan from the drive side. Examples: 9T, 9SR, 9SL, 3T, 3SR and 3SL.

SCROLL HOUSING—D/10A

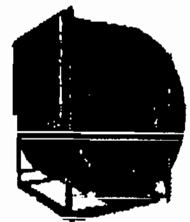
ARRANGEMENT 1, SISW
For belt drive, open inlet. Wheel overhang. For elevated temperatures, corrosive fumes or ventilation and air conditioning applications.



ARRANGEMENT 9, SISW
For belt drive. Similar to Arrangement 1 except for provision to mount motor on side of bearing pedestal.



ARRANGEMENT 3, SISW
For belt drive. Wheel centerhung between bearings. For industrial applications, ventilation and air conditioning.



ARRANGEMENT 3, DIDW
For belt drive. Similar to Arrangement 3, single width construction and application. For large volumes of air.

WHEELS & SHAFTS

"Chicago" Airfoil wheels are supplied in all fan sizes: 12¼ to 80¾ in steel, continuously welded SISW and DIDW except sizes 27 to 36¾ Class II DIDW which are stitch welded and cast aluminum in sizes 8¾ - 10.

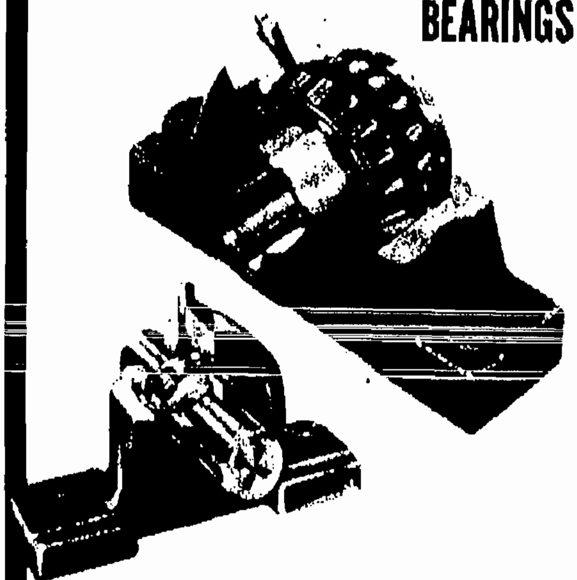
Structural strength of airfoil blading is so great that tie rods and intermediate bracing rings are unnecessary. This eliminates turbulence and permits a full flow of quiet air and increases efficiency.

The steel wheels have die-formed hollow airfoil blades welded to back and side plates making these wheels rugged for heavy service.

All wheels are balanced both statically and dynamically at factory.

Shafts are specially selected turned, ground and polished steel (SAE 1040-1045) to give tight, accurate bearing and hub fit. Shafts are sized to operate 20% or more below the first critical speed for each class of duty.

BEARINGS



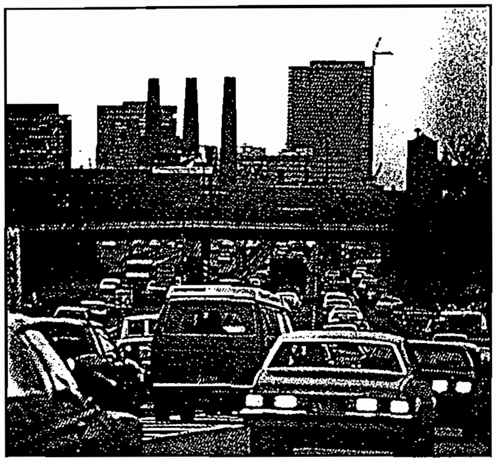
All classes of fans are furnished with grease-lubricated heavy-duty self-aligning ball bearing flange or pillow blocks with spherical roller bearings used on larger or higher class of duty fans.

Bearings are selected for continuous operation and ample size for best possible operating results.

ATTACHMENT E

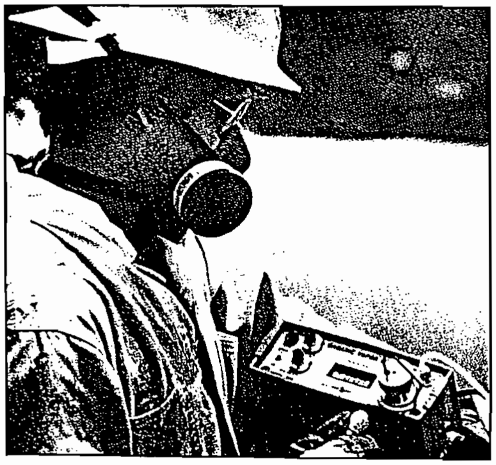
CONTINUOUS EMISSION MONITOR INFORMATION

Product Line Catalog



Source

Ambient



Toxic

Thermo Environmental Instruments Inc.

Thermo Environmental Instruments Inc.

8 West Forge Parkway
Franklin, MA 02038

(617) 520-0430
Telex: 200205 THEMO UR

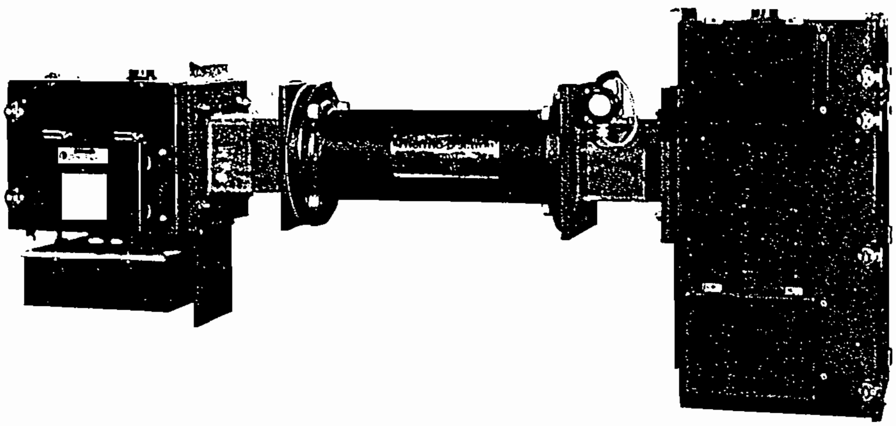
subsidiary of
Thermo Instrument
Systems Inc.

inted USA©

6/87-10M

IN-SITU SYSTEM

Model D12000 In-Situ Stack Multigas Analyzer System



The D12000 is a multigas analyzer which may be mounted on the stack wall, a duct, or other large conduits carrying gases which are products of a variety of processes.

Standard Applications Include:

Fossil fuel fired stream generators
Electric utility steam generators
Incinerators
Cement plants
Nitric acid plants
Petroleum refineries
Pulp and paper mills
Smelters
Iron and steel plants

Combustion Control (Excess Air) For:

Utility Boilers
Industrial Boilers
Recovery Boilers
Kilns

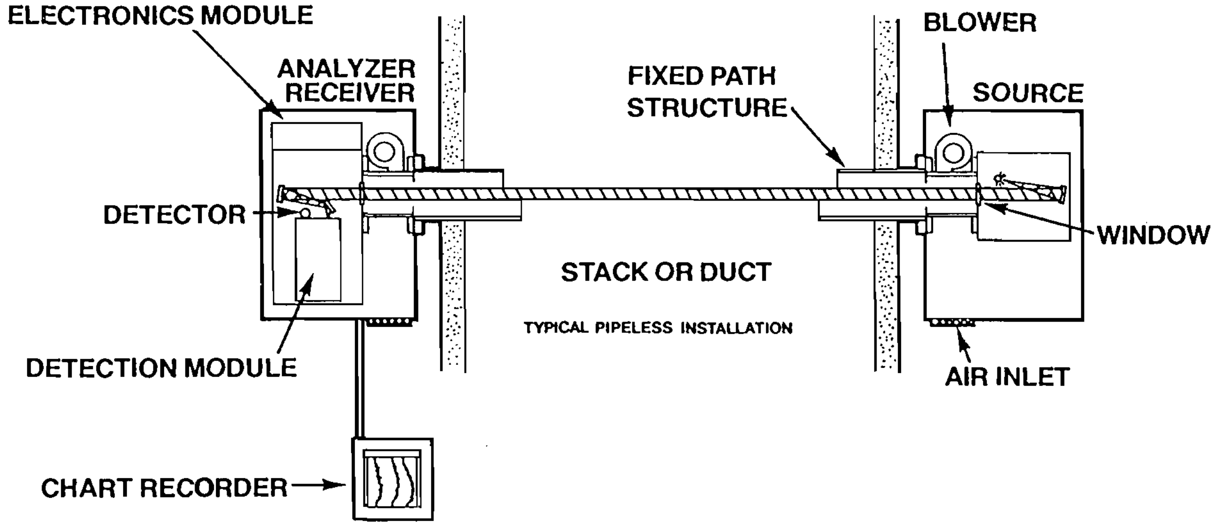
Process Analysis and Control For:

Flue gas desulfurization
Precipitator operation
Dryers

Analyzer Systems are Available For The Following Components:

Carbon monoxide (infrared absorption)
Carbon dioxide (infrared absorption)
Nitric oxide (ultraviolet absorption)
Sulfur dioxide, (ultraviolet absorption)
Opacity (visible light scattering)

The Model D12000



FLUE GAS ANALYZER SYSTEM

SOURCE

The Model D12000 Consists Of:

Source assembly — includes infrared and ultraviolet light sources, blower assembly, opacity Retro Reflector (the opactiy measurement is double pass), and source electronics.

Analyzer/receiver assembly — includes detectors for all gases, opacity, blower assembly and signal electronics.

The D12000 is a cross-stack averaging device, eliminating effects of stack gas stratification which may be present in the sample stream. Polychromatic beams of light pass from the source assembly on one side of the stack (or duct), through the stack gas, to the detector assembly on the other side of the stack.

Standard Full Scale Ranges Available Are:

	Minimum	Maximum	Accuracy
CO	10,000 ppm-ft	100,000 ppm-ft	+/-5%
CO_2	100%-ft	250%-ft	+/-2%
NO	1,000 ppm-ft	50,000 ppm-ft	+/-2%
SO_2	1,000 ppm-ft	50,000 ppm-ft	+/-2%
Opacity	0-100%		

Actual full scale range depends on the path length, for example:

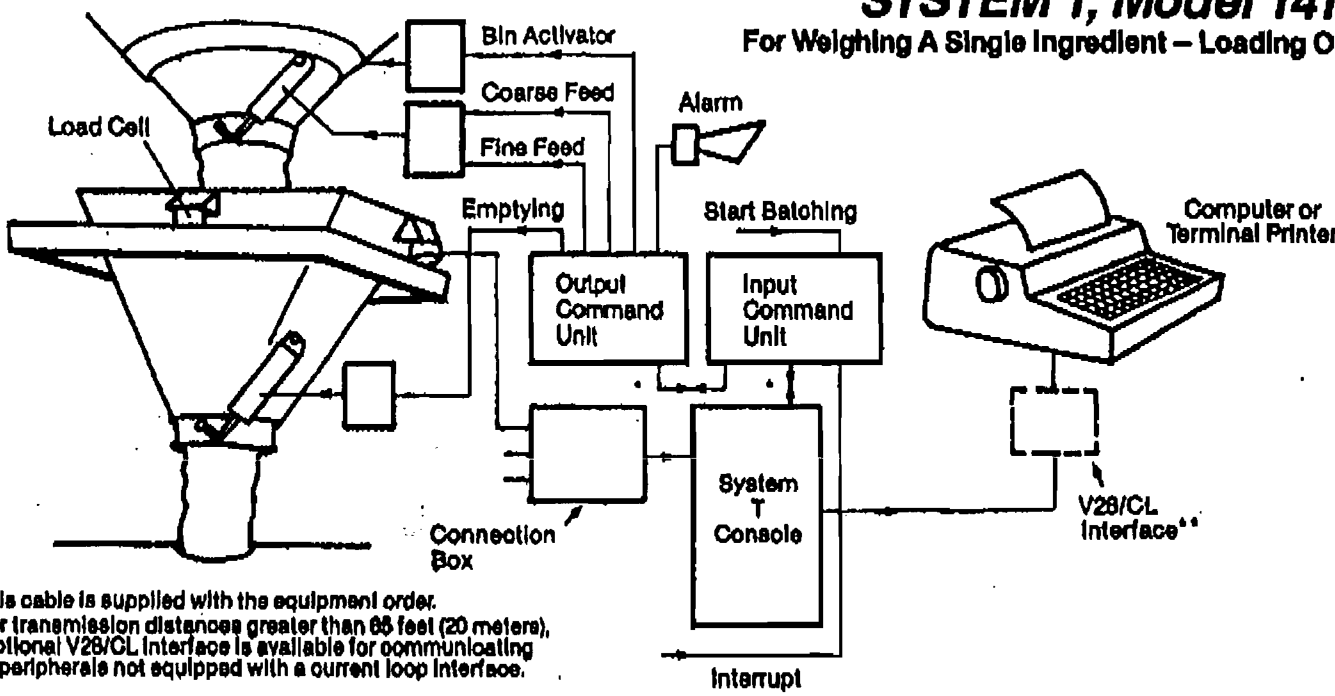
For a path length of 10 feet, CO full scale ranges are minimum 0-1,000 ppm, maximum 0-10,000 ppm

ATTACHMENT F

WEIGH SCALE INFORMATION
FUEL INPUT OPTION AND MASS BALANCE

SYSTEM T, Model 1411

For Weighing A Single Ingredient – Loading Out



*This cable is supplied with the equipment order.
**For transmission distances greater than 66 feet (20 meters), an optional V28/CL Interface is available for communicating with peripherals not equipped with a current loop interface.

SYSTEM T is a computerized system for electronic weighing and control. The Series 1400 includes models for weighing batches of a preselected size. Once the size of the order is entered, the control console calculates the number of sub-batches of a preselected size, within scale capacity, that are required to fill the total order. The smallest order acceptable is two batches of minimum size. With the Model 1411, the scale can be operated from a remote printer or computer terminal. The terminal automatically prints the ordered batch, the delivered batch, and the date.

In addition to the data shared by all models in the Series 1400 (See Form 09-3-68), the Model 1411 has the following features:

- The maximum and minimum batch sizes – taking scale capacity into consideration – are set in registers in the control console.
- The maximum and minimum batch sizes of the total order – taking the receiving vessel's capacity into consideration – are set in registers in the control console.
- Total weight delivered by the scale is maintained in a register in the control console and can be printed out on demand. This register does not automatically reset to zero at printout.
- In the "ready for loading" condition, the subtotal of several executed batch weights can be printed by the terminal printer. Printout of the subtotal automatically resets the subtotal register to zero.
- A 5-digit total order with approval, start, and printout of the weight loaded can be entered from the terminal printer.
- An ongoing weighing operation can be interrupted with a signal to the input command unit or by pressing a pushbutton on the console. The weighing of the batch in progress is then completed, the amount loaded is printed, and the equipment switches to the idle mode.
- When enough material remains in the batching hopper to complete the order, a special command is sent to shut off a feeder, actuator, etc., supplying material to the system.
- An additional indicator with an extra large digital display can be connected to the control console. It is legible from a distance of about 50 yards (45 meters).
- All control functions can be initiated at the control console or remote terminal.

MERRICK
A UNIT OF GENERAL SIGNAL

The Merrick Corporation
Sumneytown Pike
North Wales, PA 19454
(215) 699-0400
Telex 170401 or 846492

Merrick de Mexico
Foroal 76, 8B SEXTO PISO
Deleg. Cuauhtemoc
Col. Condesa
06140 MEXICO, D.F.
Phone: (905) 286-3544 or 533-6965
Telex: (383) 1771617 FROCME

SUPPLIED UNDER AGREEMENT WITH [illegible] INSTRUMENT

Console Front Control Buttons

No.	Designation	Function
1	STOP LOADING	Loading is terminated.
2	PRINT SUBTOTAL	Printout and zeroing of batch weight subtotal.
3	PRINT TOTAL	Printout of total loaded quantity. No automatic zero reset.
4	RESTART	Check function at start-up.
5	PRIMARY TARE	Operates only at start.
6	START/EMPTYING	Batching/emptying start.
7	ALARM:SKIP	Alarm acknowledgment, accepts batching weight error.
8	ALARM:RESUME	Alarm acknowledgment, permits batch weight correction.

Input Command Units. Unit 1
Operating current maximum 30 mA

No.	Function
1	START PERMISSION
2	EMPTYING PERMISSION
3	STOP LOADING
4	–
5	–
6	–
7	–
8	–

Output Command Units. Unit 2
Control current maximum 3 A, minimum 0.02 A

No.	Function
1	COARSE FEED
2	FINE FEED
3	FEED (residual flow stop)
4	EMPTYING
5	LOADING COMPLETED
6	WARNING (final batching)
7	ALARM, OVERLOAD
8	ALARM, PROCESS ERROR

Cable Length Between Console and Command Unit: Standard 3.3 feet (1 meter).

Control Console Designations

Q – T1411 – [TYPE] – [MAT'L]

EXAMPLE: Q-T1411-W-SS
Type T1411 controller, wall-mounted; stainless steel case.

TYPE refers to the method of controller console mounting.
- W – Wall mount
- P – Panel mount

MATERIAL refers to the control console enclosure.
- SS – Stainless steel (not painted)
- (Blank) – Carbon steel with enamel finish (standard)

COMMAND UNIT DESIGNATIONS: (Reference available functions in tables above).

Q – [COMMAND] – 0 [NUMBER OF RELAYS (8 MAX)]

COMMAND refers to the type command function required.
- 01 – *Input command (Required. Order with 3 relays.)
- 02 – Output command (Optional. All 8 relays recommended, minimum of 4 required.)

*Permits scale operation from either the control console or the input command unit.

EXAMPLE: Q-02-04
Output control unit with 4 relays. Relay position (1-8) can be specified or field-changed to desired position.

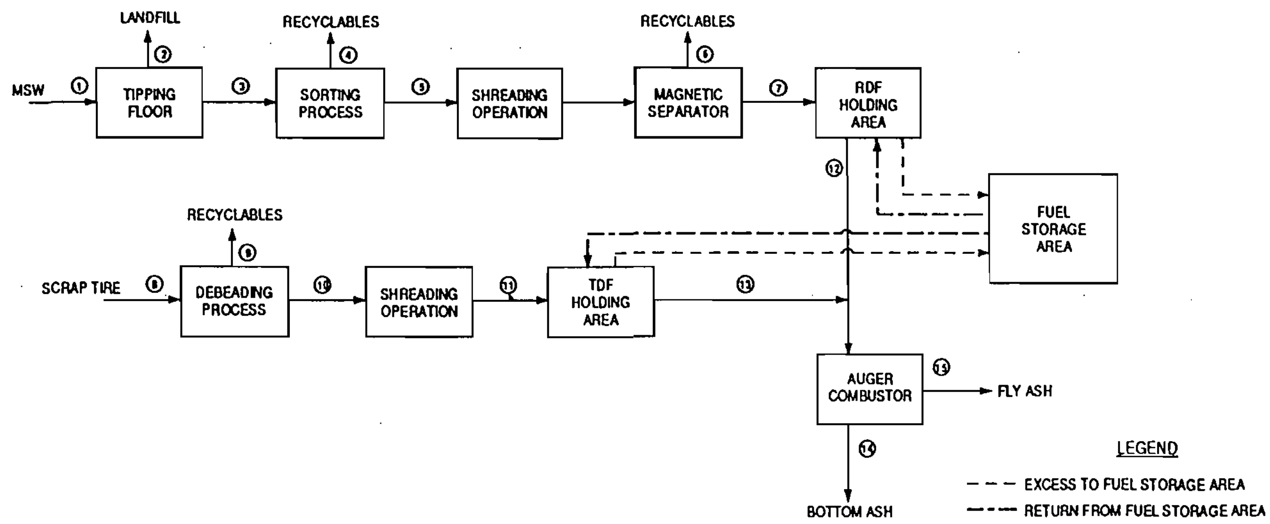
OPERATING VOLTAGE: All controllers can be field-configured for standard voltages between 110-240V, 1ϕ, 50/60Hz. All units are shipped for 110V operation unless otherwise specified. Command unit relays are for controlling AC voltages up to 220V. Consult factory DC voltage relay requirements.

PRINTER OR COMPUTER INTERFACE serial port with RS-232C or isolated 20 mA current loop, passive.

MERRICK
The Leader In Control System Technology

© Merrick 1988

END



MSW Processing Line Mass Balance

Stream Number		1	2	3	4	5	6	7
Description	Unit							
MSW	TPD	450.0	--	450.0	--	235.0	--	--
Non-Combustible	TPD	42.5	42.5	--	--	--	--	--
Household Harz. Waste	TPD	7.5	7.5	--	--	--	--	--
Recyclables	TPD	--	--	--	215.0	--	--	--
Misc. Ferrous Metals	TPD	--	--	--	--	--	10.0	--
Refuse-Derived Fuel	TPD	--	--	--	--	--	--	225.0
TOTAL	TPD	500.0	50.0	450.0	215.0	235.0	10.0	225.0

Scrap Tire Processing Line Mass Balance

Stream Number		8	9	10	11
Description	Unit				
Scrap Tire	TPD	42.0	--	25.0	--
Tire Bead	TPD	--	17.0	--	--
Tire-Derived Fuel	TPD	--	--	--	25.0
TOTAL	TPD	42.0	17.0	25.0	25.0

Auger Combustor-- Fuel Input Option and Mass Balance

Fuel Option			A	B
Stream Number	Fuel Type	Unit		
12	RDF (12.48% Ash)	lb/hr	18,800	18,000
13	TDF (4.78% Ash)	lb/hr	--	1,800
14	Bottom Ash (50%)	lb/hr	1,173	1,166
15	Fly Ash (50%)	lb/hr	1,173	1,166
TOTAL	Fuel Charging	TPD	225.6	237.6
TOTAL	Total Ash	TPD	28.2	28.0

Figure 1 SIMPLIFIED FLOW DIAGRAM AND MASS BALANCES FOR THE PROPOSED RESOURCE RECOVERY PLANT

KBN

ATTACHMENT G

MERCURY EMISSION CALCULATION AS PROPOSED FOR THE CITY OF GRETNA - MSW COMBUSTOR

**MERCURY EMISSION CALCULATION
AS PROPOSED FOR THE CITY OF GRETNA–MSW COMBUSTOR**

Hourly Emission Estimate: 0.0035 lb_m/hr (as proposed in Table 2-5 of original permit application)

Stack Flow Rate: 34,600 dscfm (as reported on permit form page 6 of 12 of original permit application)

$$34{,}600 \text{ dscfm} \times 60 \text{ min/hr} = 2{,}076{,}000 \text{ dscf/hr}$$

$$0.0035 \text{ lb}_m\text{/hr of Hg} \div 2{,}076{,}000 \text{ dscf/hr} = 1.686\times10^{-9} \text{ lb}_m\text{/dscf}$$

$$1.686 \times 10^{-9} \frac{\text{lb}_m}{\text{dscf}} \times \frac{453.593 \text{ g}}{1 \text{ lb}_m} \times \frac{10^6 \mu\text{g}}{1 \text{ g}} \times \frac{1 \text{ ft}^3}{0.028317 \text{ m}^3} - 27 \ \mu\text{g/dscm}$$

ATTACHMENT H

PAVED ROAD AND AREA FOR THE PROPOSED FACILITY

CITY OF GRETNA
WASTE TO ENEGY FACILITY