FLYASH REINJECTION

by

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INTRODUCTION

It is the aim of every power plant engineer to attain the maximum possible efficiency for the least possible cost. The history of steam generation is one of constantly increasing efficiencies. From the first inefficient, low pressure, saturated steam, hand-fired units to the present day pulverized coal units operating at high temperatures and pressures with efficiencies as high as 88 per cent, the consideration has been one of changing the greatest number of BTU available in the potential energy of the fuel to heat energy in steam. To attain the present high degree of energy change many innovations were made and much experimentation done. The most fruitful angle of approach was that for reducing the loss due to the heat in the dry flue gases since it was such a large portion of the total losses. Thus, waterwalls, economizers, air heaters, and different methods of firing were investigated and began appearing on many units. The loss today due to dry flue gases has been reduced to almost a minimum. As steam generators with their various auxiliaries have improved in efficiency, it has become increasingly difficult to reduce economically the total losses by any appreciable degree. Work now being done is mainly refining original designs, searching for new metals that will make higher pressures and temperatures economically possible, altering designs to use a greater variety of coal, or increasing the efficiencies of the different components. Any modification that will increase the overall boiler efficiency even a fraction of a per cent without incurring a very large expenditure is considered worthy of investigation by most power engineers.

It is notable that little has been or is being done toward recovering heat lost in unburned combustible produced in a pulverized coal unit. Many present day stoker-fired units are equipped with flyash reinjection systems for partially recovering this loss. Flyash reinjection for spreader stoker units is practically standard equipment because unburned carbon carryover is so great with this type of fuel feed. Burning flyash on a stoker is relatively easy since it is allowed to lay on the fuel bed a fairly long period of time whereas time for burning in a pulverized steam generator is very short.

Ash is deposited in three different places on the units used for this investigation. They are the ash pit, the last-pass hopper, and the Research Corporation electrostatic precipitator. The precipitator refuse was observed to be quite chalky in appearance whereas the last-pass hopper refuse was found to be very dark. Most of the refuse particles deposited in the last-pass hopper are larger than 100 mesh with very few larger than 50 mesh. This large particle flyash is centrifugally deposited as the flyash laden gases make an abrupt turn into the last-pass of the boiler. A check was made and it was found that this refuse contained approximately 40 per cent carbon. This value seemed sufficiently large to merit an investigation of the possibility of recovering the heat contained in last-pass hopper flyash.

Mr. H. O. Arendsee, Power Plant Superintendent of the Celco, Virginia plant of the Celanese Corporation of America believed that a study of the possibilities of burning last-pass hopper flyash should be made in view of the few and very conflicting claims and opinions of the feasibility of heat recovery from this flyash. Celanese officials approved the use of their Celco units for this determination which was under the field supervision of Mr. Arendsee.

REVIEW OF LITERATURE

Most coals used for steaming contain 15 to 40 per cent volatile matter and 50 to 80 per cent fixed carbon. Thus, approximately two-thirds of the combustible is fixed carbon and, likewise, approximately two-thirds of the heating value in coal is due to fixed carbon. It is apparent then that the burning of carbon is important.

Every steam generating station encounters a loss due to unburned carbon in flyash refuse and in the form of carbon monoxide in the flue gases. This investigation deals with the unburned carbon found in the last-pass hopper flyash. A short discussion of the nature of the burning of coal will be included to show why it is practically impossible to eliminate these losses resulting from unburned carbon. This discussion will limit itself primarily to the burning of coal in a pulverized coal unit.

Coal, after being injected into the furnace, burns in two practically distinct steps. First the volatile matter is distilled off and burned. Then the carbon remaining is burned. In comparison it is much more difficult to burn carbon than the volatile matter present in coal. The relative time for burning is 10 per cent for the volatile matter and 90 per cent for the fixed carbon.[1] The coal particles attain furnace temperature in approximately 10 to 20 milliseconds.[2] Burning of the volatile

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[1]Griffin, H. K., Adams, J. R., and Smith, David F., "Rates of Burning of Individual Particles of Solid Fuel", Industrial and Engineering Chemistry, September, 1929.

[2]Ibid.

matter is easy since the law of diffusion applies bringing the coal gases into intimate contact with the oxygen of the air rapidly. One problem, however, does present itself. As the volatile matter distilled from the coal burns it tends to create an inert atmosphere arouud the coal particle. Further distillation finds new volatile mixing only with inert gases and, if this condition were allowed to exist, the newly formed volatile matter would not be burned. This problem is solved quite easily by arrangements providing for agitation of the coal and air streams. Even though the carbon which remains after the volatile matter has been removed is of such a size that it apparently obeys the mechanics of gases it will not burn as a gas. Diffusion does not occur to the extent that it does with gases and the ignition temperature is higher for the carbon. The generally accepted theory for the burning of carbon is that complex compounds of carbon and oxygen are first formed before finally breaking down to carbon monoxide and then carbon dioxide. This adds to the time required for carbon to burn. To assure complete burning of the carbon it must remain a sufficient period of time in the furnace at the ignition temperature and must have air constantly moved relative to it. The latter requirement is important because carbon will not diffuse. A pulverized coal unit burns volatile matter better than a stoker-fired unit but due to the small amount of time the particles remain in the furnace burning fixed carbon is more difficult.

In a pulverized coal steam generating unit, coal particles burn forming empty shells, called cenospheres, whose carbon content is high. Many of these cenospheres are carried through the furnace without completely burning and are deposited in the last-pass hopper. The following theory for the creation of cenospheres is propounded by Mr. Douglas Henderson.[3] "At some point before the volatile matter is distilled off coal reaches an agglutinating point at which temperature there is a softening of the solid material." The volatile matter is driven off and the "pasty condition is followed by a hardening of the mass." This occurs on the outer surface of the coal first since it is heated by radiation from the furnace. The inside of the coal particle does not attain the agglutinating temperature until after the surface of the particle has softened and sintered. The center of the particle then softens and attempts to expell the volatile matter but cannot do so due to the sintered surface. Pressure is built up within the particle against the "fused and to a certain extent plastic exterior" forming a hollow sphere which eventually bursts leaving a thin shell with considerable carbon. Another observation made by Mr. Henderson was that "the thin walls of the cenospheres make them very active with oxygen--cenospheres of 30 mesh down reacting with oxygen at 1650°F to such an extent that the entire mass glows. Coal or coke requires a higher temperature to reach the same glow point." This would indicate that cenosphere flyash has burning possibilities.

Nowhere in reviewing literature regarding flyash burning was there found an analysis concerning the merits of a reburning system that will be applied in this study. Mr. Hudson N. Bubar[4] brings out some interesting

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[3]Henderson, Douglas, "How Pulverized Coal Burns as Shown by the Microscope", Power, July, 1931.

[4]Bubar, Hudson H., "Recirculation of Fly Ash in Boiler Furnaces", Combustion, January, 1942.

points, however. Mr. Bubar states that recirculation increases the percentage of ash passed through the boiler since the percentage of ash in flyash is considerably higher than in the coal forming it. In the case of recirculating all flyash from the separators this increase will continue until the quantity of ash discharged from the stack will equal that which would be admitted to the separator without recirculation. Increasing the gas loading of the flue gases increases maintenance of furnace walls due to increased slagging, reduces heat transfer conditions due to greater ash accumulation on boiler tubes, and further hinders economical operation caused by increased ash content being circulated. The conclusions of the analysis made by Mr. Bubar practically eliminates the possibility of recirculating the flyash collected in the separating apparatus within the same furnace. His observations and analysis were based upon the idea that the flyash produced by a boiler be recirculated in the same boiler, that the flyash be injected directly into the furnace without prior preparation, and that the flyash for recirculation was that removed from the flue gases in the separating apparatus.

In this investigation the author will be concerned only with that portion of the flyash deposited in the last-pass hopper. The flyash will be prepared for furnace injection by pulverizing it in the same manner as coal.

As previously expressed, there could be found very little information concerning the burning of flyash. From analyses made at the Celco plant of the Celanese Corporation of America last-pass hopper flyash was found to contain approximately 40 per cent carbon, representing an unburned carbon loss of sufficient magnitude to warrant this investigation.

OBJECT

To determine if it is possible to reinject for further burning the last-pass hopper high carbon flyash from pulverized fired steam generating units at the Celco, Virginia, plant of the Celanese Corporation of America.

PROCEDURE

1. Significance And Theory

The quantity and carbon content of the flyash deposited in the last-pass hopper and its ability to be burned were the fundamental items to be learned in order to fulfill the object of this investigation. Supplementary observations were made, however, and due to their applicability to the subject as a whole were incorporated.

Spot checks were made for determining the quantity of flyash deposited, the carbon content, and the size consist of the flyash. No effort was made to ascertain the effects of different types of coal, varying loads, and other factors which would cause the amount of refuse deposited to vary. Prior to making a spot check it was first learned whether the unit was functioning under average conditions. The units are normally operated on a fairly uniform class of coal and with a rather constant output.

It had previously been decided that for successful burning of the flyash a reduction of particle size would be the most practical approach.

The units in question are pulverized coal units, therefore, it follows, naturally, that the large particle material considered for reinjection should, if possible, be prepared for the combustion process by pulverization. The grindability of the flyash was determined as is explained later in this section. The results of this determination were important for deciding the feasibility of running the burning test. If this test had revealed that extreme difficulty would be encountered by the pulverizers in grinding the flyash it would have been necessary to alter the proposed method of injecting the flyash into the pulverizers prior to burning.

The burning test was of fundamental importance since upon it depended the possibility of recovering the heat available in the flyash. It was necessary to devise a method for determining positively whether the burning of flyash could be accomplished. This could not be done by taking the last-pass hopper flyash deposited by a unit and attempting to burn it at the unit's rate of deposition since the amount was so small that it would not be detectable by either a steam flow chart or an efficiency test. A greater rate of feeding was, therefore, settled upon so that the quantity was significant. By observing the flame, variation in CO_2, and the steam flow chart the ability of flyash to be burned could be found.

An ash-balance for calculating the loss due to unburned combustible in the refuse was run. Information obtained from this test was used in the following manner: (1) the available heat in last-pass hopper flyash was determined, (2) a comparison was made between ash-pit refuse allowed to lay in the bottom of the furnace exposed to the radiant heat of the furnace and refuse drawn immediately from the furnace bottom without having an opportunity to burn, (3) the available heat in and the quantity of large particle, high carbon flyash carried past the last-pass hopper into the precipitator was calculated, (4) the loss due to unburned combustible in the refuse was found, and (5) the refuse distribution in the three flyash collecting areas was determined.

It had been planned to run several ash balance tests but the unit on which the tests were to be run was subjected after the one test to a prolonged outage making discontinuing of additional tests necessary. Every effort was made to run the test under average conditions, therefore, results obtained should be representative of normal operation.

A check was made of the time required for the pneumatic conveyor to withdraw the flyash from the last-pass hopper for varying periods of deposition. The theory was that as the flyash continued to collect in the last-pass hopper the area for gas flow past the hopper became less, increasing the flue gas velocity. It was believed that a point would be reached where the high velocity gases would pick up flyash already deposited and an equilibrium condition would exist whereby no additional flyash would be collected in the last-pass hopper. Thus, the quantity of high carbon flyash usually deposited there would be carried on to the precipitators and, possibly, out the stack.

In conjunction with the analysis of the flyash, photomicrographs of flyash were made. It is known that the majority of the particles will be in the form of cenospheres (hollow spheres) and these photographs verify this. The photomicrographs were included to show the structure of the flyash since they will show it more clearly than a written description could possibly do.

2. Flyash Analysis

A1. Per cent Carbon

The three constituents of flyash are ash, carbon, and volatile matter. The volatile matter present is such a small quantity as to be considered negligible. The per cent carbon was determined by burning a flyash sample ground to 60 mesh in a muffle furnace at 700 to 750 degrees centigrade until only ash remained.

A2. Size Composition

Tyler screens of U. S. Standard 30, 50, 100, and 200 mesh and a Rotatap shaker were used. The percentage of flyash larger than 30 mesh, between 30 and 50 mesh, between 50 and 100 mesh, between 100 and 200 mesh, and smaller than 200 mesh were determined by shaking for a twenty minute period.

A3. Grindability

Grindability tests were made since it was believed that for successful burning of flyash a reduction in particle size was necessary. The standard Hargrove grindability test specifies particle sizes between 16 and 30 mesh necessitating the need for another means of comparing the grindability of flyash with that of coal. The particle size of the flyash with which this thesis is concerned is smaller than 30 mesh. A comparison of the grindability of flyash with that of coal was made by taking coals whose grindabilities were known, reducing them to the same size as the flyash, and running the grindability according to A. S. T. M. Standards with the exception of particle size. Refer to Figure 5, page 40. Grindabilities so obtained were called "comparative" grindabilities. The comparative grindability of the flyash was also determined. Then, by extrapolation of the Hardgrove line, the grindability of the flyash was found on the basis of its having a size in accordance with A. S. T. M. Requirements. The grindability so determined enables a comparison of flyash grindability with other coals in addition to those used to make this analysis.

3. Coal Analysis

The proximate analysis and the higher heating value of the coal used for the ash balance test was made according to A. S. T. M. Standards at the Celanese laboratory.

4. Test Procedure

B1. Weight of Flyash Deposited

The hopper was emptied initially and flyash allowed to collect for an hour. A fifty gallon drum (Figure 1, page 18) was placed on platform scales and the tare weight recorded. A vacuum was pulled on the drum to which was attached a hose from the bottom of the last-pass hopper. See Figure 2, page 19. The hopper was emptied and the drum reweighed.

B2. Burning Test

Unit Number 4 was used since it was equipped for natural gas usage and the operating personnel were more familiar with its operation under test conditions. There are two feeders on Number 4 which supply four horizontal

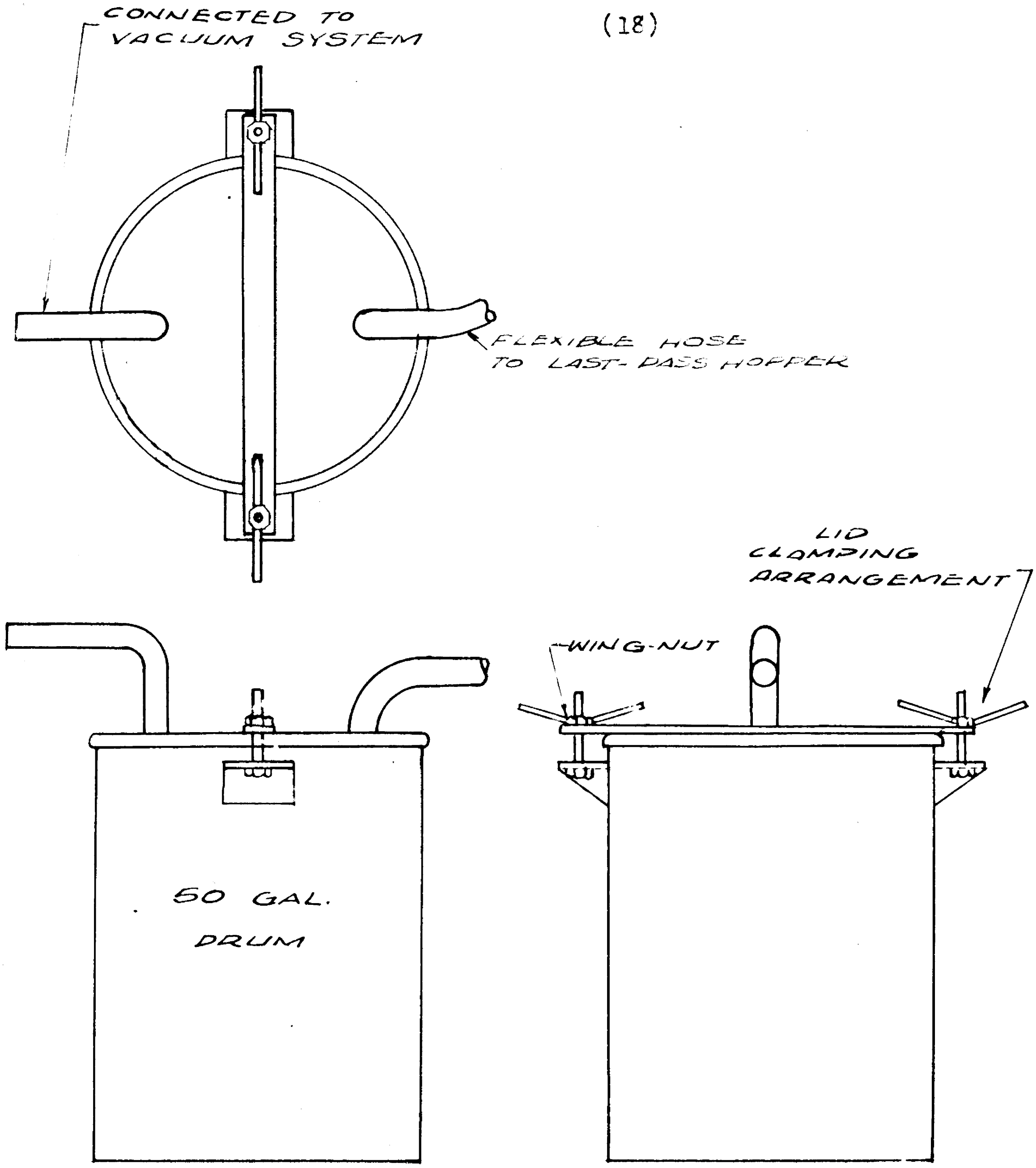


FIG. 1

DRUM FOR REMOVING
LAST-PASS HOPPER FLYASH

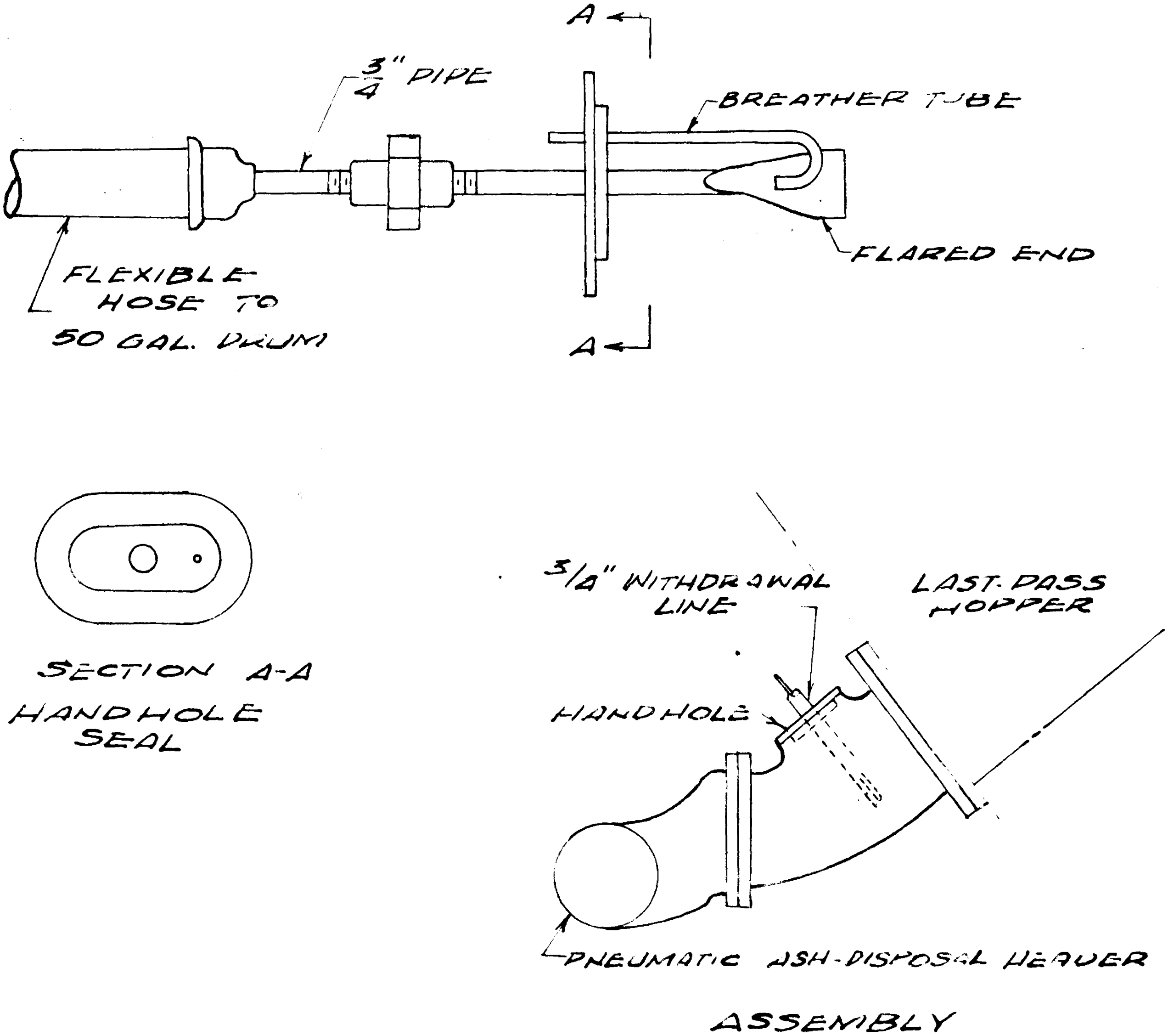


FIG. 2
METHOD FOR REMOVING
FLY ASH FROM
LAST-PASS HOPPER

turbulent flow burners. The north feeder supplies the top two burners while the south feeder supplies the bottom two burners.

The unit was placed on manual control and the north feeder set to supply coal for producing approximately 70,000 pounds of steam per hour. The south feeder's coal supply was cut off and the south bottom burner valve closed. Gas was fed to the north bottom burner at a constant rate until the total steam produced by the coal from the top two burners and the gas from the bottom north burner totaled 75,000. Then flyash was dumped into the south feeder at the rate of one bucket per ten seconds until the unit had attained equilibrium conditions. The injection of the flyash was stopped and the steam output was noted. The difference was recorded as the steam supplied by the flyash and proved conclusively that the flyash had burned. During the test the pulverizer amperage, the Ringleman Number of the stack gas, and the CO_2 were recorded.

B3. Ash Balance

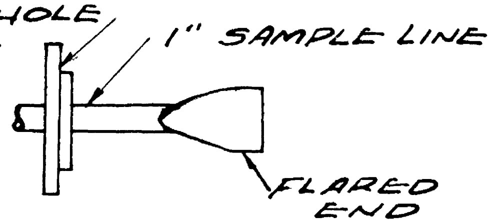
This test was made on unit Number 6. The unit was placed on manual control and a constant output of approximately 200,000 pounds per hour maintained for the test period of eight hours. The bunker had previously been filled with enough of the same kind of coal so that conditions would be maintained as constant as possible during the test.

The refuse deposited in the last-pass hopper was taken, measured, and analyzed as described on pages 15 and 16. The ash pit refuse quantity was solved by allowing the refuse to fall into the hopper in front of the pit and noting the number of times this hopper was filled during the time of the test. The quantity of refuse required for one hopper full was previously measured so that the total refuse could be calculated. To accomplish this the ash pit door was opened and the refuse was allowed to fall continously into the hopper. There is a chamber around the hopper which was completely sealed to minimize infiltration of air at this area. When the refuse had reached the desired level in the hopper the plug obstructing the refuse from flowing into the ash disposal line was pulled and the pneumatic conveying system was allowed to remove the collected refuse from the hopper. A representative sample of the precipitator refuse was taken as shown by Figure 3, page 22.

The quantity of refuse which went to the precipitator was calculated by equating the ash in the refuse equal to the total ash supplied in the coal.

The precipitator refuse was screened for flyash between 100 and 200 mesh and larger than 100 mesh in order to determine the amount of large particle high carbon flyash which passed the last-pass hopper and entered the precipitator. These large particles were analyzed for combustible content so that their recovery value might be ascertained. A photomicrograph of this large material was taken so that a comparison might be made with the photomicrographs of last-pass hopper cenospheres.

Information concerning to what extent the ash-pit refuse oxidized when exposed to the furnace's radiant heat was easily obtainable. The ash-pit refuse obtained during the ash balance test period was not exposed to the radiant heat of the furnace. With the pit door closed and the ash-pit refuse exposed to the heat of the furnace the conditions of the test,



SAMPLE TAKING DEVICE

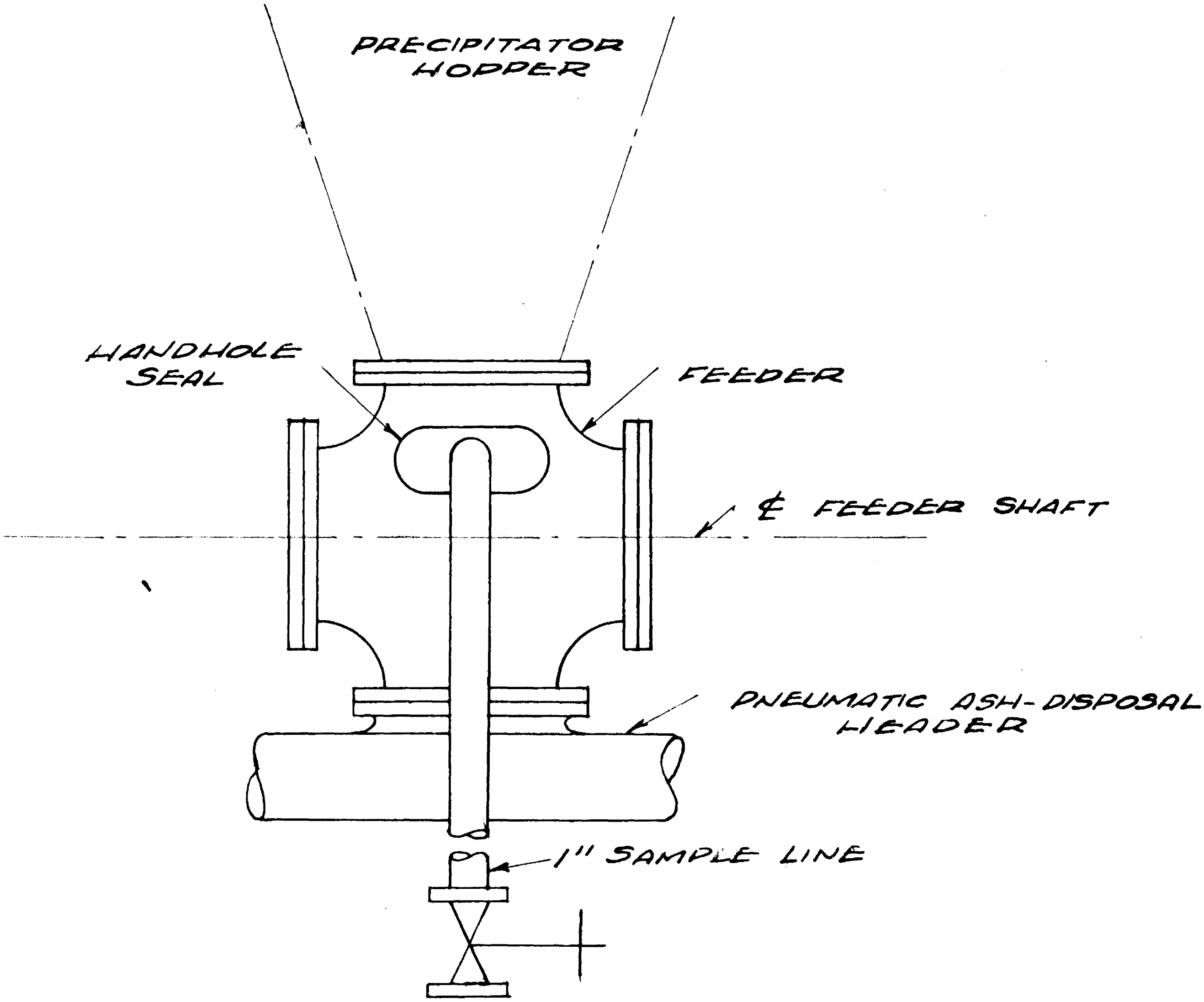


FIG. 3

PRECIPITATOR SAMPLING ARRANGEMENT

e.g., the same coal and a load of 200,000 pounds per hour, were continued for two hours after the normal test had been terminated. A sample of this refuse was taken, analyzed, and compared with the refuse of the normal run.

B4. Last-Pass Hopper Carry-Over

The United Conveyor's pneumatic ash-disposal line ends at a spring-loaded air inlet valve. When the system is pulling the spring-loaded valve is practically closed since the suction force is being expended by pulling the flyash. When the ash has been pulled the suction in the line exerts its force on the valve, pulling it down against the force of the spring. By observing the valve the end of the pull can be noted. The pull was started by opening the hopper valve exposing the flyash to the disposal system's vacuum.

The time for pulling was recorded for deposition periods of from two to fourteen hours, with a deposition increment of two hours. For example, the flyash was allowed to collect for a two hour period and the time for pulling the hopper empty recorded. Then it was allowed to deposit for a four hour period and the pulling time again recorded. Theoretically, if there were no carry over the time required to empty the quantity deposited for the four hour period would be twice that of the two hour period. If the time were less for the four hour period it was believed that the carrying over to the precipitator of flyash which normally settled out in the last pass hopper would be indicated.

DATA AND CALCULATIONS

A1. Tests For Carbon Content In Last-Pass Hopper Flyash (per cent)					
MESH SIZE	+50	+100 -50	+200 -100	-200	Aggregate
Run 1	57.1	34.5	15.7	7.2	36.9
2	55.5	30.8	36.6	11.0	35.9
3	53.6	31.9	20.3	8.3	36.3
4	58.5	32.0	22.6	7.1	38.5
Ave.	56.2	32.3	23.8	8.4	36.9

Sample Calculation:

$$C = \frac{FA - A}{FA}(100)$$

$$= \frac{1.0001 - .4390}{1.0001} \times 100$$

$$= \underline{57.1\%}$$

Where: C = per cent carbon in flyash sample

FA = weight of flyash sample in grams

A = weight of ash in flyash sample in grams

A2. Tests For Size Composition In Last-Pass Hopper Flyash (per cent)					
MESH SIZE	30	50 -30	100 -50	200 -100	-200
Run 1	6.3	32.5	35.4	18.9	6.9
2	5.9	39.3	41.3	11.3	2.2
3	5.3	39.2	40.4	12.4	2.8
4	2.7	28.3	37.4	25.0	9.6
5	-	36.1(50)	38.7	17.8	7.4
6	-	35.0(50)	39.0	19.0	7.0

(Continued on next page)

A2. (continued)

Sample Calculation:

$$FA_{sc} = \frac{FA_{scw}}{FA}(100)$$

$$= \frac{32.5}{100}(100)$$

$$= \underline{\underline{32.5\%}}$$

Where: FA_{sc} = sized flyash (per cent)

FA_{scw} = weight of sized flyash (grams)

FA = weight of flyash sample (grams)

A3. Tests For Grindability

a. Standard	Test #1	Test #2	Ave.
Logan and Kanawha (No. 2 Gas)	72	74	73
Smokeless (No. 6 Pocahontas)	109	111	110
Raven Pocahontas (Raven Red Ash)	83	84	83
b. Comparative			
Logan and Kanawha (No. 2 Gas)	81	83	82
Smokeless (No. 6 Pocahontas)	116	117	117
Raven Pocahontas (Raven Red Ash)	93	93	93
Flyash	110	117	113

Sample Calculation:

$$HGI = 6.93W + 13$$

$$= 6.93 \times 14.1 + 13$$

$$= \underline{\underline{111.0}}$$

Where: HGI = Hardgrove grindability index

W = weight through 200 mesh after grinding

B1. Weight of Flyash in Last-Pass Hopper (#/hr.)					
Hopper Designation	South	South Center	North Center	North	Total
Run 1	32	15	25	40	112
2	48	20	42	63	173
3	46	27	40	58	171
4	50	25	43	62	180
5	43	30	38	58	169
6*	63	32	45	70	210
7	33	20	35	55	143
Ave.	45	24	38	58	165

*Wet storage coal

B2. Burning Test A

	with flyash	without flyash	difference
Ringleman No.	2.8	2.7	.1
Pulverizer Amps.	95-100	70	25-30
% CO_2	14.8	12.8	2.0
Load (#/hr.)	85,000	76,000	9,000

Rate of Feeding Flyash.................................. 2250 #/hr.

BTU in Flyash Fed $= H_{rlf} = 14150 C_{rl} \times W_{rlf}$

$= 14150 \times .369 \times 2250 = 11,780,000$ BTU/hr

Heat Absorbed in Making Steam $= H_s = h_s - h_{fw}$

$= 1362 - 312 = 1050$ BTU/#

BTU in Steam Made by Flyash Fed $= H_{srlf} = H_s \times W_{srlf}$

$= 1050 \times 9000 = 9,450,000$ BTU/hr

Recovery Efficiency of Burning Flyash (Approximate)

$$= \frac{H_{srlf}}{H_{rlf}} = \frac{9,450,000}{11,780,000} = 80\%$$

Where:
H_{rlf} = heat in last-pass hopper flyash fed (BTU/hr)
C_{rl} = pounds of carbon per pound of last-pass hopper flyash
W_{rlf} = weight of last-pass hopper flyash fed (#/hr)
H_s = heat absorbed in steam made, net (BTU/#)
h_s = enthalpy of steam at P = 600 psig and T = 720°F (BTU/#)
h_{fw} = enthalpy of feedwater at P = 800 psig and T = 340°F (BTU/#)
H_{srlf} = heat in steam made from flyash fed (BTU/hr)
W_{srlf} = weight of steam made from flyash fed (#/hr)

B2. Burning Test B			
	with flyash	without flyash	difference
Ringleman No.	2.8	2.7	.1
Pulverizer Amps.	74	67	7
% CO_2	14.7	13.0	1.7
Rate of Feeding Flyash .... 2250 #/hr			

B3. Ash Balance Test

B3a. Refuse Quantities (pounds per 8 hours)					
Hopper Designation	North	North Center	South Center	South	Total
Last-pass Hopper	546	350	190	293	1379
Ash-Pit	567	315	189	252	1323

B3b. Refuse Carbon Analysis (percentage)					
MESH SIZE	+50	+100 -50	+200 -100	-200	Aggregate
Last-pass Hopper	57.1	34.5	15.7	7.2	36.9
Ash-Pit I*	-	-	-	-	24.4
Ash-Pit II**	-	-	-	-	37.1

NOTE: * Analysis of ash-pit refuse which had been exposed to the radiant heat of the furnace
** Analysis of ash-pit refuse which had not been exposed to the radiant heat of the furnace

B3c. Precipitator Refuse Data				
MESH SIZE	+100	+200 -100	-200	Aggregate
Carbon (per cent)	56.6	36.7	-	19.7
Quantities (per cent)	8.6	19.3	72.1	100

B3d. Other Data
1. Ash in coal, as received (from Celanese files) 8.6%
2. Higher Heating Value of coal, as received (from Celanese files)... .... 13850 BTU/#
3. Quantity of coal burned during test period .... 142,000 #/8 hr
4. Enthalpy of steam at P = 600 psig and T = 720° F .... 1362 BTU/#
5. Enthalpy of feedwater at P = 800 psig and T = 340°F ...... 312 BTU/#
6. Average steam produced (from integrator readings) ...... 196,000 #/hr

B3e. Calculated Data

Identification of symbols:

A_c = pounds of ash per pound of coal (as fired)

W_f = pounds of coal burned during test

A_{r1} = pounds of ash per pound of last-pass hopper refuse

W_{r1} = pounds of last-pass hopper refuse deposited during test

A_{r2} = pounds of ash per pound of ash-pit refuse

W_{r2} = pounds of ash-pit refuse deposited during test

A_{r3} = pounds of ash per pound of precipitator refuse

W_{r3} = pounds of precipitator refuse deposited during test

R = total weight of refuse deposited during test

e_p = assumed efficiency of precipitator = 94%

$\%_p$ = percentage of refuse to precipitator

C_{r1} = pounds of carbon per pound of refuse in last-pass hopper

C_{r2} = pounds of carbon per pound of refuse in ash-pit

C_{r3} = pounds of carbon per pound of refuse in precipitator

W_f = pounds of coal burned during test

HHV_f = higher heating value of coal (BTU/#)

H_s = BTU

h_s = enthalpy of steam leaving boiler

h_{fw} = enthalpy of feedwater entering boiler

H_{r1} = heat in last-pass hopper flyash (BTU/hr)

H_{r2} = heat in large particle precipitator flyash (BTU/hr)

C_{r2A} = pounds of carbon per pound of larger than 100 mesh precipitator flyash

$\%r_{2a}$ = per cent by weight of precipitator flyash larger than 100 mesh

C_{r2B} = pounds of carbon per pound of precipitator flyash between 100 and 200 mesh

$\%r_{2B}$ = per cent by weight of precipitator flyash between 100 and 200 mesh

B3e1. Quantity of Flyash to Precipitator

$$A_c \times W_f = A_{r1} \times W_{r1} + A_{r2} \times W_{r2} + A_{r3} \times W_{r3}$$

$$.086 \times 142{,}000 = .631 \times 1379 + .629 \times 1323 + .803 \times W_{r3}$$

$$W_{r3} = \underline{\underline{13{,}100\ \#}}$$

B3e2. Total Weight of Refuse Deposited in 8 Hour Period

$$R = W_{r1} + W_{r2} + W_{r3}$$

$$R = 1379 + 1323 + 13100$$

$$R = \underline{\underline{15{,}802\ \#}}$$

B3e3. <u>Refuse Distribution (per cent)</u>

(a) In Last-pass Hopper $= \frac{W_{r1}\ (100)}{R}$

$$= \frac{1379\ (100)}{15802}$$

$$= \underline{\underline{8.72\%}}$$

(b) In Ash-pit $= \frac{W_{r2}}{R}$

$$= \frac{1323}{15802}$$

$$= \underline{\underline{8.37\%}}$$

(c) To Precipitator $= \frac{W_{r3}}{R}$

$$= \frac{13100}{15802}$$

$$= \underline{\underline{82.91\%}}$$

(d) Collected by Precipitator

$$= e_p \times \%_p$$

$$= .94 \times 82.91$$

$$= \underline{\underline{77.9\%}}$$

B3e4. Loss Due to Carbon in the Refuse (per cent)

(a) Loss in Last-pass Hopper Refuse (per cent)

$$= \frac{14150\ (W_{r1} \times C_{r1})}{W_f \times HHV_f}\ (100)$$

$$= \frac{14150\ (1379 \times .369)}{142{,}000 \times 13850}\ (100)$$

$$= \underline{\underline{.366\%}}$$

(b) Loss in Ash-pit Refuse (per cent)

$$= \frac{14150\ (W_{r2} \times C_{r2})}{W_f \times HHV_f}\ (100)$$

$$= \frac{14150\ (1323 \times .371)}{142000 \times 13850}\ (100)$$

$$= \underline{\underline{.354\%}}$$

(c) Loss in Precipitator Refuse (per cent)

$$= \frac{14150\ (W_{r3} \times C_{r3})}{W_f \times HHV_f}\ (100)$$

$$= \frac{14150\ (13100 \times .197)}{142000 \times 13850}\ (100)$$

$$= \underline{\underline{1.84\%}}$$

(d) Total Loss Due to Carbon in the Refuse (per cent)

$$= .366 + .354 + 1.84$$

$$= \underline{\underline{2.56\%}}$$

B3e5. BTU in One Pound of Steam (net)

$$E_s = h_s - h_{fw}$$

$$= 1362 - 312$$

$$= \underline{\underline{1050\ BTU/\#}}$$

B3e6. BTU in Last-pass Hopper Flyash

$$H_{r1} = 14150\ C_{r1} \times \frac{W_{r1}}{8}$$

$$= 14150 \times .369 \times \frac{1379}{8}$$

$$= \underline{\underline{900,000\ \text{BTU/hr}}}$$

B3e7. BTU in Large Particle (200 mesh) Flyash Deposited in the Precipitator

$$H_{r2} = 14150\ \frac{(C_{r2A} \times \%r_{2a} + C_{r2B} \times \%r_{2B})}{100} \times \frac{W_{r2}}{8} \times e_p$$

$$= 14150\ \frac{(.566 \times 8.6 + .367 \times 19.3)}{100}\ \frac{13100}{8} \times .94$$

$$= \underline{\underline{2,600,000\ \text{BTU/hr}}}$$

B3e8. Steam Available in Large Particle Flyash (#/hr)

(a) In Last-pass Hopper $= \frac{H_{r1}}{H_s}$

$$= \frac{900,000}{1050}$$

$$= \underline{\underline{860\ \#/\text{hr}}}$$

(b) In Precipitator $= \frac{H_{r2}}{H_s}$

$$= \frac{2,600,000}{1050}$$

$$= \underline{\underline{2480\ \#/\text{hr}}}$$

(c) Total Steam Available in Large Particle Flyash

$$= 860 + 2480$$

$$= \underline{\underline{3345\ \#/\text{hr}}}$$

B4. Last-pass Hopper Carry-over	
Hours Deposited in Hopper	Time to Pull Hopper Empty (Sec.)
2	120
2	136
2	68
2	53
4	156
4	124
5	89
5	136
6	195
6	210
8	236
8	110
10	196
14	192

DISCUSSION

It had originally been proposed that the investigation be made with regards to the whole plant, the plan being to collect the last-pass hopper flyash from all units except the one into which it would be injected for burning. This was at first thought necessary because of the excessive gas loading expected due to recirculation. This theory is explained more fully in the Review of Literature section of this thesis. Once the investigation began to progress, however, it was found that the quantity of last-pass hopper flyash available was too small to cause concern and, too, the method of pulverizing the flyash prior to injecting for reburning practically eliminates the possibility of recirculation. The burned flyash will be small, light, ash particles like those carried by the gases to the precipitator. Therefore, it was decided to confine the investigation of quantity and carbon content to one unit. Another factor which aided in arriving at this decision was the expected reproducibility of results. Four of the units, numbers 3, 4, 5, and 6, are Riley Stoker Corporation make. Units 5 and 6 are larger replicas of 3 and 4. Results obtained by investigating one of the units would be applicable to any of the others. These four units constitute 82.5 per cent of the rated capacity of the installation and have a greater operating priority than do units 1 and 2.

It is of prime importance that the steam generators continuously supply sufficient process steam and steam for electrical generation. Therefore, preparations for making tests and decisions made in deciding on which unit a particular test was to be run depended considerably upon this consideration. For instance, the burning test was performed on unit number 4 since the load supplied by this unit could be absorbed by the larger units if the fire were lost. Even so, every precaution was taken to assure that no large fluctuation in the unit's output would be experienced as would be the case if the flame blacked out.

Al Per Cent Carbon in Flyash Refuse

Observing the plot of per cent carbon in refuse versus time made from data kept by the Celco plant of the Celanese Corporation of America, where this thesis investigation was made, revealed that there were large variations in the per cent carbon in refuse ranging from 10% to 58%. See Figure 4, page (36). It was these variations in per cent carbon and the resulting search to find the reason for these variations which revealed that the last-pass hopper had such a significant percentage of carbon. The analysis of the refuse was made from samples taken weekly from the silos where all the refuse material is collected prior to being loaded into trucks for final disposal. The variations in the per cent carbon in the refuse is due to the sample being taken from different places of the furnace, the value of the per cent carbon depending on what ash was in the silo at the time the sample was taken. It is obvious that such a procedure does not give a true picture of the losses resulting from unburned carbon. However, it is probably safe to assume that the average for a large period of time gives a fairly accurate picture.

FIG. 4
PERCENT CARBON
IN THE REFUSE

The carbon content of the flyash for the several checks made showed little variation. As previously stated, no attempt was made to keep anything on the unit constant strictly for a check condition. There was sometimes as much as a month's difference between times that the samples for analyses were taken. The fact that the carbon content showed such uniformity for the analyses made shows that the flyash will generally approximate the average of these results.

A2 Size Composition

The sieve analysis was made to give a clearer picture of what makes up last-pass hopper flyash. No data corresponding to that taken regarding last-pass hopper flyash could be found in any books or periodicals the author screened. So the subject was new and any information attainable within the limitations of the time available was felt a gain of knowledge concerning the nature of flyash. In any event, the data taken is only applicable to the units in question and if similar data for other units are required they would have to be taken from those units. But it is believed that the information obtained throughout this thesis is comparable, at least, to units of parallel construction, particularly those built by the Riley Stoker Corporation.

There is noticeable agreement between the data of the several sieve analyses made. There are variations between runs but generalities can be drawn. Seventy to seventy-five per cent of the material is made up of flyash between 30 and 100 mesh, divided about equally between 50 to 100 mesh and 30 to 50 mesh. About 20 per cent of the flyash is between 100 and 200 mesh with the remainder divided between the large over 30 mesh and the small under 200 mesh sizes. It will be noted that there was no attempt to average the analyses made to get decimal point accuracy for size consist since the day by day changes in the analyses due to the many variables of operation would make such an average meaningless. The generalities made from the data are of importance in that they bracket the main quantities making up last-pass hopper flyash and enable a comparison to be made of last-pass hopper material with that which goes to the precipitator.

A3 Grindability

It has been observed by many men in the steam generation field that grindability indices of coal as obtained by A. S. T. M. methods are not the perfect criteria on which to base a comparison of power requirements of coal for pulverization. It is used due to a lack of a more universally accepted method and the impetus it has gained through the years. To a large extent the method fulfils its need but sometimes breaks down as a comparison when applied to different methods of pulverization and to coals of different sizes fed to a pulverizer mill. For instance a coal having a high grindability index may require more power in a hammer mill than one having a lower index. This coal might be more susceptible to pulverization by crushing or attrition forces than to an impact force such as is employed by a hammer mill. The size of the coal fed to a mill is an important consideration. It is easily seen that more power is required to pulverize a large diameter piece than the small nut variety. The A.S.T.M.

machine is a miniature ball-race pulverizer using a crushing action. Coal sized between 16 and 30 mesh is specified for the grindability index.

The last-pass hopper flyash is smaller than 30 mesh, therefore, the standard A. S. T. M. grindability method could not be used. The method for getting a comparable figure for flyash grindability is described on page 16.

The apparent density of flyash is less than that of coal, therefore, the required 50 gram sample of flyash gave a larger volume than a 50 gram sample of coal. This caused the space for pulverizing in the Hardgrove machine to be more crowded when flyash was used and, conceivably, created forces which caused more complete pulverization. This, of course, would be a source of error for the comparative grindability obtained.

Comparative grindability of the flyash was only slightly worse than that of the Smokeless coal, being 113 as compared to 117. The true grindability of the Smokeless coal was 110 and that of the flyash obtained from Figure 5, page 40, was 106.

The important result obtained from the grindability analysis was that the flyash could be pulverized and it apparently could be done easily. This was quite important since, prior to the investigation, the belief of those the author contacted was that flyash grinding, if at all possible by standard coal pulverizing apparatus, would be extremely difficult. It was also important since it would now be possible to pulverize before burning which would increase the possibility of more complete combustion and reduce the possibility of recycling. The problems involving the injection of the flyash both for the burning test and in the case of a permanent

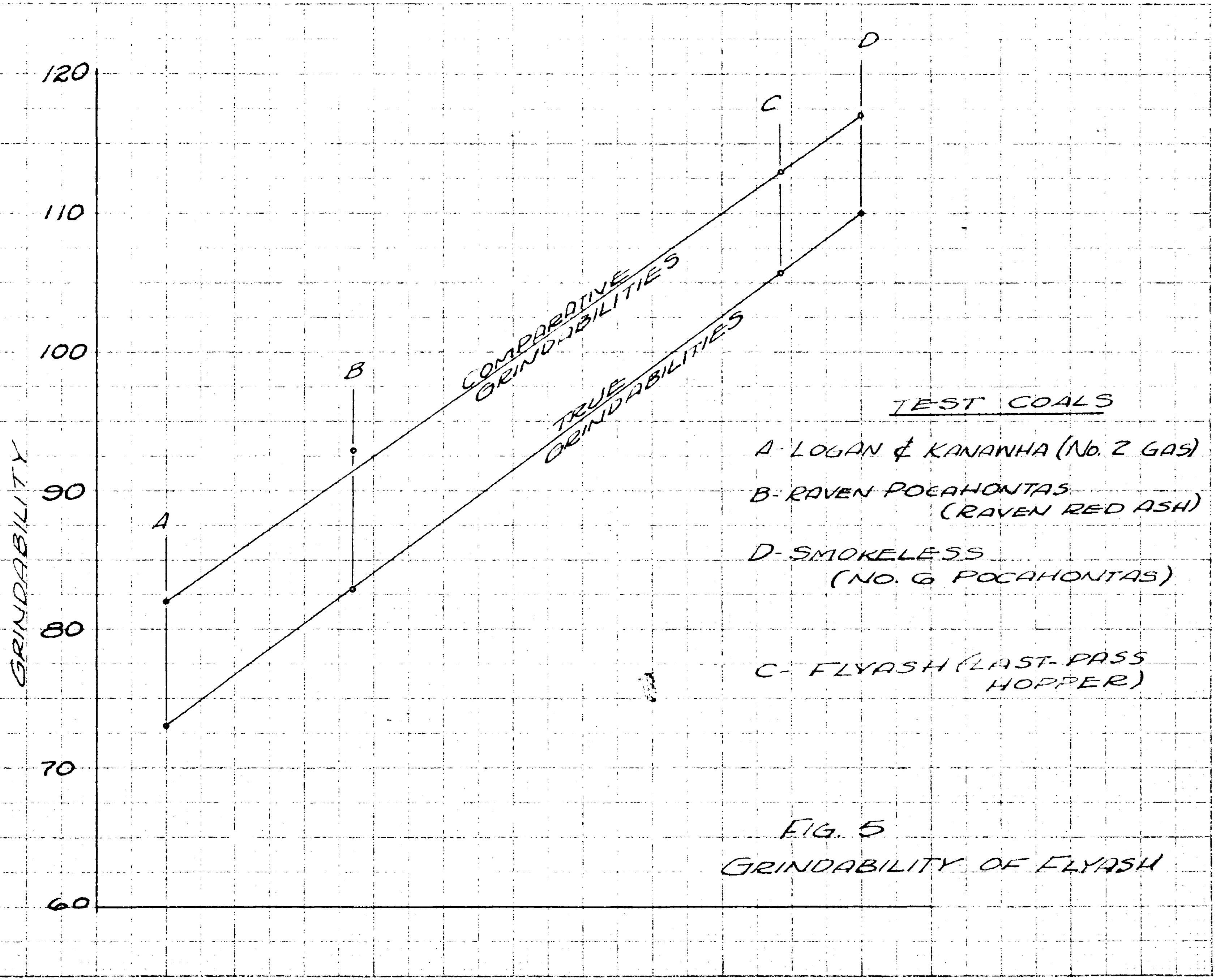


FIG. 5
GRINDABILITY OF FLYASH

arrangement for reburning were more easily solvable since it was necessary only to get the flyash to the pulverizer from whence the primary air would convey it into the furnace.

B1. Weight of Flyash Deposited

The quantity of flyash in the last-pass hopper was disappointly small from the standpoint of recoverable heat from this material. The amount deposited for the spot checks gave a deposition rate of from 112 pounds per hour to 210 pounds per hour. Most of the runs, however, were around 175 pounds per hour. This was done on unit number 6 with the load at the times of the tests being anywhere from 170,000 pounds of steam per hour to 200,000 pounds of steam per hour. The only observation made of the coal was for the test giving the largest amount, 210 pounds of flyash per hour. For this run it was observed that the fuel was wet storage coal although it was the average type used. This seems reasonable since a pulverizer does not do as good a job of pulverization when moisture in the coal increases. Therefore, since a greater percentage of large particle coal was being discharged from the pulverizer and injected into the furnace, it follows that more large particle cenospheres were formed and ultimately dropped out into the last-pass hopper. It did not fall within the scope of this thesis to follow through with this observation and even go further into an investigation of various types of coal upon flyash distribution. It is suggested, however, that such an investigation would be both interesting and worthwhile.

All of the checks made gave a higher deposition rate for the north hopper. This is probably due to the way the turbulent burners are set to swirl the air-coal mixture. This fact that the outer hoppers contained more flyash than the center ones is due in part at least, to the velocity gradient. The velocities toward the outside are less than in the center and are not as great as the terminal velocities of the particles, which allows them to fall into the hopper.

It was noticed that there was carrying over into the vacuum system of some of the small dust particles when the last-pass hopper flyash was being deposited into the 50 gallon drum. A check revealed that this material was smaller than 200 mesh and approximated one per cent of the total, a small enough quantity to be considered negligible.

B2. Burning Test

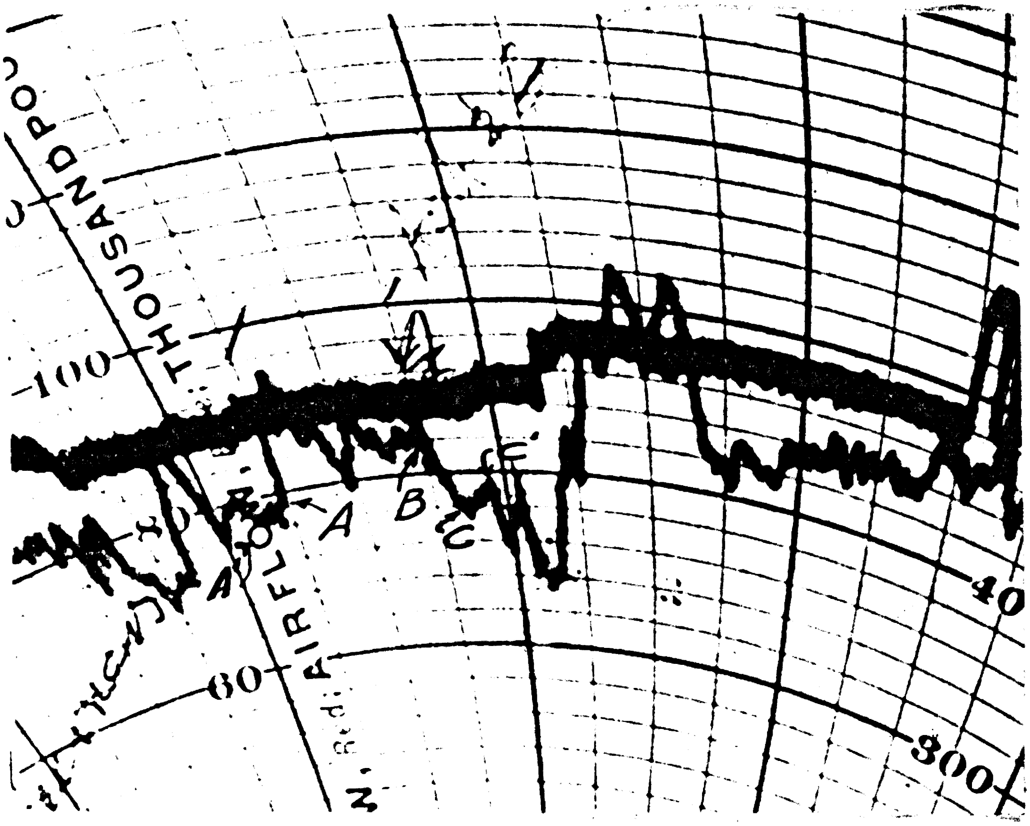
The theory governing the performance of this test was that if a large amount of flyash would burn with a small amount of natural gas then a small amount of flyash would burn with a large amount of medium volatile coal, the kind normally used by the Celco plant. This seemed reasonable enough to the author and to those whose advice he was able to receive immediately. A trip was made to the Batelle Memorial Institute, however, for a discussion of the thesis work in general and, in particular, to get the opinion regarding this burning test theory of men whose work is of a practical research nature. They, unanimously, were of the opinion that such a conclusion was a sound one.

The procedure employed for the burning test was necessary for three reasons. First, the means of injecting the flyash was considerably simpler by injecting with gas rather than mixing with coal. Second, the load imposed on the pulverizer by the flyash could be observed and interpreted more closely. Third, the general procedure of starting and stopping segments of the load could more readily be handled.

Two items of the data give an indication as to the extent of the burning of the flyash. The most direct and significant is the load as read from the steam flow chart, Figure 6, page 44. The constant load produced by the coal from the top two burners and the gas and flyash from the north bottom burner was read as 85,000 pounds per hour. When the flyash feeding was discontinued this load dropped immediately to 76,000 pounds per hour. The other item which indicated the flyash was burning to a good degree, verifying the results of the steam flow chart, was the CO_2. With just coal and gas this value was 12.8 per cent but with flyash injection it was 14.8 per cent, indicating that the carbon in the flyash was being burned to CO_2, a product of complete combustion.

The efficiency of the flyash burning amounted to approximately 80 per cent. This is considered approximate since the amount of steam produced is only as accurate as the ability of the observer to read the flows recorded on the steam flow charts. Very accurate readings are impossible here due to the scale of the chart and the normal fluctuations of the unit's output even when on hand control, maintaining as constant a load as possible. This value was, however, high enough to say safely that a percentage of heat conversion was obtained approaching the normal efficiency the unit attains when burning coal.

The Ringleman Number of the gases emitted from the stack was read from an electronically operated meter for the two conditions of the test.



A - FLYASH FEEDING BEGUN

B - FLYASH FEEDING STOPPED

A-A' & C-C' LOAD WITH GAS AND COAL ONLY

FIG. 6

BURNING TEST FLOW CHART

There was only a slight increase in this value when flyash was burned. The stack emission at the Celco plant is considered important and, even though the Ringleman Number of 2.8 which was recorded during the flyash burning period is not considered prohibitive for the unit, the fact that an increase in Ringleman Number accompanied the burning of flyash is undesirable.

The pulverizer load was quite high for the first burning test, making the results obtained from the flyash grindability data seem paradoxical. Therefore a recheck was made to verify or nullify the pulverizer load recorded from the original burning test. This check, carried on in much the same manner as the first burning test, revealed more satisfactory results in that the load required for pulverization of the flyash approximated more closely that which is needed to pulverize a similar quantity of coal.

It was planned to get data for the second burning test corresponding to that of the first but steam production data was, unfortunately, not obtainable. This was due to the inability to keep the unit's load from swinging which, of course, made the recording of meaningful loads impossible. It was observed, however, that the Ringleman Number and the CO_2 behaved as they had previously.

Air conveying the flyash from the pulverizer to the furnace was increased for the second burning test since it was felt that this was responsible for the unduly high pulverizer load experienced in the burning test. With too little air flyash which had been pulverized sufficiently would remain in the pulverizer to be repulverized an unnecessary amount, tending to overload the pulverizer.

B3. Ash-Balance

Since the last-pass hopper quantities were small, giving a low recovery value for this material, it was thought advisable to determine the amount of similar material which deposited in the precipitator. This was the prime reason for running the ash balance test. If this quantity proved large enough future plans for the recovery of the large particle precipitator flyash might be justifiable. The burning of large particle flyash had previously been proven, thus, the assumption that the large particle precipitator material would be adaptable for heat recovery seemed logical, providing its analysis paralleled that of the last-pass hopper flyash.

The quantity and distribution in the various hoppers of the last-pass hopper flyash during this check were comparable to that found for previous checks. The hopper distribution has already been discussed on page 42. The quantity is lower than the average of the previous spot checks made which seems to verify the flyash carry-over theory. For this test the flyash was permitted to collect for an eight hour period, whereas, for the spot checks the period of deposition was for only one hour. The quantity of refuse deposited in the ash pit and the hopper distribution of this refuse was similar to the last-pass hopper quantities and distribution. An explanation for the distribution is the same as for the last-pass hopper's found on page 42.

The carbon in last-pass hopper refuse is much the same as found from previous checks. The ash pit refuse carbon percentage was found for refuse exposed to the furnaces radiant heat and for refuse not exposed to the radiant heat. That which was exposed contained 24.4 per cent carbon and that not exposed contained 37.1 per cent carbon showing that 12.7 per cent of the refuse oxidized to CO liberating some heat or, putting it another way, one-third of the carbon in the refuse which dropped to the furnace bottom oxidized liberating heat. Because of unfavorable air conditions in this area some engineers doubt if this CO burns to CO_2 unless a grate and correct amount of air is provided. One new large utility plant puts flyash on a grate and provides air to assure its complete combustion. This was an incidental portion of the test, included so that the value of allowing refuse to lay in the furnace might be observed. This observation might prove valuable if the possibility of laying the high carbon last-pass hopper flyash on the furnace bottom is given future consideration.

The precipitator refuse data from which calculations were made of the worth of high-carbon precipitator material was made from a sample drawn from the precipitator hopper as shown on Figure 4, page 36. It was noticed that the sized precipitator samples contained a higher percentage of carbon than like sizes of last-pass hopper material. This is explainable from the standpoint of the effect of the particle's apparent density on the terminal velocity. As the apparent density increases so does the terminal velocity of the particle. The velocity of the gases required to carry the less dense material is thus smaller than for the heavier material. And, since the ash of the refuse is the heaviest and most dense of the flyash constituents it follows that the lighter material containing less ash and more carbon is carried on to the precipitator. Likewise the heavier particles are influenced more by the centrifugal force created by the change in direction around the baffle into the last pass than are the light particles.

To find the refuse distribution it was first necessary to determine the quantity of refuse which went to the precipitator. This was done by calculating the ash in the coal equal to the total ash in the refuse. Once the percentage of the refuse to the precipitator was found a precipitator efficiency of 94 per cent was assumed to evaluate the percentage of the refuse collected by the precipitator. This is one of the sources of error for this test. The Research Corporation test engineers ran several tests on the same precipitator and found its efficiency to range from 93 per cent to 95 per cent. Since this element is relatively new it was assumed that it is doing as well now. Another source of error is the value used for the carbon content of the aggregate precipitator refuse. Although this value in itself is correct it was used assuming the refuse in the precipitator and that out the stack to be of the same value. This is not true since one of the characteristics of an electrostatic precipitator is its inability to separate large high carbon material. This means that the 6 per cent which was discharged to the stack was good high carbon flyash making the recovery value of high carbon flyash as calculated somewhat on the conservative side. It is regrettable that limitations of time and available equipment did not permit a true determination of the value of stack refuse. The refuse distribution and the value of high carbon flyash actually collected were affected little by this since, in proportion, the stack discharge is small as compared to the total.

The loss due to combustible in the refuse was 2.56 per cent which is not unusually large. The breakdown of this loss is significant. The loss due to last-pass hopper flyash amounted to .366 and, considering an approximate recovery efficiency of 80 per cent, would give only .293 per cent increase in efficiency utilizing last-pass hopper flyash. The steam available in the last-pass hopper flyash was 860 pounds per hour and, with a recovery efficiency of 80 per cent, would yield only 690 pounds per hour. The precipitator high carbon material is a much larger figure, with 2480 pounds of steam available and with a recovery efficiency of 80 per cent would make 1984 pounds of steam per hour. This quantity of steam amounts to an increase in efficiency of .85 per cent. If the total of the last-pass hopper flyash and the large particle precipitator material were utilized the increase in efficiency would be 1.143 per cent and produce 2674 more pounds of steam per hour.

B4. <u>Last-Pass Hopper Carry Over</u>

The data from the last-pass hopper carry over test were very discouraging. The resulting trend of the plotted data, Figure 7, page 50. is hardly perceivable. The points are so scattered that a conclusion that there is any trend at all is questionable. Therefore, no conclusions can be definitely drawn from the data obtained.

A discussion of the reasons for such random results is all that is applicable to this data. In the first place the time that the air inlet valve opened wide was not as clearly defined as was desirable. Thus, the time recorded depended to some extent upon the man who was making the reading and, since there were several people taking this data, depending on the operating crew that was on at the end of a deposition period, a good percentage of the error can be attributed to this. Another source of

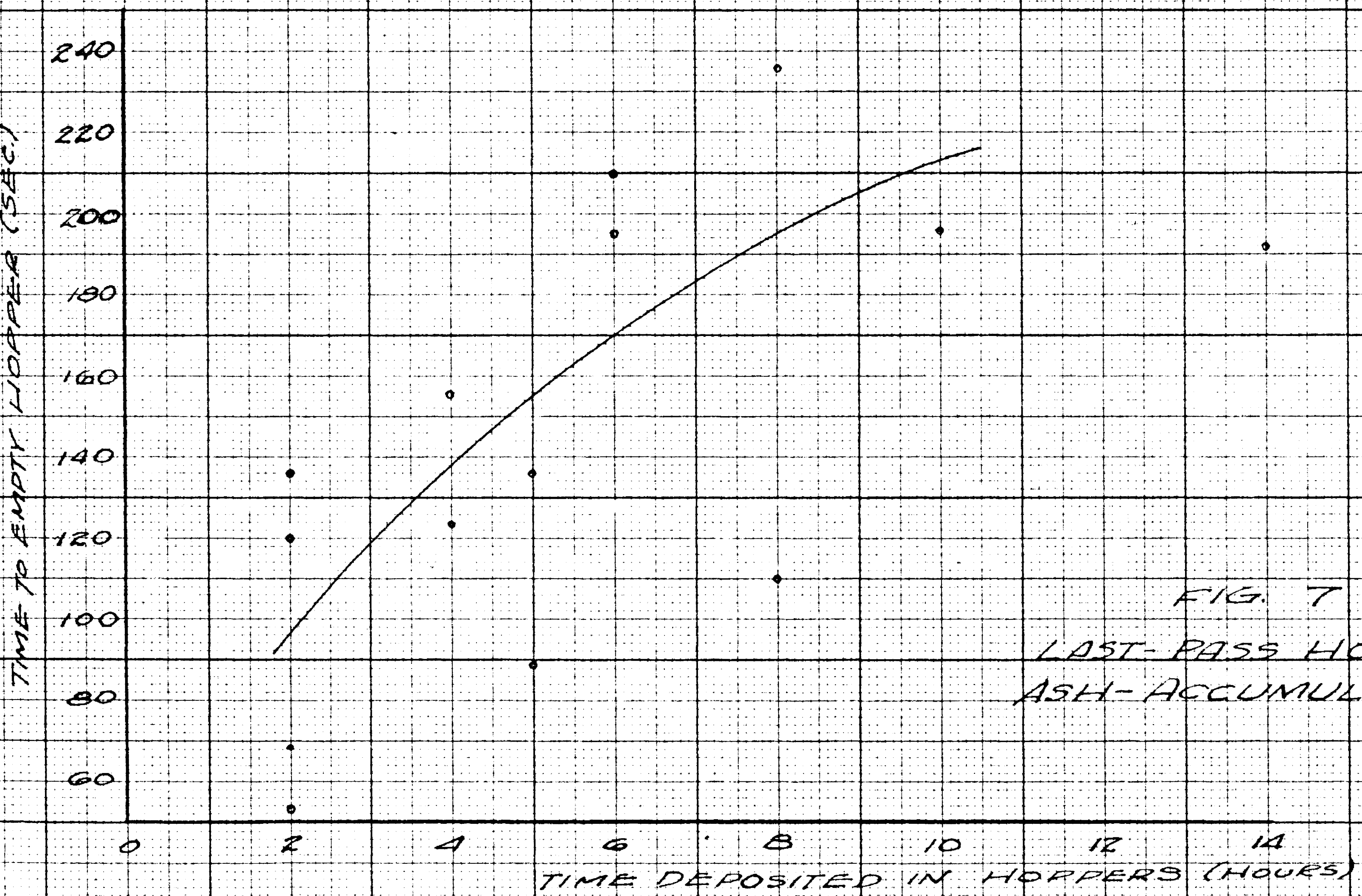


FIG. 7
LAST-PASS HOPPER
ASH-ACCUMULATION

(50)

error lies in the original premise that the rate of pull would be equal at all the hoppers and during the entire time of the pull. It is conceivable that such would not be the case since, as the hopper emoties a point is reached where flyash is still flowing into the ash disposal header but not in a sufficient quantity to keep the inlet pipe filled. This, of course, would allow more of the suction to be applied to gasses from the hopper and to the air inlet valve.

C. Photomicrographs

Pictures of flyash, Figure 8(a,b,c), magnified 19 diameters were made (see pages 52 and 53) For a clearer conception of the reduction in particle size which took place in the pulverizer a picture of flyash before and after pulverization was made. The increased surface area resulting from pulverization is clearly shown by comparing these pictures. The photomicrograph of the flyash before pulverization shows clearly the thin-walled cenosphere structure. The ash particles stand out quite clearly, being much lighter than the high carbon cenospheres. In reality microscopic observations revealed them to be anywhere from white to yellow.

The large particle precipitator flyash picture shows it to be composed, essentially, of the same material that is collected in the last-pass hoppers. They, too, are cenospheres with interspersed particles of pure ash.

D. Reburning Discussed

The author is not going to attempt to arrive at a conclusion as to whether it is advisable to burn high carbon flyash or not. For the benefit

8a

Figure 8

PHOTOMICROGRAPHS OF FLYASH

8a. Large Particle (+200 Mesh)
Precipitator Flyash

8b. Last-pass Hopper Flyash
(Aggregate Sample)

8c. Last-pass Hopper Flyash
(Pulverized Aggregate Sample)

8b

8c

Figure 8

of those who may use the data to arrive at such a decision a few of the things which must be considered will be discussed.

It was proved that high carbon flyash will burn, therefore, the following discussion will be concerned with the advantages and disadvantages of a system devised to continuously burn high carbon flyash.

Accompanying the injection of flyash will be an increased quantity of ash to the furnace. This produces the possibility of slag build-up and erosion. Before the effects of flyash on these two factors can be known the system would have to actually be tried and observations made for a long period of time. The additional ash by just injecting last-pass hopper flyash would increase the percentage of ash to the furnace but a small amount, however. In the case of the ash balance test run in this investigation it would have amounted to only 0.6 per cent which means that, as far as ash content is concerned, it would have been comparable to burning coal of 9.2 per cent ash rather than coal of 8.6 per cent ash.

It would normally be expected that flyash would create additional wear on a pulverizer, but from the grindability determination it is seen that the flyash introduces no unusual grinding problem. This also was borne out by the second burning test since the pulverizer load was small. Because of its cenosphere structure last-pass hopper flyash is quite easily ground.

In order to make a continuous injection system for last-pass hopper flyash additional piping will be required. The pressure at the last-pass hopper averages about one inch of water and at the pulverizer inlet is about 1.3 inches of water which means that a jet or some similar arrangement will be necessary to get the flyash into the pulverizer. This should prove an easy problem. The expenditure for additional piping could partially be written off by the salvage value of the existing last-pass hopper ash removal system. Maintenance and replacement for an injecting arrangement would hardly be any greater than that for the existing set up.

A monetary gain for an injecting system would be received by (1) an increase in steam output for a given quantity of coal, (2) discontinuance of the use of steam to operate the pneumatic conveying system, and (3) the decrease in amount of haulage for refuse disposal. This value is admittedly small being approximately $0.35 per hour for the ash balance test of this investigation. A much larger savings could be made if a means were provided for the recovery of the large particle precipitator material. The author believes that the quantity found there is well worth further investigation.

CONCLUSIONS

It is evident from the literature read, experience of operating engineers, and the results from the various tests and observations made in connection with this study that there is very little known about fly-ash. A few things were found out in the investigation that add a small bit to the knowledge of this very elusive subject.

1. It can be said that last-pass hopper flyash in a pulverized coal unit can be pulverized, reinjected, and will definitely burn with a fair efficiency.

2. There was not enough last-pass hopper material to justify much reinjection equipment to recover it, but more complete separation at this point is possible and may be practical.

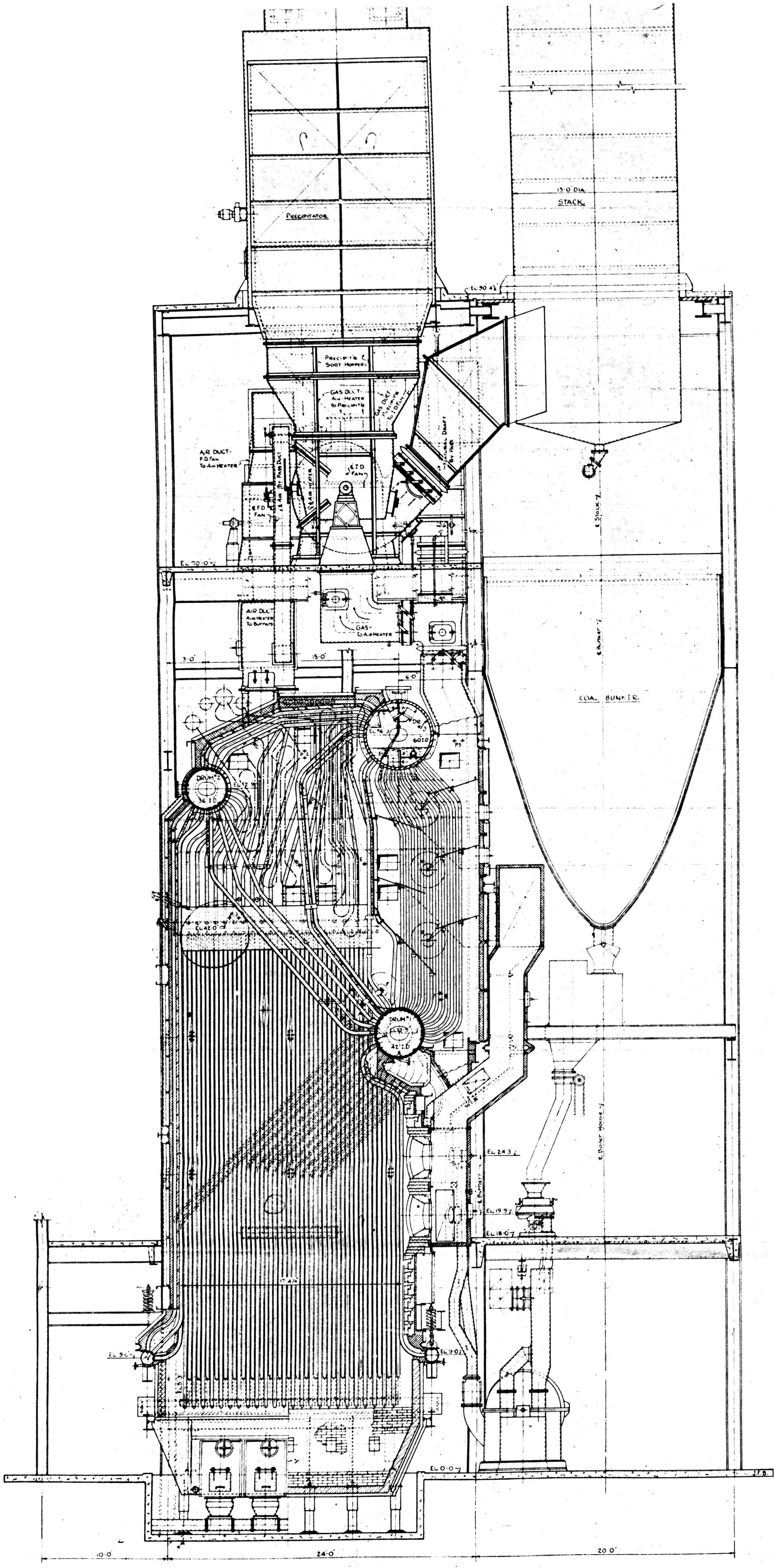
3. In a pulverized coal steam generator about 70 per cent of the unburned carbon loss is in large sizes which could be separated from the low carbon refuse. This carbon rich flyash contains only about 30 per cent of the total ash. From this standpoint, then, the recirculation of carbon rich flyash begins to be attractive.

RECOMMENDATIONS

The results of this investigation indicate that further study should be made on a number of items. Some of these would be necessary before practical use could be made of the facts uncovered.

It is suggested that the Celco plant investigate:

1. the cost of various methods of separating a greater percentage of large particle flyash.
2. the value these methods have by (1) increasing boiler efficiency and (2) reducing the plant dirt problem.
3. what it would cost to pulverize the flyash directly in existing pulverizers as compared with pulverizing it in small auxiliary pulverizers.
4. more fully investigate the test data of this thesis, especially the irregular and uneven rate of deposition in the last-pass hopper and ash-pit.
5. the formulation of a routine procedure for obtaining more complete plant data. This may point to higher efficiencies.



CELANESE CORPORATION OF AMERICA

Narrows, Va.

TWO RILEY STEAM GENERATING UNITS

Consisting of Riley Boiler, Water-Cooled Furnace, Steel-Clad Insulated Setting. Riley Pulverizers and Burners. Capacity 150,000 pounds of steam per hour.

Engineering Data:

Efficiency - 86.2% @ 150,000 lbs.

Working Pressure - 600 lbs.

Temperature - 800° F.

Furnace Volume - 8,800 cu. ft.

Heat Release - 22,700 B.T.U.

Heating Surfaces:

Boiler - 11,100 sq. ft.

Water Walls - 5,500 sq. ft.

Scale: 1/8 inch equals 1 foot

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