TABLE 15. - Royster stove data for selected coal runs of October 12 and 13 on pilot-plant generator (Cont'd.)

Date	October 12 A	October 12 B	October 13 A	October 13 B	October 13 A	October 13 B
Thermocouple in products of combustion outlet at bottom of stove:						
Ave. temp. at end of blast period ...... °F.	312	362	465	488	362	437
Ave. temp. at end of steam period ..... do.	238	270	256	322	240	318
Estimated temperature of superheated steam from stove, assuming same temperature difference between top of pebble bed and superheated steam as in first two runs of October 12 . °F.	2,950	3,060	3,050	3,090	3,040	3,070

Projected Program

Based on the work to date, it appears that the fundamental approach to the problem is sound. During the succeeding months, the mechanics of the operation and construction of the pebble stoves will be completed, so that data for large-scale design will be available. It will be necessary to conduct extensive tests to determine the best method of coal, oxygen, and steam injection. Methods for handling slag deposits in the generator must be worked out and the problem of dust removal from the gas stream studied. Adequate supplies of gas for the study of other purification problems will be available early next year.

Pneumatic Feeder for Finely Divided Solids

In the course of development work on the gasification of pulverized coal at the Synthesis-Gas Production Laboratories at Morgantown, W. Va., a mechanism to feed finely pulverized coal to a reactor became necessary. The feeder described in this report was developed to fill that need, but it should be applicable to the feeding of any finely divided solid.

In the gasification of pulverized coal in entrainment, the total residence time of a coal particle in the gasifying zone is probably, at most, about a second; hence, if the coal feed varies over even fractions of a second, then both the ratio of coal to gasifying agents and the gas composition will vary widely, resulting in poor operation. Although this average rate is steady, mechanical feeders are inherently unsteady over short time intervals. Therefore, a pneumatic feeder was desired, with the volume of conveying gas kept to a minimum.

Pulverized coal, when flowing by gravity, often sticks to the walls of the container and arches over the opening. When kept moving slightly by a gas, however, pulverized coal flows easily, even through small-diameter tubes. To make use of this property, the feeder described herein consists of a fluidized bed in which the coal is kept agitated, a fluidizing air outlet, and a coal-delivery tube. The coal and the conveying gas flow through the coal-delivery tube from the fluidized bed to the reactor, while the fluidizing air used is vented from the top of the fluidization chamber.

Operation

A diagram of the experimental apparatus is shown in figure 54. A 4-inch, schedule 40 pipe, 5 feet long, is used as the fluidization chamber. Coal is charged into the apparatus until it is about one-half full. Air enters at the bottom, is

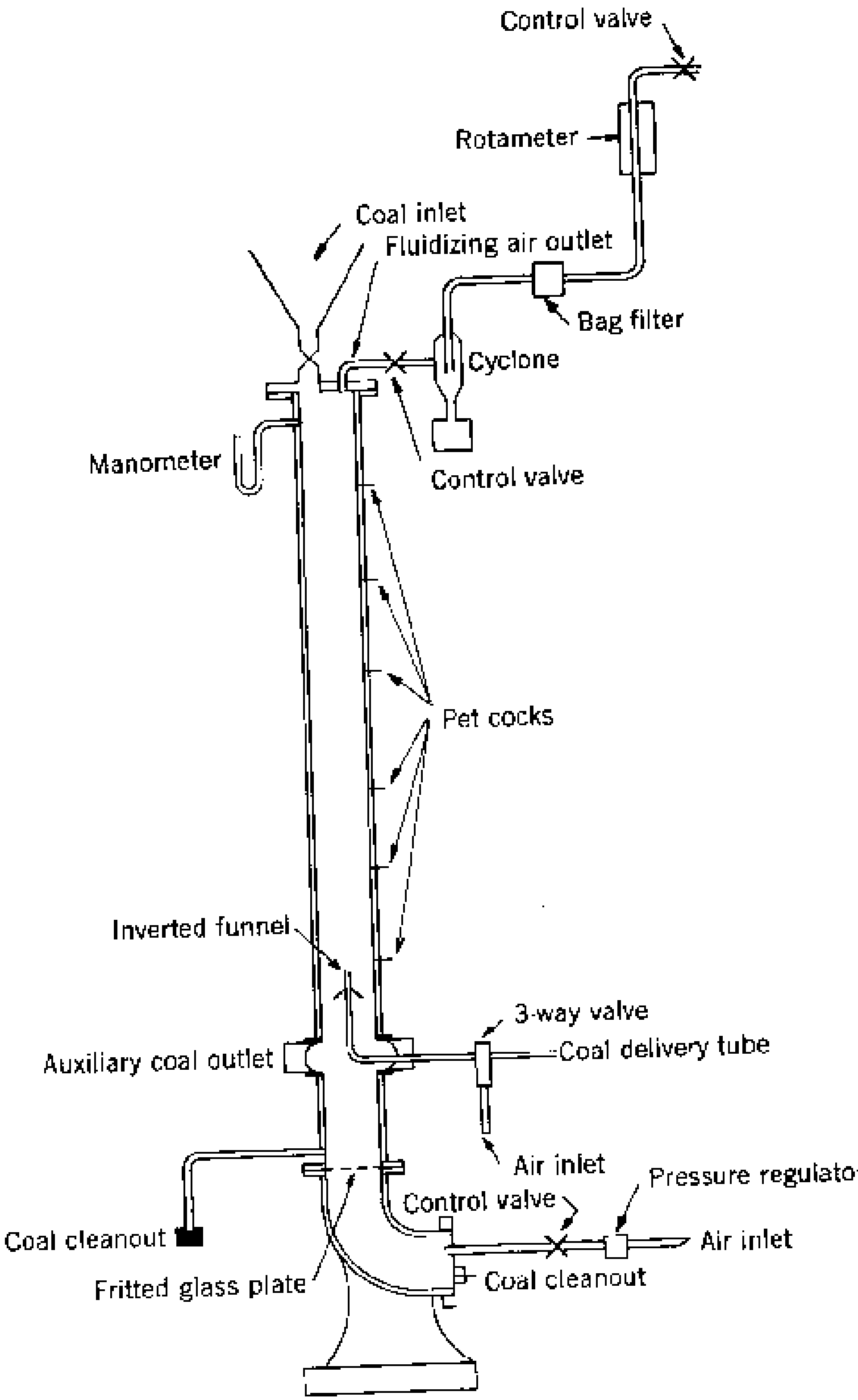

Figure 54. - Pneumatic feeder for finely divided solids.

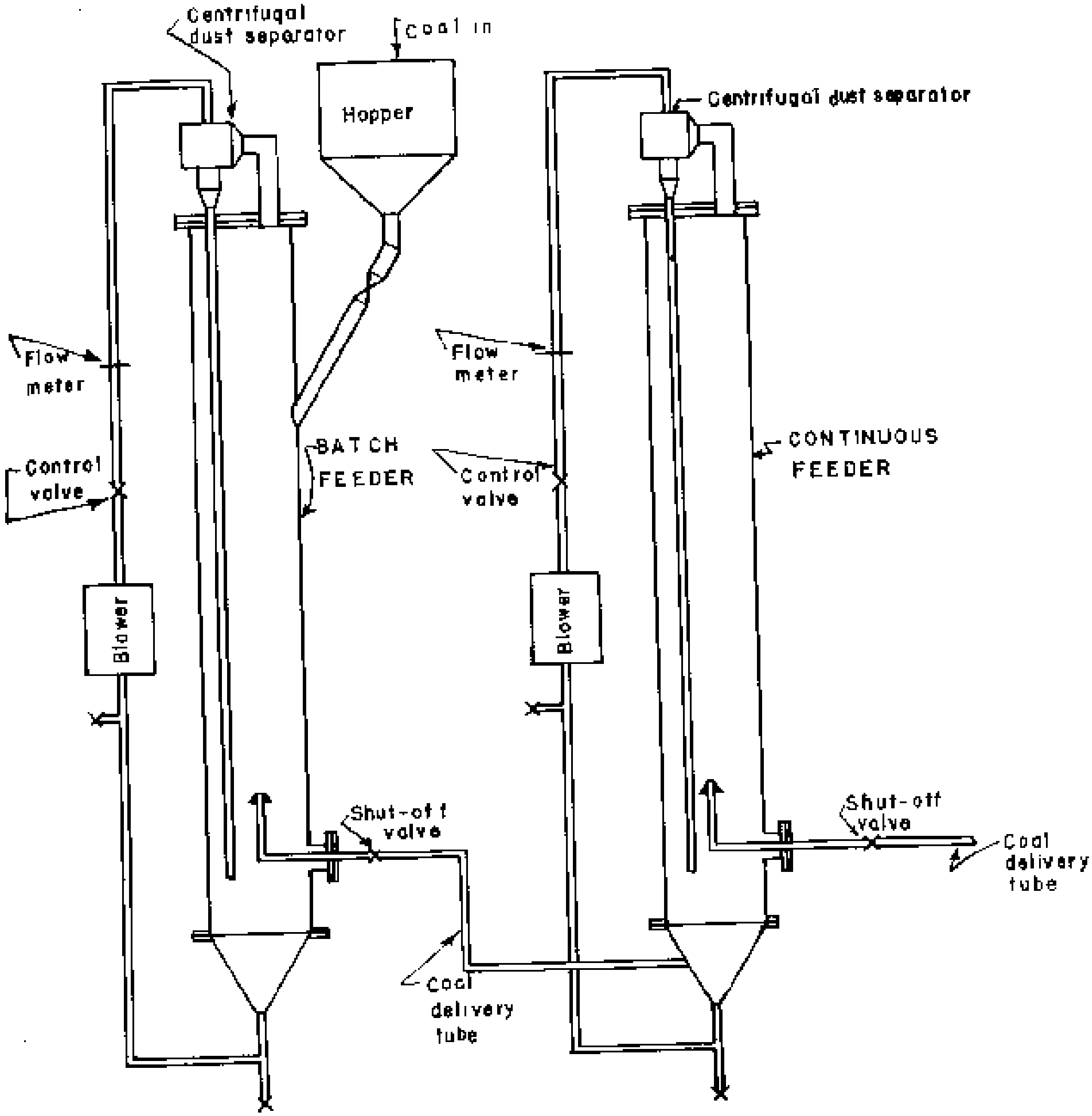

Figure 55. - One arrangement for supplying pneumatic feeder for continuous operation.

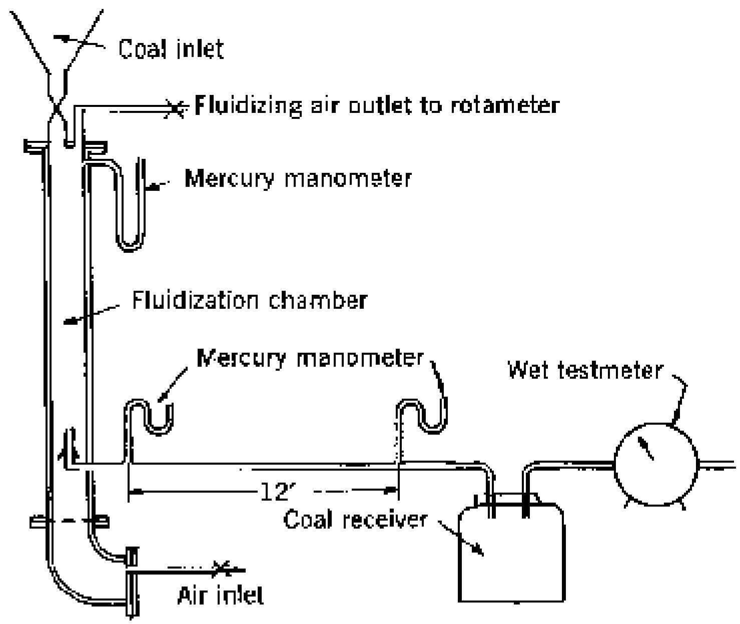

Figure 56. - Apparatus used in test runs on pneumatic feeder.

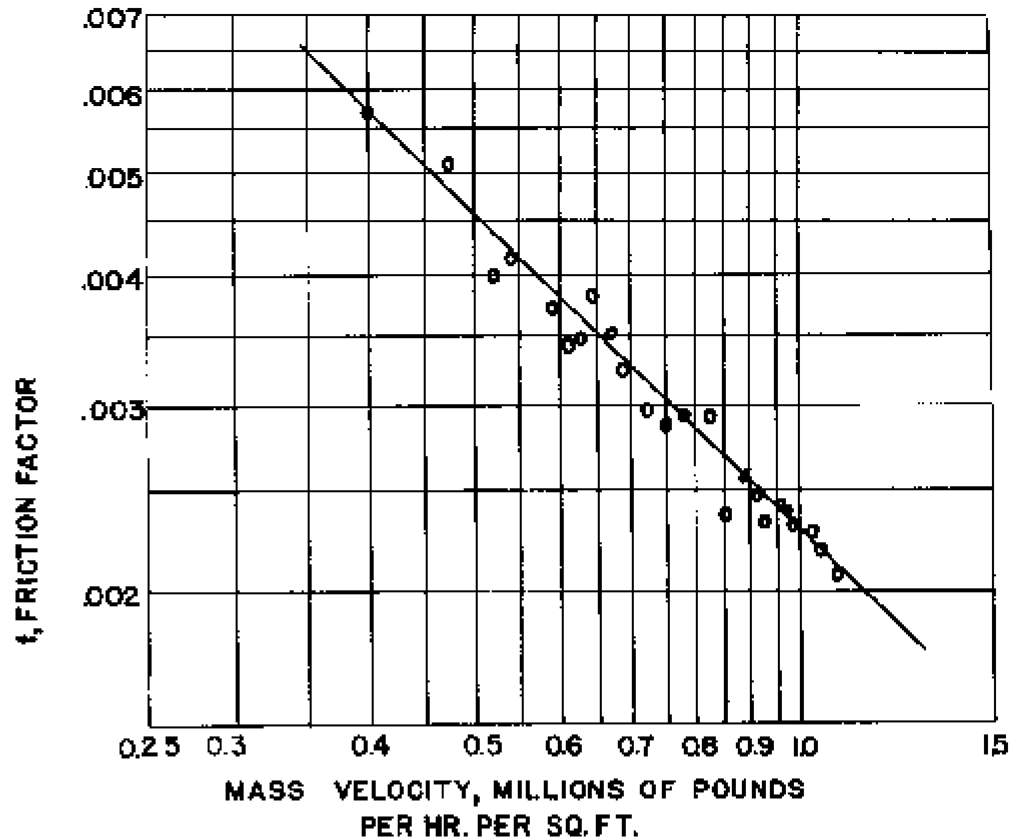

Figure 57. - Effect of mass velocity of coal-air mixture flowing at high density on friction factor in tubes.

distributed by a fritted-glass plate, and fluidizes the coal. The coal then fills about two-thirds of the pipe, and the level may be checked by the petcocks. Fluidization air is adjusted to the desired rate, as measured by the rota-meter. The coal line is blown out by admitting air through a three-way valve, and the coal flow is started by turning the valve to the straight-through position. The operation is steady and the mixture of coal and air uniform. Weight ratios of coal to air of about 200:1 are regularly passed through the coal-delivery tube. No additional air is added to the coal-delivery tube for conveying.

One arrangement for making the apparatus continuous also is shown in figure 55. Coal is fed to the fluidization chamber of the original apparatus from a second feeder, which is operated as a batch feeder. The continuous feeder is operated at a constant coal level in the fluidization chamber, except when the batch feeder is stopped for charging. The continuous feeder has enough capacity to continue operating while the batch feeder is being charged. After the batch feeder has been charged, the coal level in the continuous feeder is restored to its original position and steady operation resumed. In this arrangement, the apparatus is operated without the necessity of shutting down for recharging, and the pressure drop through the coal-delivery tube may be kept constant. In all other respects, the operation is the same as that of the original apparatus.

Results

Test runs were made to learn the operating characteristics of this new feeder and also to obtain data on fluid flow properties of coal-air mixtures at the new extremely high coal:air ratios made possible by this feeder.

The arrangement used in the test runs is shown in figure 56. The fluidization chamber was connected with a 12-foot length of 3-mm. i.d. copper tubing for a coal-delivery tube. The coal was collected in a jar and weighed on scales. The separation of coal and air in the jar was surprisingly complete, only a slight amount of dust being carried over. At the more usual conveying ratios of 5 pounds of coal per pound of air, the separation of coal and air would have required the use of cyclones or bag filters. The volumetric rate of flow of conveying gas was measured by the wet test gas meter as illustrated. Data obtained are plotted in figure 57.

In order to calculate the pressure drop for dense phase flow, the equation below is used.

$$\frac{RT}{M}\ln\frac{p_1}{p_2} + \frac{y}{\varrho_c}(p_1 - p_2) = \frac{y+1}{2g}\left(u_2^2 - u_1^2 + \frac{4fLu_a^2}{D}\right)$$

Nomenclature:

D = tube diameter, ft.

f = friction factor, no units

g = gravitational constant, ft/sec.^{2}

L = length between pressure taps, ft.

M = molecular weight of conveying gas, lb.

P_1, P_2 = pressure at first and second taps respectively, lb./sq. ft.

R = gas constant, ft.-lb./°R

T = temperature, °F.

u_1, u_2, u_a = velocity of coal-air mixture at first tap, at second tap, and average, respectively, ft/sec.

V_a, V_c = specific volume of air and coal respectively, cu. ft./lb.

y = lb. of coal per lb. of air, no units

ρ_c = true coal density, taken as 84 lb./cu.ft.

For dense phase flow in small-diameter smooth tubes, viscous flow prevails beyond the usual transitional range. From this condition, the viscosity mixture of about 200 pounds of coal per pound of air has been found to be about 0.6 centipoise.

Advantages

The feeder produces a steady flow of coal in a solid stream at weight ratios of coal to air of about 200:1. Previous practice in coal conveying used ratios of less than 5 pounds of coal per pound of air. As the coal from the pneumatic feeder flows in a settled state, low velocities in the range of 5 to 10 feet per second may be used in the coal-delivery tube without having the coal settle out. Using coal to air ratios of about 5:1, velocities of 50 to 100 feet per second are necessary to keep the coal from settling out.

The main contribution of the feeder, however, is that it now is possible to charge finely divided solids to an apparatus at a controlled, uniform rate with low contamination due to carrier gas. In the case of a heterogeneous reaction requiring a controlled rate of feeding of finely divided solids, the pneumatic feeder presents an easy method of introducing the powder, regardless of the pressure required in the reactor. The feeder itself has no moving parts, thus minimizing wear.

In using the feeder on a larger scale, it may be arranged in several ways. The powder may be blown into the fluidized bed in the dilute phase, and by entering at the bottom, the carrier gas will serve as fluidizing gas. The feeder then concentrates the solid in the gas stream and removes the fluctuations in the feed rate. If adequate capacity is provided in the feeder, the dilute phase flow to the feeder may be discontinuous. A feeder may also be made continuous by having a mechanical charging device. The feeder promises to solve many problems whose solution previously has been difficult.

Two feeders of the continuous type shown are now in use at Morgantown. One is used with the pilot-plant-scale gasification apparatus. Both are operating satisfactorily. An investigation of the properties of the feeder at higher pressures also is under way.