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DESCRIPTION AND OPERATING CONDITIONS OF THE AUTOMATED LABORATORY HOT BRIQUETTING FACILITY

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DESCRIPTION AND OPERATING CONDITIONS OF THE AUTOMATED LABORATORY HOT BRIQUETTING FACILITY

by

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ABSTRACT

This report describes the construction and typical operating procedures used in an automated laboratory hot briquetting facility.

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1. INTRODUCTION

The use of formed coke for the blast furnace carries with it some potential advantages over coke-oven coke[1,2,3,4,5]. The processing conditions and suitability for formed coke made from coals of different ranks needs investigation, in particular those obtained from Canadian sources[6]. To do this the Canadian Metallurgical Fuel Research Laboratory (CMFRL) with support from the Canadian Carbonization Research Association (CCRA) has undertaken to build laboratory-scale automated equipment with sufficient production capability to produce briquettes under known conditions for statistical evaluation[7,8].

The hot briquetting system consists of an automatic facility using fluidized-bed units to heat and mix coal and char particles, and a heated automatic briquetting press that produces cylindrical briquettes.

The total system is capable of operating continuously for several hours. The controllable variables are briquetting pressure, temperature and time, and the feed ratio and temperatures of the char and coal.

The briquetting press was built by Hovey and Associates Limited, a local consulting engineering firm, and will only be described briefly. The fluidized-bed facility that is used to charge the briquetting press was built at CMFRL. The object of this report is to describe this fluidized-bed facility and its operation in some detail.

Construction of the automated laboratory hot briquetting facility is part of the CANMET, Energy Research Program Processing Project Work Element EP2.2 - New Coking Methods. The work commitment objective is "to provide facilities in CANMET that simulate semi-commercial hot briquetting and pitch bound types of formed coke processes" (EP2.2.1).

2. DESCRIPTION OF FLUID-BED FACILITY

2.1 Overall Description

The fluidized bed facility was built to charge the briquetting press with a hot mixture of char and coal on a timed interval, typically two minutes. The principal features of the facility are shown in Figure 1 with a complete schematic diagram in Figure 2. These figures are used as a basis of reference in this report.

The facility consists of two functionally similar parts of three fluidized bed units (fluidizers) for each of the mixture's components that will be referred to as the holding reservoir, measuring reservoir and heater unit (see Figures 1 and 2). A seventh fluidizer that will be referred to as the mixer (Figures 1 and 2) is common to both parts. It serves to mix the two components and discharges the blend to the briquetting press. All seven beds were fluidized using compressed nitrogen. Each has its own pressure regulator and flow control valve and the gas flow is monitored by flow meters to five of the bed fluidizers. The flows to the two holding reservoirs are not monitored as these are only fluidized briefly.

The principal means of moving material from one fluidizer to another is by a "pressure transfer" method. In this method the gas exhause of a fluidizer is closed causing the fluidizing gas to exhaust into the next fluidizer through a transfer tube submerged in the first fluidized bed. The exhausting fluidizing gas carries material with it.

Borosilicate glass (Pyrex) was used extensively in the construction of the facility for ease of fabrication and convenience.

The essential dimensions of all the fluid bed units together with their construction materials are listed in Table 1.

2.2 The Holding Reservoirs

The holding reservoirs contain the bulk amounts of each of the component materials (Figures 1 and 2). They feed the measuring reservoir where each of the components is proportioned. This occurs when the measuring reservoir fluidized bed level is low. At the low bed level, the fluid in a manomoter that measures the bed pressure drop, moves to a point that exposes a photo-conductive cell to a light source. This triggers the following sequence. The reservoir bed is fluidized for five seconds (SV_1 and SV_{11} open). Transfer of feed material to the measuring reservoir occurs by closing RV_1 and RV_7 until the measuring reservoir original bed level has been restored.

A switch in the photo-conductive cell circuit ensures that no transfer from the holding reservoirs can take place when material is transferred between any of the other beds in the facility.

The construction material of the holding reservoirs is not critical and for reasons of convenience clear acrylic plastic was used. A porous disc of sintered stainless steel serves as the distributor.

2.3 The Measuring Reservoirs

Every two minutes the briquetting press receives a charge of material for one briquette. The charge is composed of char and coal in proportions set by the operation of the measuring reservoirs. The heaters transfer to the mixer an amount equal to that which they receive from the measuring reservoirs. Since the repeatability of this transfer with the measuring reservoirs will influence the final ratio of char to coal in the hot briquettes, this step has a direct influence on briquette quality and consistency.

A vacuum system is used to suck out the necessary amounts. A schematic of the system is seen in Figure 3. The heart of the system is a flask, partly evacuated by a regulated vacuum source. A solenoid valve (S_3 or S_9) switches the flask from the vacuum source to the top of a cyclone, through which gases and material move and separate. The char or coal then drops down to a closed rubber valve above the heater units (RV_2 or RV_6). The construction of the rubber squeeze valve is seen in Figure 4. The quantities transferred are controlled through the setting of the regulated vacuum source and by the length of time that the flask is connected to the cyclone.

The system of vacuum transfer was found to be more accurate than pressure transfer and in a series of transfers the weights typically have a standard deviation of about five percent of the mean (coefficient of variance 5%)[8]. Other inaccuracies are introduced before a charge is delivered to the briquetting press but the end product has sufficient consistency for statistical evaluation.

2.4 The Heater Units

The measuring reservoirs transfer material into the heater units. After the material enters the units it is kept in a hot environment whenever possible. The fluid-bed levels in both heater units and the amounts transferred from them to the mixer, are self-regulating. The transfer tubes of both heater units are placed so as to skim the surface of the beds. As material is transferred into the heater units the level is raised above the inlet of the transfer tubes. The heater unit exhausts are closed by valves (RV_3 and RV_5) and material is transferred out until the bed levels again drop below the transfer tubes. Consequently as much material should be transferred out as is transferred into the heater units. The heater unit exhausts can remain closed until after the next step in the procedure where the hot coal/char charge for the briquetting press has been fully transferred from the mixer unit. The amounts in the heater units are fixed by the placement of the transfer tubes and are designed to be about ten times the quantity of a single transfer. Thus the fluidized beds in the heater units serve as heat sinks that quickly increase the temperature of the incoming material.

The char component is held at a temperature of 700 to 900°C in the heater unit, to overcome heat lost during the subsequent transfer to the mixer unit. These temperatures require that the heater unit be made of stainless steel. The fluidizing gas distributor is constructed out of Fiberfrax sandwiched between nickel-chromium alloy screens. The temperature of the coal component in the coal heater unit must remain below the softening temperature of the binder coking coal (350 to 425°C). The coal heater unit was made by adapting a Pyrex Buchner funnel.

The temperatures of the beds are monitored continuously using a thermocouple immersed in the beds while bed temperature control is maintained by a thermocouple placed on the heating elements on the outside of the fluid-bed units.

2.5 The Mixer

The char heater and coal heater units transfer material to the mixer through heated stainless steel transfer tubes. The function of the mixer is to blend the two components and allow the char to transfer heat to the coal. After a short period of mixing the mixer discharges the contents to the briquetting press through a heated transfer tube.

The mixer need only maintain the equilibrium temperature of the mixture, as heat transfer takes place mainly within the mixture. The equilibrium temperature of the char and coal mixture is arranged to be close to the softening temperature of coal, for example, about 410 to 430°C. Because heating element temperatures approach the softening temperature of Pyrex glass, it was necessary to construct the mixer from a Vycor (96% silica glass) sealing tube. It contains a sintered silica glass disc that is used for the distributor.

The temperature of the coal/char mixture is monitored using a thermocouple with a bare junction which is immersed in the bed to give a rapid response.

2.6 Transfer Tubes

Transfer tubes for the most part are $\frac{1}{4}$ inch O.D. Heated transfer tubes are made of stainless steel, unheated ones of copper. Exceptions are, the transfer tube connecting the char heater unit to the mixer (3/8 inch O.D.)

and the transfer tubes connecting the holding to the measuring reservoirs (½ inch O.D.).

The outlet of the transfer tubes from the measuring reservoirs connects to a cyclone and is fitted with rubber squeeze valves.

2.7 Rubber Squeeze Valves

Simple and effective rubber squeeze valves are used in several places where valves are required to close on particle laden gases. This occurs in the exhausts of the fluidizers (RV_1, RV_3, RV_4, RV_5 and RV_7) and particularly below the cyclones in the transfer tubes from the measuring reservoirs (RV_2 and RV_6). The construction of the valves is shown in Figure 4. Although the details of the valve have appeared previously, it will be described briefly(9).

A short section of an exhaust line or transfer tube is replaced with soft rubber tubing and jacketed with a slightly longer length of glass tubing. A closed annular space is made by two rubber stoppers fitted tightly onto the line. Pressurizing the space within the glass jacket collapses the rubber tubing, closing the valve. The glass jacket is wrapped with clear scotch tape as a precaution against explosion and the rubber stoppers are wired securely into the jacket. The rubber tube is collapsed by nitrogen under pressure (140 kPa).

2.8 Solenoid Valves

There are seven rubber squeeze valves in the facility, each operated through a 3-way solenoid valve (see S_2, S_4, S_5, S_6, S_7, S_8 and S_{10} connected) as shown in Figure 4. Two other 3-way solenoid valves operate the suction transfer (S_3 and S_9). The two holding reservoirs have their supply of fluidizing gas switched on and off through a 2-way solenoid valve, one for each unit (S_1 and S_{11}).

2.9 Timers

A cycling camtimer with 12 cams regulates the sequence of transfers between beds. Except for the valves in the exhausts of the holding reservoirs, all other solenoid valves that operate rubber squeeze valves are directly controlled through switches actuated by the cams. The timing sequence controlled by the camtimer is illustrated in Figure 5.

Each of the solenoid valves on the flasks of the vacuum systems has a delay action controlled by delay timers with separate cam switches (one for each of the coal and char systems) that energize and de-energize the solenoid valves. Two other delay timers control fluidization of the beds in the holding reservoirs for five seconds before a transfer from these units is initiated by the closing of the exhaust valves.

Other cams on the camtimer operate a warning light, start the operating cycle of the briquetting press, operate a buzzer which functions as a vibrator and activate a photo-conductive cell circuit.

2.10 The Vacuum System

The vacuum source for the transfer system (Figure 3) of the measuring reservoirs is provided by a small pump. The reduced pressure is regulated by a Cartesian diver-type regulator. The regulated vacuum source stays connected to a 6-litre flask through a 3-way solenoid valve (S_3 or S_9). These solenoid valves switch the flasks to the transfer systems for a length of time determined by the settings on the delay timers.

The vacuum on the flask is monitored by means of a manometer. The vacuums used were 12.5 kPa for the char and 8.1 kPa for the coal transfer systems.

2.11 Controllers

The temperatures of the heating elements on the heated fluidizers are sensed by insulated thermocouples inserted inside the open coiled wires of the elements. Each thermocouple leads to a Thermo-Electric Series 100 controller with a narrow proportional band and manual reset. The power to the elements is controlled through an electronic relay capable of breaking 20 A currents.

2.12 Heating Elements

The heating elements on all of the heater units consist of two semi-cylindrical ceramic units of sufficient length to extend above and below the fluidized beds. They are standard Lindberg heating elements capable of operating at 1000^{o}C.

The transfer tubes are heated by heating tapes wound around them. The temperatures of the heating tapes are not monitored. Power is applied through Variacs adjusted initially to give some desired temperature as determined by a thermocouple slipped into the transfer tube.

2.13 Exhaust

The exhaust is a straight piece of black ABS pipe about seven feet long with an I.D. of two inches. The fluidizers exhaust into the pipe at various points along it. A squirrel cage fan, rated at 120 cubic feet per minute, draws air through the duct where the pressure is kept slightly below atmospheric pressure by means of a butterfly damper at the intake of the duct. The exhaust of the fan is lead to a fumehood. No provision is made for the removal of particulate matter from the exhausted gases.

3. OPERATION OF THE FLUID BED FACILITY

The fluid bed facility operates in the following manner. Reference should be made to Figures 1 or 2 and the timer sequence in Figure 5 during this discussion. In the essential part of the operating sequence the holding reservoirs and their valves (S_1, S_{11}, RV_1 and RV_7) are inactive. Before entering the operational sequence, rubber squeeze valves RV_2 and RV_6 are closed and valves RV_3, RV_4 and RV_5 are open. The sequence starts when the exhausts of both heater units are closed through valves RV_3 and RV_5. This causes material from both heater units to be transferred into the mixer unit. After an interval, RV_4 closes to send the hot coal/char blend to the briquetting press. Note that with RV_2, RV_3, RV_4, RV_5 and RV_6 closed, the transfer tube from the mixer unit is the only escape route for the fluidizing gases of all three units.

Coal and char are now transferred from the measuring reservoirs and held above valves RV_2 and RV_6. Valves RV_3, RV_4 and RV_5 release. RV_2 and RV_6 then open to allow the heater units to be replenished and close again after sufficient time has elapsed for all of the material to enter. With the closing of the two valves, the essential part of the operational sequence is completed and the holding reservoirs may become active.

Typical operating conditions are outlined in Table 2.

4. OPERATION OF THE BRIQUETTING PRESS

The operational sequence of the briquetting press is as follows. The fluid bed facility signals the briquetting press to start (Figure 5), the top die piston is extracted from the die body and a charging funnel swings in. The press then signals the fluid-bed facility to send a charge (close RV_4), compresses it for a preset length of time at a preset pressure, then ejects the hot briquette. After ejection, the die pieces are fully inserted into the die body and the briquetting press stops.

The die body is placed vertically with the top and bottom die pieces moving up and down. The bottom die piece always remains in the die body; the top die piece is completely extracted from the die body when the die is charged and when the briquette is ejected. The die pieces are attached to hydraulic cylinders powered by a hydraulic pump external to the press.

The motions of the die pieces and the charging funnel that directs the charge into the die body are programmed through relays. A timer on the control panel sets the pressing time. The pressure is set by a regulator on the hydraulic pump and monitored by a gauge on the structure of the press. The maximum force on the 1 sq inch die piston is 10,000 lbs.

The control panel has a counter to indicate the number of cycles completed and switches that modify the program for operation in a manual mode, a single cycle, or a continuous cycle. An emergency switch is prominently placed.

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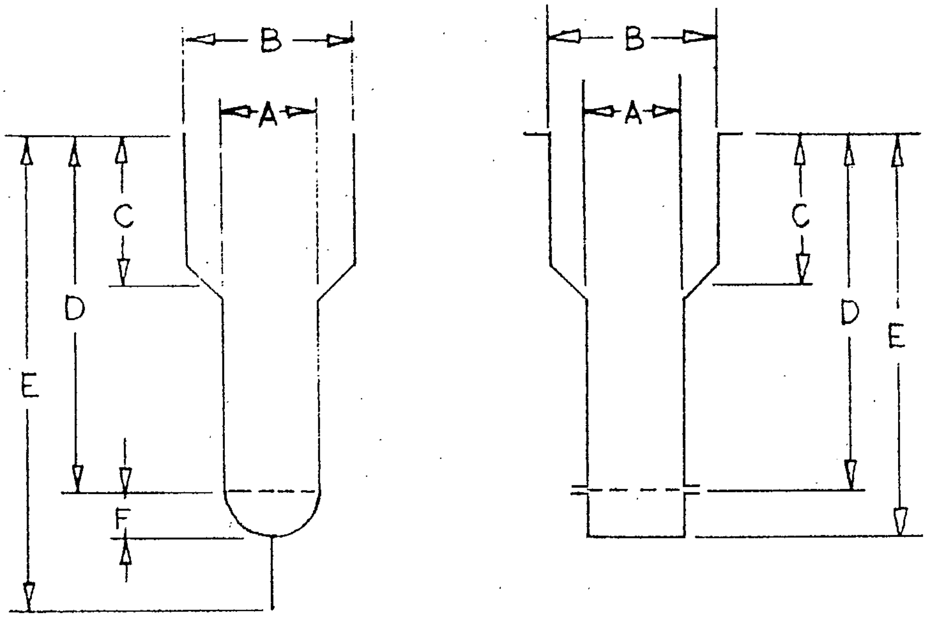


Fluidizer Bed	Type	Dimensions (inches) A	B	C	D	E	F	Construction Material
Mixer	I	1 5/16	1 13/16	6½	11¼	31	3	Vycor Glass
Coal Heater	I	2 9/16	2 9/16*	0*	15½	30	1	Pyrex Glass
Char Heater	II	3	6	6	15¼	17½	-	Stainless Steel
Coal Meas.	I	3 11/16	3 11/16*	0*	4	9½	1½	Pyrex Glass
Char Meas.	I	2 9/16	2 9/16*	0*	15½	30	1	Pyrex Glass
Coal Holder	I	3 11/16	3 11/16*	0*	4	9½	1½	Pyrex Glass
Char Holder	II	6¾	6¾	0*	24	26½	-	Acrylic Plastic

*These fluid beds do not have an expanded section

TABLE 1

Fluidizer Dimensions

TABLE 2

Facility Operating Conditions

1. Fluidizers

(a) Temperatures °C

Temperatures °C	Controller Settings	Fluidized Bed
Char heater	1000	890
Coal heater	400	330
Mixer	440	405-420

(b) Gas Flows (1/min)

Char measuring reservoir	4.2
Coal measuring reservoir	11.8
Char heater - cold	8.3
Char heater - hot	4.7
Coal heater - cold	5.0
Coal heater - hot	3.1
Mixer - cold	1.5
Mixer - hot	1.2
Char/Coal holding reservoirs	N/A - by visual appearance

2. Vacuum Transfer Settings

Vacuum for char	12.5 kPa (3.7 inches Hg)
Vacuum for coal	8.1 kPa (2.4 inches Hg)
Time for char	1.5 seconds
Time for coal	0.5 seconds

3. Transfer Tube Inner Temperatures °C

Char heater to mixer	350
Coal heater to mixer	300
Mixer to press	530

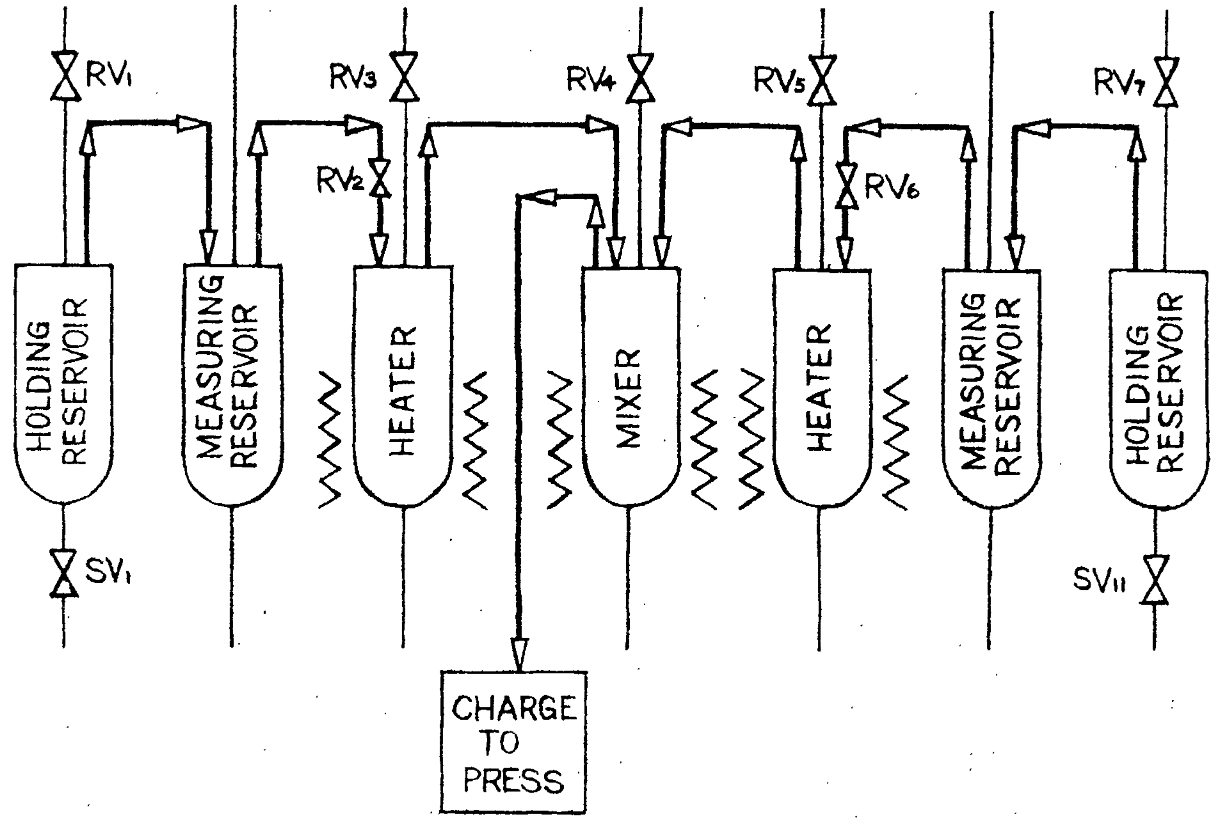


FIGURE 1. Principal features of the fluid-bed facility.

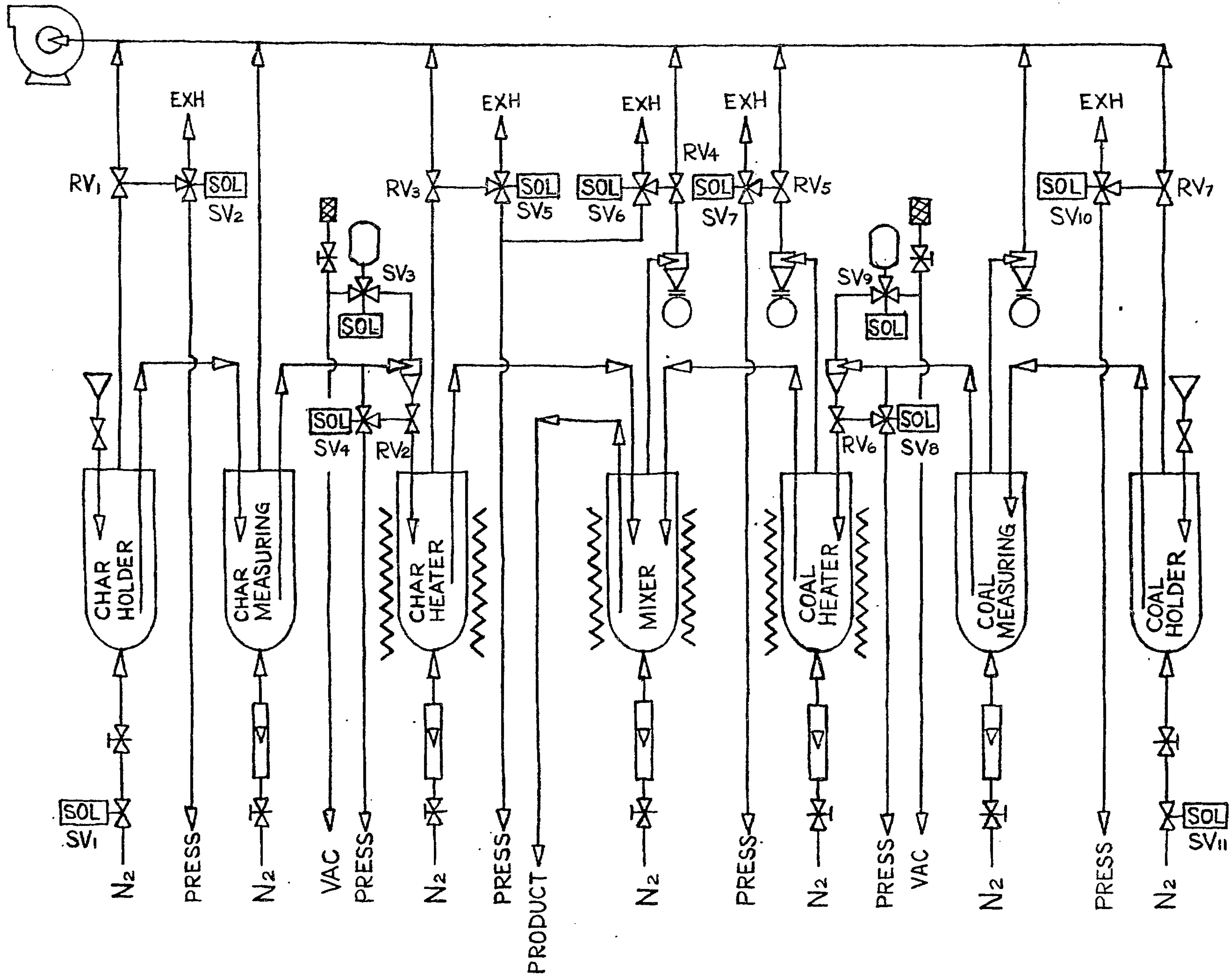


FIGURE 2. Complete schematic of the fluid-bed facility.

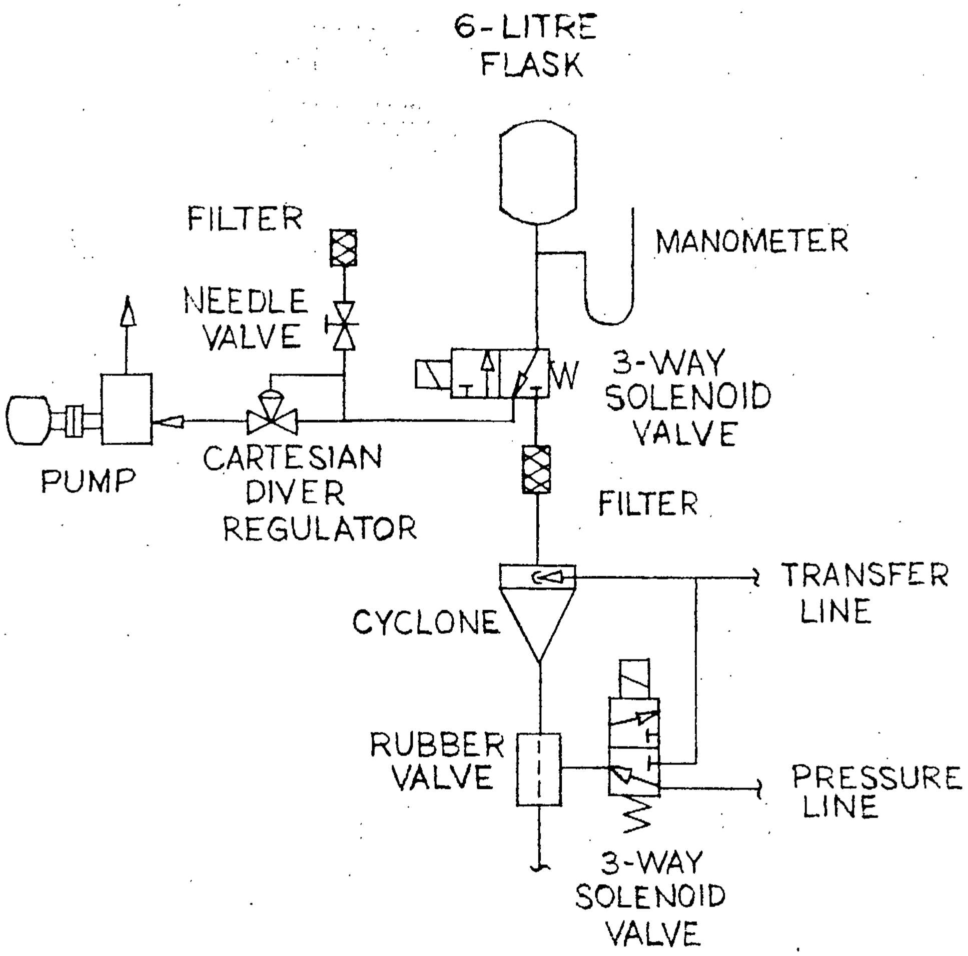
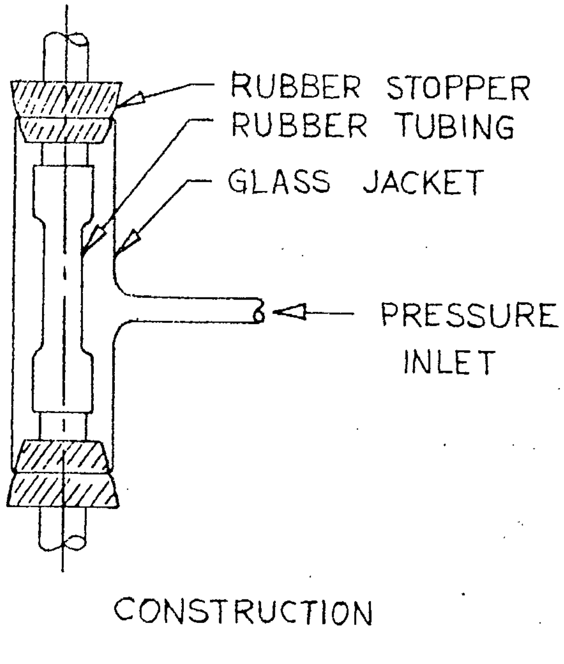


FIGURE 3. Schematic of the vacuum system.



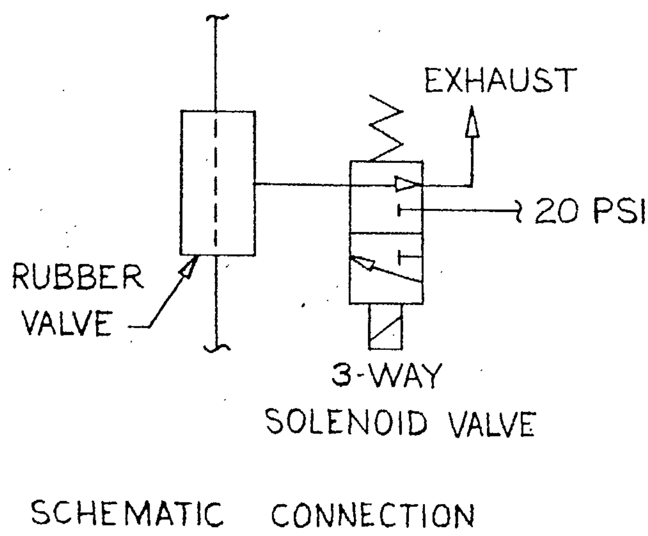


FIGURE 4. Rubber squeeze valve.

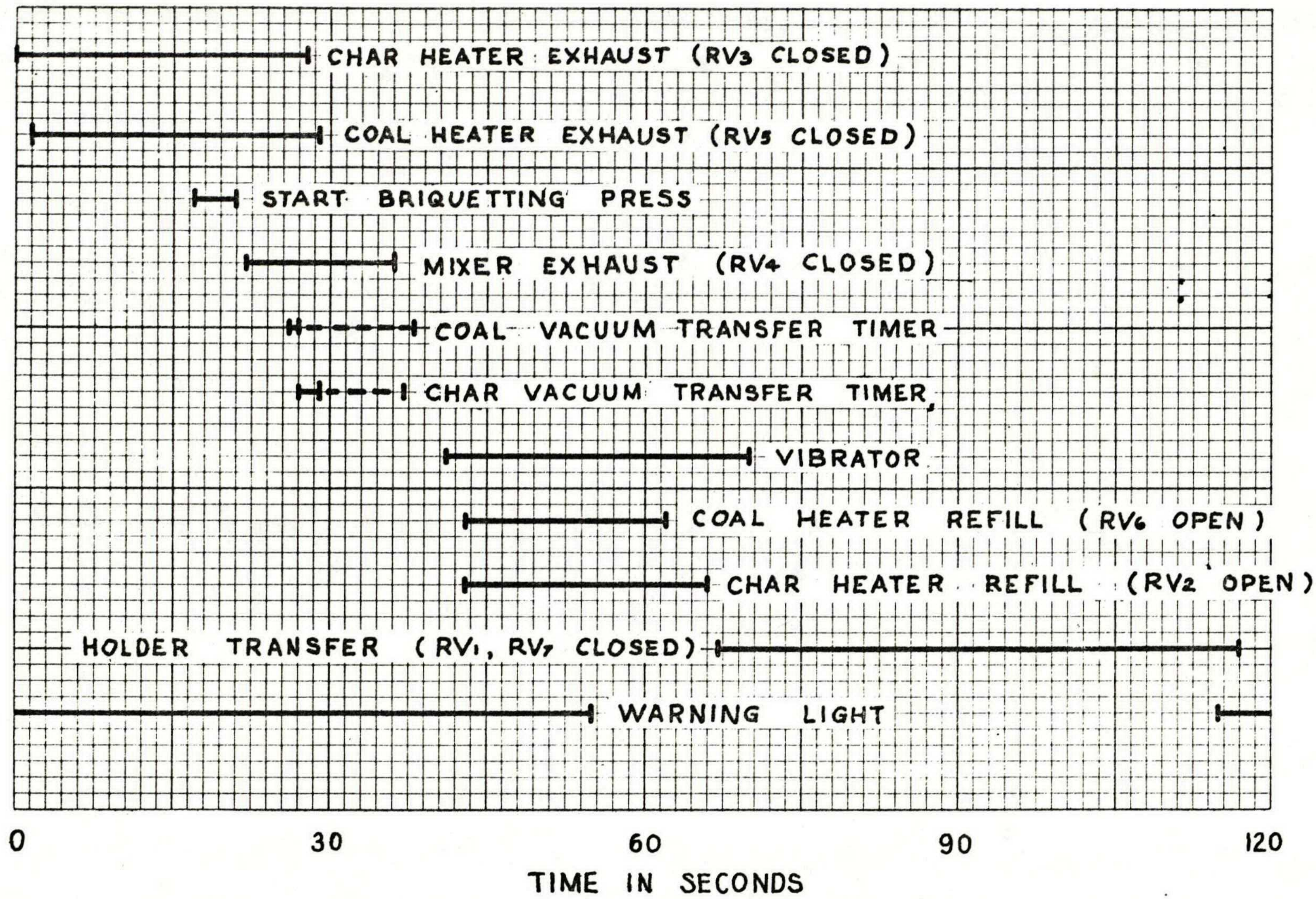


FIGURE 5. Timing sequence.