FORMED COKE PROGRAM

EXTERNAL CONSULTANT'S PROGRESS REPORT

-SAND BED COKER

-DESIGN FEATURES OF A HOT BRIQUETTING PILOT DEVELOPMENT UNIT

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by

B.B. Pruden*, P. Eng., Ph.D.

REPORT OBJECTIVE

This report summarizes the progress made under a CANMET Personal Services Contract to assist in the CANMET/CCRA Formed Coke Program. The overall objectives of the contract were "to advise CANMET (Canada Centre for Mineral and Energy Technology) in research activities pertaining to the construction and operation of a fluidized sand coker and any other activities that are deemed to be relevant to the overall objectives of the Formed Coke Program. The consultant will be required to operate the sand coker at 1000°C to introduce a spouted column, then attempt to demonstrate briquette circulation; to submit a report of his progress. Initial engineering concepts for formed coke equipment additions or modifications will be calculated and drawn up by the consultant."

This report is divided into two parts. In the first part, progress on development of the sand coker is discussed, its current status at the end of September, 1975 is described in detail, and recommendations for changes are outlined. The second part of the report discusses a design for a hot briquetting pilot development unit utilizing screw feeders to handle -1/8"x0 mesh sized materials.

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PART 1 - SAND COKER

INTRODUCTION

The Formed Coke Project requires a facility to heat treat and carbonize hot briquettes. Previous studies outlined the construction of a heated sand fluid bed that could fulfil these functions and the unit was run routinely at temperatures up to 650°C[1,2]. Routine operation of the unit at temperatures above 650°C was not attempted until the sand coker was reconstructed according to the previous recommendations[2]. The following section describes the experimental progress made towards this objective. Due to failure of the equipment at the high temperatures, the spouted column was not introduced into the bed.

EXPERIMENTAL PROGRESS

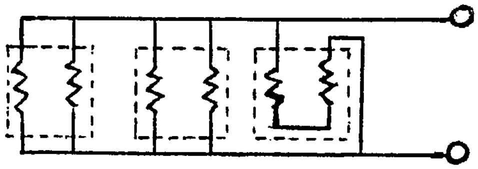
In May, June and July the sand coker was used for heat treating "green" briquettes at 500-700°C. Due to a backlog of work from the formed coke program it was not available for higher temperature trials until August. However, on August 7, 15 and 21 attempts were made to heat the sand coker to 900°C. The shell, 8" diameter by 42" high was made from schedule 10, 316 stainless steel pipe. The sand coker contained 80 pounds of Ottawa sand whose size analysis is below.

Table 1 - Sand Sieve Analysis (Canadian)

Size Distribution	Percent
-25x35	15
-35x50	82
-50x70	3
-70x0	0.05

The density of sand was 165 lb/ft^3. With 29 inches of sand in the bed, the minimum fluidization velocity was 0.55 ft/sec at room temperature with a bulk density of 95 lb/ft^3.

The shell was heated by three Lindberg 8716 KSP 16" long heaters strapped to the bottom of the shell and two Samox tape heaters on the top. The Lindberg heaters were connected in series and parallel as shown in the following diagram. Each heater had two elements, with a measured resistance of 50 ohms per element.



One electrical measurement of the combined Lindberg heating elements, when the bed was at 720°C, indicated a measured resistance of 182/15 = 12.1 ohms. The calculated (equivalent) resistance of the circuit from the wiring diagram, was computed to be 11.1 ohms. The upper heaters were Samox 2½" x 96" tapes (nominally 1728 watts at 110 volts at room temperature) which were run at 7.2 amps and 110 volts with two connected in series. With a total heat input of over 2 Kw the heat-up time was quite slow, partly because about 70% of the heat entering the bottom was coming from one heater and partly because there was sand above the heaters which heated up additional portions of the wall.

On August 15, 750°C was reached in the bed with 15 amps in the lower heaters and the upper tape at 7.2 amps. The rate of heating was 0.9°C/minute at this temperature. On August 21, 820°C was obtained although 900°C was expected. On August 26, two heaters burned out. Based on data obtained from these runs we made the following changes.

1. The sand was screened to the following size distribution by discarding all sand which did not pass a 40 mesh screen.

Mesh Size Distribution	Percent
-40x50	91
-50x75	9
-70x0	0.15

2. The amount of sand was reduced to 46 pounds so that there was no sand in contact with the wall above the heaters.

3. The insulation was increased in the lower section.

The sand size was reduced to improve heat transfer from the shell to the sand bed (proportional to the surface/volume ratio of the sand) and to reduce the amount of nitrogen required to fluidize the bed. The amount of sand was reduced so that the fluidized bed is in contact with a heated section of shell only, thus reducing heat losses.

These changes enabled the bed to be operated at lower heat inputs. With these changes the bed temperatures in Table 2 were obtained.

Table 2 - Heater Current and Resulting Bed Temperature

Heater Current Amperes (1)	Heater Current Amperes (2)	Equilibrium Bed Temperature
4	0	535°C
5	6	555
7	6	655
9	6	765
10	6	840
12	6	950°C (heater burnt out after one day)

(1) Bottom Lindberg heaters
(2) Top heater (Samox tapes)

On the last run, a temperature of 950°C was reached. This is close enough to the objective temperature of 1000°C to consider this objective achieved. This run was terminated when the lead-in wire to one of the heaters separated. Examination of the heaters showed that one had burned out and the other discolored. Both were from the parallel part of the circuit. The heater that burned out caused severe oxidation and flaking of metal from the shell. The heater ceramic had melted. The heater wire melted in places and was very brittle adjacent to the melted wire. These findings were unexpected. Based on the information available about the Lindberg heaters and the past experience of CMFRL with them, such severe heater problems were not foreseen at this temperature (950°C). Degradation of the 316 stainless shell had been anticipated and replacement Inconel 601 had been ordered on April 10. The new material has been received and work orders issued to fabricate a new shell from it.

CURRENT STATUS OF SAND BED COKER

For construction details refer to Metals Reduction and Energy centre Divisional Report MREC 74/4. In this report the drawings should include the following changes.

Figure 1 The air rotameter has been replaced. The current rotameter delivers 8.75 SCFM of air or nitrogen at 100% and at 15 psig rotameter pressure. The flow is timed to give 15 seconds of a preset flowrate every 3 minutes.

Figure 2 The shell material is 316 stainless steel. The thermocouples are located at 5¾", 8¾", 12" and 30" from the flange joining the shell and the bottom section. The outlet for sand removal, a 1½ pipe nipple is located one inch from the flange joining the shell and the bottom section.

Figures 3 and 4 No change.

Figure 5 The heaters are now Lindberg 8716 KSP heaters, 16" long and quarter circular in shape, such that four heaters would cover the whole pipe circumference. Only three heaters have been used because of the space taken by thermocouple connectors.* They are connected in parallel. There are two Samox heaters in the top section, 2½" x 96" long each, connected in series.

Figures 6, 7, 8, and 9 The figures are not applicable to the current apparatus because of the decision to go to electrical heating. Figure 6 is for propane flow and Figure 7 is a calibration for a rotameter no longer in use. Figure 8 is obsolete, and Figure 9 is obsolete because the size of sand used has been decreased.

RECOMMENDATIONS

1. The Inconel 601 should be used only in the lower part of the shell where the Lindberg heaters are located.

2. New heaters that can stand higher temperatures should be used. Kanthal wire heaters might be recommended, as these can be operated routinely at 1350°C. (The Lindberg heaters supplied were rated at 1100°C).

3. Use of the narrow sand size range should be continued as this reduces the heat input necessary. More sand may be used.

4. A nitrogen line from the hot briquetting pilot development unit nitrogen supply should be installed to the sand coker. The present use of about two cylinders of compressed nitrogen a day for the high temperature runs (>750°C) on the sand coker is cumbersome and expensive. Also, the use of cylinders make it awkward to leave the bed above 750°C over week-ends or more extended periods. The large nitrogen reservoir of the hot briquetting unit would overcome this problem.

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*There are only 2 heaters in use at this date due to the burn-out of one heater.

PART 2

DESIGN FEATURES OF A HOT BRIQUETTING PILOT DEVELOPMENT UNIT

INTRODUCTION

The CANMET fluidized bed system for hot briquetting utilizes -60+200 mesh (Canadian Standard Sieve) feed.[3] If the feed size is increased, then there is increasing particle size segregation in the fluidized units with resulting uneven feed and inconsistent results. Crushing and screening are difficult for this small size and a hot briquetting system to handle larger particle sizes would be desirable, within the limitations on coal and char size outlined by Lehmann.[4] With this in mind a design for a hot briquetting pilot development unit using a maximum size of 1/8" particles was conceptualized. The maximum size of 1/8" is certainly too large for all the coal (binder) particles, and may be too large for the char. It represents the maximum size to be considered and the unit will be able to handle materials in any combination of sizes up to this maximum.

Design Basis

Max. Feed rate - 80 lb/hr

Length of run at this rate - 6 hrs.

Typical Feed composition - 30% coal
- 70% coke

Temperatures - Coal reservoir 0-200°C, nitrogen purge
Char reservoir 0-400°C, nitrogen purge
Mixer outlet - 420°C

Coal Feeder - Continuous control of feed up to 30 lb/hr

Char Feeder - Continuous control of feed up to 70 lb/hr

Mixer-Feeder-Double screw, one to two minutes residence time for mixture.

DESIGN PROCEDURE

1. Initial study of patents and literature.
2. Design, fabricate and operate a model char screw feeder to obtain information on control of feed rates and heat transfer.
3. Design a pilot plant for study in committee (submitted June 17, 1975).

4. Meeting of committee (Aug. 21, 1975, R. Leeder, D. Misener, B. Pruden).
5. Submission of final design for CCRA/CANMET consideration.

Model Char Screw Feeder

1. Design Details

The model char feeder was 22" long and 1" in outside diameter, fabricated from one inch copper tubing as shell, and 15/16" twist drill bits as a screw. Flow data were as follows for -28x60 mesh sized char.

Dial Setting	RPM	KG/HR
5.5	25	1.9
5.5	29	2.1
7.0	43	2.9
7.0	44	2.95
10.0	68	4.5

The driving mechanism was a Zero-Max, 0-400 rpm unit. Flow was linear with rpm, but not with dial setting. Accordingly some means to measure rpm should be provided, with dial setting as a rough indication.

2. Heat Transfer Characteristics

The outside of the shell was heated with electrical tape and measurements were made of heat transfer coefficients (U) for feedrates of 2.1 to 4.5 kg/hr of char (-28x60 mesh sized). Overall "U" values averaged at about 11 Btu/(hr ft^2 ^oF) with an error of about 10%. There was no significant variation of "U" with char feedrate in this range. This "U" value was used in subsequent char and coal feeder design.

FINAL DESIGN

The design is given in Figures 1 to 5 respectively. The preliminary design results were not included in this report in order to avoid confusion.

Figure 1 is an overall schematic diagram showing the location of equipment and the flow of material. Figure 2 gives details of the coal handling facility, and Figure 3 gives details of the char facility. Figures 4 and 5 give details of the screw mixer-feeder and the suggested thread design.

The design basis can be met by filling the coal and char hoppers, heating them overnight to their respective temperatures (nitrogen purge) and then starting a run.

Initial runs should be made with only char in both storage vessels to ensure that the equipment will operate smoothly, and that the temperature criteria will be met. Both feeders should be calibrated before any runs are made. The mixer-feeder screws should operate at about 15 rpm to give a residence time of 1 minute in the mixer-feeder.

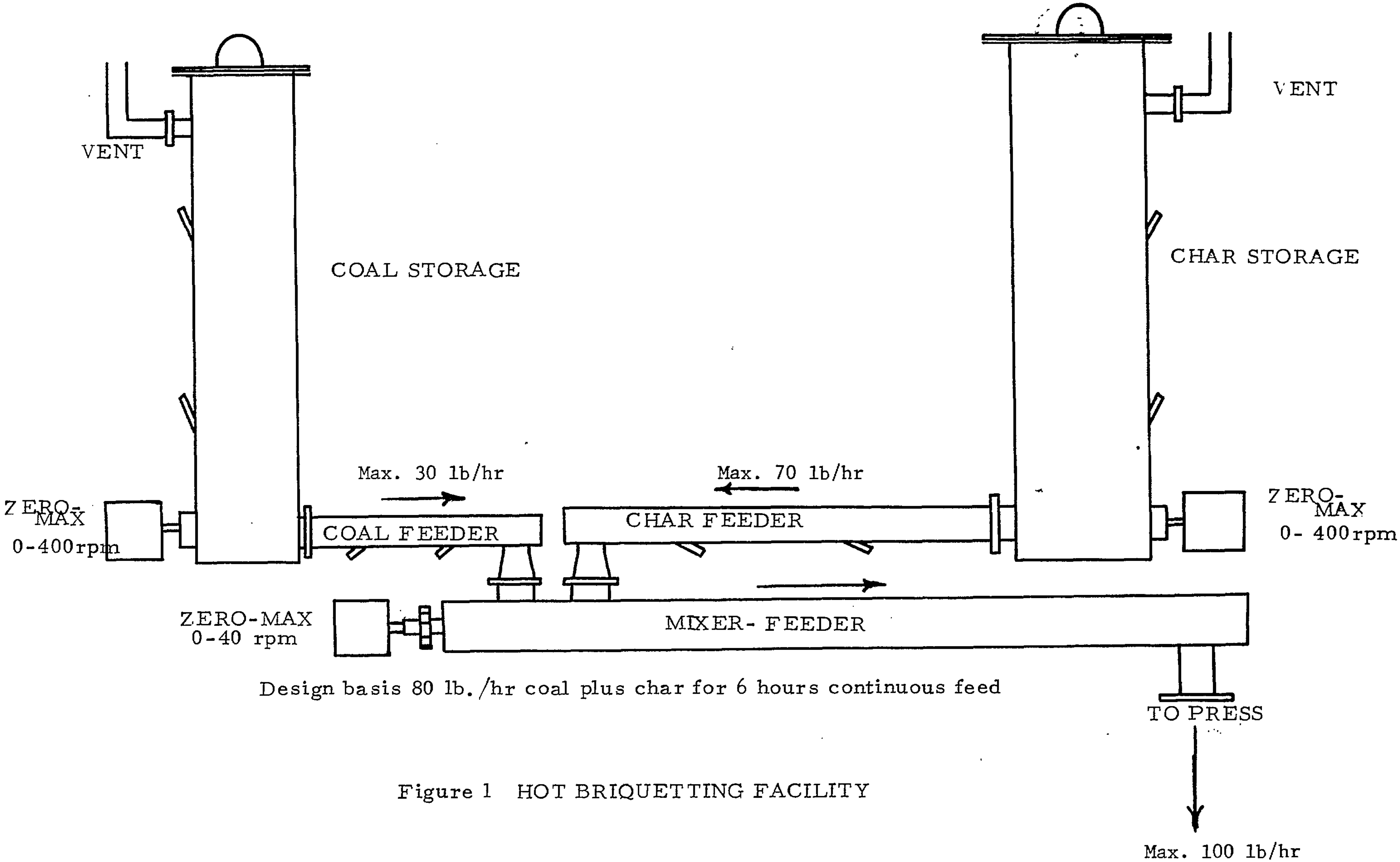


Figure 1 HOT BRIQUETTING FACILITY

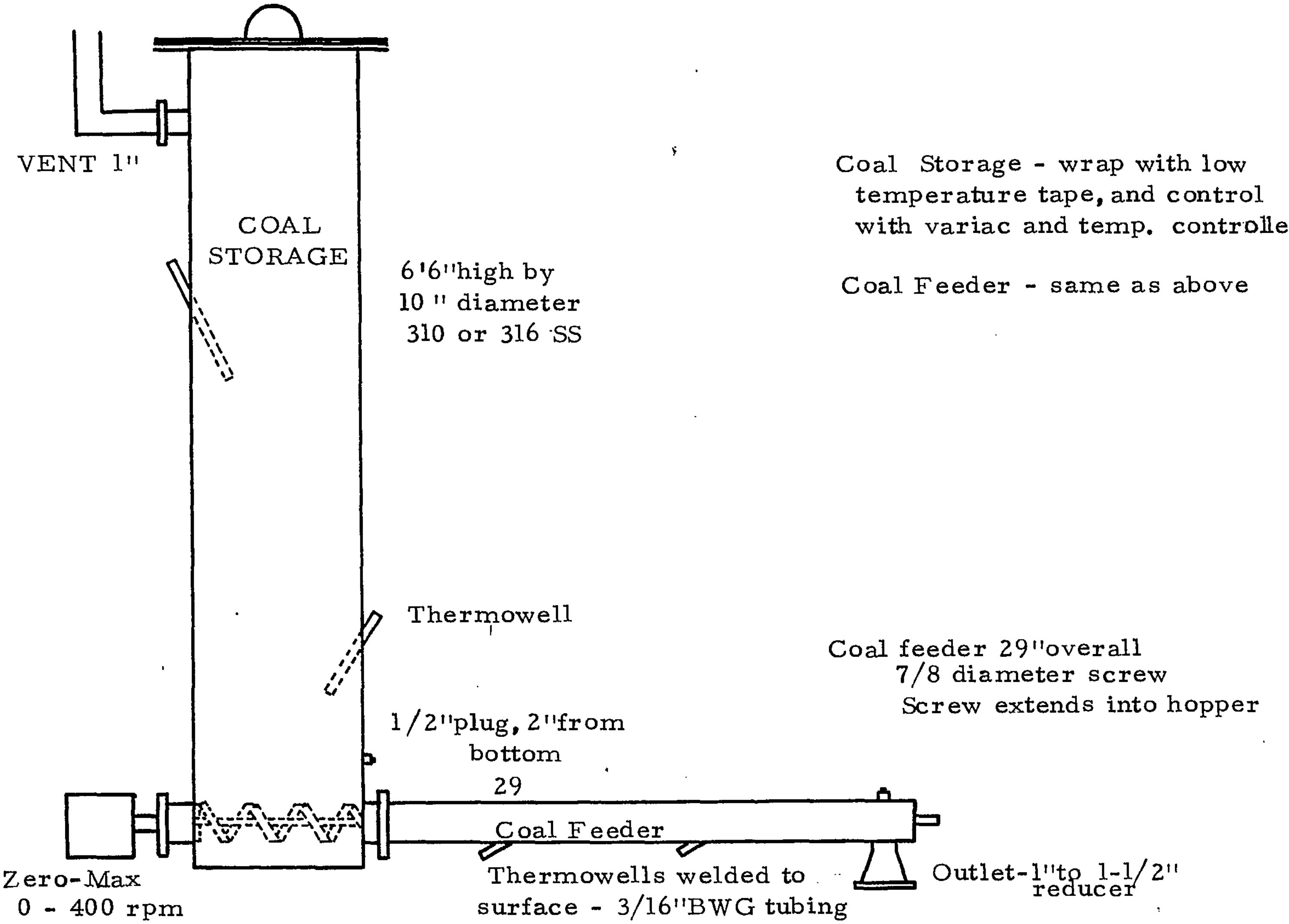
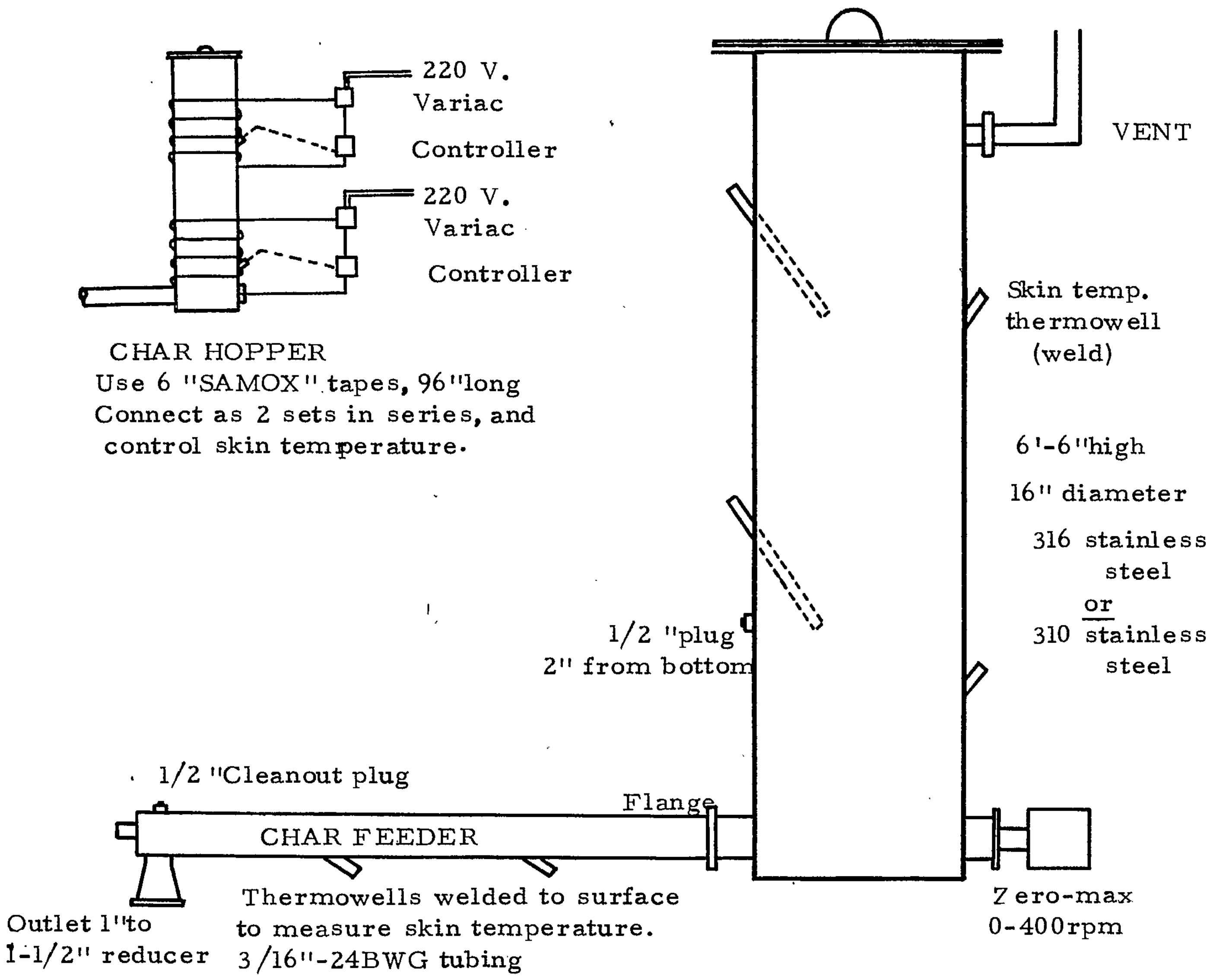
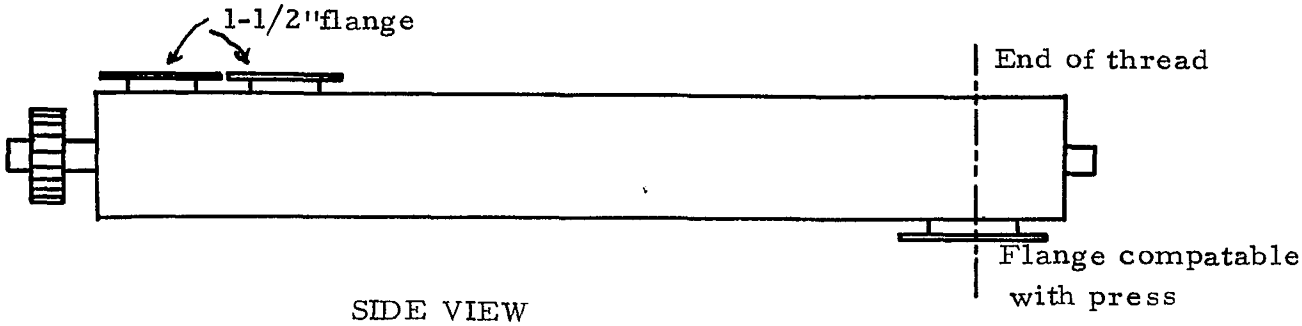


Figure 2 COAL HANDLING FACILITIES

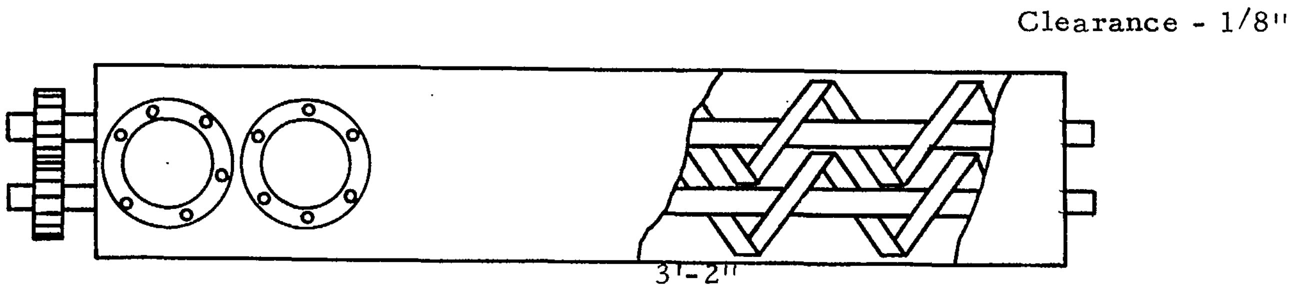


CHAR FEEDER - 4'long by 7/8" diameter screw,
threads extend into char hopper.
-Heat with one 8'long by 1-3/4"SAMOX tape
- Fabricate from 316 or 310 SS, and use
7/8 drill bits welded and finished as conveyor

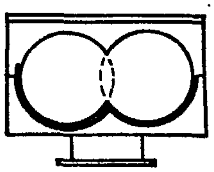
Figure 3 CHAR HANDLING FACILITY



SIDE VIEW



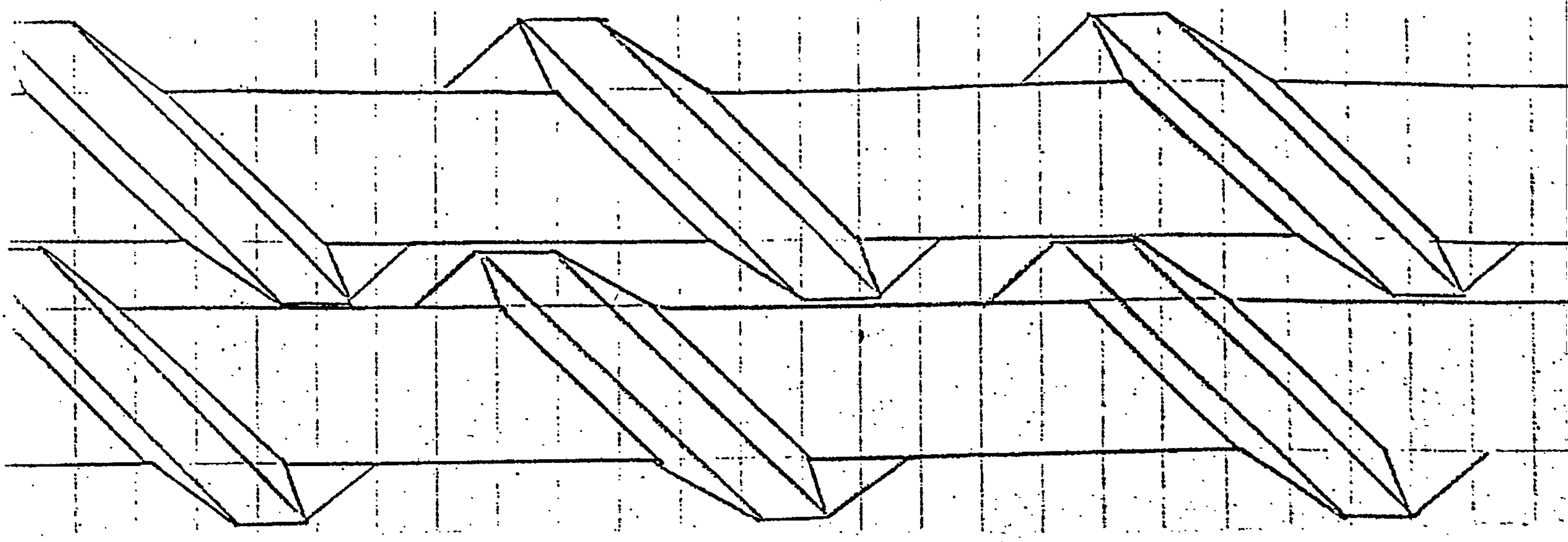
TOP VIEW



END VIEW

Screws from 1- 1/2" diameter stock, mild steel
Thread depth 1/2"
One screw right hand, one left hand
Screw length -3'
Overall length 3'-6"

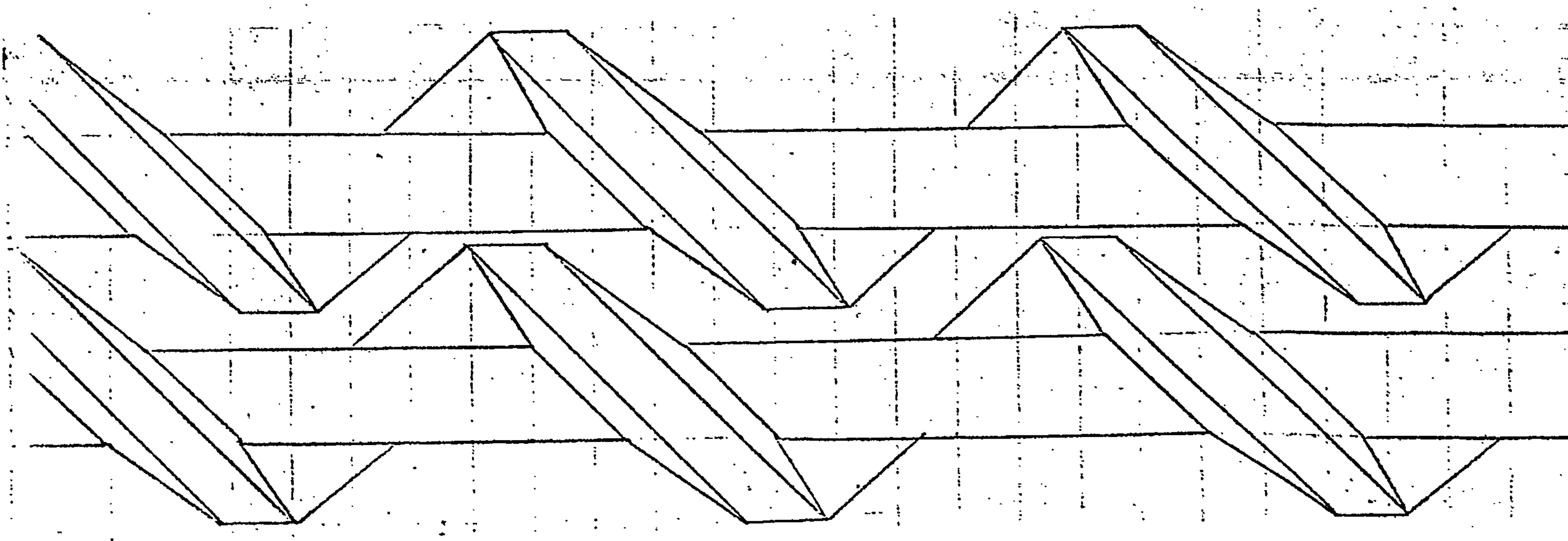
Figure 4 - MIXER - FEEDER FOR COAL AND CHAR



Threads: 1 - 1/2" , 45° , 3" Pitch

Thread depth 3/8", Clearance 1/8"

Distance between shafts - 1/2 "



Threads : 1 - 1/2" , 45° , 3" Pitch

Thread depth 1/2 " clearance 1/8"

Distance between shafts - 5/8"

FIGURE 5 Thread design for mixer- feeder

REFERENCES

1. Pruden, B.B., Development of a Spouted-Fluidized Sand Coker, Divisional Report MREC 74/4 (1974), Metals Reduction and Energy Centre, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

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3. Lau, I.T., Formed Coke Program - Studies of the Fluidization Behaviour of Coal and Char in a Pilot-Plant Scale Hot-Briquetting Fluid-Bed Facility, Divisional Report 75/1 (1975), Energy Research Laboratories, CANMET, Department of Energy, Mines and Resources.

4. Lehmann, J., (1970), Fundamental Technological Investigation about the Process of Coke Formation by Hot Briquetting of Mixtures of Coal and Char, PhD Thesis, Technical University of Aachen.