Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY
(Former Mines Branch)

FORMED COKE PROGRAM

INVESTIGATION OF VARIABLES OF FORMED COKE

(PROJECT NO. EP2.2.05)

PART III - INFLUENCE OF TEMPERATURE, SIZING AND BINDER COAL ON MANUALLY PRODUCED HOT BRIQUETTES - PRELIMINARY RESULTS

W.R. LEEDER AND M.J. MALETTE

DECEMBER, 1975

ERP/ERL 75-154 (TR)

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES

REPORT ERP/ERL 75-154 (TR)

FORMED COKE PROGRAM

INVESTIGATION OF VARIABLES OF FORMED COKE

(Project No. EP2.2.05)

PART III - INFLUENCE OF TEMPERATURE, SIZING AND BINDER COAL ON MANUALLY PRODUCED HOT BRIQUETTES - Preliminary Results

by

W.R. Leeder* and M.J. Malette**

REPORT OBJECTIVE

One of the objectives of the CCRA-CANMET Formed Coke Program is to conduct research on the chemical and physical variables of formed coking[1,2]. To be able to conduct hot briquetting tests in CANMET that are similar to those carried out for the CCRA by Bergbau-Forschung GmbH (BBF)[3], it is necessary to understand and perhaps in part duplicate the BBF laboratory-scale formed coke methods in CANMET. The last report in this series discussed how initial green and carbonized hot briquettes made at CANMET compared with those produced at BBF[4]. This report summarizes and discusses the results of a preliminary study of the influence of some of the experimental variables on the quality (crushing strength) of CANMET green hot briquettes. This work was carried out using the manual laboratory equipment, since it is more flexible than the automatic laboratory facility that has recently become operative at CANMET.

*Research Scientist, ** Technologist, Canadian Metallurgical Fuel Research Laboratory, Energy Research Laboratories, CANMET

EXPERIMENTAL

Manual Hot Briquetting

The manual equipment which makes single hot briquettes consists of a muffle furnace to dry and preheat a blend of char (coal carbonized to a low temperature) or coke with a binder coal, a fluidized bed unit to heat the blend into the plastic range of the binder coal and a heated die in which the briquette is formed. Typically 13 and 7 g of char (or coke) and binder coal are mixed in a beaker and preheated in a muffle furnace at 300°C for 30 minutes. The preheated mixture was poured into a hot (430-490°C) 5 cm diameter electrically heated fluidized bed unit and heated to about 400-480°C. Nitrogen was used for fluidization. After heating the blend, the fluid-bed was turned side-ways and the sticky mixture poured and scraped into a hot (350-450°C) 1 $in.^2$ cylindrical die where it was briquetted at 8000 psi until the pressure became constant (2-3 seconds). The die has been constructed so that a briquette is pushed out of the bottom and is removed from a slot by hand.

Hot Briquette Testing

Hot briquette quality was assessed by determining their crushing strength, since it has been related to the conventional coke oven quality parameter - the ASTM Coke Tumble Test Stability Index[5]. CANMET hot briquette crushing strengths were determined on a Hounsfield Tensometer between parallel plates that work manually closed at a rate of approximately 0.05 in/min. The briquettes were typically about 1 1/8 in. diam by 1 in. high and weighed in the order of 20 g.

Crushing strength determinations are a convenient method of assessing briquettes since large numbers are not necessary. For example, 10 kg or about 600 briquettes would be necessary to do an ASTM coke tumble test, yet the CANMET manual production method only produces about 10 briquettes per day. The average crushing strengths of two briquettes was normally calculated. If the individual values were different by more than 10 percent of the average, further briquettes were made. If one value remained too different (statistical outlier) after making 4 or more briquettes, it was discarded and the remaining values averaged.

Materials

In this study, char made from Canmore Mines Ltd. (Canmore, Alta.) semianthracite or a blend of discarded ERCO (Electric Reduction Co, Montreal, P.Q.) "course" and "fine" coke size fractions were hot briquetted with a SYSCO (Sydney Steel Co., Sydney, N.S.) hvb blend and several other coals. The plastic properties of the binder coals appear in Table 1. The size analysis of the Canmore char, the ERCO coke fractions and a typical hot briquette binder sample coal appear in Table 2.

RESULTS AND DISCUSSION

The results of the preliminary tests to study the variables that affect green hot briquette crushing strengths will be discussed in chronological order. Consequently, it will be seen that the briquette strengths continue to increase with optimization of each variable considered. For the remainder of this report "Green" hot briquettes, or the briquette after it is hot briquetted, will be referred to as a hot briquette.

Influence of Fluidized Bed Unit

Briquette strength should be a function of the blend final temperature (e.g. where in the binder coal plastic range) as well as the rate at which the blend is heated (plastic properties are strongly influenced by heating rates). Consequently, the thermal characteristics fluidized bed unit, that was used to heat the char/binder coal mixtures into the plastic range of the binder coal, should have a strong influence on hot briquette quality.

Experiments were carried out by preheating in a 300°C muffle furnace, a mixture of -30x0 mesh sized Canmore semianthracite char (70%) and SYSCO hvb blend (30%). This mixture was poured into the fluidized bed unit whose wall temperature had previously been set to a given temperature (400 to 500°C) using a bed of fluidized coke fines. The char/binder coal mixture was held in the bed for 15 seconds to 10 minutes. The hot briquette die was preset to 410°C and the briquettes pressed at 8000 psi. After cooling in air, the hot briquettes were crushed. The influence of the wall temperature of the fluidized bed unit and the char/binder blend retention time in the unit are seen in Figure 1.

However, the results in Figure 1 did not indicate the influence of the final blend temperature. Consequently, Figure 2 was derived from tests to correlate the time in the bed of the briquetting blend with temperature. Figure 2 relates the final blend temperature and the fluidized bed unit wall temperature (e.g. rate of heating) for the experimental conditions described. After these tests all hot briquetting blends temperature in the fluidized bed unit were carefully monitored with an immersed thermocouple.

Figure 2 suggests that the best fluidized bed unit temperature for the -30 x 0 mesh sized blend of 70 percent by weight Canmore semianthracite char and 30 percent by weight SYSCO hvb blend occurred at abour 470^{o}C, or at a temperature corresponding to the Gieseler Plastometer final fluid temperature of the SYSCO hvb binder coal (alone). The strongest briquettes were made from the char/binder coal mixture when it was removed at about 435^{o}C, or at the point of the Gieseler Plastometer maximum fluid temperature of the SYSCO hvb binder coal (alone). The rate of increase in temperature for the optimal strength hot briquettes was in the order of 40^{o}C/min (see Figures 1 & 2). It can be concluded, as might be expected, that the strongest hot briquettes were obtained at conditions that allow the maximum plastic properties of the binder coal to be attained. These conditions are somewhat different from those previously used at CANMET(4).

Influence of Char Size

The influence of the size of the char & binder coal has been shown to be of importance to hot briquette crushing strengths(6). To test this variable, hot briquettes were made by the CANMET manual method using 70 percent by weight of different combinations of a blend of two screened components of ERCO metallurgical coke, to be referred to as "coarse" and "fines", with 30 percent by weight of the SYSCO hvb blend as the binder coal. The optimum temperature conditions determined in the previous section, a die temperature of 410^{o}C and a pressure of 8000 psi were used to make the briquettes. The results of varying the percentage of the "coarse" component in the blend of the "coarse" and "fines" ERCO coke fraction on the hot briquette crushing strengths is seen in Figure 3.

Figure 3 indicates that the best hot briquette crushing strengths corresponded to an ERCO coke blend containing about 60 to 80 percent of the "coarse". The sizing of the coke components are seen in Figure 4. The shaded area is the coke sizing that gives the optimum strength hot briquettes. It is of interest to note that the size of the char component used in the BBF Laboratory study of Canadian and American Coals also fell in this shaded area [3], but the char sizing in previous CANMET studies was finer and fell outside the shaded area[4].

Influence of Die Temperature

The influence of the hot briquetting die on the hot briquette crushing strengths was studied. Experiments were carried out using the optimum size and temperature conditions discussed in the preceeding sections, with a mixture of the ERCO coke components (70 percent by weight) and the SYSCO hvb blend (30 percent by weight) as the coking coal. The results appear in Figure 5.

Figure 5 indicates that the best briquetting temperature was just below the plastic range of the binder coal. There appears to be a range in die temperature of approximately 100^{o}C over which changes of only 10 percent in hot briquette crushing strength were observed. The best temperatures were found to be somewhat lower than used in previous CANMET studies[4]. The drop in strength of the CANMET cylindrical briquette made at die temperatures within the plastic range of the binder coal, was probably due to the distorted shape of the resulting hot briquette that was caused by its softened condition. When such distorted cylindrical briquettes were crushed between parallel plates, the crushing strengths tended to be lower since the pressure was not being applied to all of the briquette surface. Higher temperatures may be acceptable in a roll press.

Influence of Binder Coal

Although low fluid coals generally are poor as hot briquette binder coals, good quality hot briquettes have been made when larger percentages of the binder coal was used in the briquette[3,6]. Consequently, it was decided to try and quantitatively study the influence of the percentage of binder coal on a hot briquette, and the plastic properties of the binder coal, on hot briquette crushing strengths.

Several coals of varying Ruhr dilatation were chosen and hot briquetted with the ERCO coke mixture (30/70; Fines/Coarse). The binder coals were used in portions of 20, 30 and 40 percent by weight of the briquette. The optimum die and blend heating conditions were used. The chemical and plastic analysis of the coals appear in Table 1. The results of the tests relating binder coals to hot briquette strengths appear in Figure 6. The acceptable hot briquette crushing strength level that is believed to approximate the desired conventional coke stability of 55, was calculated to be 2000 psi. It was derived from a relationship between coked briquette stabilities and crushing strengths(5), and the ratio of crushing strengths found between hot briquettes and carbonized hot briquettes(3). This value could be altered in the future to reflect new evidence or test conditions.

Figure 6 quantitatively indicates the relationship between hot briquette crushing strength and the binder coal Ruhr total dilatation for different portions of binder coal (20, 30 and 40 percent by weight). In an attempt to determine if this type of relationship is generally true, regardless of the method used to prepare the hot briquettes, data from the BBF report was used to derive the plot shown in Figure 7. The results were not the same, but similar to the CANMET trend. The results of both figures suggest that the total dilatation necessary for a binder coal to be the sole binder in a laboratory hot briquette with an acceptable crushing strength, is of the order of 100-150 percent. The CANMET results suggest that more than 20 percent of hot briquettes should be binder coal.

REFERENCES

1. Leeder, W.R., (1974), "Formed Coke Program - Background - Part 1 - Incentives For and Suggested Objectives", Dept. of Energy, Mines and Resources, Mines Branch Divisional Report MREC 74/12.

2. Leeder, W.R., (1975), "Carbonization Task - Formed Coke Sub-Task Progress Report - Present Status and Short-Term Program Objectives and Organization", Department of Energy, Mines & Resources, CANMET, Divisional Report ERL 75/10 - CMFRL.

3. Lehmann, J., (1973), "Assessment of Combinations of Canadian and U.S. Coals for the Manufacture of Formed Coke in the Bergbau-Forschung/Lurgi Process", Dept. of Energy, Mines and Resources, Mines Branch Divisional Report MREC 73/86.

4. Leeder, W.R. and Malette, M.J., (1974), "Formed Coke Program - Investigation of the Physical Variables of Formed Coking - Part II - A Comparison Between MREC Handmade Hot Briquettes with BBF Hot Briquettes", Department of Energy, Mines and Resources, CANMET, Divisional Report MREC 74/40.

5. Clendenin, J.D. and Schoenberger, R.W., (1961), "Some Relationships of Strength Properties for Carbonized Briquettes and Cokes", Proc. 7th Bien. Conference International Briquetting Assoc., 7, 1961, pp 58-67.

6. Lehmann, J. (1970), "Fundamental Technological Investigations about the Process of Coke Formation by Hot Briquetting Mixtures of Char and Coal", Ph.D. Thesis, Technical University of Aachen.

TABLE 1

PLASTIC PROPERTIES OF BINDER COALS

	SYSCO Hvb Blend	Lingan Hvb	Kaiser Hosmer Adit 14	Old Chisholm Hvb	Chisholm Chase 1
Description	hvb blend Lingan & Devco-26	hvb	lvb to mvb Western Cdn.	Eastern U.S. hvb (oxidized)	Eastern U.S. hvb (fresh)
Gieseler Plasticity					
Start ....°C	384	390	416	402	395
Fusion Temp ....°C	395	408	436	418	410
Max. Fluid Temp .....°C	435	433	437	434	436
Final Fluid Temp ....°C	474	460	456	454	468
Solidification Temp..°C	478	464	462	457	472
Melting Range ....°C	91	70	40	51	73
Max. Fluidity .....dd/m	22,200	1365	6.6	122	2190
Ruhr Dilatation					
Ti -Softening Temp..°C	350	370	396	380	381
Tii -Max. Contraction Temp..°C	407	416	440	427	415
Tiii-Max. Dilatation Temp..°C	467	449	465	459	457
Contraction .... %	27	29	30	30	28
Dilatation .... %	247	90	- 5	31	144
Total Dilatation - (Contraction & Dilatation) ..... %	274	119	25	61	172

TABLE 2

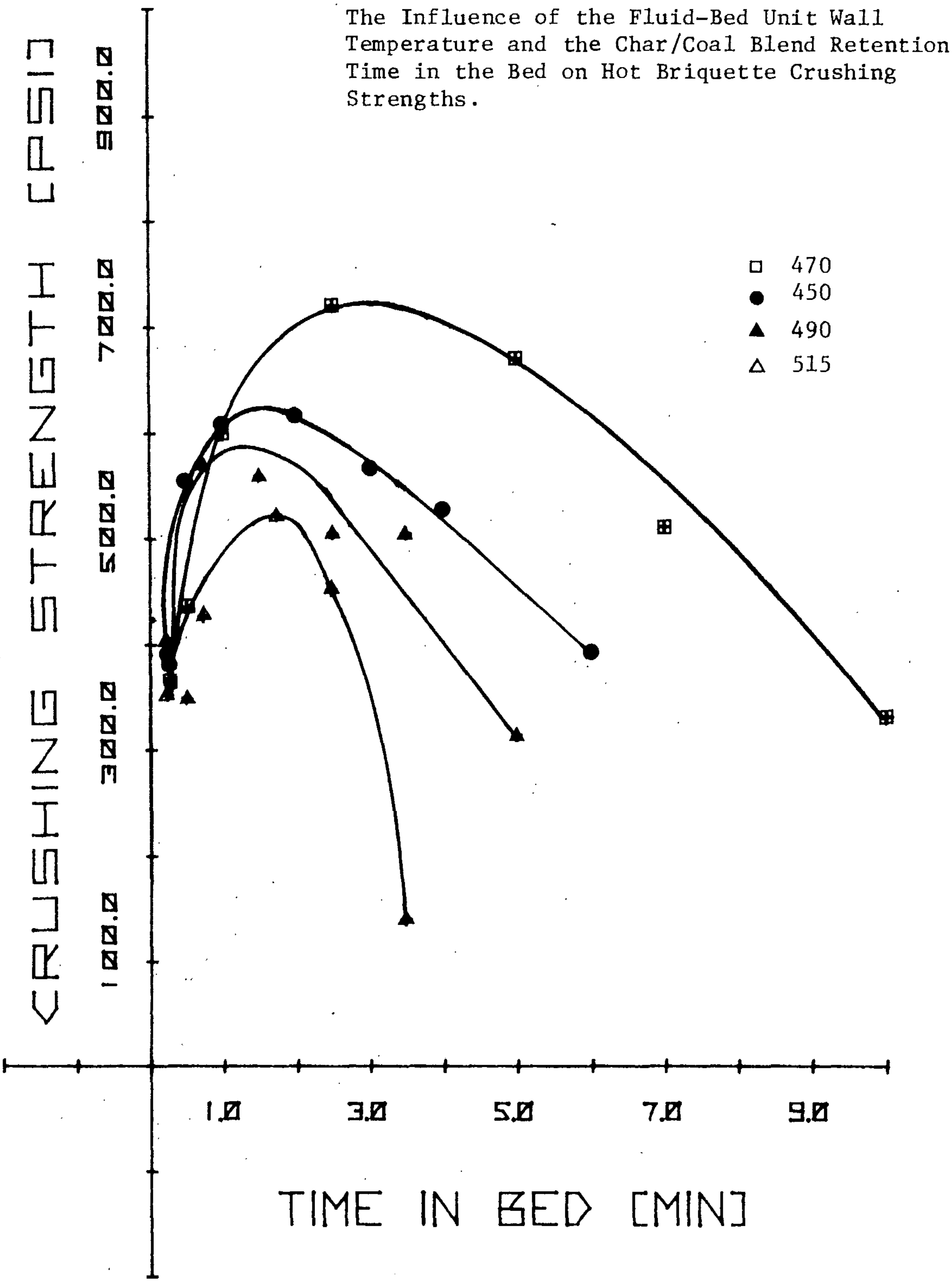
Screen Analysis of the Canmore Char, ERCO Coke "Coarse" and "Fines" Fractions and the Lingan Coal as determined with an Allen-Bradley Sonic Siever

	Percent by Weight in Each Sieve Size Range			
Sieve Size Range	Canmore Char	ERCO Coke "Fines"	ERCO Coke "Coarse"*	Lingan Coal
+ 60	41.8	15.3		50.9
-60 + 100	27.9	50.1		15.4
-100 + 140	11.7	16.3		7.7
-140 + 200	10.6	10.5		8.0
-200 + 325	6.3	5.1		7.3
-325 + 0	1.7	2.7		10.6
+ 6			2.8	
- 6 + 12			35.2	
- 12 + 20			25.1	
- 20 + 30			12.3	
- 30 + 50			20.1	
- 50 + 70			3.1	
- 70 + 0			1.4	

* Ro-Tap Testing Sieve Shaker

FIGURE 1

The Influence of the Fluid-Bed Unit Wall Temperature and the Char/Coal Blend Retention Time in the Bed on Hot Briquette Crushing Strengths.



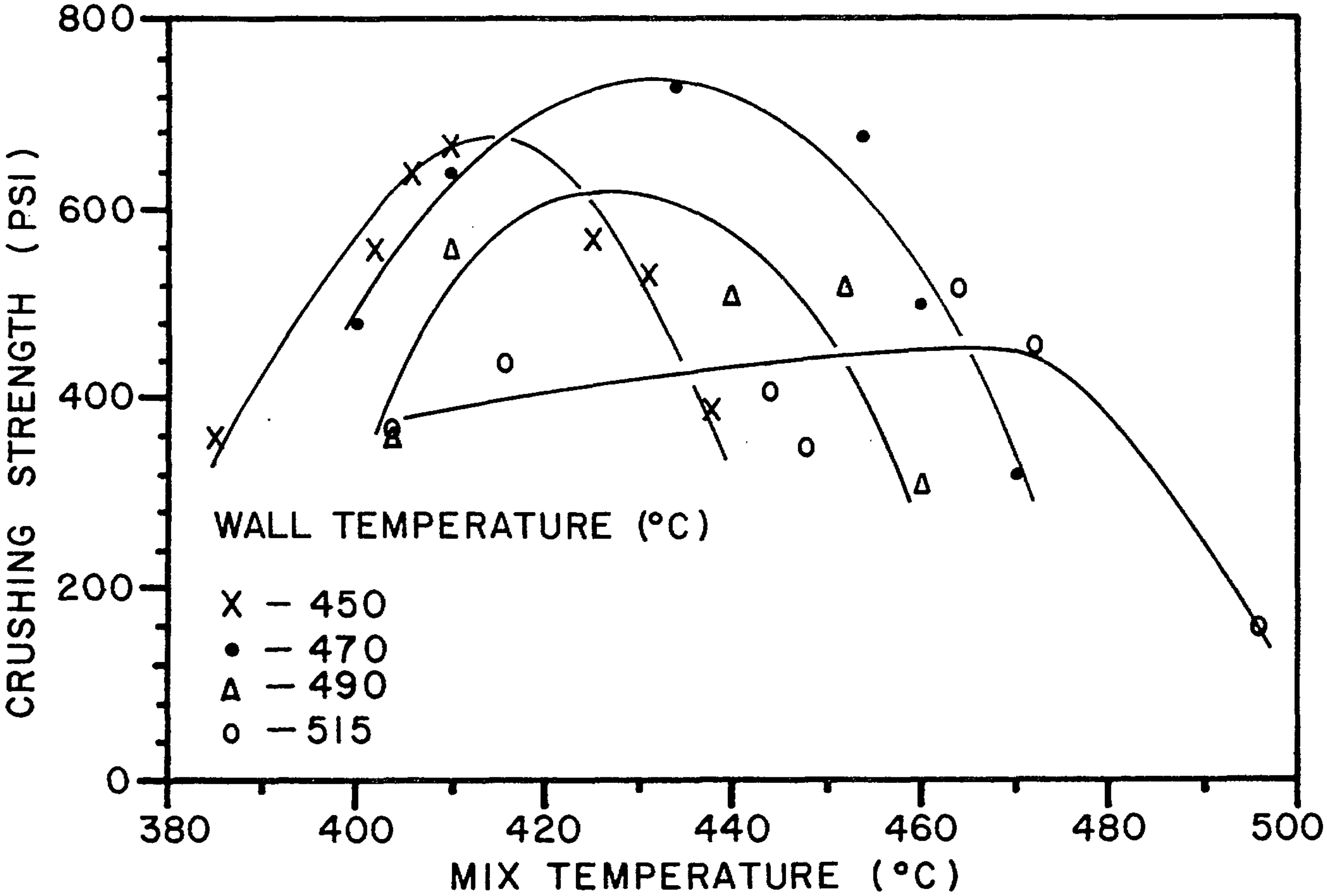


FIGURE 2: The Influence of the Fluid-Bed Unit Wall Temperature and the Final Char/Coal Mix Temperature on Hot Briquette Crushing Strengths.

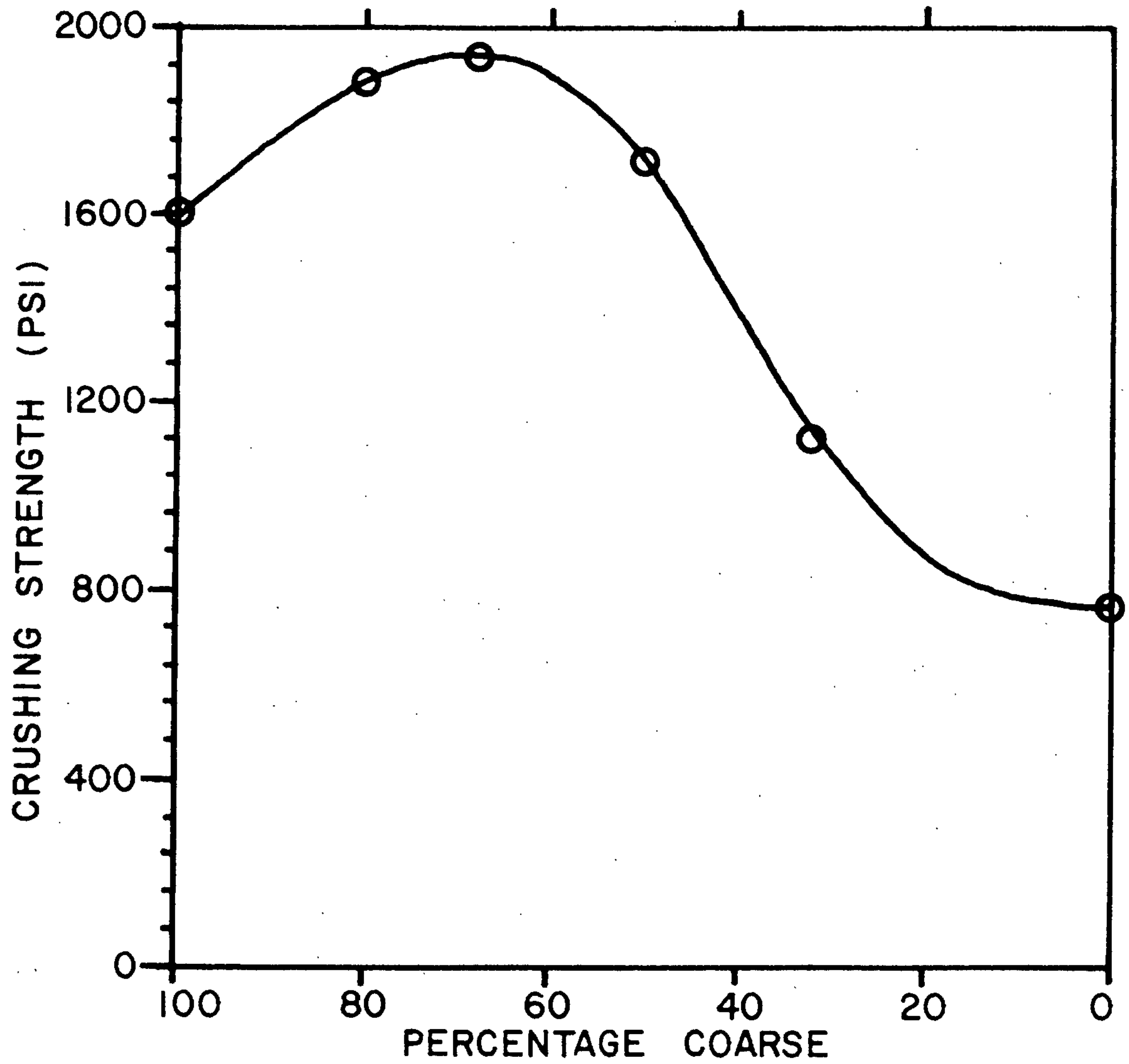


FIGURE 3: The Influence on Hot Briquette Crushing Strength of Varying the Percentage of the "Coarse" Fraction (Size) in the Blend of the "Coarse" and "Fine" ERCO Coke Components. (See Figure 4 for size analyses)

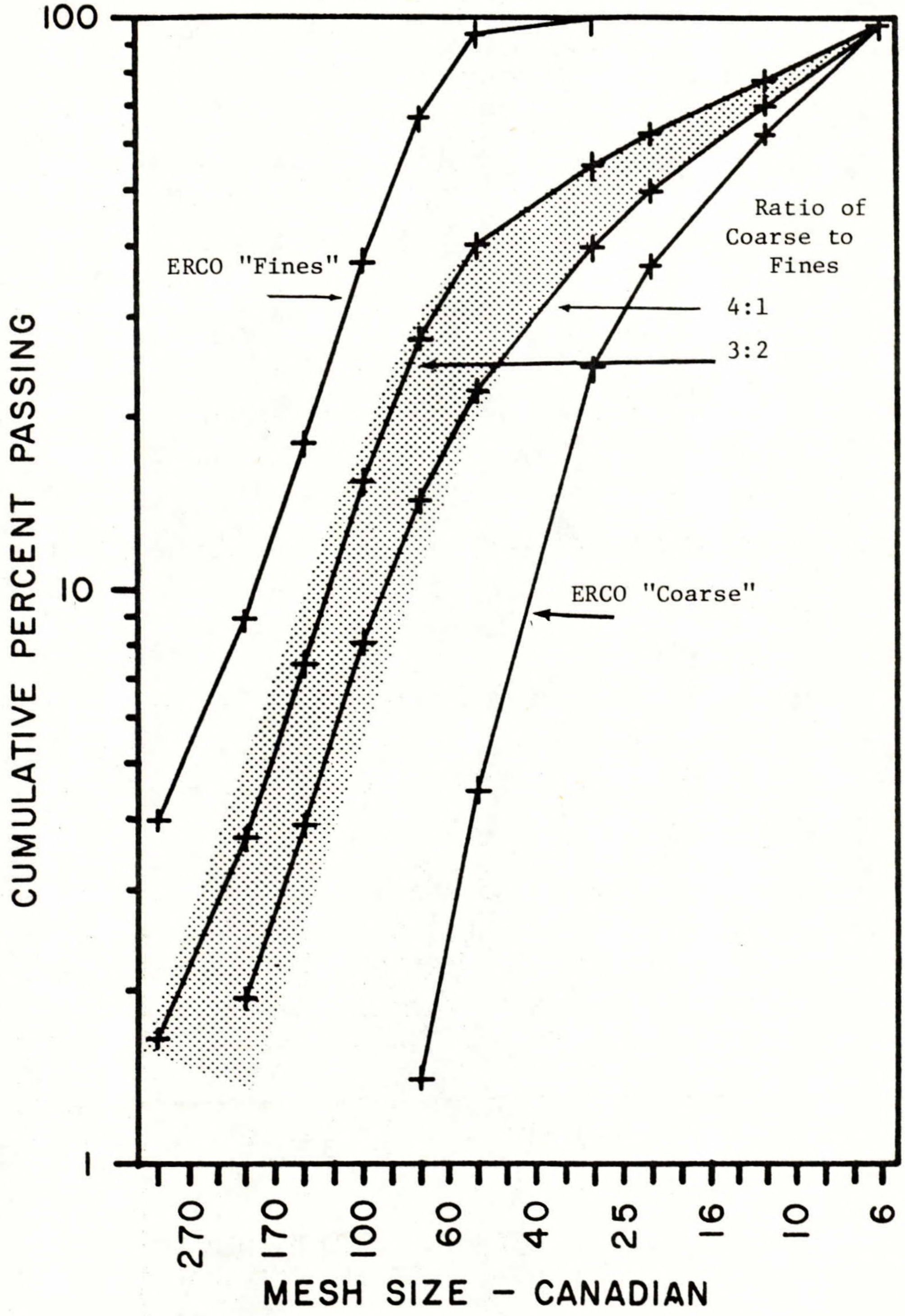


FIGURE 4: Size Analysis of Some of the ERCO Coke Components Used to Make Hot Briquettes.

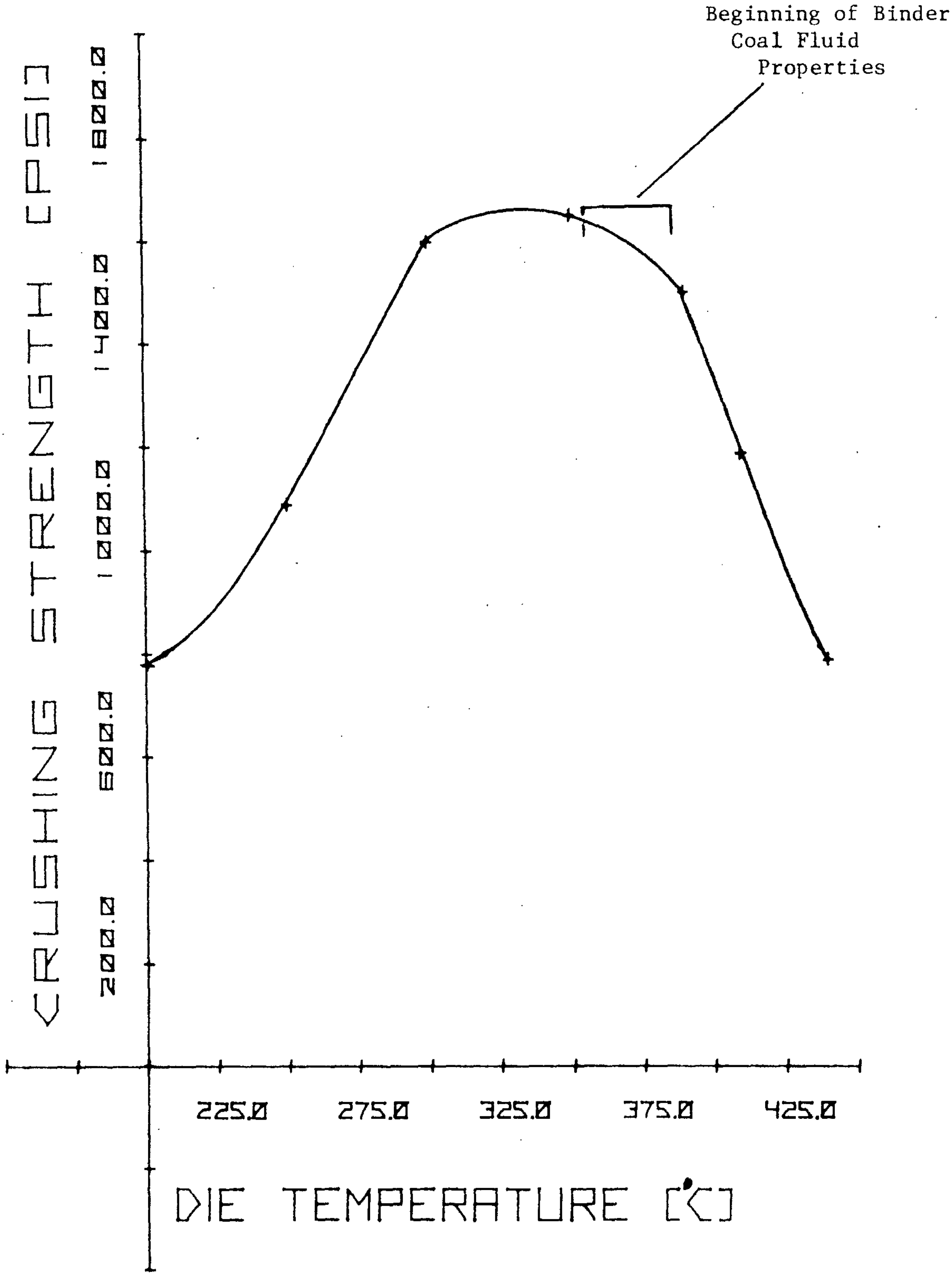


FIGURE 5: The Influence of the Hot Briquetting Die Temperature on the Resulting Hot Briquette Crushing Strength.

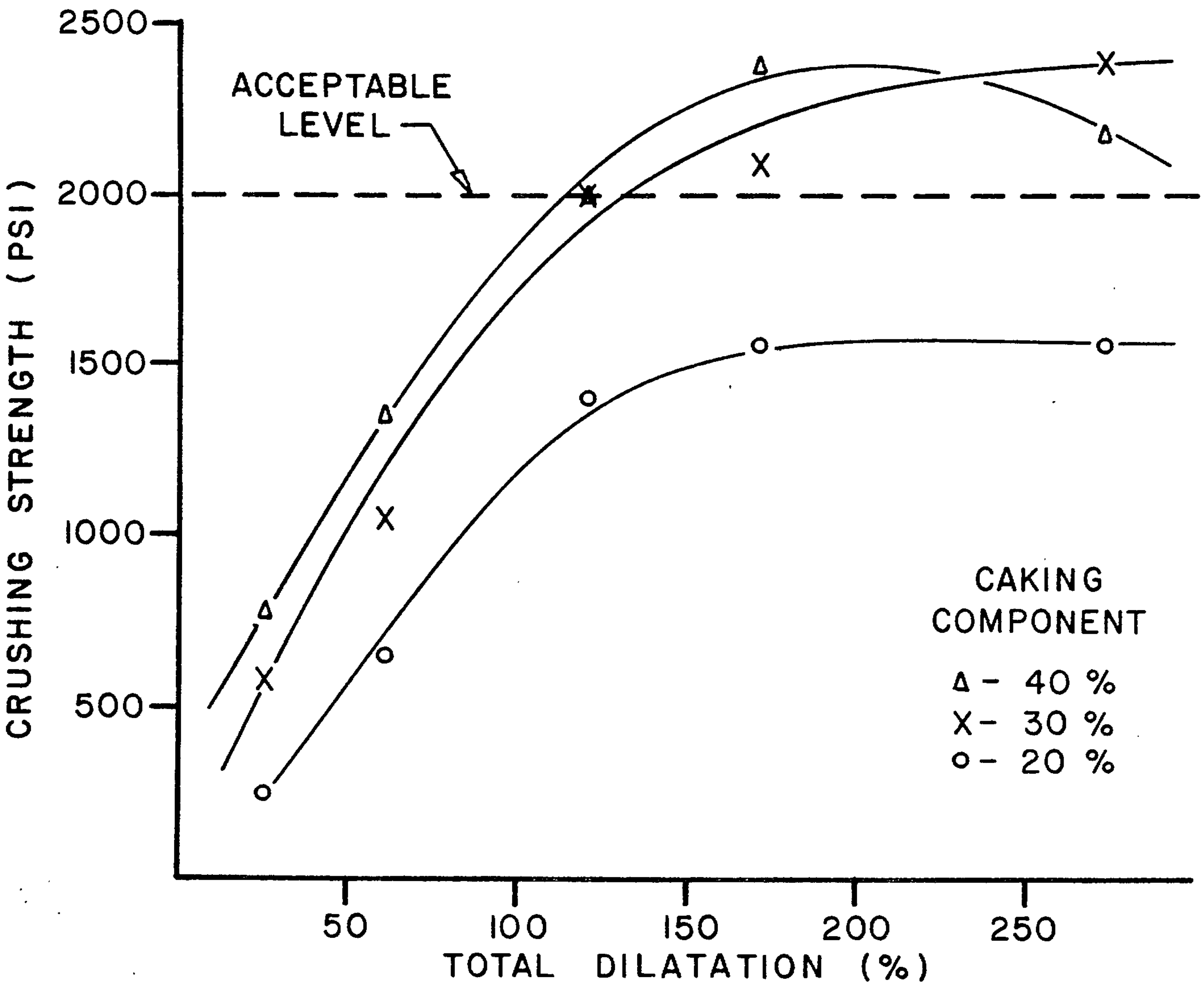


FIGURE 6: The Influence of the Binder Coal (Coking Coal) Content and Total Dilatation (Contraction & Dilatation) on Hot Briquette Crushing Strengths - CANMET Manual Method

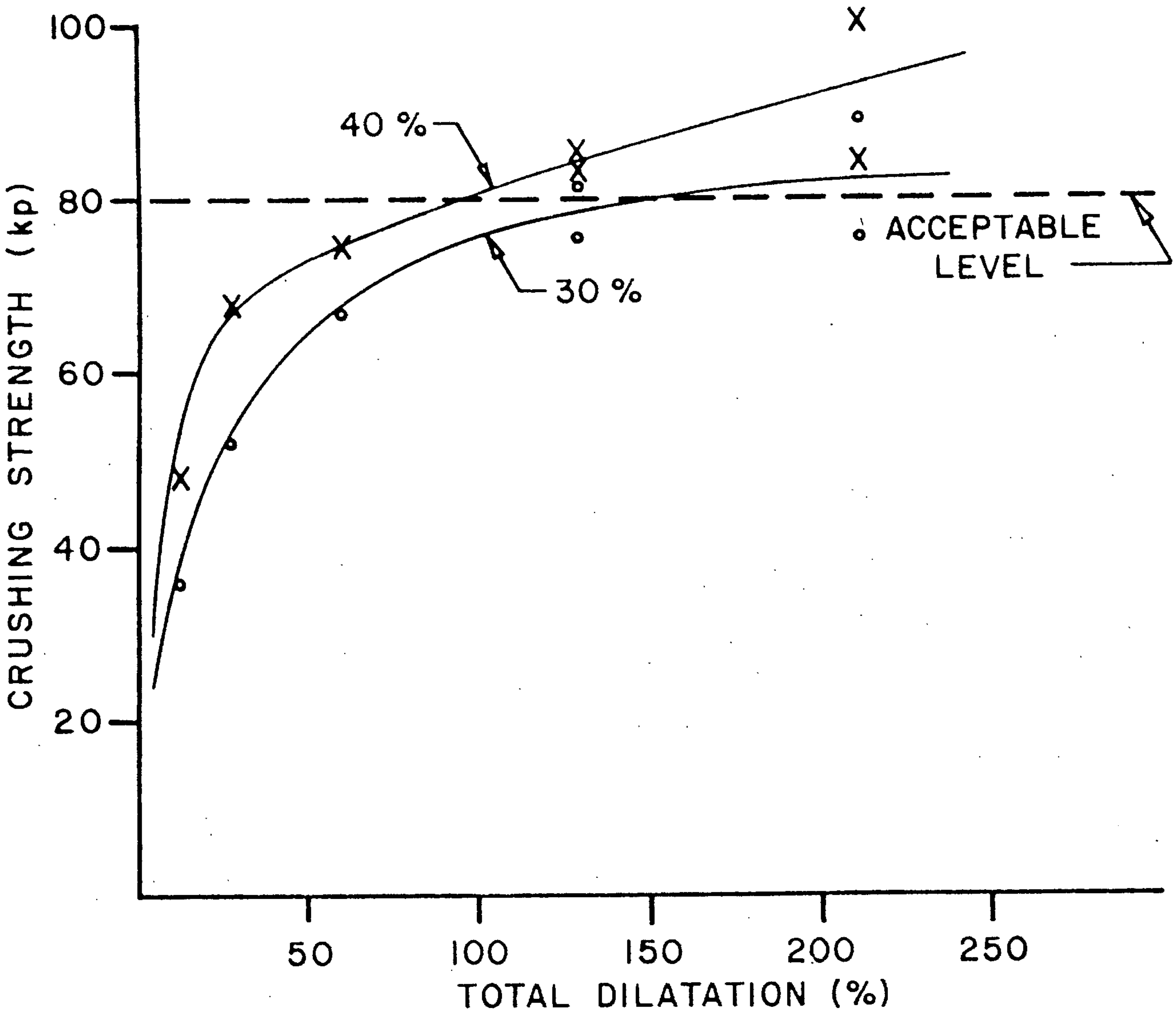


FIGURE 7: The Influence of the Binder Coal (Coking Coal) Content and Total Dilatation (Contraction & Dilatation) on Hot Briquette Crushing Strengths - BBF Laboratory Method