SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 14

EFFECTIVE FUEL VALUES OF SOUTH DAKOTA COAL

AND

SUGGESTIONS AND NOTES ON THE USE OF SOUTH DAKOTA COAL IN COMMON STOVES AND FURNACES

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EFFECTIVE FUEL VALUES OF SOUTH DAKOTA COAL

INTRODUCTORY STATEMENT

Costs of necessities are being subjected to close scrutiny all along the line from the producer to the ultimate consumer. In no class of commodities is attempted cost reduction more persistent than in that of fuel. This is true whether fuel serves industrial uses in production of power or for domestic use in home heating and cooking.

The industrial user of coal and the operators of coal mines are frequently familiar with the determination of actual fuel costs either from experimental tests on coal or from the study of coal analyses and tests of calorific values. The layman, however, is commonly at a loss to know whether or not he is receiving the greatest amount of fuel value or heat for each dollar spent. He is forced to rely on the advice and opinions of others who may be equally uninformed or prejudiced in favor of this or that coal. Inquiries are frequently made of the State Geological Survey as to whether South Dakota coal can be burned more economically than coals commonly imported into the state. In many instances the question is so stated that it can be answered with difficulty. For example a man asks whether coal from a certain mine in South Dakota, bought at a certain price,can be burned with greater economy than a certain brand of coal imported into the state. Obviously such a question cannot be answered with definiteness since the State Geological Survey is not in the coal business and cannot recommend the burning of any particular coal. The Survey can, however, furnish the results of tests and analyses which if properly interpreted give much information as to the actual heating values of South Dakota coals.

Study of the coals suggests that considerable economies are possible in many places where South Dakota coal is available and that recent expansion of coal mining in the state is wholly merited and that continued expansion in our coal industry is to be expected and encouraged as a matter of economy, if for no other reason.

The data in the following pages has been brought together for the information of all citizens in the state, coal dealers, and salesmen, as well as for the information of the producer of coal in South Dakota.

CHEMICAL ANALYSES OF COAL AND THEIR USES

Practically speaking, the coal consumer buys heat units. Most analyses of coals include their calorific or heating values. Unfortunately, however, the user of coal cannot utilize from a coal the number of heat units shown in the analysis, even though he burn it with utmost efficiency. As an example, any coal as mined contains water and ash. In burning the coal some of the total heat units are utilized in converting the water into steam and in superheating this steam to the temperature of the chimney.

Engineers find that in operating steam boilers approximately 1256 B.t.u. are utilized in heating one pound of water to the boiling point, evaporating it, and superheating the steam to the temperature of the flue.[1] If a coal contains 10 per cent moisture when burned each pound of coal contains 1/10 pound of water which requires 1/10 of 1256 B.t.u. or 125.6 B.t.u. of heat which must be deducted from the B.t.u. value of the coal as shown in analyses.

Ash in the coal does not burn but actually serves as a retarder of combustion, and in excessive quantities effectively cuts down the heat units actually utilized. It should also be understood that, when moist coal is burned, the retarding effect of the ash progressively increases. For example, a coal as introduced into a furnace contains 20 per cent moisture and only 10 per cent ash. As combustion begins the water is progressively driven off by heat. When the moisture content has been reduced to 10 per cent, the relative amount of ash rises to 11.1 per cent. When the coal is completely dried the ash rises to 12.5 per cent. In tests made with a chain-grate stoker it was found that, in coals commonly used, the dry ash reduces the fuel value of the coal one per cent for each one per cent of aditional ash.[2] Thus, in an increase of one per cent of ash in drying out a coal originally containing 7000 B.t.u., the additional one per cent reduces the usable heat 70 B.t.u. and an increase of 2.5 per cent reduces the actual available heat obtainable by 175 B.t.u. This seems a small item. When, however, the consumer pays from $10.00 to $15.00 for coals brought into South Dakota, a difference of 2.5 per cent in ash between two coals is a difference in actual value of 25 cents to 37½ cents per ton or $2.50 to $3.75 for 10 tons.

Thus water and ash must be correctly compensated for in order to determine the actual heating value of any coal as it is used in a stove or furnace.

The heat producing or combustible ingredients in coal are combustible volatile matter (gas), fixed carbon, and sulphur. The latter, sulphur, is commonly regarded as an impurity since the heat value is much less than the remaining combustible substance, the calorific value of sulphur being only 4050 B.t.u. per pound. It is probably concerned in clinker formation also, although it is not the most important factor in the production of clinkers.

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1. Bement, A., Illinois Coal, Illinois State Geological Survey Bulletin 56, p. 93, 1929.

2. Abbott, W. L., Some characteristics of coal as affecting performance with steam boilers: Journal Western Society of Engineering, vol. 11, p. 534, 1906.

The remaining ingredients of coal, volatile matter and fixed carbon are the real heat producers. Both may be burned completely. The ratio between volatile matter and fixed carbon does not indicate heating or fuel value since volatile matter may have a heat value equal to or greater than the fixed carbon.

The chemical analyses of coals, theoretically at least, furnish a basis for comparison of the heat which may be utilized. Comparison must be made on the basis of total laboratory calorific value which is derived from volatile matter, fixed carbon and sulphur, minus the heat expended in driving off the water and minus the loss due to the heat retarding effect of the ash. Two coals may readily be compared by making corrections based on the excess moisture and ash contained in one with the moisture and ash contained in the other. Such comparisons are made in later pages.

CHEMICAL CHARACTER OF SOUTH DAKOTA COALS

Numerous analyses of South Dakota coals have been made by various agencies and compiled and published by the Survey.[1] These analyses indicate a similarity in the general distribution of their essential constituents although there is considerable variation in chemical character and heat value.

An average of the proximate, as received analyses of South Dakota coals available at this time gives the following distribution of the chemical constituents:

Table 1

The Average Analysis of South Dakota Coal As Received

Moisture	36.65
Volatile Matter	25.87
Fixed Carbon	28,68
Ash	9.50
Sulphur	0.93
B.t.u.	6855

Moisture,as indicated by analyses, varies between 29.8 per cent and 46.5 per cent as received. After drying in air the moisture content is reduced to a point from 2.2 per cent and 17.8 per cent. Ash ranges between 4.84 per cent and 15.1 per cent in coal as received and increases to between 6.86 per cent and 22.5 per cent in dry samples. It averages 13.91 in dry coal. Sufficient

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1. Searight, W. V., A preliminary report on the coal resources of South Dakota, S. Dak. Geol. and Nat. Hist. Survey, Report of Investigations No. 3, pp. 26-31, 1930.
   Searight, W. V., The Isabel-Firesteel coal area. S. Dak. Geol. and Nat. Hist. Survey, Report of Investigations No. 10, pp. 24-24a, 1931.

variations occur in moisture and ash content to produce a difference in actual heating value utilized in burning equal to 17 per cent or more of those South Dakota coals with the highest heating value. That is, some of our South Dakota coals are actually worth 83 cents or less on the dollar spent for our best coals.

It should be noted, in this connection, that relatively little South Dakota coal containing the maximum amounts of water or ash is marketed. In an average of 10 analyses showing the highest heating values, moisture (as received) is 32.91 per cent, ash (dry coal) 10.35 per cent, and B.t.u. value (as received) 7205 B.t.u. The figures are probably very near those of most of the South Dakota coal actually marketed since the average of all analyses contains samples of low grade coals which are not marketed.

EFFECTIVE FUEL VALUES

Effective fuel value of a coal is the B.t.u. value of the coal as determined by laboratory test corrected for loss of heat due to moisture and ash.[1] By means of these corrections, it is possible to compare the effective fuel value of two coals and thus also to determine what price the consumer can pay for one, the price of the other being known. For example, in the following table two coals are compared, 1256 B.t.u. being allowed for each pound of excess moisture and one per cent of the B.t.u. value being allowed for each one per cent of excess ash.

Table 2

Effective Fuel Value of Two Coals

	Coal A	Coal B
1. Moisture - - - - - - - - - - - - - -	40.10	35.35
2. Excess moisture- - - - - - - - - -	4.75	
3. Ash in dry coal- - - - - - - - - -	10.59	8.38
4. Excess ash in dry coal - - - - - -	2.26	
5. B.t.u. (laboratory)- - - - - - -	6150	7134
6. B.t.u. loss due to excessive moisture, 1256 x 0.0475 - - - -	62	
7. B.t.u. loss due to excessive ash, 6150 x 0.0226- - - - - - -	139	
8. Total B.t.u. loss due to excess moisture and ash- - - - - - - -	201	
9. Effective B.t.u. - - - - - - - - -	5949	7134
10. Relative value of Coal A and B -	0.83	1.00

Thus if Coal B sells for $2.00 the consumer should not pay more than $1.66 for Coal A.

In the following pages comparisons are made (Tables 3, 5, 7, 9, 11, 13) by this method between the average composition of South

1. Bement, A., Illinois Coal, Ill.State Geol.Survey Bull. 56, pp. 93-94, 1929.

Dakota Coal (Table 1) and averages of coals commonly imported into South Dakota from other fields. In order to give a more accurate comparison an average of the best 10 South Dakota analyses is compared with the same imported coals (Tables 4, 6, 8, 10, 12, 14). This higher average is certainly more nearly representative of the South Dakota coal marketed than the average of all analyses. No comparison with North Dakota coals has been made because the average North Dakota coal is very similar to the average of South Dakota coal. These comparisons indicate that when burned with equal efficiency, for every dollar expended for coals commonly imported into South Dakota (the nearly identical coals of North Dakota and eastern Montana excepted) the consumer can spend from 40 to 63 cents for the average South Dakota coal. He can spend from 44 to 67 cents for the best South Dakota coals for every dollar expended for coals commonly imported into South Dakota. Thus, if $16.00 per ton is the price of West Virginia coal he can pay $0.44 x 16 or $7.04 per ton for the best South Dakota coal, provided that he burns either with equal efficiency. Inversely, if the consumer pays $5.00 for the best South Dakota coal he should not pay more than $11.36 per ton for West Virginia coal. In the latter case a saving of 29 per cent is possible to the consumer who buys the best South Dakota coal if the selling price of West Virginia coal is $16.00 per ton.

Table 3

Comparison of the Effective Fuel Values of Average South Dakota Coals[1] and Average of Typical Arkansas Coals[2]

		South Dakota	Arkansas
1.	Moisture	36.65	1.66
2.	Excess moisture	34.99	
3.	Ash in dry coal	13.91	9.38[3]
4.	Excess ash in dry coal	4.53	
5.	B.t.u., average laboratory	6855	13928
6.	B.t.u. loss due to excess moisture 1256 x 0.3499	439	
7.	B.t.u. loss due to excess ash 0.453 x 6855	311	
8.	B.t.u. loss (total)	750	
9.	Effective B.t.u.	6105	13928
10.	Relative value	0.44	1.00

Table 4

Comparison of the Effective Fuel Values of Average of Best Ten South Dakota Coal Analyses and Average of the Typical Arkansas Coals.[2]

		South Dakota	Arkansas
1.	Moisture	32.91	1.66
2.	Excess moisture	31.25	
3.	Ash in dry coal	10.35	9.38[3]
4.	Excess ash in dry coal	0.97	
5.	B.t.u., average laboratory	7205	13928
6.	B.t.u. loss due to excess moisture 1256 x 0.3125	392	
7.	B.t.u. loss due to excess ash 7205 x 0.0097	70	
8.	Total B.t.u. loss	462	
9.	Effective B.t.u.	6733	13928
10.	Relative value	0.48	1.00

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1. Average of available analyses, February, 1933.
2. Average of analyses omitting those not giving calorific value from Branner, G. C., Outlines of Arkansas Mineral Resources; Bur. of Mines, Manufactures, and Agriculture and State Geol. Survey, p. 109, 1927.
3. Computed from analyses as received.

Table 5

Comparison of Effective Fuel Values of Average South Dakota Coals[1] and Average of Iowa Coals[2].

		South Dakota	Arkansas
1.	Moisture	36.65	8.54[3]
2.	Excess moisture	28.11	
3.	Ash in dry coal	13.91	15.03[4]
4.	Excess ash in dry coal		1.12
5.	B.t.u., average laboratory	6855	10019 to 11027
6.	B.t.u., loss due to excess moisture 1256 x 0.2349	353	
7.	B.t.u., loss due to excess ash 105235 x 0.0112		118
8.	Total B.t.u. loss	235	
9.	Effective B.t.u.	6620	10523[5]
10.	Relative value	0.63	1.00

Table 6

Comparison of Effective Fuel Values of Average of Best 10 South Dakota Coal Analyses and Average of Iowa coals.[2]

		South Dakota	Arkansas
1.	Moisture	32.91	8.54[3]
2.	Excess moisture	24.37	
3.	Ash in dry coal	10.35	15.03[4]
4.	Excess ash in dry coal		4.68
5.	B.t.u., average laboratory	7205	11027[6]
6.	B.t.u. loss due to excess moisture 1256 x 0.2437	306	
7.	B.t.u. loss due to excess ash 11027[6] x 0.0468		516
8.	Total B.t.u. loss		210
9.	Effective B.t.u.	7205	10816
10.	Relative value	0.67	1.00

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1. Average of available analyses, February, 1933.
2. Lees, J. H., and Hixon, A. W., Analyses of Iowa Coals, Iowa Geol. Survey, Vol. xix, p. 519, 1908.
3. Obtained by subtracting remaining ingredients from 100.
4. Computed from average as received analysis, Lees and Hixon.
5. Average of extremes, Item 5.
6. Maximum from Table 5, Item 5.

Table 7

Comparison of the Effective Fuel Values of Average South Dakota Coals[1] and Average of Typical Illinois (Franklin County) Coals[2].

	South Dakota	Illinois[2]
1. Moisture	36.65	9.13
2. Excess moisture	27.52	
3. Ash in dry coal	13.91	9.44
4. Excess ash in dry coal	4.47	
5. B.t.u. average laboratory	6855	11832
6. B.t.u. loss due to excess moisture 1256 x 0.2752	346	
7. B.t.u. loss due to excess ash 6855 x 0.0447	306	
8. Total B.t.u. loss	652	
9. Effective B.t.u.	6203	11832
10. Relative value	0.52	1.00

Table 8

Comparison of the Effective Fuel Values Of Average of 10 best South Dakota Coal Analyses and Average of Typical Illinois (Franklin County) Coals[2].

	South Dakota	Illinois[2]
1. Moisture	32.91	9.13
2. Excess moisture	23.78	
3. Ash in dry coal	10.35	9.44
4. Excess ash in dry coal	.91	
5. B.t.u., average laboratory	7205	11832
6. B.t.u., loss due to excess moisture 1256 x 0.2378	299	
7. B.t.u. loss due to excess ash 7205 x 0.0091	64	
8. Total B.t.u. loss	363	
9. Effective B.t.u.	6832	11832
10. Relative value	0.58	1.00

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1. Average of available analyses, February, 1933.
2. Bement, A., Illinois Coal, Illinois State Geol. Survey, Bull. 56, p. 99, 1929 (average of 21 mines).

Table 9

Comparison of the Effective Fuel Values Of Average South Dakota Coals[1] and Average of Typical Eastern Kentucky Coals[2]

	South Dakota	Kentucky
1. Moisture	36.65	2.99
2. Excess moisture	33.66	
3. Ash in dry coal	13.91	4.85[3]
4. Excess ash in dry coal	11.06	
5. B.t.u., average laboratory	6855	13659
6. B.t.u., loss due to excess moisture 1256 x 0.3366	423	
7. B.t.u. loss due to excess ash 6855 x 0.1106	758	
8. Total B.t.u. loss	1181	
9. Effective B.t.u.	5674	13659
10. Relative value	0.42	1.00

Table 10

Comparison of the Effective Fuel Values of Average of Best 10 South Dakota Coal Analyses and Average of Typical Eastern Kentucky Coals[2].

	South Dakota	Kentucky
1. Moisture	32.91	2.99
2. Excess moisture	29.92	
3. Ash in dry coal	10.35	4.85[3]
4. Excess ash in dry coal	5.45	
5. B.t.u., average laboratory	7205	13659
6. B.t.u, loss due to excess moisture 1256 x 0.2992	376	
7. B.t.u. loss due to excess ash 7205 x 0.0545	293	
8. Total B.t.u. loss	669	
9. Effective B.t.u.	6536	13659
10. Relative value	0.48	1.00

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1. Average of available analyses, February, 1933.
2. Kentucky Geological Survey, Ser. IV, Vol. 1, Pt. 1, pp. 115-179 (1913); Average of analyses giving B.t.u.
3. Computed from as received analyses.

Table 11

Comparison of the Effective Fuel Values of Average South Dakota Coals[1] and Average of Typical West Virginia Coals.[2]

		South Dakota	West Virginia
1.	Moisture	36.65	3.30
2.	Excess moisture	33.35	
3.	Ash in dry coal	13.91	4.51[3]
4.	Excess ash in dry coal	9.40	
5.	B.t.u., average laboratory	6855	14603
6.	B.t.u. loss due to excess moisture, 1256 x 0.3335	419	
7.	B.t.u. loss due to excess ash 6855 x 0.0940	644	
8.	Total B.t.u. loss	1063	
9.	Effective B.t.u.	5792	14603
10.	Relative value	0.40	1.00

Table 12

Comparison of the Effective Fuel Values of Average of Best Ten South Dakota Coal Analyses and Average of Typical West Virginia Coals.[2]

		South Dakota	West Virginia
1.	Moisture	32.91	3.30
2.	Excess moisture	29.61	
3.	Ash in dry coal	10.35	4.51
4.	Excess ash in dry coal	5.84	
5.	B.t.u., average laboratory	7205	14603
6.	B.t.u. loss due to excess moisture 1256 x 0.2961	372	
7.	B.t.u. loss due to excess ash 7205 x 0.0584	421	
8.	Total B.t.u. loss	793	
9.	Effective B.t.u.	6402	14603
10.	Relative value	0.44	1.00

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1. Average of available analyses, February, 1933.
2. West Virginia Geol. Survey, Bull. 2, Table No. 2, opp. p. 212. (1911). (Average 64 analyses, Pocahontas No. 3).
3. Computed from As received analyses.

Table 13

Comparison of the Effective Fuel Values of Average South Dakota Coals[1] and Average of Typical Wyoming (Roundup) Coal.[2]

		South Dakota	Wyoming (Roundup)
1.	Moisture	36.65	13.2
2.	Excess moisture	23.4	
3.	Ash in dry coal	13.91	8.2
4.	Excess ash in dry coal	5.7	
5.	B.t.u., average laboratory	6855	10904
6.	B.t.u. loss due to excess moisture 1256 x 0.234	291	
7.	B.t.u. loss due to excess ash 6855 x 0.057	391	
8.	Total B.t.u. loss	685	
9.	Effective B.t.u.	6170	10904
10.	Relative value	0.57	1.00

Table 14

Comparison of the Effective Fuel Values of Average of Best Ten South Dakota Coal Analyses and Average of Typical Wyoming (Roundup) Coal[2].

		South Dakota	Wyoming (Roundup)
1.	Moisture	32.9	13.2
2.	Excess moisture	19.7	
3.	Ash in dry coal	10.3	8.2
4.	Excess ash in dry coal	2.1	
5.	B.t.u, average laboratory	7205	10904
6.	B.t.u. loss due to excess moisture 1256 x 0.197	247	
7.	B.t.u. loss due to excess ash 7205 x 0.021	151	
8.	Total B.t.u. loss	398	
9.	Effective B.t.u.	6807	10904
10.	Relative value	0.62	1.00

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1. Average of available analyses, February, 1933.
2. U. S. Bur. Mines, Tech. Paper 529, pp. 52-53, (1932). (Averages from 32 analyses Roundup).

The comparative figures shown in Tables 3 to 14 inclusive may be used to indicate comparative effective fuel values graphically. The graphs may easily be read to show the relative dollar values of the two coals compared. Thus, in the succeeding figure (Fig.1) the two coals, A and B compared in Table 2, (p. 4) are compared graphically.

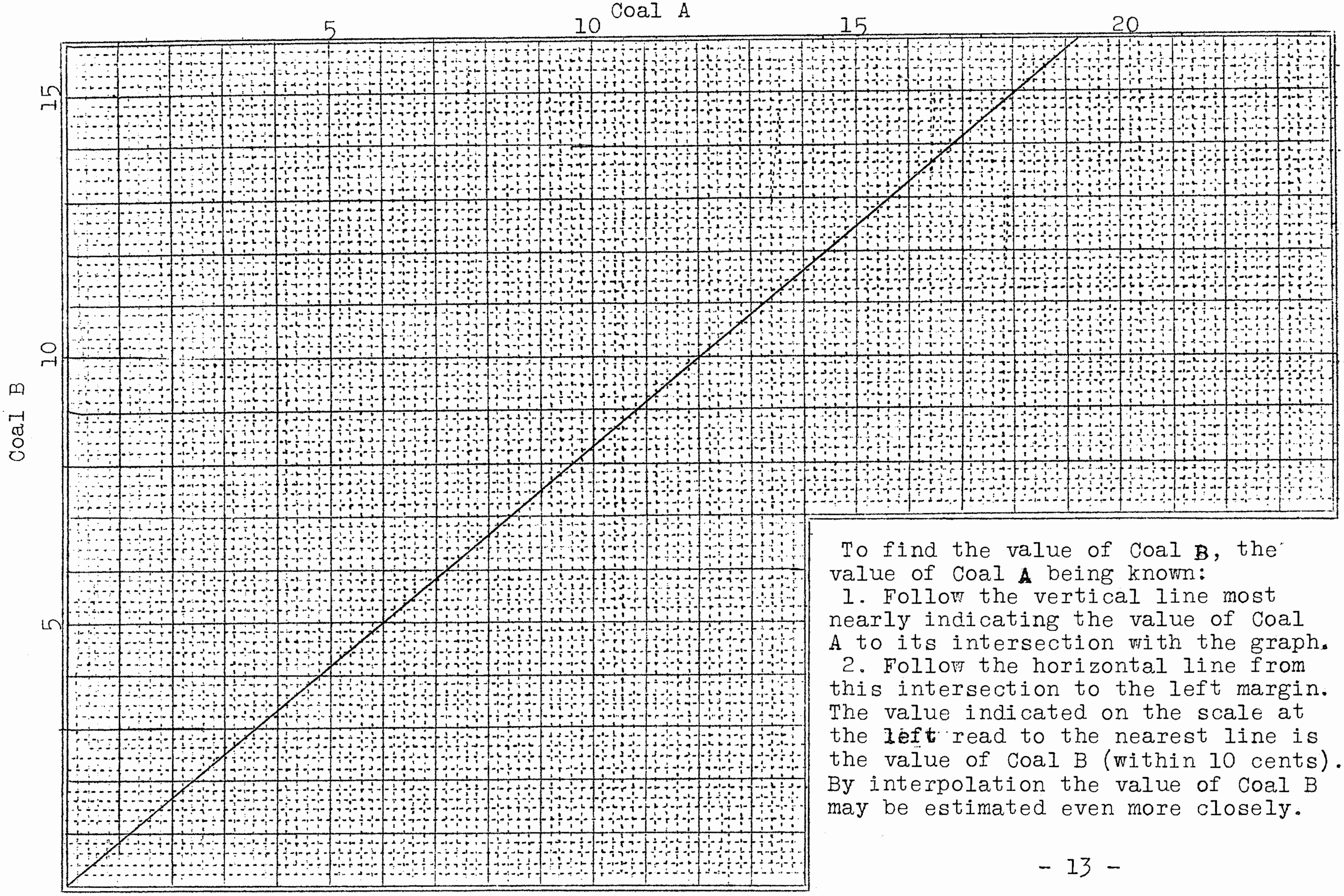
The effective fuel values and cost of coal are represented on the graph by vertical lines. The value of Coal B is represented by horizontal lines. The comparative values of the two coals is represented by the diagonal line. If the cost of Coal A is $5.00, the point at which the vertical line crosses the diagonal line represents the comparative value of Coal B. The latter value, thus determined is more than $4.00 and less than $4.20 (actually $4.15). At $10.00 per ton for Coal A the relative value of coal B is half way between $8.20 and $8.40 or $8.30, which is the computed value.

In the figures which follow, (figures 2 to 7 inclusive) the effective fuel values are shown for the computed relative effective fuel values shown in tables 3 to 14. These graphs show the relative effective fuel values of the averages of the coals compared and may be used as suggested in the foregoing paragraph to show the relative price values.

It will be noted from these graphs that South Dakota coal can be used at a substantial saving to the consumer over much of the state. The nearer to that coal field the coal buyer lives the greater the saving, since cost of freight is increasingly less on South Dakota coal and increasingly greater on imported coals. It is believed that if the coal consumer uses reasonable diligence in burning coal produced in the state he can approximate the relative values indicated in the graphs.

GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES OF TWO COALS (A AND B)

Figure 1



To find the value of Coal **B**, the value of Coal **A** being known:

1. Follow the vertical line most nearly indicating the value of Coal A to its intersection with the graph.

2. Follow the horizontal line from this intersection to the left margin. The value indicated on the scale at the **left** read to the nearest line is the value of Coal B (within 10 cents). By interpolation the value of Coal B may be estimated even more closely.

Figure 2.

GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES OF SOUTH DAKOTA AND ARKANSAS COALS

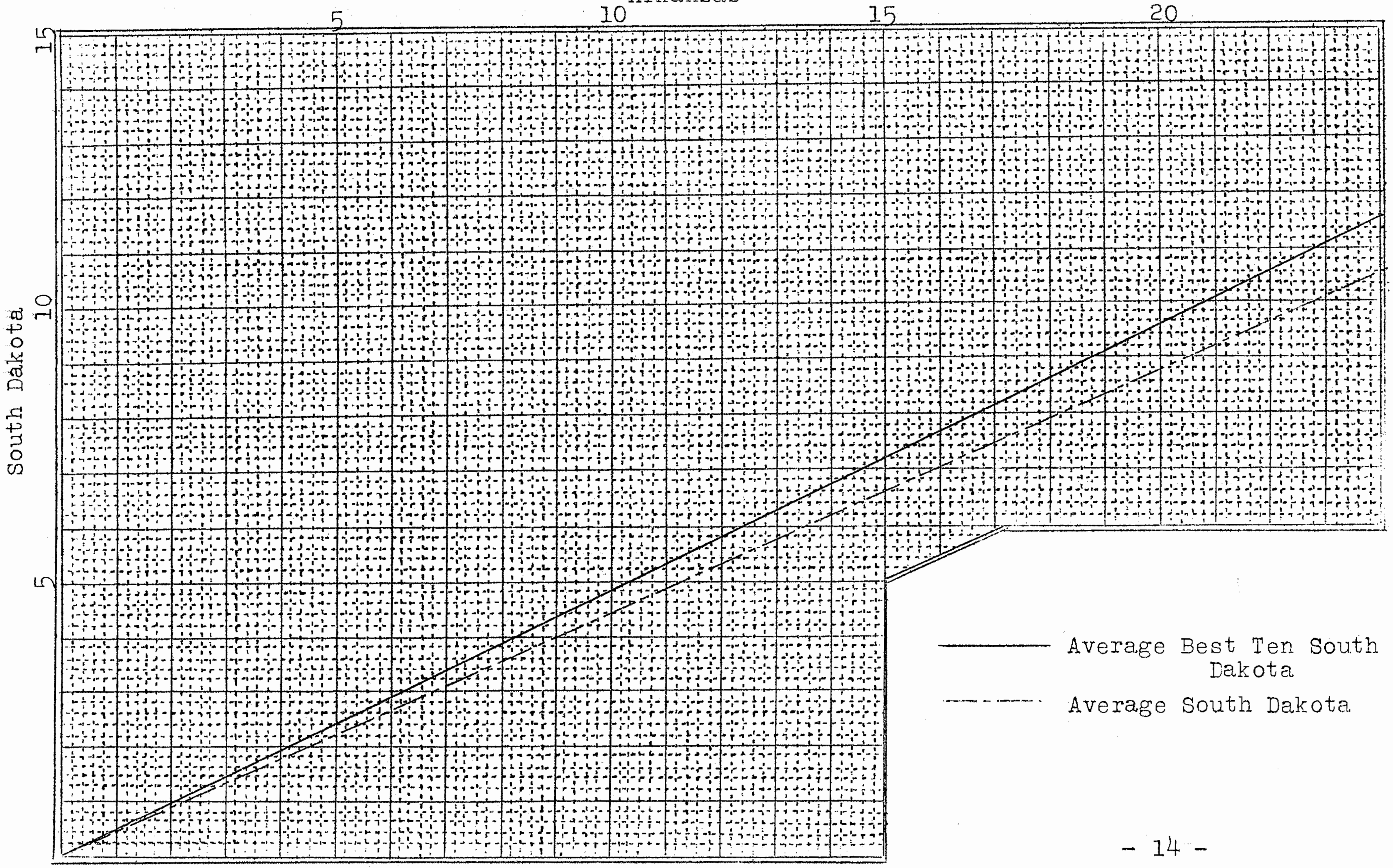
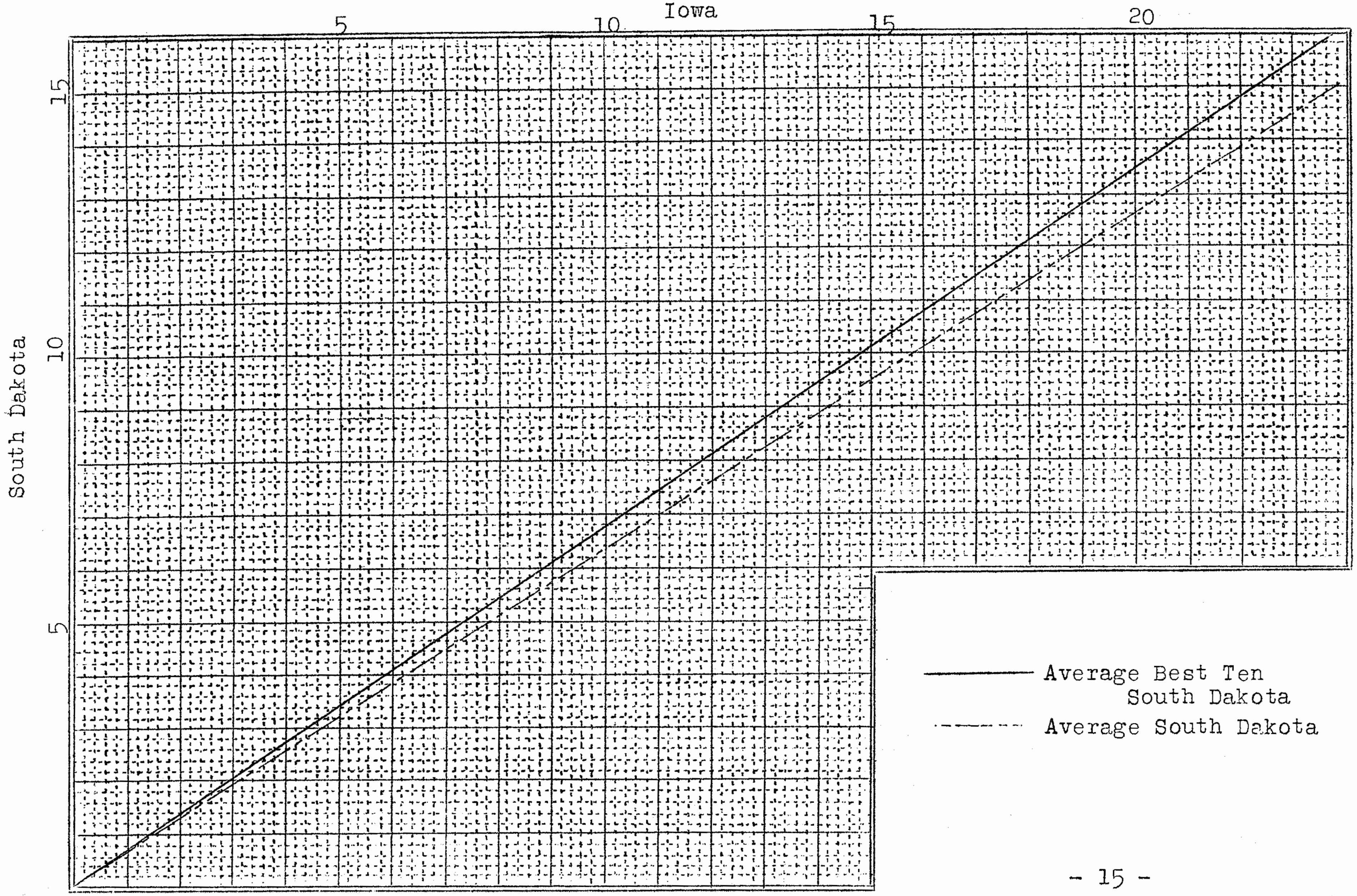


Figure 3

GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES
of SOUTH DAKOTA AND IOWA COALS



GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES
OF SOUTH DAKOTA AND ILLINOIS COALS

Figure 4

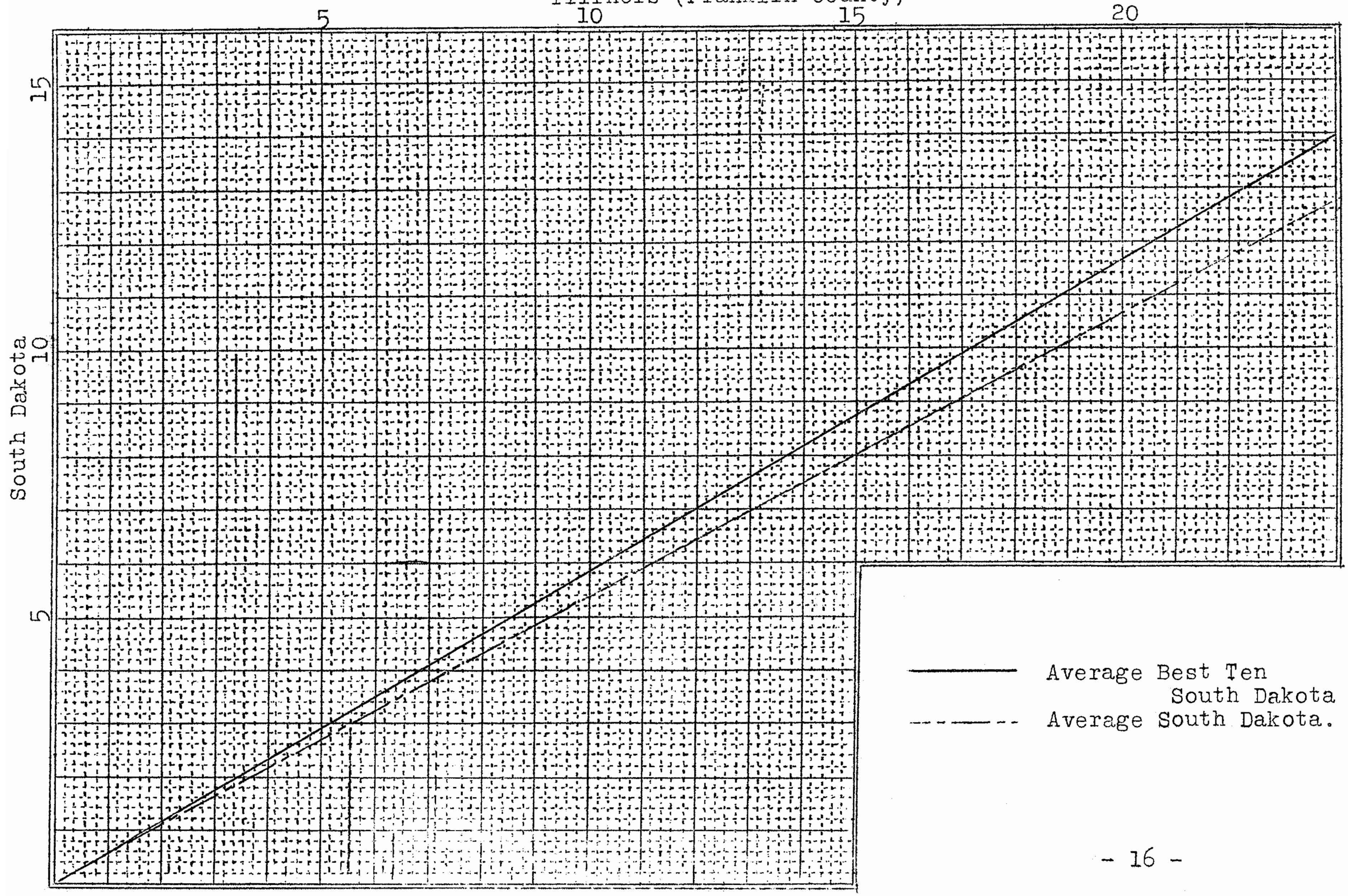
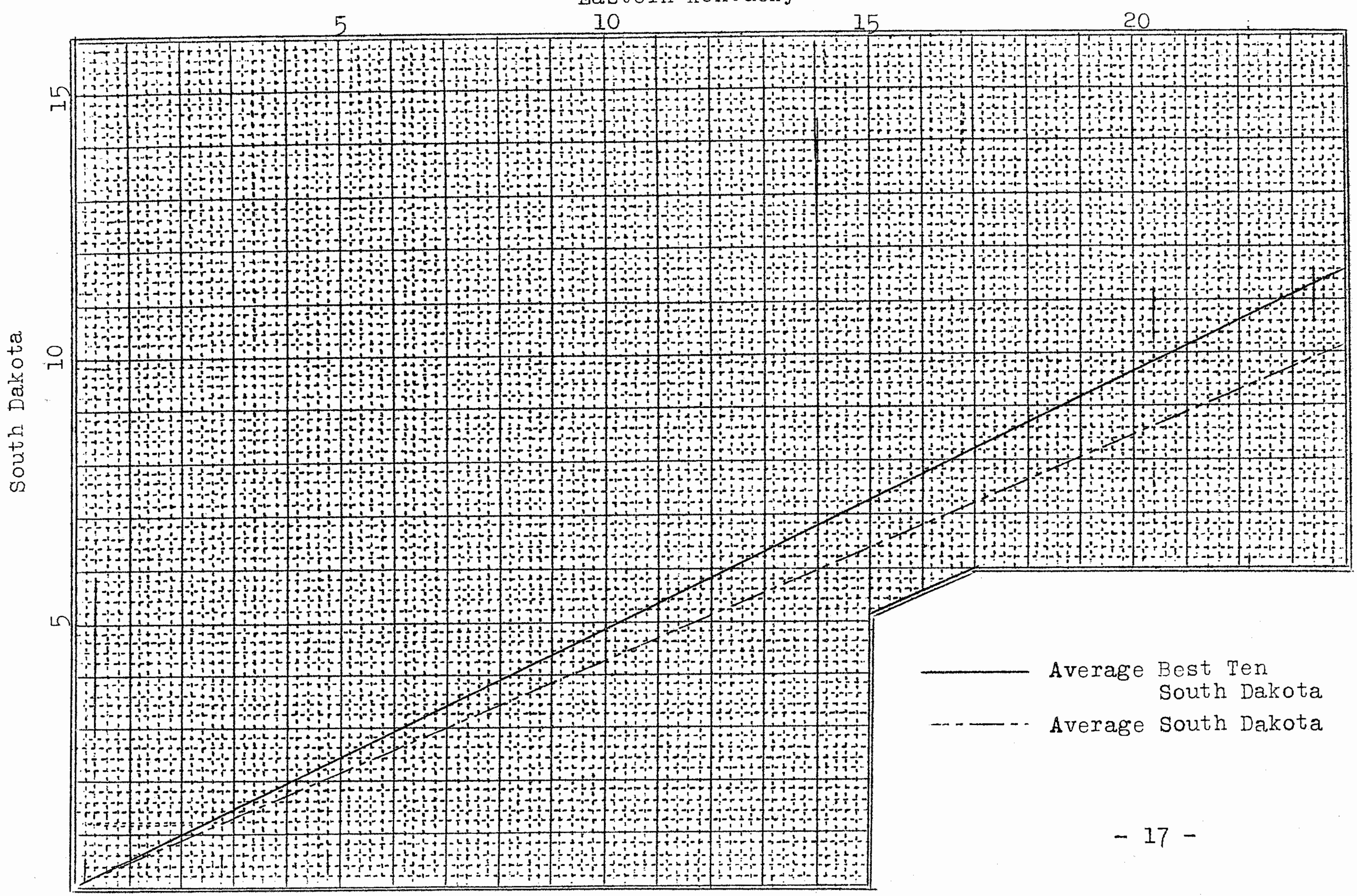


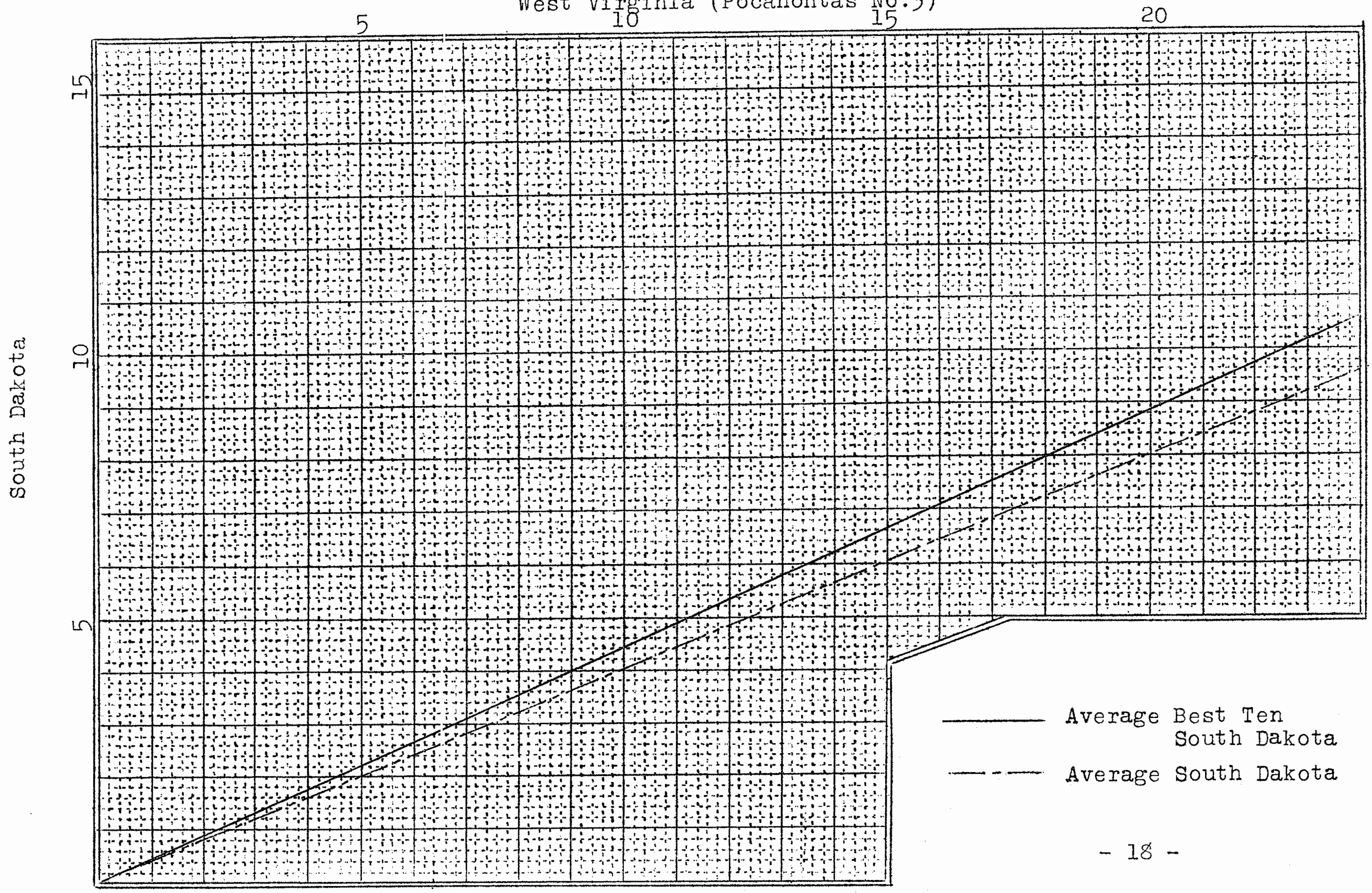
Figure 5

GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES OF SOUTH DAKOTA AND EASTERN KENTUCKY COALS

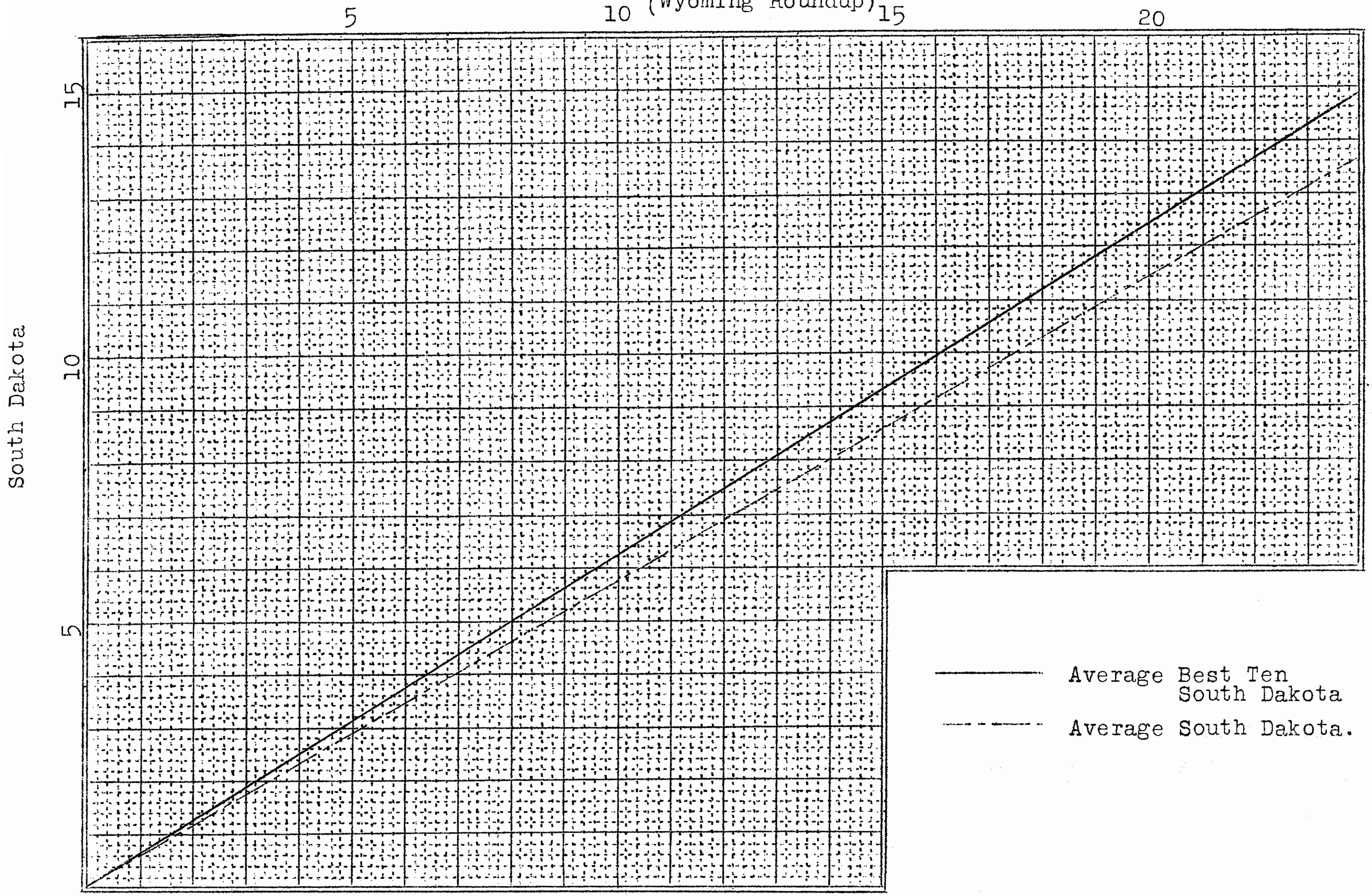


GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES OF SOUTH DAKOTA AND WEST VIRGINIA COALS

Figure 6



GRAPHIC COMPARISON OF THE EFFECTIVE FUEL VALUES
OF SOUTH DAKOTA AND WYOMING COALS
(Wyoming Roundup)*



SUGGESTIONS AND NOTES ON THE USE OF SOUTH DAKOTA COAL

IN COMMON STOVES AND FURNACES

In order to obtain greatest heat efficiency from South Dakota coal, the physical and chemical character of the coal must be considered and burning conditions accommodated as closely as possible to the character of the coal. Ideally, heating devices should be designed specifically for each of the several fuels commonly burned. For example, a furnace could be designed to burn a certain low-grade bituminous coal at maximum efficiency. Such a furnace, however, would probably be so unsuited to the combustion characters of a high grade bituminous coal as to be unsatisfactory when fired with the latter fuel. In designing and building domestic heating and cooking devices, except those for burning gas, gasoline, kerosene, oil and anthracite coal, stoves and furnaces are not adapted specifically to individual fuels. The manufacturer attempts to build the burning device with sufficient elasticity of control as to burn fuels with a variety of combustion requirements. It is not uncommon to find stoves which are sufficiently elastic in adjustment to burn fuels with combustion characters differing as widely as wood and bituminous coal, burning each with fairly satisfactory results. As a result, South Dakota coal can be burned with considerable success in most of the stoves, ranges, and coal burning furnaces commonly sold in the region, although some of these devices are of course, more nearly suited or maybe more closely adjusted to the characters of South Dakota coals than others.

Drafts

South Dakota coals are rich in volatile matter and require abundant draft for complete combustion. Sufficient chimney or stack draft is necessary to insure the drawing of air through and over the coal. Long and undersized smoke pipes to the chimney should be avoided. Drafts below the firebox should be such as to insure the flow of air up through the coal uniformly when rapid combustion is desired. Drafts over the firebox should also be adequate. An excess of air is necessary to combustion of the gases released at the fuel bed. It will be noted in burning these South Dakota coals that, as the coal ignites, long yellow flames two feet or more in length extend from the fuel bed to the smoke pipe outlet. In some South Dakota coals after initial combustion of the fresh charge the flames shorten to a foot or less in length and become blue in color. The long flames produced at the beginning of combustion show the path of the combustible gases released at the fuel bed and demonstrate the necessity of adequate air to insure combustion before these gases pass into the flue where they are lost without producing heat.

Grates

For best results, South Dakota coal requires relatively large grates. Openings in the grates should be small but abundant to best accommodate the behavior and character of the fuel as it is fired. The fuel has no tendency to coke in the firebox. On the other hand, loss of water produces quite a different tendency, that of the coal to break up into small pieces when first heated. The lack of the coking property and the tendency of the coal to break up in the firebox will permit fine, unconsumed fuel to be lost into the ashpit if the grate openings are too large. The coal requires abundant draft up through the coal because of its richness in volatile matter. Therefore abundant but small grate openings are desirable.

Firebox:

The firebox should be of fairly deep dimensions so that it has some reserve capacity and so that too frequent firing is not necessary.

Coal Sizes:

South Dakota coal is commonly mined in pieces too large for domestic use. These reach the consumer in a more or less broken condition but much of the coal remains in pieces of too great size for efficient firing. Small sizes are best for use in ordinary stoves and furnaces since these insure sufficient combustion surface and air is readily distributed between them. Sizes between two and six inches seem most desirable in practice. Fine slack is undesirable in quantities for most domestic uses since it is difficult to admit sufficient air through the ordinary firebox filled with this material. Furthermore, much coal is lost through grates of the ordinary type. The experienced user of South Dakota coal burns the fines a little at a time with the larger pieces over a well-filled firebox thus preventing their accumulation in quantity at the end of the season.

Smoke and Soot:

Burning of South Dakota coal without smoke and soot is a minor problem since the fuel is almost smokeless. It can be burned essentially without soot or smoke more easily than most coals imported into the state, probably even including Pocahontas coal. Indeed, cleanliness in burning is one of the most desirable attributes of South Dakota coals.

Clinkers:

Some South Dakota coals clinker, but probably no more readily than most imported coals. Clinkers are due to fusion of the ash. Fusion appears to be due to a complex relation between siliceous substances and fluxes in the ash. Clinkering of the ash of South Dakota coals is an important subject for future research. When burned as domestic fuel in the raw state in ordinary stoves and furnaces clinkering does not, however constitute a major problem, because the clinkers formed from South Dakota coal are light in weight, soft and porous.

Rate of firing:

Because of lower heating value per pound, South Dakota coal must be fired somewhat more frequently than most eastern coals unless there is considerable latitude in firebox and grate capacity. A firing rate sufficient to maintain between six and twenty pounds of coal per square foot of grate space seems to be most efficient.

Relative Efficiency of South Dakota and Other Coals in Ordinary Stoves and Furnaces:

In a test of South Dakota coal against a processed bituminous coal of high heating value the relative efficiency as shown by computed effective fuel values was approached within 1.7 per cent. The furnace used was an ordinary house furnace. The comparative heating efficiency of the two coals was determined by checking the degrees of heat maintained per pound per hour by each coal. While not conclusive the test indicates that the South Dakota coal may be burned satisfactorily in stoves and furnaces not of special design.