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FUEL GASIFICATION PROCESSES AND THEIR EXPRESSION
IN THE TERBECK DIAGRAM

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Graphic expressions of processes are important in the study
of any problems. Methods of water gas production differ in principles;
a satisfactory graphic expression of the processes would therefore be
highly desirable. Efforts were made in the past to express equilibrium
conditions in concentration-temperature diagrams, in which the equilibrium
concentrations for every gas component could be found for any temperature.
Such concentration-temperature diagrams are difficult to read and give
the practical man no help in planning his experiments according to some
simple scheme as an aid in his investigations.

W. Terbeck has recently proposed a diagram based on stoichiometry
of the water gas production, which is supposed to give valuable help to
the practical chemist because of its simplicity and its clarity.

I.

The two equations:

$$C + H_2O \longrightarrow CO + H_2, \text{ and} \qquad (I)$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad (II)$$

express the basic processes of interaction of steam with carbon according
to the practical experience in water gas production. Reaction I proceeds

practically completely towards the right, while reaction II is a typical equilibrium reaction in which the four gas components are generally present in appreciable amounts after the termination of the reaction. The mass action law demands that when equilibrium condition is reached, the products of concentration of the reacting substances divided by the product of concentration of the reaction products equals a characteristic number for a given temperature, the so-called equilibrium constant; for the water gas equilibrium (reaction II) we have therefore

$$\frac{(CO) \cdot (H_2O)}{(CO_2) \cdot (H_2)} = K_w \, ,$$

where the expressions in parentheses are symbols for molecular concentrations of the components.

The producer gas equilibrium (Boudouard) as well as the water gas equilibrium is important in reactions of carbon:

$$C + CO_2 \rightleftharpoons 2\ CO. \tag{III}$$

The equilibrium constant of the producer gas equilibrium assumes the form

$$\frac{(p_{CO})^2}{p_{CO_2}} = K_b \, ,$$

where p_{CO} and p_{CO_2} are the partial pressures of CO and CO_2. The question whether the simultaneous equilibrium of the water gas and producer gas equilibria (complete equilibrium) is reached in the interaction of steam and carbon will not be discussed here, and demands special investigation. The assumption of a simultaneous water gas and producer gas equilibria offers the possibility, however, to refer gasification processes to an ideal process, similar to the thermodynamic methods which test the operations of a motor on the basis of an ideal cycle process.

Should the gasification be referred to 1 mol C (12 kg.), the carbon balance will require that

$$CO + CO_2 = 1;$$

the oxygen of CO and CO_2 is furnished by the decomposed steam, so that

$$H_2 = CO + 2 CO_2;$$

moreover, the hydrogen introduced as total steam w forms elementary hydrogen according to the equation, while the undecomposed steam leaves as $(H_2O)_{exc.}$. It follows, therefore, from the carbon balance:

$$CO + CO_2 = 1; \qquad CO_2 = 1 - CO.$$

From the oxygen balance:

$$H_2 = CO + 2 CO_2; \qquad H_2 = 2 - CO.$$

From the hydrogen balance:

$$w = (H_2O)_{exc.} + H_2; \quad (H_2O)_{exc.} = w - (2 - CO).$$

In addition, assumption of gas equilibria requires that

$$K_w = \frac{(CO) \cdot (H_2O)_{exc.}}{(CO_2) \cdot (H_2)} \qquad\qquad (IV)$$

and

$$K_B = \frac{(p_{CO})^2}{p_{CO_2}} \qquad\qquad (V)$$

CO, CO_2, H_2 are expressed in mols per mol of gasified carbon, $(H_2O)_{exc.}$ is the excess steam in the gas and w the amount of steam introduced, with both values also in terms of mols/mol C gasified.

Five equations are therefore available for the determination of the five values CO, CO_2, H_2, $(H_2O)_{exc.}$ and w, and permit a definite solution.

Should CO be equal to x mols/mol gasified C, equation IV assumes the form for water gas equilibrium:

$$K_w = \frac{x (w - 2 + x)}{(1 - x) (2 - x)} \qquad\qquad (IVa)$$

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The following must be considered in the determination of partial pressures (equation V): 1 mol C produces by interaction with w mols of steam

$(CO) + (CO_2) + (H_2) + (H_2O)_{exc.}$ total mols;

since $(CO) + (CO_2) = 1$ and $(H_2) + (H_2O)_{exc.} = w$,

$w + 1$ is the total mols of wet water gas.

The total pressure is assumed to be equal to 1 and partial pressures are converted to molar concentration by

$$p_{CO} = \frac{(CO)}{w + 1} \text{ and } p_{CO_2} = \frac{(CO_2)}{w + 1}.$$

Introducing the partial pressures in equation V gives

$$K_B = \frac{(p_{CO})^2}{p_{CO_2}} = \frac{x^2}{1 - x} \cdot \frac{1}{1 + w}. \qquad (Va)$$

for the producer gas equilibrium.

Finding K values by solving the two equations IVa and Va for different temperatures gives the relationship between gas composition and temperature as shown, e.g. by Terbeck [1] in figure 6. This concentration-temperature diagram is difficult to read and not suited to practical applications.

II.

The Terbeck diagram expresses graphically the reactions given by chemical equations, and all conversions are referred by definition to 1 mol C. For pure water gas gasification of carbon we get

$$CO + CO_2 = 1,$$

$$H_2 = 2 - CO - 1 + CO_2.$$

CO_2 and H_2 are now expressed as functions of the CO content, x, in the water gas. The upper part of the diagram represents, therefore, the composition of the dry gas formed by interaction of steam and carbon.

The composition of the wet gas is found by assuming simultaneous water gas and producer gas equilibria from equations IV and V. This explains the basis of the Terbeck diagram for the gasification of carbon with steam. The bottom part of the Terbeck diagram may contain in addition the temperature curve from equilibria values, as shown in figure 1.
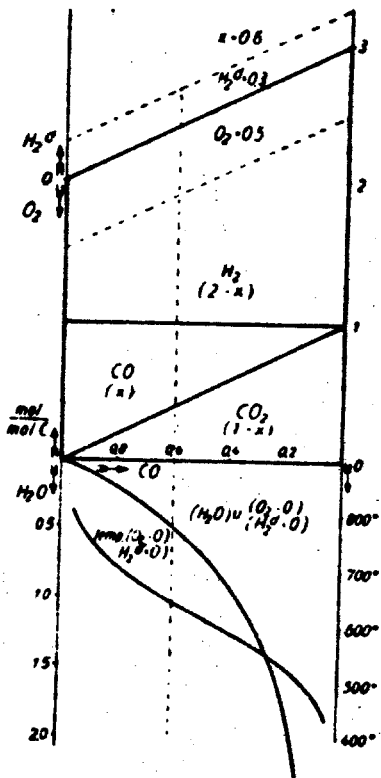

Figure 1. - Terbeck diagram.

The Terbeck diagram was first designed for the gasification of pure carbon. It can be directly used for the gasification of bituminous fuels with steam. In this case, the amount of hydrogen from steam is increased by the net hydrogen in the fuel $d \cdot H_2^n$ mols/mol C; the hydrogen line of pure water gas production from carbon is then increased by the value $d \cdot H_2^n$. The addition of the net hydrogen shifts the water gas equilibrium,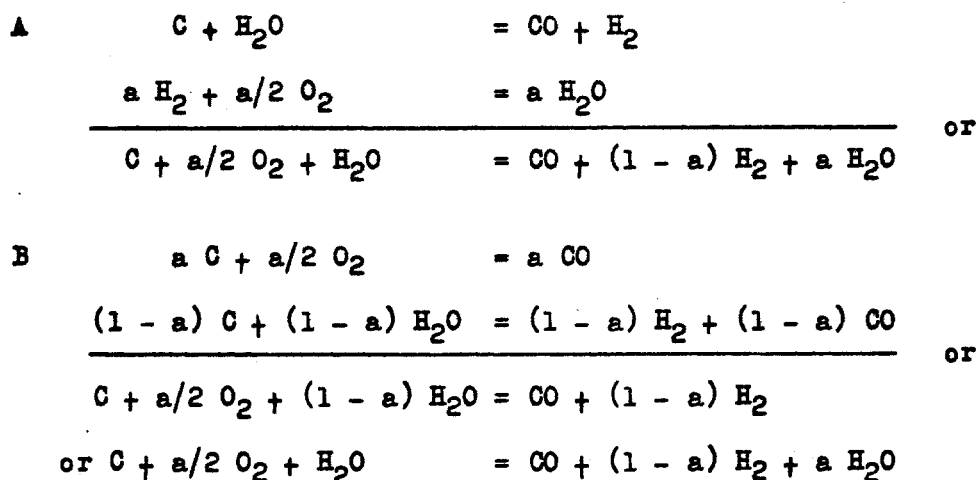 and different values for $(H_2O)_{exc.}$ will therefore be obtained for different fuels, and the equilibrium temperatures in the bottom part of the diagram must always be made to agree with the different fuels used.

Gasification with oxygen and steam (oxy-water gas) can be derived in a way similar to that for pure steam gasification.

Were we to assume that the oxygen added will burn the corresponding amount of hydrogen in the gas with formation of water, each

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mol O_2/mol C in the oxygen-steam mixtures will reduce the hydrogen content of pure steam gasification by 2 mols H_2. The Terbeck diagram represents these conditions by lines parallel at proper distances to the hydrogen line. The curve for the $(H_2O)_{exc.}$ must again be determined for each case.

The manner in which the oxidation with oxygen proceeds in the oxy-water gas production is unimportant for calculations (application of stoichiometrical and thermochemical laws) as may be shown in one example.

A
$$C + H_2O = CO + H_2$$
$$a\, H_2 + a/2\, O_2 = a\, H_2O$$
$$\overline{C + a/2\, O_2 + H_2O = CO + (1 - a)\, H_2 + a\, H_2O} \quad \text{or}$$

B
$$a\, C + a/2\, O_2 = a\, CO$$
$$(1 - a)\, C + (1 - a)\, H_2O = (1 - a)\, H_2 + (1 - a)\, CO$$
$$\overline{C + a/2\, O_2 + (1 - a)\, H_2O = CO + (1 - a)\, H_2} \quad \text{or}$$
$$\text{or}\ C + a/2\, O_2 + H_2O = CO + (1 - a)\, H_2 + a\, H_2O$$

Final results obtained by both methods are the same. The understanding of the different physical and chemical partial processes during gasification based on observation and experiment is not merely useful but is of the greatest importance for progress to supplement the formal treatment discussed above. The role of the net hydrogen in the powdered fuel gasification should, in this connection, be especially considered (Terbeck, loc. cit.). The explanation of the role of equilibrium during the action of H_2-CO_2 mixture of the fuels of different reactivity permits making important conclusions on gasification processes of these fuels.[2] A discussion of the use of computations based on experiment might be of interest in this connection. The words of Partington may be remembered:

"In the older treatises...a proper balance between theory and experiment was observed, but the later tendency has been to write books more and more devoted to the mathematical theory, without any regard being paid to experimental methods or their results, which are introduced merely for the purpose of proving or disproving the theory set out.
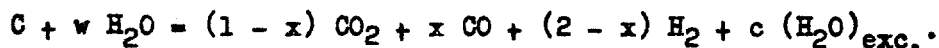
III.

Computation and diagrams are based on simultaneous water gas and producer gas equilibria, as previously mentioned. Changes in the

diagram without the simultaneous formation of the Boudouard equilibrium might be of interest. The basic equation of water gas formation is used as before as a basis for the water gas equilibrium. The measure of conversion of carbon monoxide, according to the computation shown and the notations in the diagram, is assumed to be $(1 - x)$, i.e. $(1 - x)$ mols were converted with steam into CO_2 from each 1 mol of CO, and x mols of CO are left behind:

$$C + H_2O = CO + H_2$$

$$(1 - x) \, CO + (1 - x) \, H_2O = (1 - x) \, CO_2 + (1 - x) \, H_2 .$$
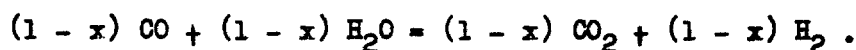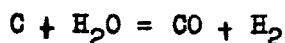
Should c represent the amount of undecomposed steam,

$$C + w \, H_2O = (1 - x) \, CO_2 + x \, CO + (2 - x) \, H_2 + c \, (H_2O)_{exc.} .$$

It must be remembered, that hydrogen balance requires that the excess steam (c), be equal to the amount of the total steam (w) reduced by the equivalent amount of hydrogen produced $(2 - x)$. Water gas equilibrium can be expressed, therefore, as

$$K_w = \frac{CO \cdot (H_2O)_{exc.}}{CO_2 \cdot H_2} = \frac{x}{1 - x} \cdot \frac{c}{2 - x} .$$

Disregarding the formation of the Boudouard equilibrium, only the indefinite equation IVb remains, and

$$\frac{c}{K_w} = \frac{(1 - x) \cdot (2 - x)}{x}$$

K_w determines the equilibrium temperature, c is the excess steam, and the non-formation of the Boudouard equilibrium requires that a given dry gas analysis will correspond to a number of wet gas analyses, for which must be maintained a simple relationship between the equilibrium temperature and the amount of undecomposed steam, namely,

$$\frac{c}{K_w} = const. = f(x) = \frac{(1 - x) \cdot (2 - x)}{x} .$$

TABLE 1. – Equilibrium constants for water gas equilibrium:

$$K_w = \frac{(CO) \cdot (H_2O)}{(CO_2) \cdot (H_2)}$$

°C.	K_w	°C.	K_w	°C.	K_w
400	0.08445	600	0.3861	800	0.9465
410	0.09324	610	0.4081	810	0.9800
420	0.1026	620	0.4308	820	1.0140
430	0.1127	630	0.4542	830	1.0485
440	0.1234	640	0.4784	840	1.0835
450	0.1348	650	0.5034	850	1.1191
460	0.1469	660	0.5289	860	1.1553
470	0.1597	670	0.5553	870	1.1921
480	0.1732	680	0.5824	880	1.2290
490	0.1875	690	0.6101	890	1.267
500	0.2025	700	0.6386	900	1.305
510	0.2183	710	0.6677		
520	0.2349	720	0.6976		
530	0.2520	730	0.7278		
540	0.2690	740	0.7572		
550	0.2868	750	0.7874		
560	0.3052	760	0.8179		
570	0.3244	770	0.8492		
580	0.3443	780	0.8810		
590	0.3649	790	0.9135		

Different x values derived from this equation are:

x	= 0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
c/K_w	= 0.122	0.300	0.547	0.933	1.500	2.400	3.967	7.300	17.100

The following c values are therefore obtained for given temperatures by substituting K_w values in c/K_w.

TABLE 2. – c Values of $(H_2O)_{exc.}$

°C.	K_w	x=0.9	x=0.8	x=0.7	x=0.6	x=0.5	x=0.4	x=0.3	x=0.2	x=0.1
300	0.021	0.003	0.006	0.012	0.020	0.032	0.050	0.084	0.150	0.350
400	0.084	0.010	0.025	0.047	0.079	0.127	0.200	0.336	0.600	0.140
500	0.20	0.024	0.061	0.111	0.187	0.303	0.476	0.800	1.430	3.333
600	0.39	0.047	0.118	0.217	0.363	0.590	0.929	1.560	2.786	6.500
700	0.64	0.078	0.194	0.356	0.598	0.970	1.524	2.560	4.572	10.667
800	0.95	0.116	0.288	0.528	0.888	1.455	2.262	3.800	6.786	15.833
900	1.31	0.160	0.397	0.728	1.224	1.985	3.119	5.240	9.357	21.833
1000	1.69	0.206	0.512	0.939	1.580	2.561	4.024	6.760	12.071	28.167
1100	2.10	0.256	0.636	1.167	1.963	3.182	5.000	8.400	15.000	35.000

For instance, the value of c/K_w is equal to 0.933 for a gas with 0.6 mols CO/mol C.

Selecting a few values at random, the excess steam c in the wet gas for temperatures

°C.	500	600	700	corresponding to
K_w	0.20	0.39	0.64	is
$c = (H_2O)_{exc.}$	0.187	0.363	0.598	mols H_2O/mol C

Assuming the formation of both the water gas and the Boudouard equilibria for

$$x = 0.6$$

$$K_w = 0.496 \text{ corresponding to } 647° \text{ C., i.e.}$$

$$c = (H_2O)_{exc.} = 0.463 \text{ mols } H_2O/\text{mol C}$$

which is a definite composition of the equilibrium gas, as was shown elsewhere (Brennstoff-Chemie, vol. 32, 1951, in print).

The composition of the dry gas is in both cases:

    0.6 mols CO/mols C............ 25.0% CO
    0.4 mols CO_2/mols C........... 16.6% CO_2
    1.4 mols H_2/mols C............ 58.4% H_2
                                100.0%

The assumption of an incomplete equilibrium leaves, therefore, the upper part of the Terbeck diagram unchanged, since both cases are referred to the same dry gas composition; this also applies to the amount of net hydrogen in a fuel and to the application of the Terbeck diagram to oxygen-steam gasification. The lower part of the diagram will be changed correspondingly by replacing the $(H_2O)_{exc.}$ curve in figure 1 by the curve for $(H_2O)_{exc.}/K_w$. Substitution of constant K_w values at constant temperatures gives the isotherms of the c values (fig. 2) for different x values.

This fully explains what Terbeck has stated in these words: "A closer examination shows that the Terbeck diagram tells nothing more than the effect of the conversion reaction $CO + H_2O = CO_2 + H_2$."
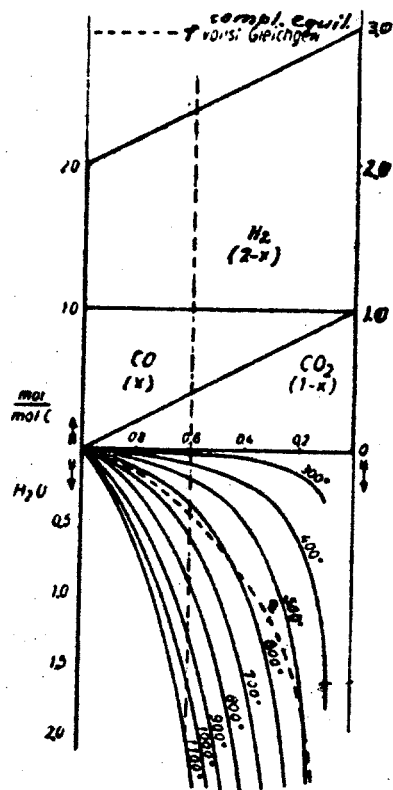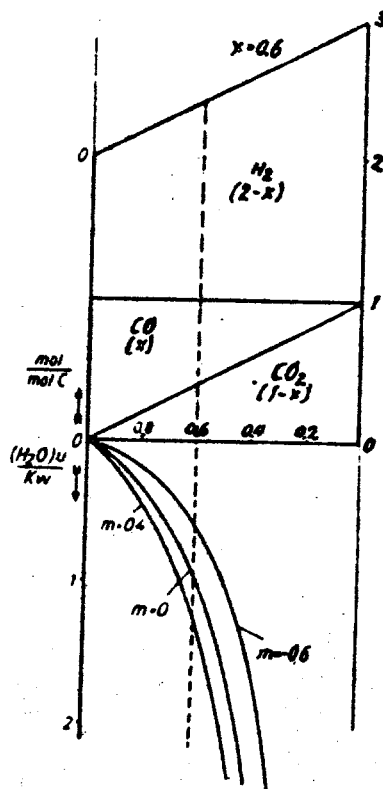
Figure 2. - Isothermal diagram.

Figure 3. - General form of the Terbeck diagram.

It should be added that the Terbeck diagram can be generally used for chemical conversions in which carbon monoxide and steam, or carbon dioxide and hydrogen, are participating, as e.g. in cracking reactions, or in the formation of hydrogen cyanide from ammonia and carbon monoxide:

$$CO + NH_3 = HCN + H_2O.$$
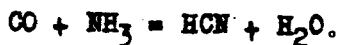
The wet gas analysis can be derived from the Terbeck diagram when the Boudouard equilibrium is not reached, when proper assumptions are made from the experimental evidence on the equilibrium temperature. This applies first of all to the interaction of steam and carbon. The relationships are retained in the gasification of bituminous fuels and for the production of oxy-water gas, but undergo formal changes by increasing the $(H_2O)_{exc.}$ by the amount of H_2O formed by combustion of

hydrogen, i.e. by having $(H_2O)_{exc.} = (w - b - x - 2)$, and the amount of
hydrogen in the gas is increased by the net hydrogen in the fuel, and
the oxygen reduced by a corresponding amount, i.e.

$$(H_2) = (2 + d - b - x). \text{ This leads to}$$

$$(H_2O)_{exc.}/K_w = \frac{(1 - x)(2 + d - b - x)}{x}.$$

Should the difference $(d - b)$ be used as a parameter, all the possible
experimental results will be included in the Terbeck diagram in the
curves at the bottom for $(H_2O)_{exc.}/K_w$.

The corresponding $(H_2O)_{exc.}/K_w$ curves are shown in figure 3 for

$$m = d - b = \begin{array}{l} 0.0 \\ +0.4 \\ -0.6 \end{array}.$$

The Terbeck diagram in this form is an exact expression of the gas com-
position and of the processes during gasification of any fuels with steam
and with steam-oxygen or with steam-air, and is of general significance.
This "general form of the Terbeck diagram" expresses accurately all gasi-
fication processes in a single diagram, but lacks the clarity of the iso-
thermal diagram of Terbeck, of the composition of wet gas and the effect
upon it of changes of operating conditions (temperature, amount of steam,
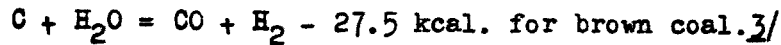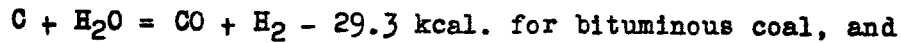etc.).

IV.

Examples of practical applications of the deductions will be
shown below. The problem of composition of the water gas produced under
given operating conditions will be first treated in a general form. It
will be followed by a practical example, and in conclusion, operating
conditions will be found from fuel and gas analyses in a further example.

A. General Case

Net hydrogen d in the fuel, expressed in mols H_2^n/mol C gasified,
the steam input w mols H_2O/mol of C and the oxygen input b/2 mols O_2/mol C

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are given. The temperature of formation of water gas equilibrium, which varies with operating conditions, concurrent or countercurrent gasification, and the reactivity of the fuel (bituminous coal or lignite) are taken from experimental data. Computations permit a simultaneous derivation of heat changes, taking into consideration the heat required for the conversion of the <u>solid</u> carbon with steam which is different for lignite and bituminous coal carbon:

$$C + H_2O = CO + H_2 - 29.3 \text{ kcal. for bituminous coal, and}$$

$$C + H_2O = CO + H_2 - 27.5 \text{ kcal. for brown coal.}3/$$

Bituminous coal is used in the example below.

The following applies to partial processes:

I $\quad (C + d\,H_2^n) + w\,H_2O = CO + (1 + d)\,H_2 + (w - 1)\,H_2O - 29.3 \text{ kcal.}$

II $\quad b\,H_2 + b/2\,O_2 = b\,H_2O + 57.6 \cdot b \text{ kcal.}$

A $\quad (C + d\,H_2^n) + w\,H_2O + b/2\,O_2 = CO + (1 + d - b)\,H_2$
$$+ (w - 1 + b)\,H_2O + (57.6 \cdot b - 29.3) \text{ kcal.}$$

III $\quad (1 - x)\,CO + (1 - x)\,H_2O = (1 - x)\,CO_2 + (1 - x)\,H_2 + 10.1\,(1 - x) \text{ kcal.}$

B $\quad (C + d\,H_2^n) + w\,H_2O + b/2\,O_2 = (1 - x)\,CO_2 + x\,CO + (2 + d - b - x)\,H_2 +$
$$(w - 2 + b + x)\,(H_2O)_{exc.} + \left[57.6 \cdot b + 10.1\,(1 - x)\right.$$
$$\left. - 29.3\right] \text{ kcal.}$$

IV $\quad K_w = \dfrac{(CO) \cdot (H_2O)}{(CO_2) \cdot (H_2)} = \dfrac{x\,(w - 2 + b + x)}{(1 - x)\,(2 + d - b - x)}$

B gives directly the values for H_2, $(H_2O)_{exc.}$ and the heat changes for

$$H_2 = (2 + d - b - x) \text{ mols/mol C}$$

$$(H_2O)_{exc.} = (w - 2 + b + x) \text{ mols/mol C}$$

$$Q = 57.6 \cdot b + 10.1\,(1 - x) - 29.3 \text{ kcal./mol.}$$

The composition of the wet and dry gases is, therefore:

Mol/mol C	Wet gas	Dry gas

$CO_2 = 1 - x$ $CO_2 \ldots \dfrac{1 - x}{1 + w + d} \cdot 100\%$ $CO_2 = \dfrac{1 - x}{3 + d - b - x} \cdot 100\%$

$CO = x$ $CO \ldots \dfrac{x}{1 + w + d} \cdot 100\%$ $CO = \dfrac{x}{3 + d - b - x} \cdot 100\%$

$H_2 = 2 + d - b - x$ $H_2 \ldots \dfrac{2 + d - b - x}{1 + w + d} \cdot 100\%$ $H_2 = \dfrac{2 + d - b - x}{3 + d - b - x} \cdot 100\%$

$H_2O = w - 2 + b + x$ $H_2O \ldots \dfrac{w - 2 + b + x}{1 + w + d} \cdot 100\%$

$S = 1 + w + d$ $S \ldots\ldots\ldots\ldots\ldots 100\%$ $S \ldots\ldots\ldots\ldots\ldots 100\%$

B. Computations for bituminous coal (6% ash, 4% moisture) with 35 percent

volatile matter in the m.a.f. coal of the following composition:

84.66% C = (7.06 mol C)   Calorific value: Gross 8300 kcal.
 5.41% H   Net   8100 kcal.
 7.26% O

$H_2^n = 5.41 - 7.26/8 = 4.5\%$, i.e. 2.25 mols/7.06 mols C, or

$H_2^n = 0.32$ mols/mol C.

The gasifying agent consists of

40% steam
60% oxygen

per mol C introduced:

0.75 mols of gasifying agent with 0.3 mols H_2O and
0.45 mols O_2, i.e.

$w = 0.3$; $b = 0.9$

Substituting these values

$H_2 = (2 + d - b - x) = (1.42 - x)$ mol H_2/mol C and
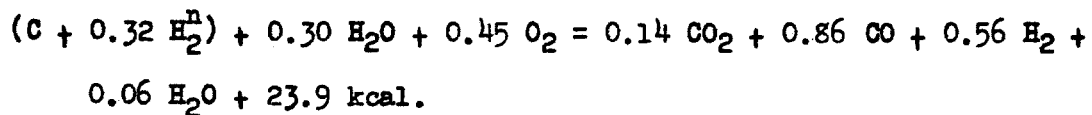
$(H_2O)_{exc.} = (w - 2 + b + x) = (x - 0.8)$ mols $(H_2O)_{exc.}$/mol C

$$K_w = \frac{x}{1 - x} \cdot \frac{x - 0.8}{1.42 - x}$$

$x = 0.86$ for the equilibrium temperature of $700°$ C. ($K_w = 0.64$)

Mol/mol C	Wet gas	Dry gas
CO_2 = 0.14 mol	8.64% CO_2	8.97% CO_2
CO = 0.86 mol	53.09% CO	55.13% CO
H_2 = 0.56 mol	34.57% H_2	35.90% H_2
H_2O = 0.06 mol	3.70% H_2O	
S = 1.62 mol	100.00%	100.00%

Water gas is formed according to the equation

$$(C + 0.32\ H_2^n) + 0.30\ H_2O + 0.45\ O_2 = 0.14\ CO_2 + 0.86\ CO + 0.56\ H_2 + 0.06\ H_2O + 23.9\ kcal.$$

Should the dry gas composition of the water gas be assumed known, the gasification processes are derived from the dry gas composition as follows:

The net hydrogen content (H^n) of the gasified fuel is assumed to be known for exact computations, since otherwise the oxygen consumed in the combustion of the net hydrogen cannot be calculated and the oxygen requirements found will be too low, as already pointed out by Terbeck in discussing Sabel's results (loc. cit., p. 65).

Since
$$\begin{array}{l} CO = x \\ H_2 = 2 + d - b - x \\ \hline (CO + H_2) = 2 + d - b \end{array}$$

and the relation between oxygen consumption ($b/2$) and the amount of ($CO + H_2$) in the water gas can be derived from the effect of net hydrogen in the fuel:

The oxygen consumption is, therefore

$$b = d + 2 - (CO + H_2).$$

The fuel is assumed to be the same as above, but calculations are made in the reverse direction by trying to find the gasification processes from the dry gas composition.

Composition of dry gas: Mols/mol C

8.97% CO_2	0.14 mols CO_2
55.13% CO	0.86 mols CO
35.90% H_2	0.56 mols H_2
100.00%	

The excess steam $(H_2O)_{exc.}$ in the gas and the composition of the wet gas
are found for the equilibrium temperature 700° C. (K_w = 0.64).

$$K_w = \frac{0.86 \cdot (H_2O)_{exc.}}{0.14 \cdot 0.56} = 0.64, \text{ also } (H_2O)_{exc.} = 0.06$$

Gasification results, in mols/mol C, are expressed by the general formula
B:

$$(C + 0.32 \ H_2^n) + w \ H_2O + b/2 \ O_2 = 0.14 \ CO_2 + 0.86 \ CO$$

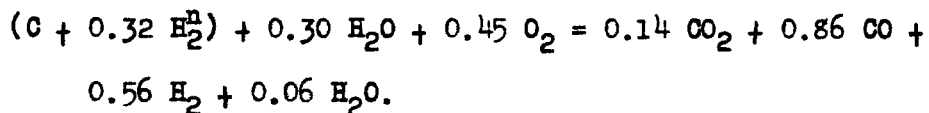$$+ \ 0.56 \ H_2 + 0.06 \ (H_2O)_{exc.}$$
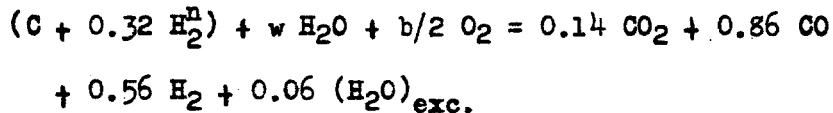
From the hydrogen balance:

$$w + 0.32 = 0.56 + 0.06,$$

$$w = 0.30 \text{ mols } H_2O/\text{mol C.}$$

From the oxygen balance:

$$0.30 + b = 0.28 + 0.86 + 0.06; \ b = 0.90, \text{ and}$$
$$b/2 = 0.45 \text{ mols } O_2/\text{mol C.}$$

The total conversion with oxygen-steam mixture and the above fuel is:

$$(C + 0.32 \ H_2^n) + 0.30 \ H_2O + 0.45 \ O_2 = 0.14 \ CO_2 + 0.86 \ CO +$$

$$0.56 \ H_2 + 0.06 \ H_2O.$$

Starting with the fuel and gas compositions, we get results which were
the basis for finding the gas composition and gas yield.

In conclusion, an example will be shown of arranging the results
of computations into the Terbeck diagram (fig. 4).

The example used is the oxygen-steam gasification of a bituminous
fuel, and the trapezoid AEDC in the Terbeck diagram is first plotted for
the amounts of H_2^n, d (line GH). The application to the Terbeck diagram
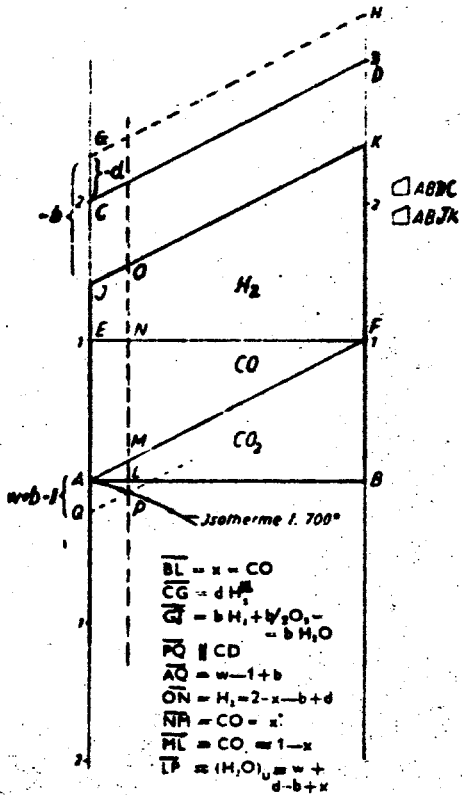may now proceed either on the basis of composition and amount of

Figure 4. - Terbeck diagram, special case.

gasifying agent to determine the composition of the gas produced, or the reverse, finding the amount and the composition of the gasification agent from the composition of the gas.

A. w and b are given, the composition of the gas is to be found:

1. $\overline{JK}$ is drawn parallel to $\overline{GH}$ at a distance b (hydrogen line).

2. In the bottom part of the diagram, the isotherms for the given operating conditions (b, w, d) are drawn in accordance with:

$$(H_2O)_{exc.}/K_w = \frac{(1-x)}{x} \cdot (2 - x - b + d)$$

3. A parallel is drawn to the hydrogen line through the point Q at a distance v + b - 1 from point A, and it intersects the equilibrium curve at the point P: Determination of $(H_2O)_{exc.}$.

4. A vertical through P gives the composition of the gas in mols/mol C.

B. The composition of the dry gas is given, and w and b are to be found.

1. Location of the gas composition on the diagram (hydrogen line). $\underline{b} = GJ$

2. The intersection P with the equilibrium curve determines $(H_2O)_{exc.}$.

3. The intersection Q with the abscissa of a line through P parallel to the hydrogen line gives $\overline{AQ} = w + b - 1$, i.e. $v = \overline{AQ} + 1 - b$.

Results of computations and the graphic expression of the process of gasification in a Terbeck diagram show that the diagram gives a comprehensive, simple, and readily understood expression.

LITERATURE

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