STUDY ON VARIATION OF GAS CONCENTRATION EMITTED DURING PROCESS OF SPONTANEOUS HEATING OF COAL AND EVALUATION OF DIFFERENT FIRE INDICES

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भारतीय कोयला खनन की प्रमुख समस्याओं में से एक है - खान में आग लगना, जिस पर गंभीरता से ध्यान दिया जाना अपेक्षित है। ईस्टर्न कोलफील्ड्स लिमिटेड की मधुजोरा खदान के जामबाद कोयला संस्तर के कोयले में स्वत:स्फुटन गुणधर्मों की जानकारी प्राप्त करने के लिए उसके नमूने पर ताप विनियोजन का अध्ययन किया गया। 150° सेंटीग्रेड के स्थिर तापक्रम एवं विविध समय अन्तराल पर यह अध्ययन किया गया। इसके अतिरिक्त ताप के साथ गैस की सान्द्रता में परिवर्तन का पता लगाने के लिए एक अन्य प्रयोग भी किया गया। कोयले के स्वत:स्फुटन से संबंधित गुणधर्मों को समझने के लिए विभिन्न अग्निनिर्देशों की भी गणना की गई।

इस आलेख में विभिन्न तापक्रम पर कोयले में गैस की सान्द्रता में परिवर्तन एवं तत्पश्चात विभिन्न अग्नि निर्देशों के मूल्यांकन की कोशिश की गई है।

INTRODUCTION

The history of fire in mines is as old as the history of coal mine itself. Critical analysis of cause of fire reveals that fire takes place due to auto-oxidation of coal at ambient temperatures [1]. About 75% of fires in mines occur due to spontaneous heating. Coal in the process of oxidation interacts with oxygen at ambient temperature liberating heat continuously. If in the process, heat is allowed to accumulate, the rate of oxidation will enhance resulting in fire [2]. During the processes of oxidation various gases are evolved, including Carbon Monoxide, Carbon Dioxide, Hydrogen and Hydrocarbons [3]. The unsaturated hydrocarbons especially ethylene (C_2H_4) and propylene (C_3H_6) are most important gases for the assessment of the development stage of self heating that may enhance danger to the safety of mine workers.

In spontaneous combustion stage, slow reactions are initiated even at ambient temperature and the main oxidation products are CO and CO_2 in small concentrations while it increases with increase in temperature. The rate of conversion to CO_2 becomes faster, particularly above the auto-ignition temperature (150 °C) where rapid oxidation occurs [3]. H_2 formation also becomes noticeable at this temperature.

In the paper the results of chromatographic analysis of gases emitted from externally heated coal samples of Jambad Seam, Madhujore Colliery of ECL have been presented. The change of concentrations of CO, CO_2, O_2, H_2, CH_4, C_2H_4, C_2H_6, C_2H_2 with rise of coal temperature and value of different fire indices have been indicated in Fig. 2 to Fig. 5. The results obtained can constitute a basis for the assessment of endogenous fire hazard. On the basis of the coal examination and the chromatographic analysis of gases the self heating temperature can be determined.

ARRANGEMENT FOR THERMAL OXIDATION OF COAL AND EXPERIMENTAL PROCEDURE

Variations in concentration of gases emitted during process of heating of coal can be monitored in laboratory in conditions of quasi-adiabatic oxidation or of enforced temperature rise.

The arrangement for thermal oxidation of coal is shown in Fig. 1. 40 grams coal sample of 0.4 mm size from Jambad Seam of Madhujore Colliery, ECL was placed in a reaction vessel, and temperature was measured by means of a thermo-couple. The reaction vessel with coal sample is placed in the heating chamber/oven. Air was passed through vessel at the rate of 90 cc/min. The gases emitted during heating of coal were collected in sampling tube at temperature ranging from 40 ° to 280 °C at 20 °C intervals. Another experiment was conducted in same condition at a constant temperature. The details of experimental conditions and findings in both conditions are discussed below.

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Table 1 : Results of analysis of gas concentration with time at a constant temperature of 150 °C

Content of Gases								
Sample No.	Time (Minutes)	C_2H_6 Ethane (ppm)	C_3H_4 Ethylene (ppm)	C_3H_6 Propylene (ppm)	C_2H_2 Acetylene (ppm)	C_XH_y Hydro-carbons (ppm)	CO Carbon Monoxide (ppm)	H_2 Hydrogen (ppm)
1	30	16	8	19	2	45	2647	181
2	60	13	4	17	1.05	35.05	2613	167
3	90	12	3	16	0.9	31.9	2550	160
4	120	11	2	12	0.8	25.8	2460	154
5	150	8	0.00006	0.9	0.3	9.20	2403	150
6	180	7	0.00006	0.7	0.2	7.90	1633	151
7	210	5	0.00003	0.6	0.1	5.7	1250	92

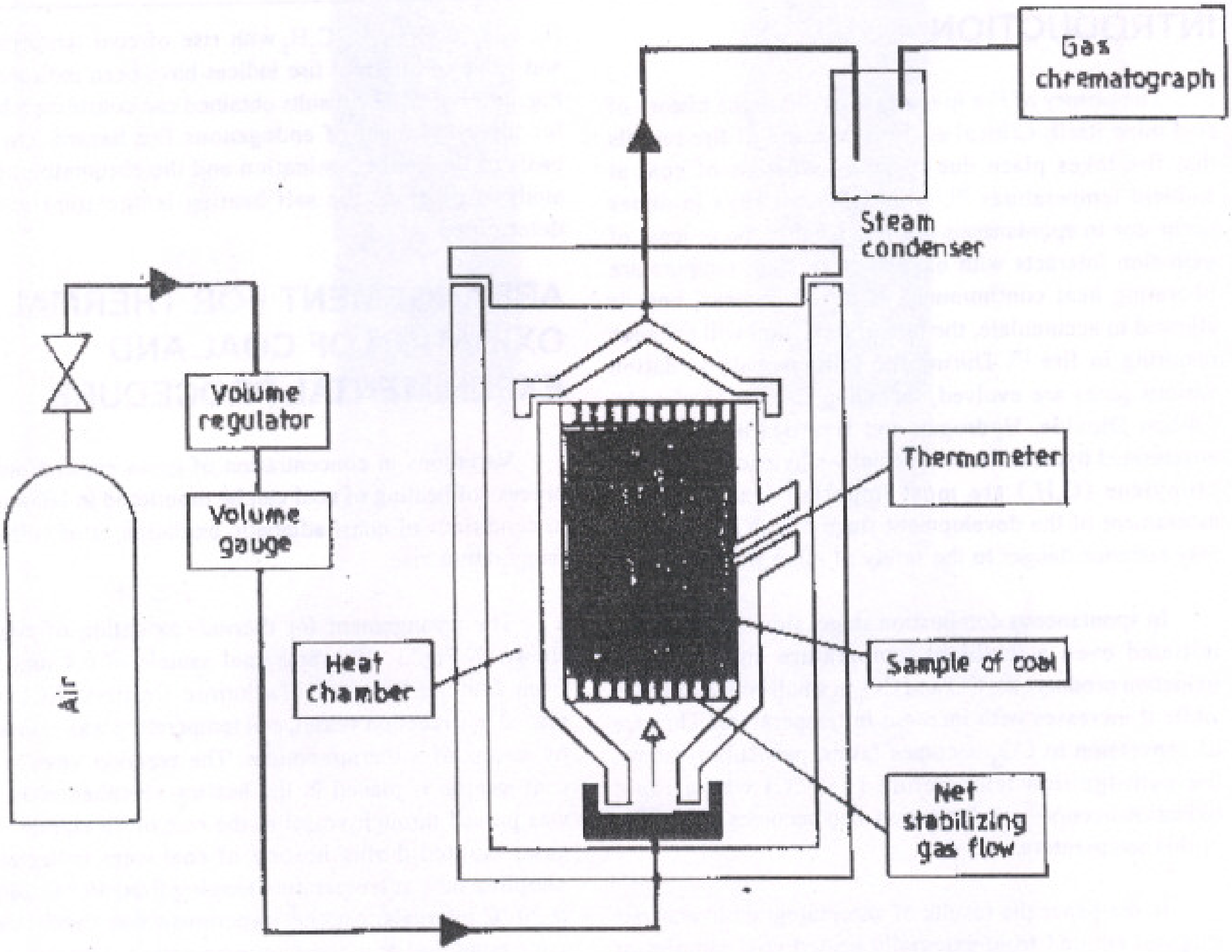

Fig. 1 : Diagram of the device for thermal oxidation of coal in air

Table 2 : Value of fire indices with time at a constant temperature of 150 °C

Sample No.	Time in minutes	$\frac{C_2H_4}{C_2H_2}$	$\frac{CO}{H_2}$	$\frac{100 . C_2H_4}{H_2}$	$\frac{C_3H_6}{C_2H_2}$	$\frac{100. C_XH_Y}{H_2}$
1	30	4	14.62	4.42	19.5	24.86
2	60	3.81	15.65	2.40	16.19	20.99
3	90	3.33	15.94	1.88	17.78	19.94
4	120	2.50	15.97	1.30	15.00	16.75
5	150	0.0002	16.02	0.00004	3.00	6.13
6	180	0.003	10.81	0.00003	3.5	5.23
7	210	0.003	13.59	0.00003	2.0	6.19

Table 3 : Variation of gas concentration with temperature

Sample No.	Temperature °C	O_2 %	CO_2 %	CO ppm	H_2 ppm	C_2H_6 ppm	C_2H_4 ppm	C_3H_6 ppm	C_2H_2 ppm	C_XH_Y ppm
1	40	19.5	0.1629	10	116	0	0	0	0	0
2	60	18.96	0.2530	40	118	0	0	0	0	0
3	80	18.75	0.4448	75	136	0	0	0	0	0
4	100	18.00	0.8881	274	140	0	0	0	0	0
5	120	17.50	1.4099	562	146	90	29	19	1.50	139.50
6	140	16.12	1.6165	672	150	100	35	50	1.60	186.00
7	160	11.20	8.740	3101	156	104	174	150	7.000	435.00
8	180	8.35	10.750	6504	165	1328	286	330	19.00	1663.00
9	200	6.25	12.85	9405	170	2430	1103	1290	80.00	4903.33

Table 4 : Value of fire indices with temperature

Sample No.	Temperature of sample °C	$\frac{C_2H_4}{C_2H_2}$	$\frac{CO}{H_2}$	$\frac{100 . C_2H_4}{H_2}$	$\frac{C_3H_6}{C_2H_2}$	$\frac{100. C_XH_Y}{H_2}$
1	40	0	0.09	0	0	0
2	60	0	0.34	0	0	0
3	80	0	0.55	0	0	0
4	100	0	1.96	0	0	0
5	120	19.33	3.85	19.86	12.67	95.55
6	140	21.88	4.48	23.33	31.25	124.40
7	160	24.86	19.88	111.54	21.43	278.85
8	180	15.05	39.42	173.33	17.37	1007.88
9	200	13.79	53.32	648.82	16.13	2884.11

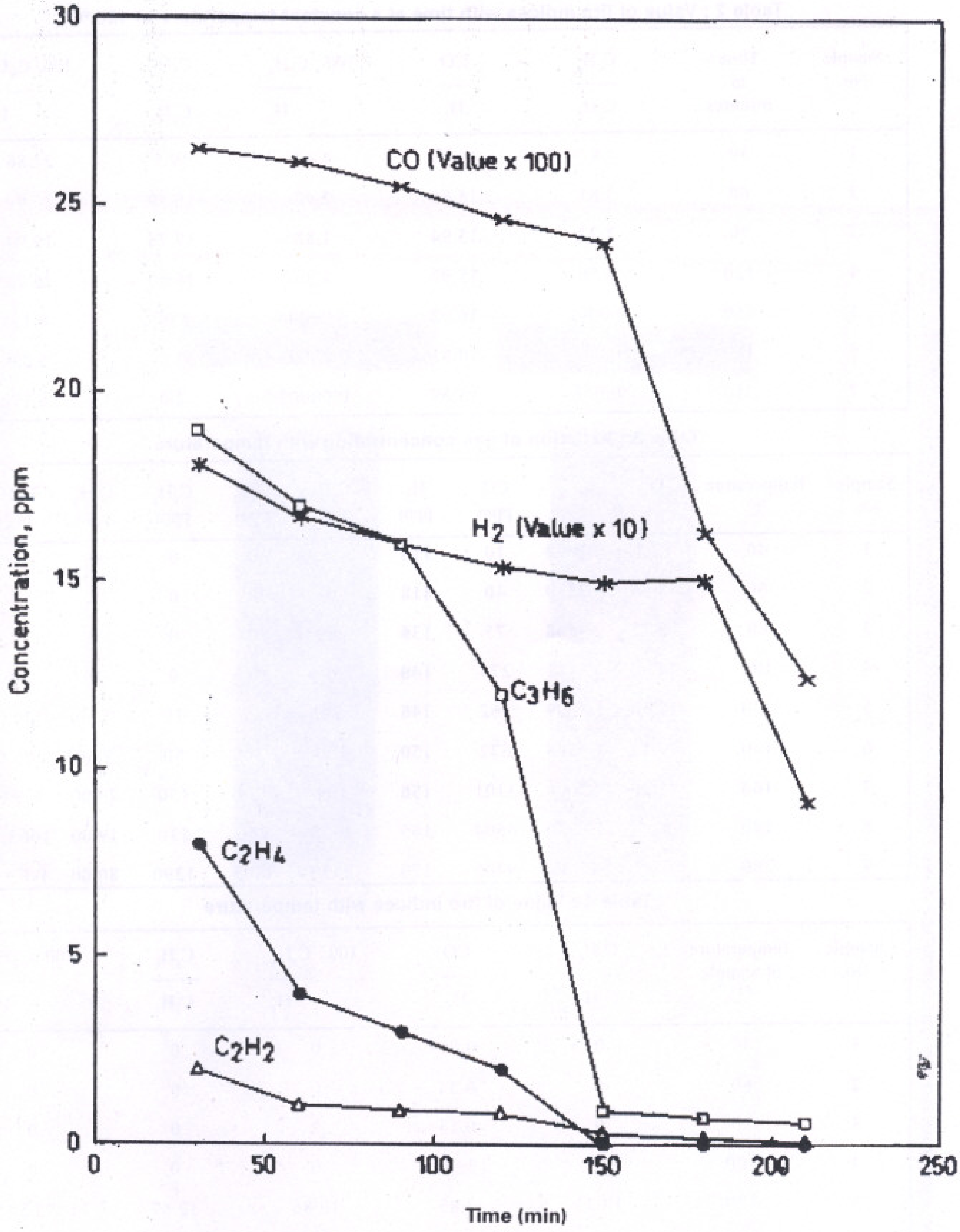

Fig. 2 : Variation of gas concentration with time at a constant temperature 150 °C

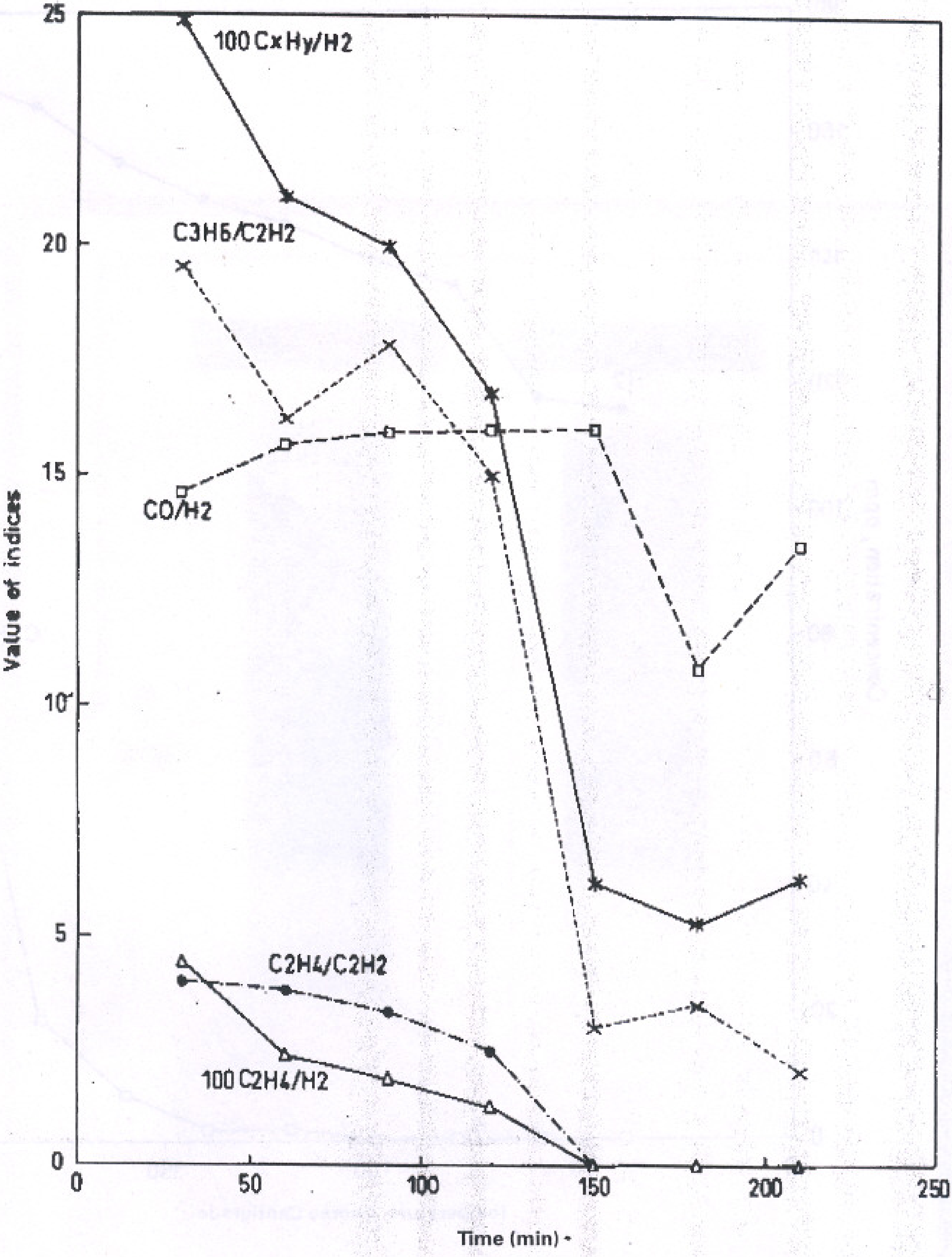

Fig. 3 : Variation of fire indices with time at a constant temperature 150 °C

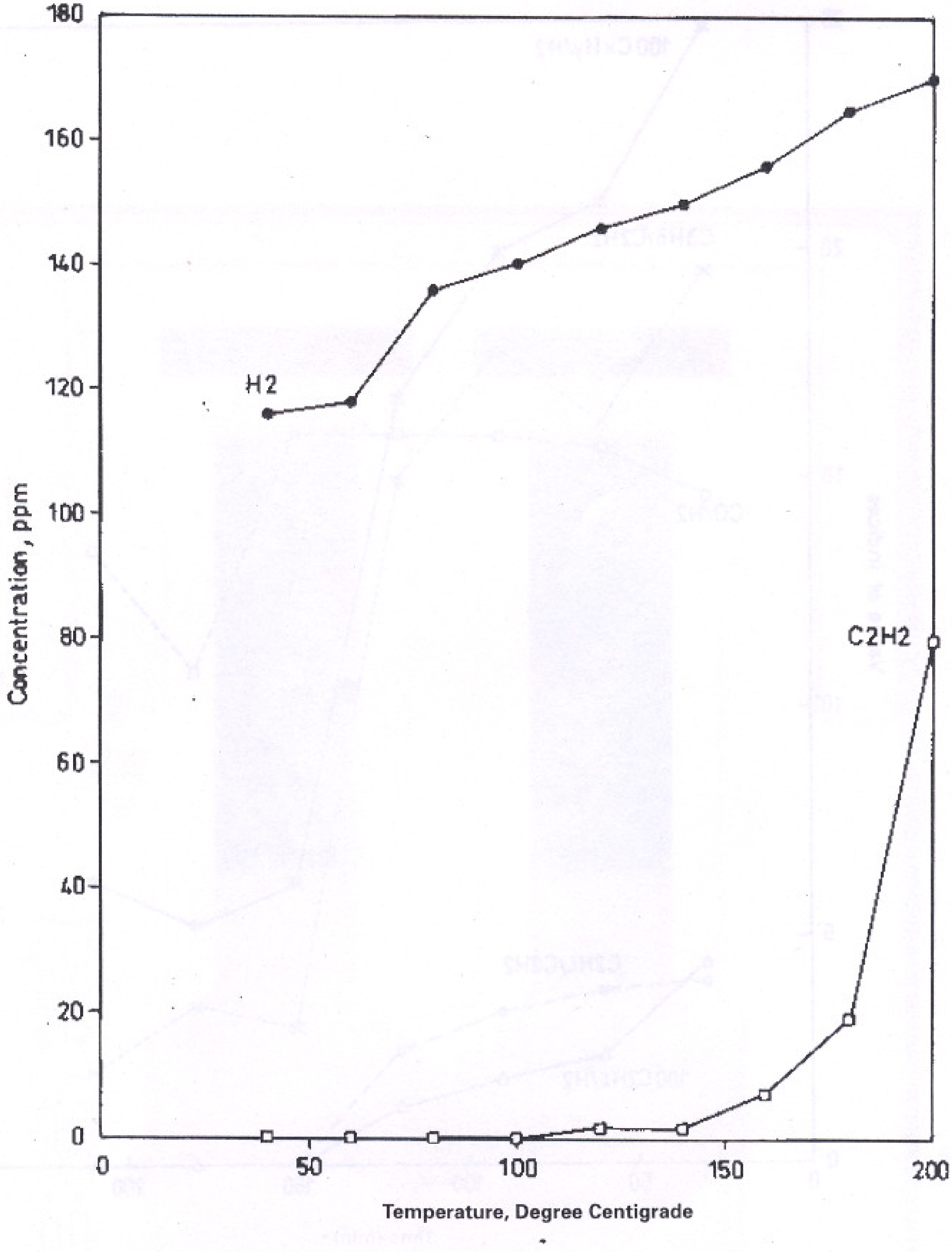

Fig. 4a : Variation of gas concentration with temperature

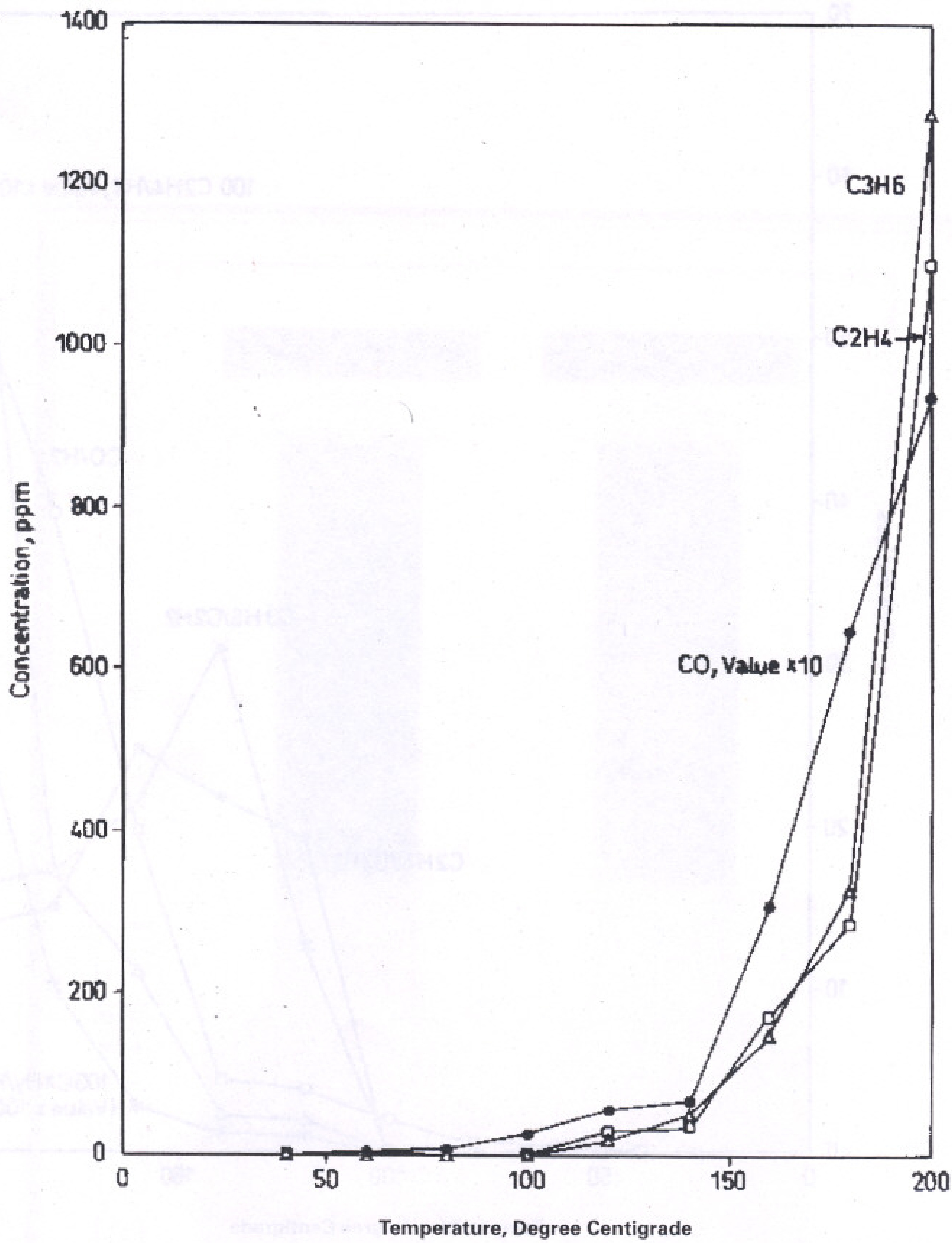

Fig. 4b : Variation of gas concentration with temperature

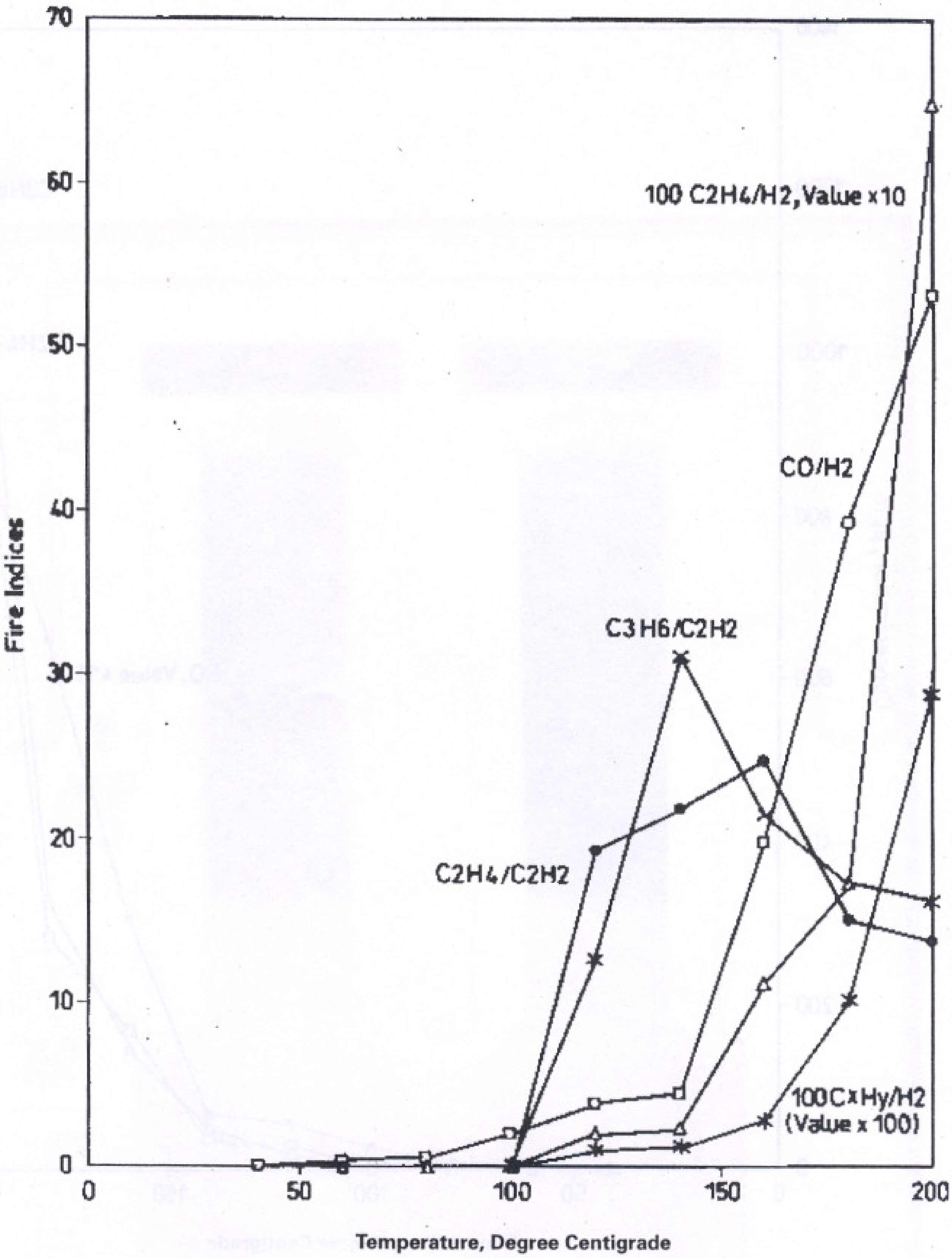

Fig. 5 : Variation of fire indices with temperature

After collecting the sample the gases were analyzed by Gas Chromatograph Model - Micro - 9100 and results are incorporated in Table 1 to Table 4.

A. Determination of gas concentration amid fire indices during oxidation of coal at a constant temperature for assessment of coal self heating stage

A coal sample of 0.4 mm size grade and mass of 40 gm from Jambad Seam of Madhujore Colliery, ECL was placed in the reaction vessel at a constant temperature 150 °C. The collection of gases were started after reaching the temperature inside the vessel at 150 °C at every 30 minutes interval up to 160 minutes. The samples were analyzed by Gas Chromatograph Model – Micro - 9100. Changes of fire indices with time also were determined. Emission of acetylene (C_2H_2), ethylene (C_2H_4) propylene (C_3H_6), Carbon monoxide (CO) and Hydrogen (H_2) gases were taken into consideration. Table 1 and Fig. 2 show the variation of gas concentration with time. From the graph it is clear that concentrations of measured gases were higher initially and it goes down with time

On the basis of the results of analysis it can be inferred that the concentration of gases emitted from a coal sample decreases with time, especially in the case of carbon monoxide (CO). The fire indices C_2H_4/C_2H_2, C_3H_6/C_2H_2, $100.(C_2H_4/H_2).(C_3H_6/C_2H_2)$, $100.(C_XH_Y/H_2)$ and CO/H_2 have been analysed and presented in Table 2 and Fig. 3. It is clear that the indices do change with time and then these stabilize after 2.5 hrs. of heating

B. Analysis of concentration of gases emitted from coal sample in conditions of enforced temperature rise

The coal sample of same specification and quantity as discussed earlier was placed in reaction vessel and heated at temperatures range from 40 °C to 200 °C at interval of 20 °C. The gases emitted were analyzed by Gas Chromatograph. The results of analysis of gases emitted from the samples are presented in Table 3 and Fig. 4 (a) and (b). The calculated values of fire indices are give in Table 4 and Fig. 5.

It is clear from the Table 3 and Table 4 that concentration of CO, CO_2, H_2 and hydrocarbons rise with increase in temperature and at the same time the concentration of oxygen follows the opposite trend. The concentration of oxygen gas goes down from 19.5 % at temperature of 40 °C to 6.25% at 200 °C. The symbol $C_X H_Y$ denotes the sum of concentrations of hydrocarbons. The value of all fire indices also rise with increase in temperature.

The analysis results indicate that before assessment of fire hazard in coal mine workings it is essential to undertake thermo decompositional study of coal from the relevant seam.

CONCLUSION

The following conclusions may be drawn from the study which are worth mentioning.

- At constant temperature the concentration of gases emitted from coal sample decrease with time especially in case of carbon monoxide.
- It is apparent that concentrations of CO, CO_2, H_2 and hydrocarbons rise with increase in temperature. At the same time concentration of oxygen decreases with temperature thus following a reverse trend.
- Increase in the concentration of CO, H_2, hydrocarbons enable us to determine fire indices for evaluation of temperature at which self heating starts.
- This method has great importance especially in mines with methane hazards because endogenous fire can cause methane ignition.

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