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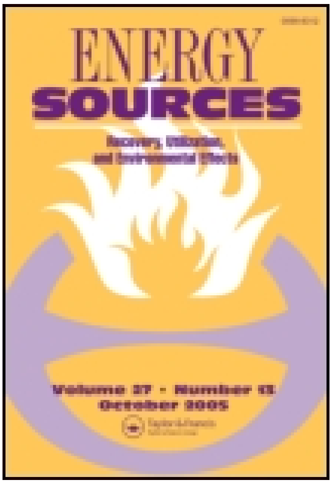

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Determination of Spontaneous Combustion in Industrial-scale Coal Stockpiles

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Abstract *Many companies unavoidably store coals at their stock areas for later usage. Stock fires take place due to long-term stay of these coals at the stock areas and cause serious damages in terms of economy and environment. In order to determine the occurrence conditions of spontaneous combustion of coals due to long-term stay under natural air conditions, an industrial-scale coal stockpile composed of 10 to 18 mm coal grains, having the dimensions of 5 m width, 3 m height, and 10 m length and weighing approximately 120 tons, was formed in a coal stock area of a company using great amounts of coal annually. Recording the temperature values measured at the stockpile, the temperature-time diagrams were plotted. Moreover, the atmospheric effects on the stockpile were investigated by continuously measuring air temperature, air humidity, atmospheric pressure, velocity, and direction of wind, which are some of the parameters affecting the stockpile.*

Keywords coal stockpile, spontaneous combustion

1. Introduction

Spontaneous combustion is an event that begins with the oxygen absorption of coal during its contact with atmosphere, continues with oxidation, and sometimes turns into a flaming fire due to heat accumulated in the medium (Sarac, 1992). It is a result of heat increase that occurs at the coal body when the heat produced as a result of many reactions is greater than the heat loss given to the environment due to various factors. This heat speeds the oxidation with the increasing medium temperature, i.e., the thermal transmission occurred due to adsorption of oxygen molecules on the coal surface turns into a chemical reaction with the effects of thermal transport (transfer) and diffusion mechanisms (Unver and Ozozen, 1998). Knowing the spontaneous combustion tendency of coals has practically great importance for determining the event occurrence before and taking necessary precautions.

Up to now, although many laboratory-scale studies on the spontaneous combustion of Tunçbilek coals have been carried out, there haven't been any serious studies made on the stockpiles formed for industrial purposes. The previous laboratory-scale studies have been performed on the coals in gram levels, in whichthe effects of a limited number of parameters that were related to the event and only valid under laboratory conditions could be investigated. Therefore, the whole investigation of the spontaneous combustion event of coals and the application of the obtained results into practice is difficult with the laboratory-scale studies. Hence, the large-scale (industrial-scale) studies have great

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importance especially when the determination of the general behavior of coals during spontaneous combustion, which includes most or all of the parameters acting on the spontaneous combustion, is purposed (Ozdeniz, 2003; Sensogut and Ozdeniz, 2005; Ozdeniz and Sensogut, 2006; Sensogut and Ozdeniz, 2008; Fierro et al., 1999a, 1999b, 2001). However, since this type of study needs so much money and long periods of time, there exist only a limited number of studies about this subject. In this study, the behaviors of coals during their storage at the stock areas under natural air conditions were investigated.

2. Test Mechanism and Test Procedure

The industrial-scale coal stockpile on which the tests were performed was formed in a stock area of a company in Turkey/Konya which annually consumes great amounts of coal. The coals obtained from both open and underground mines of Western Lignite Corporation are enriched in coal preparation plants. The coals used in this study were the enriched coals with particle sizes between 10 and 18 mm. The length of the stockpile was about 10 m by 5 m in width with a height of 3 m, while the mass of it was approximately 120 tons of coal in total. The general view of the stockpile shaped as a triangular prism is given in Figure 1.

Seventeen heat sensors (Pt100) were placed at the preset points of the stockpile, which can sense the temperature values precisely. The temperature detectors that were used in this work have three-wire configuration, and the technical characteristics of the Pt100s are given in Figures 2 and 3.

Ten of the sensors, namely T1, T2, T3, T4, T5, T6, T7, T8, T9, and T10, were placed at the 1st meter of the stockpile from the bottom, and seven of them, namely T11, T12, T13, T14, T15, T16, and T17, were placed at the 2nd meter. The distances between the sensors at the 1st and 2nd layers were set as homogeneous as it can be. The plan view of the sensors can be seen in Figure 4.

3. Discussion of Results

Measurements were taken at 17 different points to determine the spontaneous combustion in an industrial-scale coal stockpile. The total elapsed time for the measurements on

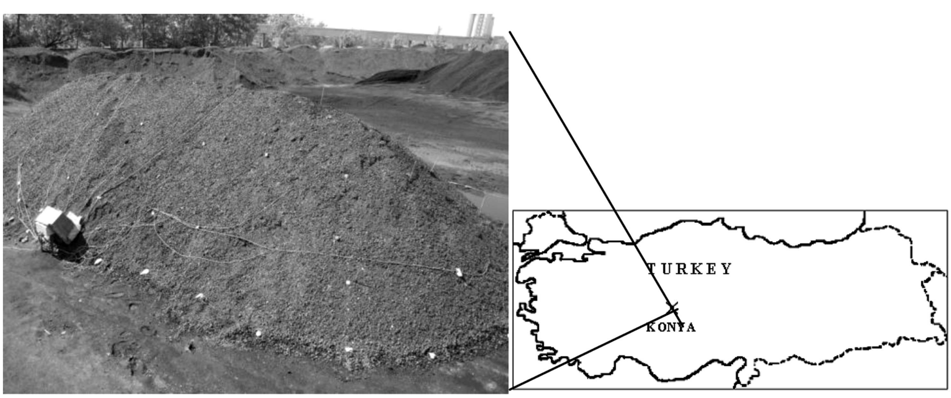

Figure 1. General view from the coal stockpile formed at Konya, Turkey.

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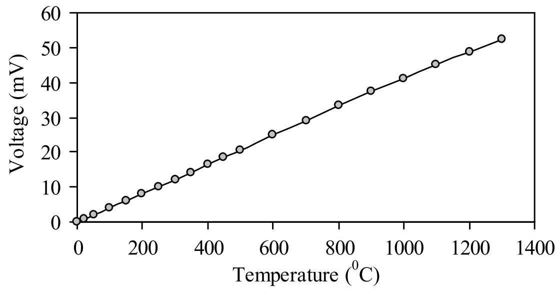

Figure 2. Voltage-temperature diagram of Pt100.

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the stockpile was 2,710 h between the dates of April 17, 2006 and August 10, 2006. Additionally, the parameters, i.e., air temperature, air humidity, atmospheric pressure, wind velocity, and wind direction, that affect the stockpile were measured continuously. While the total number of the data taken from the coal stockpile is 11.033, the number of data measured for atmospheric parameters, i.e., air temperature, air humidity, atmospheric pressure, wind velocity, and wind direction that are effective on stockpile, is 3.245. Then the total sum of the number of the recorded data becomes 14.278.

In every measuring system, a filtering process is required to preserve the measurement values from fluctuations. A previously written software filter was applied for this measuring system. The data measured at the stockpile was filtered using the Moving Average Method (Canan et al., 1998) in the Microsoft Excel computer program. The purpose of this filtering was to overcome the negative effects of voltage fluctuations in the electric network and the huge machines (grader, dozer, etc.) working near the stations. The chemical analysis results of samples taken from coal stockpile are given in Table 1. As seen in Table 1, a decrease in the calorific value and an increase in the ash values were observed due to the spontaneous combustion. In addition, the filtered data up to 24 h is given in Table 2.

Figure 5 shows the time-temperature diagrams of the T5, T11, T12, and T13 stations and Figure 6 shows the time-temperature diagrams of the T14, T15, T16, and T17 stations, all of which were exposed to spontaneous combustion. Air temperature-time and air humidity-time values being the most important factors considerably affecting the coal stockpile during the time of measuring, are given in Figures 7 and 8, respectively.

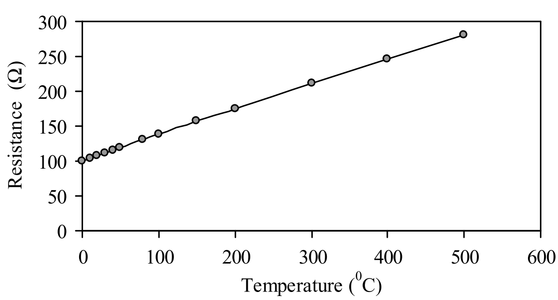

Figure 3. Resistance-temperature diagram of Pt100.

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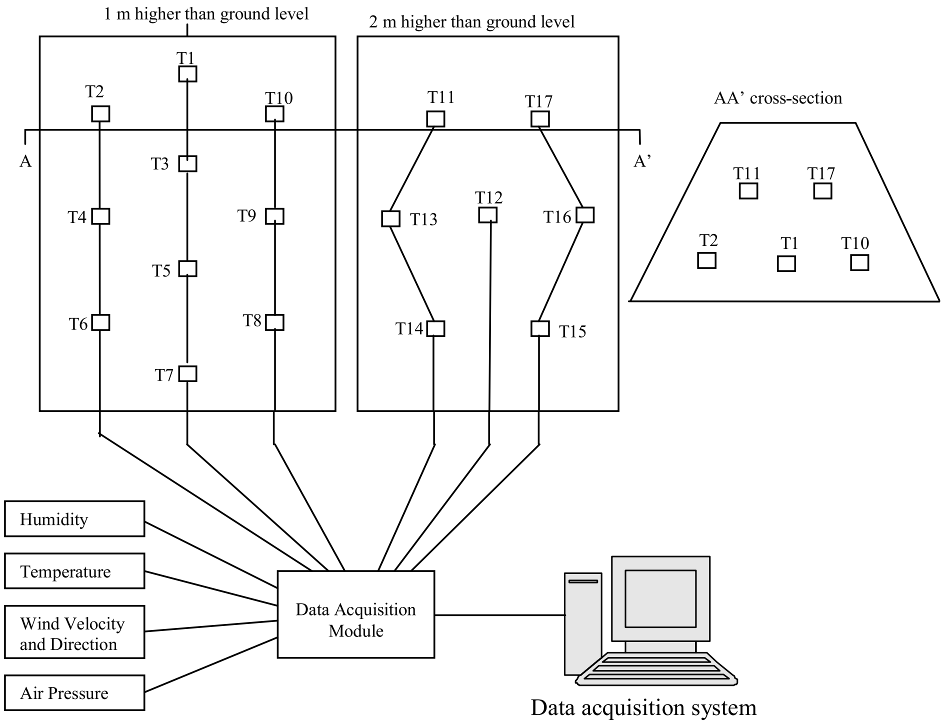

Figure 4. Schematic presentation of Pt100's in the stockpiles and measurement system.

The effects of high humidity and low air temperature on the stockpile can be seen up to the 700th hour. The inner temperatures of the stockpile reached up to about 50°C during a month and reached the critical temperature values of 70°C at the 2,500th hour converging to the horizontal. The spontaneous combustion inside the stockpile took place after this value and the temperature values increased rapidly. While the oxidation of the coal was proceeding very slowly until the critical temperature, after this value, the increase in the speed of the oxidation can also be seen in the study of Chamberlain et al. (1976). Due to higher air temperature and lower air humidity occurring between the 700th and 2,500th hours, the effects of these parameters on the stockpile and the occurrence of spontaneous combustion at the top layer's all stations can be clearly seen. At this stage, the study was ended in order not to cause any damage to the equipment used for the tests.

Table 1
Short analysis of the coals in stockpiles

Period	Humidity, %	Ash content, %	Calorific value, kcal/kg	Volatile matter, %	Combustible sulphur, %
April 17, 2006	17.31	17.21	5,102	36.10	1.59
May 19, 2006	15.64	21.04	4,925	35.03	1.47
June 22, 2006	8.35	28.03	4,622	29.12	1.62
August 10, 2006	3.02	47.12	3,225	24.09	1.68

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Table 2
24-h records of the stations

Z	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	S	N	B	RH	RY
0	26.8	26.3	26.4	28.5	28.2	28.4	27.0	28.2	25.8	25.7	29.1	29.9	29.3	28.5	29.0	28.6	26.0	25.7	17	893	0.63	SN
1	26.8	26.5	26.7	28.5	28.5	28.4	27.5	28.3	25.8	25.7	29.2	29.6	29.4	28.4	29.1	28.8	26.2	27.6	16	894	0.35	SN
2	26.9	26.6	26.8	28.7	28.6	28.3	27.6	28.5	26.0	25.8	29.4	29.9	29.6	28.6	29.3	29.0	26.3	27.2	21	893	0.40	SN
3	27.0	26.4	26.9	28.7	28.7	28.3	27.6	28.5	26.0	25.8	29.4	29.6	29.6	28.6	29.3	29.2	26.4	26.1	25	893	0.20	WE
4	27.1	26.4	27.0	28.8	28.8	28.4	27.7	28.6	26.1	25.9	29.5	29.6	29.8	28.7	29.5	29.4	26.5	25.0	29	893	0.30	SN
5	27.2	26.4	27.1	29.0	28.9	28.5	27.8	28.8	26.2	26.1	29.7	29.6	29.9	28.8	29.7	29.7	26.6	23.2	32	894	0.40	SN
6	27.3	26.3	27.2	29.0	29.0	28.7	27.9	28.9	26.3	26.1	29.8	29.5	30.0	28.9	29.8	29.8	26.7	21.3	34	894	0.20	SN
7	27.4	26.4	27.3	29.1	29.1	28.8	28.0	28.9	26.4	26.2	29.9	29.6	30.1	29.0	29.9	29.9	26.8	18.8	36	894	1.14	SN
8	27.3	26.4	27.3	29.1	29.1	28.7	27.9	28.9	26.3	26.2	29.9	29.6	30.1	29.0	29.8	29.8	26.9	17.0	38	894	0.70	SN
9	27.3	26.3	27.3	29.1	29.1	28.7	27.9	28.9	26.3	26.2	30.0	29.6	30.1	29.0	29.8	29.8	26.9	15.9	41	894	0.65	SN
10	27.4	26.3	27.3	29.1	29.1	28.7	27.9	28.9	26.3	26.2	30.0	29.6	30.1	29.0	29.8	29.8	26.9	15.4	42	894	0.30	SN
11	27.3	26.2	27.3	29.0	29.0	28.6	27.7	28.8	26.2	26.0	29.8	29.4	29.8	28.9	29.7	29.6	26.7	14.8	48	894	0.20	SN
12	27.3	26.1	27.2	28.9	28.9	28.7	27.6	28.7	26.1	25.9	29.7	29.4	29.8	28.8	29.6	29.6	26.6	13.4	50	894	0.40	SN
13	27.3	26.0	27.2	28.9	28.9	28.8	27.5	28.6	26.0	25.8	29.7	29.5	29.7	28.7	29.5	29.5	26.6	13.2	54	894	0.02	WE
14	27.2	25.9	27.1	28.7	28.8	28.8	27.4	28.5	25.9	25.7	29.6	29.4	29.5	28.6	29.4	29.4	26.5	12.7	57	894	0.27	SN
15	27.3	26.0	27.3	28.9	28.9	29.1	27.6	28.7	26.1	25.9	29.7	30.3	29.7	28.7	29.5	29.6	26.6	12.5	59	894	0.64	SN
16	27.5	26.2	27.4	29.0	29.1	29.3	27.7	28.9	26.3	26.0	29.9	31.0	29.9	28.9	29.6	29.7	26.7	11.7	63	894	0.35	SN
17	27.7	26.3	27.5	29.2	29.2	29.4	27.8	29.1	26.4	26.0	30.0	31.5	30.0	28.9	29.6	29.7	26.8	10.9	65	895	0.40	SN
18	27.9	26.3	27.7	29.2	29.3	29.4	27.8	29.1	26.4	25.9	29.9	31.6	30.0	28.8	29.4	29.6	26.7	10.4	66	895	0.20	WE
19	27.8	26.1	27.4	29.0	29.1	29.2	27.6	28.9	26.1	25.6	29.7	30.8	29.7	28.6	29.1	29.4	26.6	11.4	64	896	0.30	SN
20	27.8	25.9	27.3	28.9	29.0	29.1	27.5	28.8	26.1	25.5	29.6	30.2	29.6	28.6	28.9	29.2	26.5	14.4	56	896	0.40	SN
21	27.6	25.7	27.2	28.7	28.9	28.9	27.3	28.6	26.0	25.2	29.4	29.6	29.5	28.4	28.7	29.0	26.4	17.1	46	896	0.20	SN
22	27.4	25.6	27.1	28.6	28.8	28.9	27.4	28.6	26.0	25.1	29.5	29.5	29.5	28.5	28.8	29.0	26.4	19.6	41	896	1.14	SN
23	27.6	25.7	27.2	28.8	29.0	29.1	27.6	28.8	26.2	25.1	29.6	29.8	29.9	28.7	29.0	29.2	26.6	23.5	36	896	0.70	SN
24	27.7	25.8	27.3	28.9	29.1	29.2	27.6	28.9	26.3	25.0	29.7	29.7	30.1	28.7	29.2	29.4	26.7	25.1	32	896	0.65	SN

Z—time, (h); T—temperature inside the stockpile, (°C); S—air temperature, (°C); N—humidity, (%); B—atmospheric pressure, (mb); RH—wind velocity, (m/s); RY—wind direction.

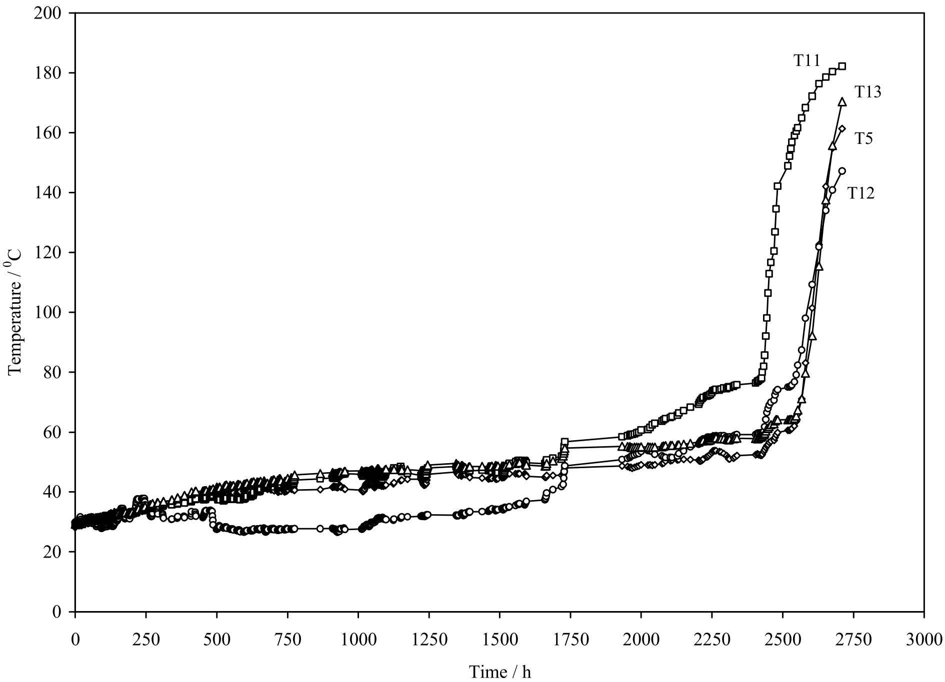

Figure 5. Time-temperature diagrams of T5, T11, T12, and T13.

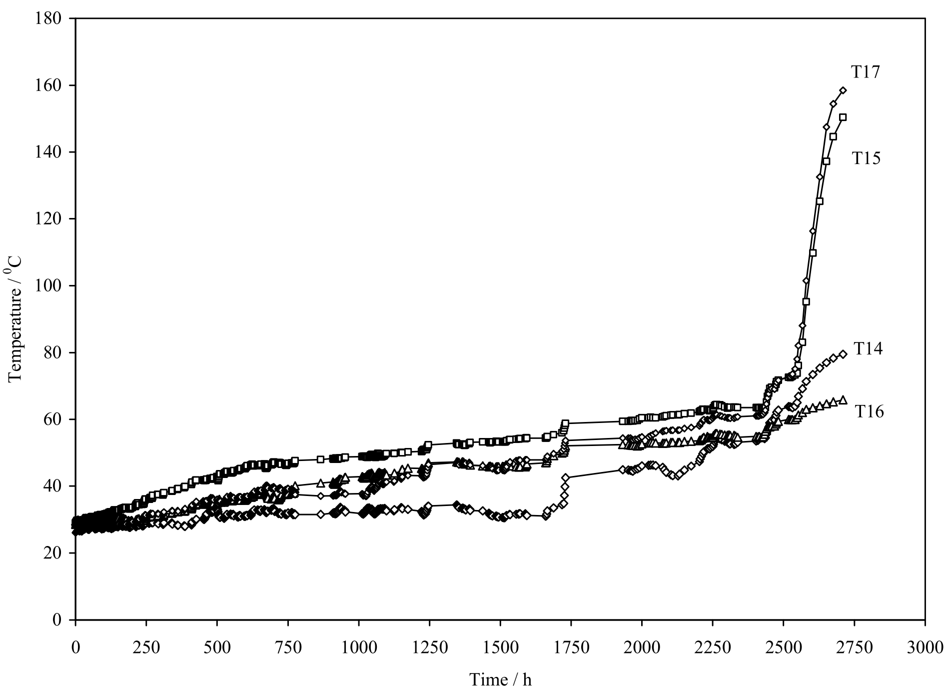

Figure 6. Time-temperature diagrams of T4, T15, T16, and T17.

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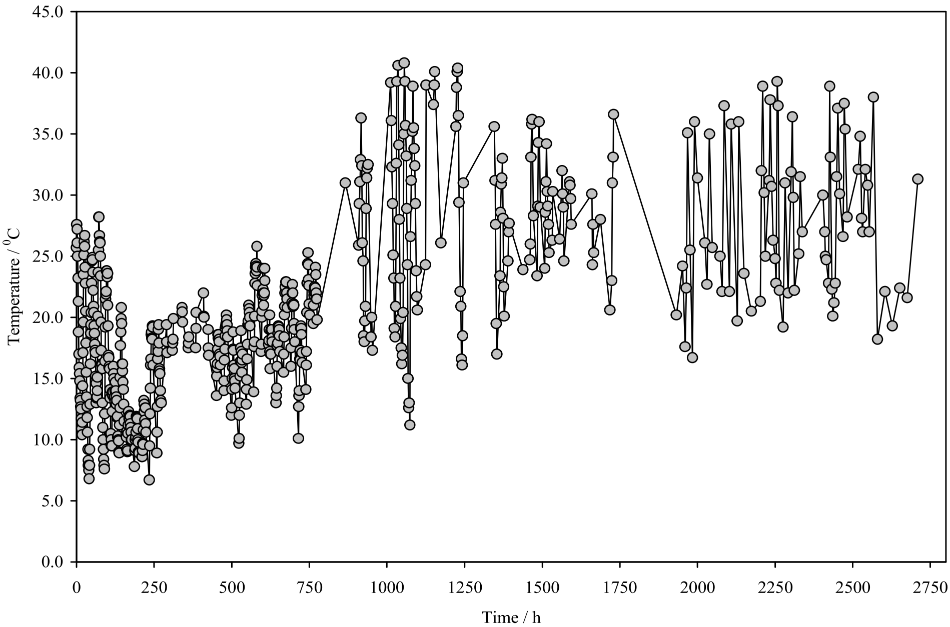

Figure 7. Air temperature-time diagram obtained during the measurement period.

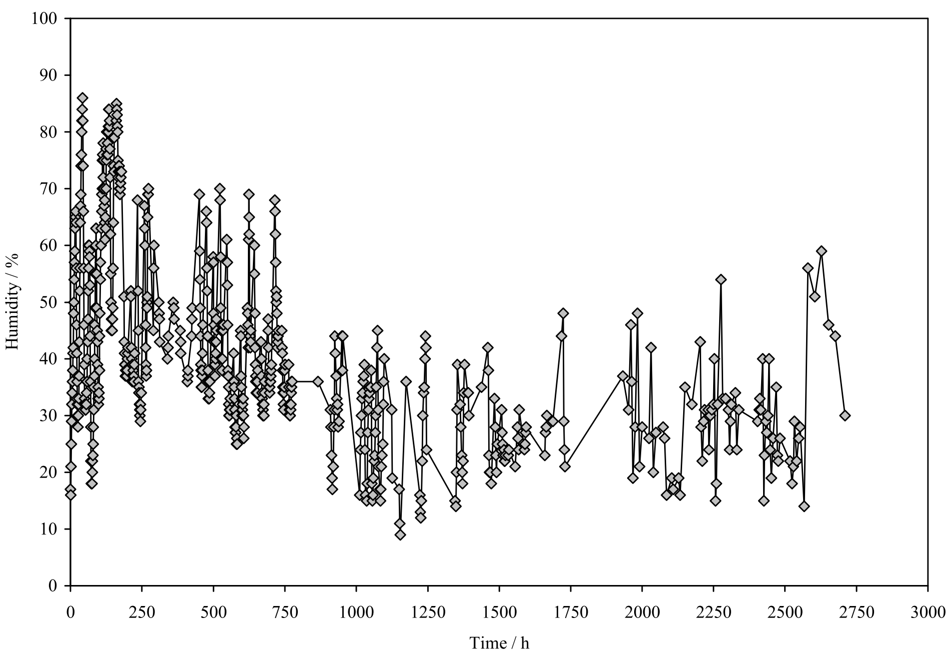

Figure 8. Air humidity-time diagram obtained during the measurement period.

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4. Results

The industrial-scale studies performed on the coals of Turkey/Tuncbilek include only the studies on coals carried out with 18 to 50 mm grain sizes by Ozdeniz (2003), Sensogut and Ozdeniz (2005), and Ozdeniz and Sensogut (2006). This study is also about the Tuncbilek coals but deals with a different coal stockpile formed with 10 to 18 mm grain sizes. For this purpose, a coal stockpile having the dimensions of 3 m height, 5 m width, and 10 m length was formed and the measurements were made with 17 precise sensors placed inside the coal stockpile. The occurrence of the spontaneous combustion inside the coal stockpile was determined at the T11, T12, T13, T14, T15, T16, and T17 stations of the top layer and at the T5 station of the bottom layer with the temperature exceeding the critical value. The temperature values of the T2, T3, T4, T6, T8, T9, and T10 stations of the bottom layer were closer to the critical value, therefore, if the tests had not been ended, the occurrence of spontaneous combustion could have been observed at these stations. The critical temperature values could not be reached at the T1 and T7 stations of the bottom layer.

The spontaneous combustion could not be observed in the previous study of Ozdeniz (2003), which was performed on the coals having coarser grain sizes between 18 to 50 mm. However, in this study, the spontaneous combustion was observed inside the coal stockpile having 10 to 18 mm coal grain sizes. The cause of this was the smaller grain sizes of the coal that the smaller the grain sizes the larger the surface area and the more contact with oxygen, and heat was continuously accumulated in the medium and could not be taken out. Therefore, the occurrence of spontaneous combustion became inevitable. Moreover, the decreases in the dimension and calorie of the coals due to the long-term stay as a stockpile, brings the company against serious economical losses.

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