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Application of Adaptive Resonance Theory for the classification of coal seams with respect to their spontaneous heating susceptibility

by

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Spontaneous Heating

Immediately a Coal is mined

It is subjected to:

- A Chemical process whereby Oxygen reacts with Coal
- A Physical process whereby Coal tends to Disintegrate into smaller pieces

Second process increased by handling & weathering

As a result of second process more surfaces of coal are exposed to react with oxygen

Coals when exposed absorbs O_2 even at temperatures much lower than the average ambient ones and evolve heat because adsorption, absorption processes results in exothermic reaction

The heat generated, if not dissipated results in further rise in temperature

Accelerates the rate of oxygen sorption and production of heat, culminating in fire.

$$CH_{1.18}N_{0.15}O_{0.35}S_{0.005} + 1.12O_2 + 4.15N_2 \rightarrow CO_2 + 0.58H2O + 0.005SO_2 + 4.15N_2 + 138.4\text{Kcal}$$

Depends upon two major parameters:

- Intrinsic properties
- Mining parameters

Intrinsic properties:

Associated with the nature of coal

- ✓ Physico-chemical characteristics
- ✓ Petrographic composition

Extrinsic parameters:

- ✓ **Atmospheric**
- ✓ **Geological**
- ✓ **Mining**

❖ **Site specific**

Intrinsic properties of Coal Samples

PROXIMATE ANALYSIS

Method: Indian Standard:1350 (Part –1) –1969

ULTIMATE ANALYSIS

- Carbon and hydrogen:
  IS:1350 (Part IV/Sec1) – 1974
- Nitrogen : Kjeldhal method IS: 1350 – 1975
- Sulphur : IS: 1350 (Part – III) - 1969
- Oxygen by difference

Total sulphur content of all the coal samples is <u>less than 1.20%</u>

A part of this pyretic sulphur.

If pyretic sulphur > 5% => appreciable effect

< 5% => effect would not be of much importance from spontaneous heating point of view.

Therefore, for all further analysis

Carbon (C)

Hydrogen (H)

Oxygen (O)

of ultimate analysis have been considered.

Intrinsic properties of coal samples

Sampl e no.	Seam & Colliery	Proximate analysis			Ultimate analysis			
		M%	VM%	A%	C%	H%	O%	S%
1	Seam-IX Hingula	11.13	25.19	38.46	66.38	8.77	21.22	0.62
2	Seam-VII Lingaraj	14.29	31.25	16.27	72.62	6.63	17.44	0.55
3	Seam-V Lingraj	7.25	23.9	40.50	71.48	8.71	17.23	0.41
4	Seam-IV Lingaraj	9.59	28.93	7.68	80.61	5.69	11.23	0.72
5	Seam-III Ananta	8.97	29.49	22.88	75.78	7.00	14.50	0.69
6	Seam-III Bharatpur	10.02	26.06	31.57	71.91	7.76	17.67	0.61
7	Seam-II Ananta	14.5	31.97	12.35	73.85	6.33	17.83	0.25
8	Seam-II Bharatpur	11.32	29.81	21.80	73.67	6.98	16.93	0.48
9	Seam-II Jagannath	6.67	27.9	36.40	77.72	8.43	15.74	0.53

Continued …

Determination of Spontaneous Heating Susceptibility of Coal samples

CROSSING POINT TEMPERATURE

- Gives an idea about the proneness of coal to auto oxidation
- May vary depending upon whether the bath is maintained at
  - Constant temperature
  - Increasing temperature

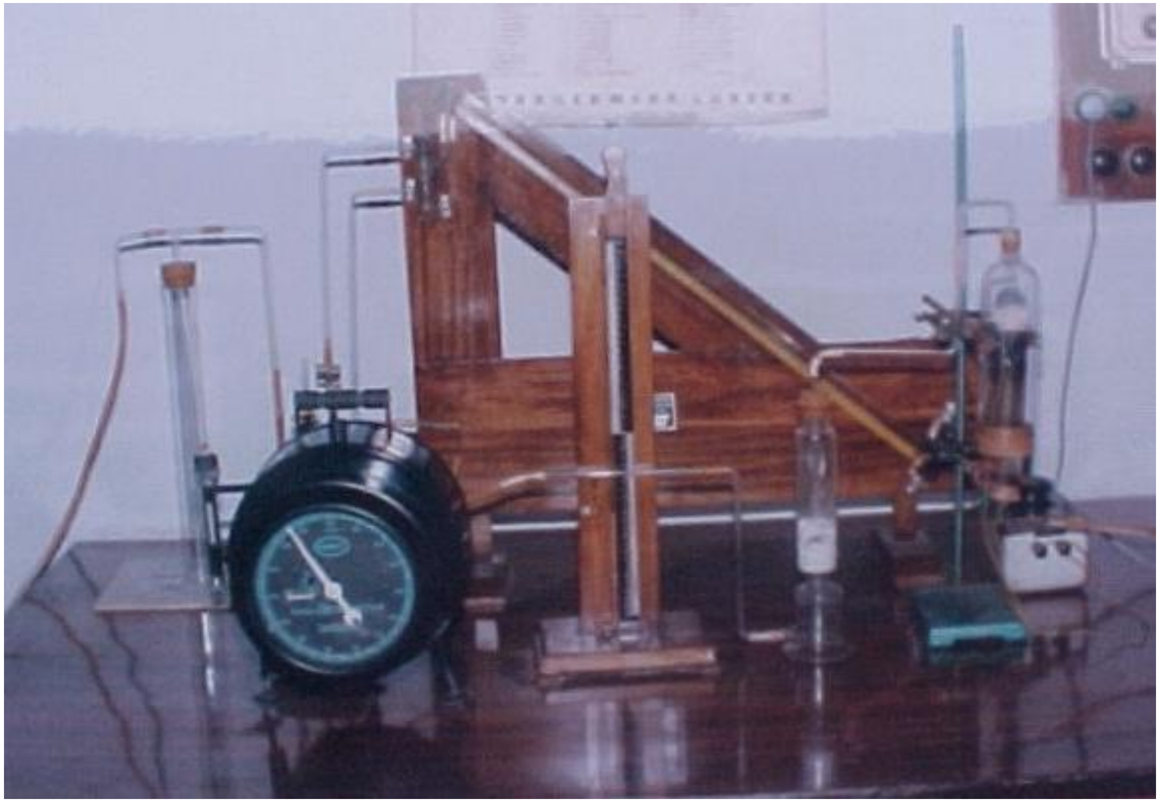
Experimental Procedure

- Amount of sample taken: 20g
- Size of sample: -212 micron
- Rate of heating: 1°C/minute
- Rate of oxygen flow: 80 cc/minute

Photographic view of CPT Apparatus

CRITICAL AIR BLAST ANALYSIS

- A measure of reactivity of coal to air
- It is the minimum rate of air blast which will maintain combustion of coal in an ignited bed of specific dimension
- The more reactive the coal towards air, the lower is the CAB value

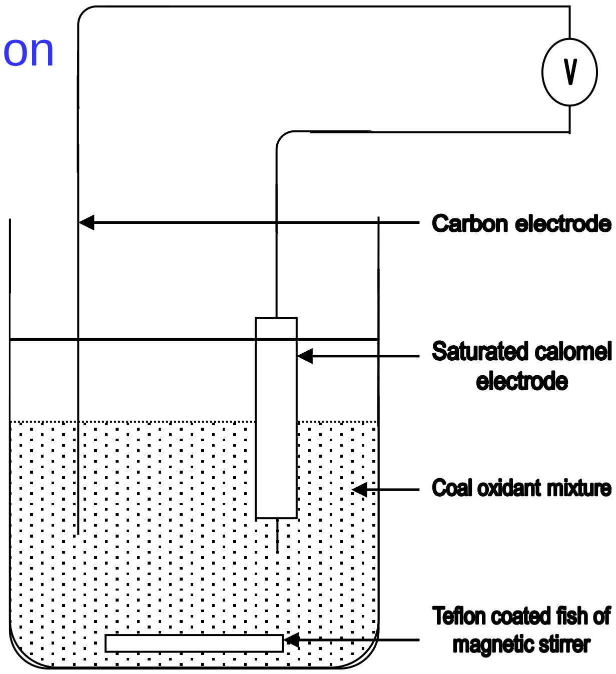


Photographic view of critical air blast apparatus

WET OXIDATION POTENTIAL ANALYSIS

Coal is oxidised in alkaline medium

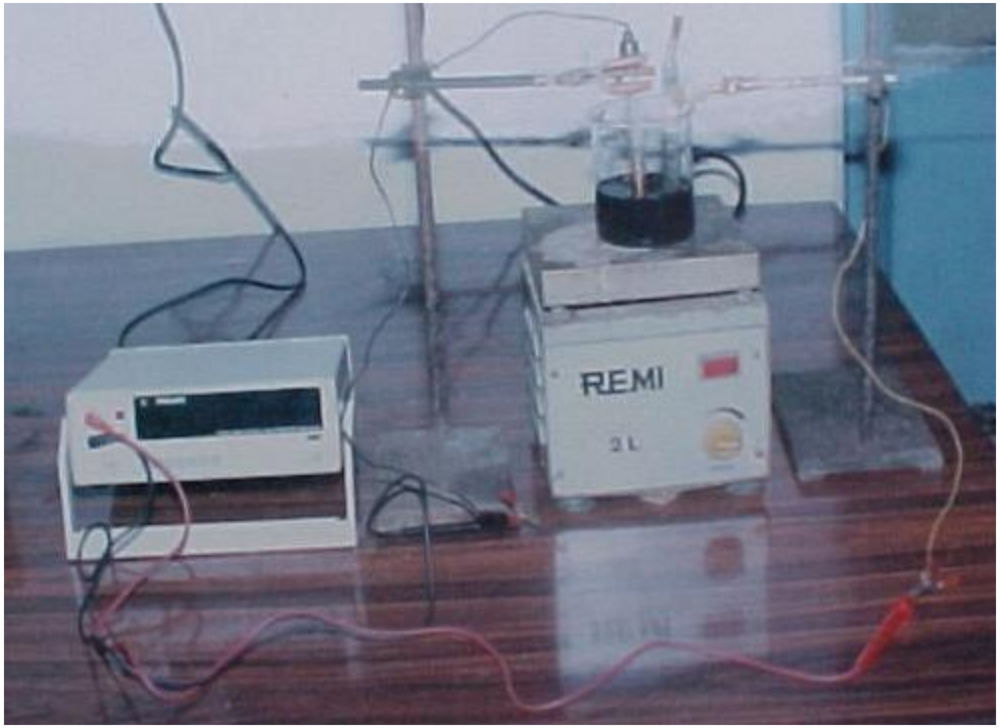
- The change in potential difference during an oxidation process is the measure of reactivity of coal



Experimental setup for wet oxidation process

Experimental Procedure

- Amount of sample: 0.5 g
- Size of sample: –212 micron size
- Medium: 100 ml of decinormal solution of $KMnO_4$ in 1N KOH solution in a beaker
- The coal sample was subjected to wet oxidation process
- Suspension was continuously stirred using the magnetic stirrer
- EMF between the calomel and carbon electrodes was recorded till the potential difference attained a nearly constant value



Photographic view of complete setup of wet oxidation potential measurement

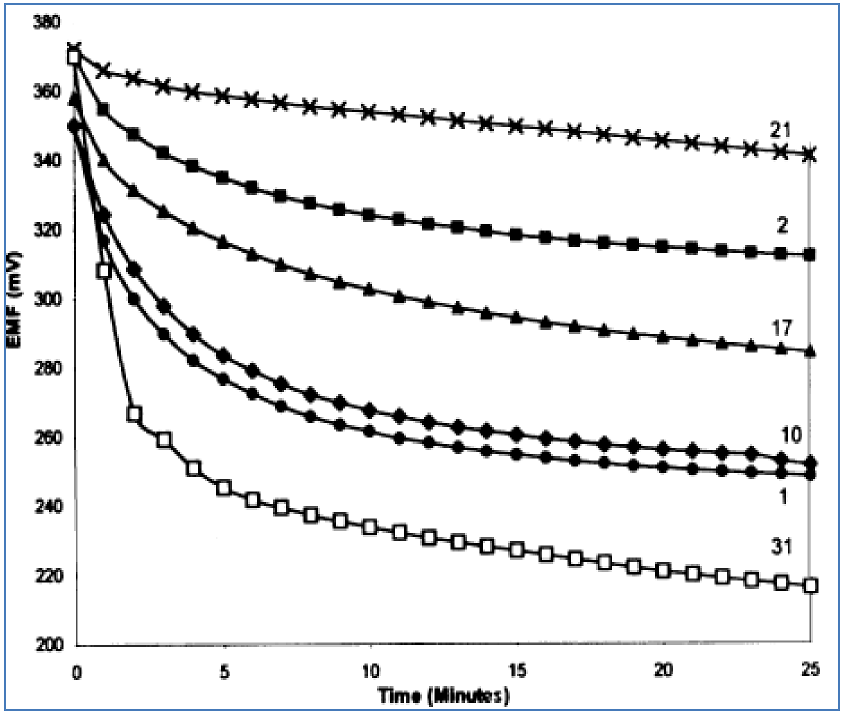


Fig. EMF Vs time in wet oxidation process for sample nos. 1, 2 10, 17, 21 and 31

DIFFERENTIAL SCANNING CALORIMTERY

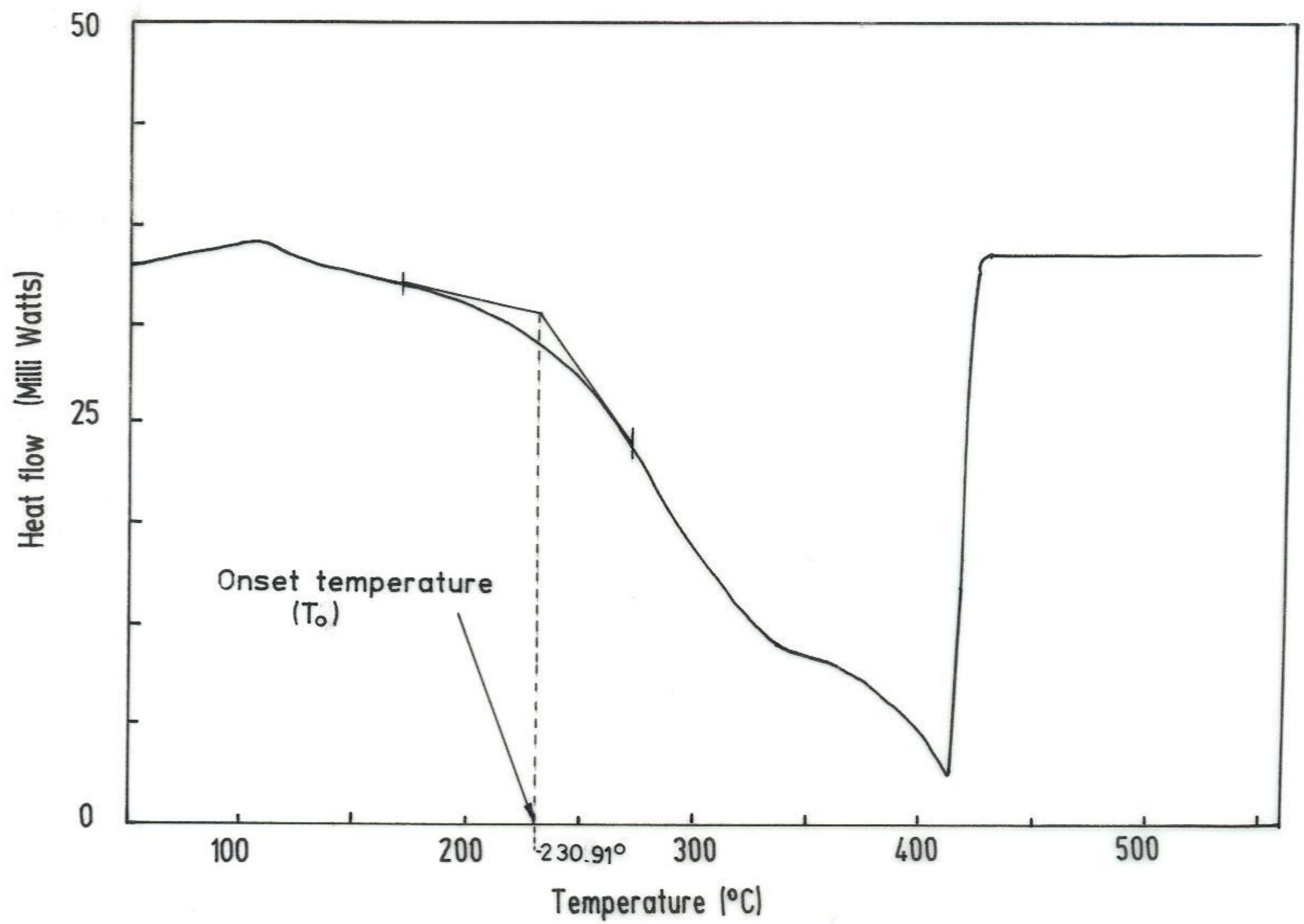
- **Used to measure heat flow into or out of a sample as it is exposed to a controlled thermal profile.**

Experimental Set up

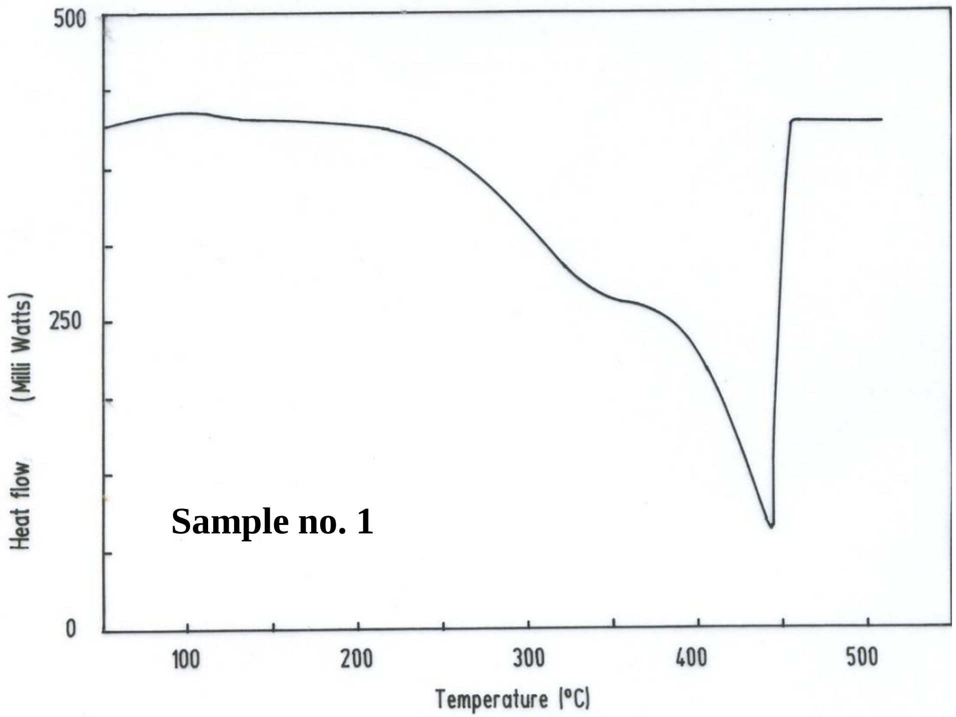
(1) Differential scanning calorimeter **(2) Thermal analysis controller**

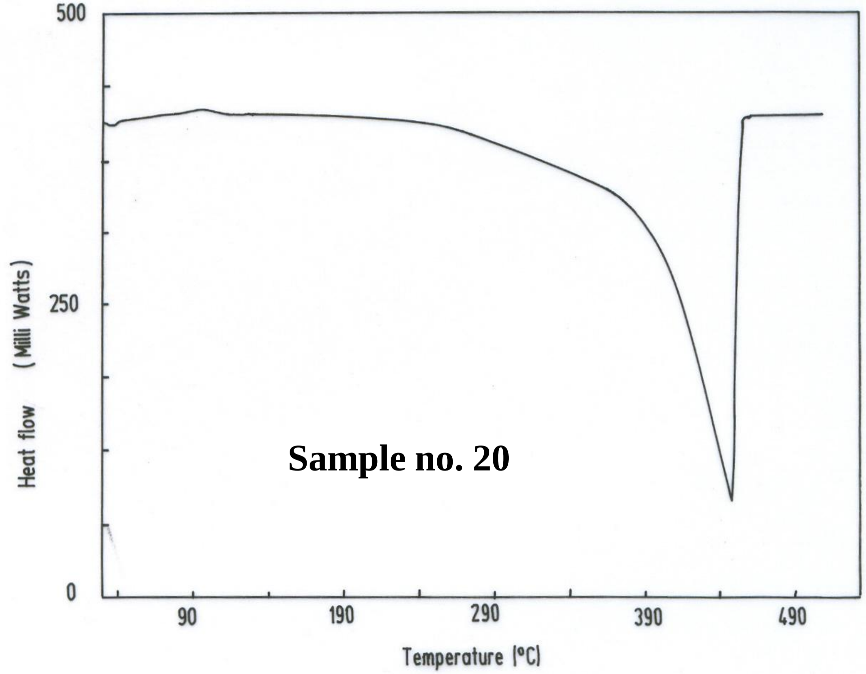
(3) Personal computer **(4) Graphics plotter**

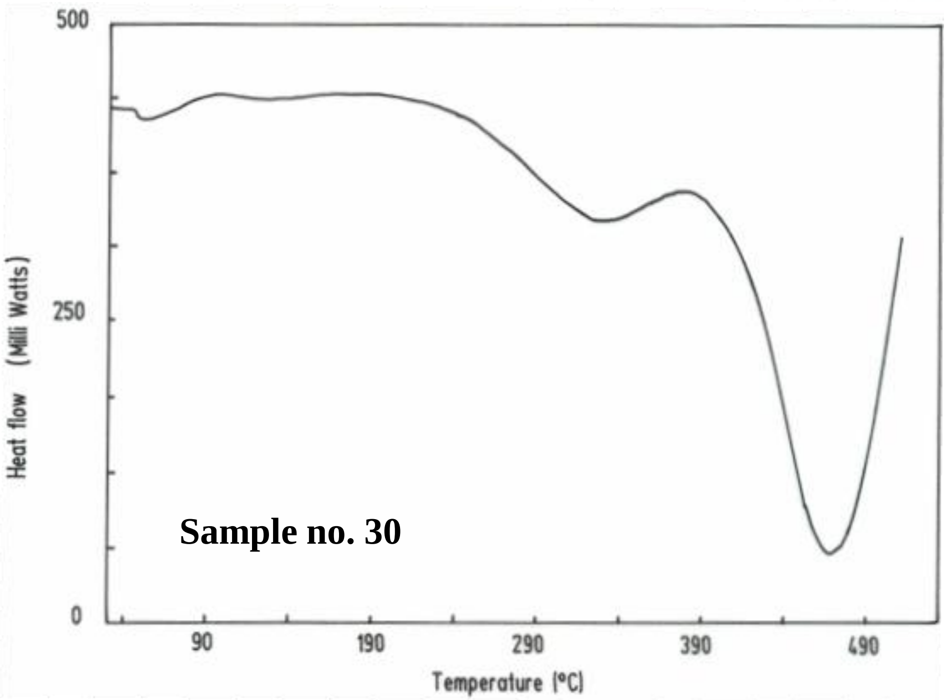
Photographic view showing experimental setup of Differential Scanning Calorimeter

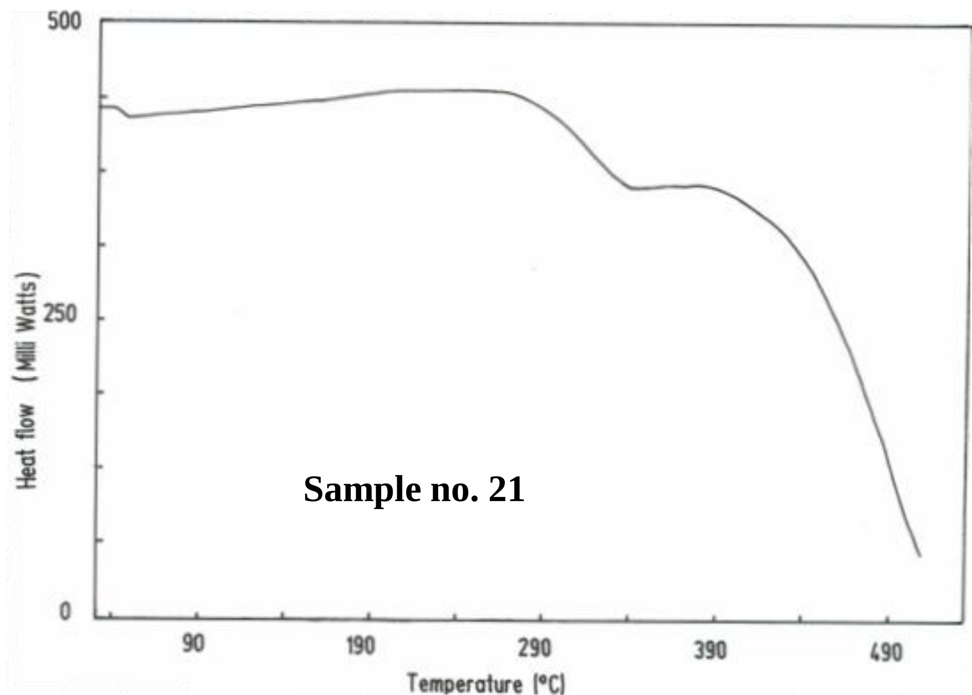


Determination of onset temperature for sample No. 24


500
250
0
Heat flow (Milli Watts)
100
200
300
400
500
Temperature (°C)
Sample no. 1


500
250
0
Heat flow (Milli Watts)
90
190
290
390
490
Temperature (°C)
Sample no. 20


500
250
0
Heat flow (Milli Watts)
90
190
290
390
490
Temperature (°C)
Sample no. 30


500
250
0
Heat flow (Milli Watts)
90
190
290
390
490
Temperature (°C)
Sample no. 21

Results of different susceptibility indices of coal samples

Sample No.	CPT (^{0}C)	CAB (litre/min)	WOPD (ΔE) at the end of 20 min. (mV)	DSC T_0 (^{0}C)
1	149	0.54	99.3	249.37
2	149	0.57	55.8	235.21
3	146	0.58	50.9	240.76
4	148	0.57	54.1	240.02
5	147	0.65	47.5	234.30
6	148	0.97	52.9	236.39
7	155	1.06	51.2	225.40
8	150	1.03	49.3	233.22
9	148	0.59	77.8	236.96
10	147	0.59	94	229.17
11	144	0.56	77.2	229.89
12	144	0.41	70.3	226.66
13	150	0.66	63.5	240.79
14	151	0.63	53.5	242.75
15	142	0.72	56.9	233.89

Contd…

Correlation Analysis

Independent variables:

- Constituents of Proximate and Ultimate Analyses

Dependent variables:

- Crossing point temperature (CPT)
- Critical air blast (CAB) value
- Wet oxidation potential difference (ΔE)
- Onset temperature (T_0) of DSC thermogram

Correlation coefficients between different susceptibility indices and constituents obtained from proximate and ultimate analyses

Sl. No.	Susceptibility Indices → / Intrinsic Characteristics ↓	CPT (^{0}C)	CAB (litre/min)	WOPD ΔE) (mV)	DSC T_0 (^{0}C)
1.	M	0.76	0.68	0.37	0.69
2.	VM	0.65	0.80	0.39	0.74
3.	A	0.50	0.28	0.29	0.43
4.	C	0.47	0.55	0.34	0.56
5.	H	0.45	0.40	0.50	0.06
6.	O	0.79	0.85	0.32	0.63

Table : Correlation between the constituents of proximate analysis and susceptibility indices

Sl. no.	Dependent variable	Empirical relation	Correlation coefficient
1	CPT	$146.7262M^{-0.027} + 7417.875\ VM^{-2.056} + 353.6539A^{-1.925}$	0.76
2	CAB	$0.878M^{-0.406} + 8021VM^{-3.111} - 2.5A^{-2.623}$	0.79
3	ΔE	$-37.375M^{-0.392} + 6.676VM^{0.812} + 9751.5A^{-4.428}$	0.48
4	T_o	$103M^{-0.037} + 609.6461VM^{0.443} + 1638.623A^{-2.996}$	0.85

✓ **Correlation between CPT,CAB value, WOPD (ΔE) and T_0 of DSC and the constituents of proximate analysis taken together have improved.**

This clearly reveals that

- **M, VM, A jointly influence the susceptibility indices**

- **For classification of Indian coals the following three susceptibility indices have been chosen along with moisture, volatile matter and ash content of the proximate analysis:**
  - **Crossing point temperature (CPT)**
  - **Critical air blast (CAB) value**
  - **T_0 of DSC thermogram**

ADAPTIVE RESONANCE THEORY

- Developed by Carpenter and Grossberg (1987)
- Serves the basic purpose of cluster discovery
- This network learns clusters in an unsupervised mode
- The novel property of ART network is the controlled discovery of clusters
- Can accommodate new clusters without affecting the storage or recall capabilities of clusters already learned

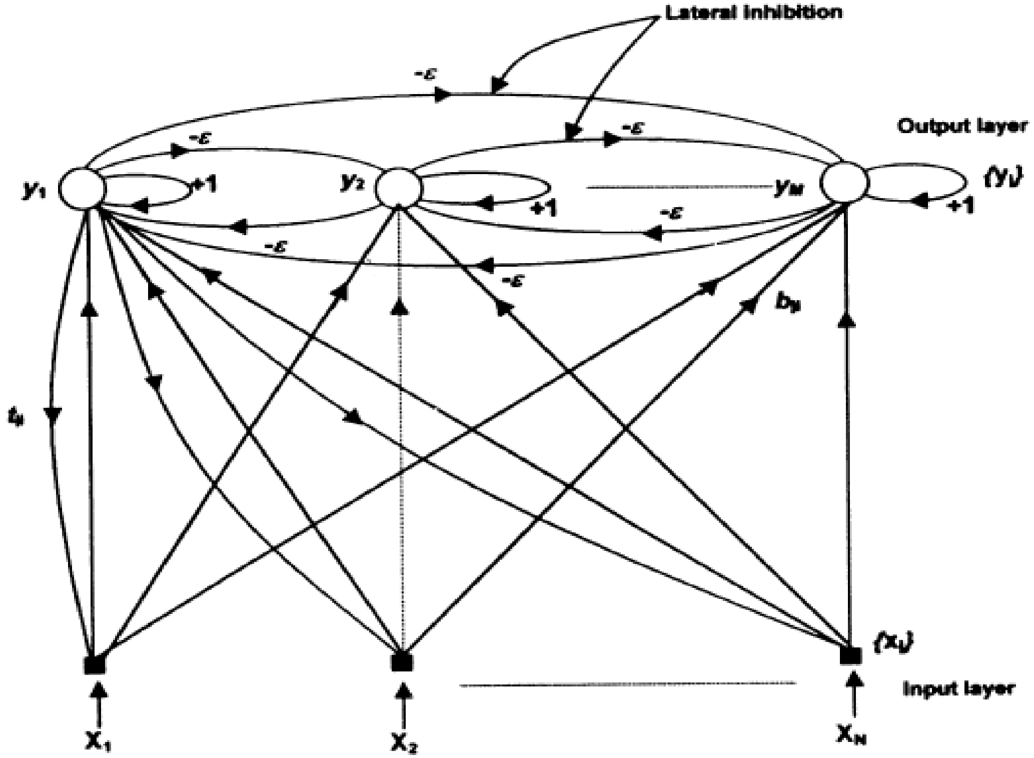
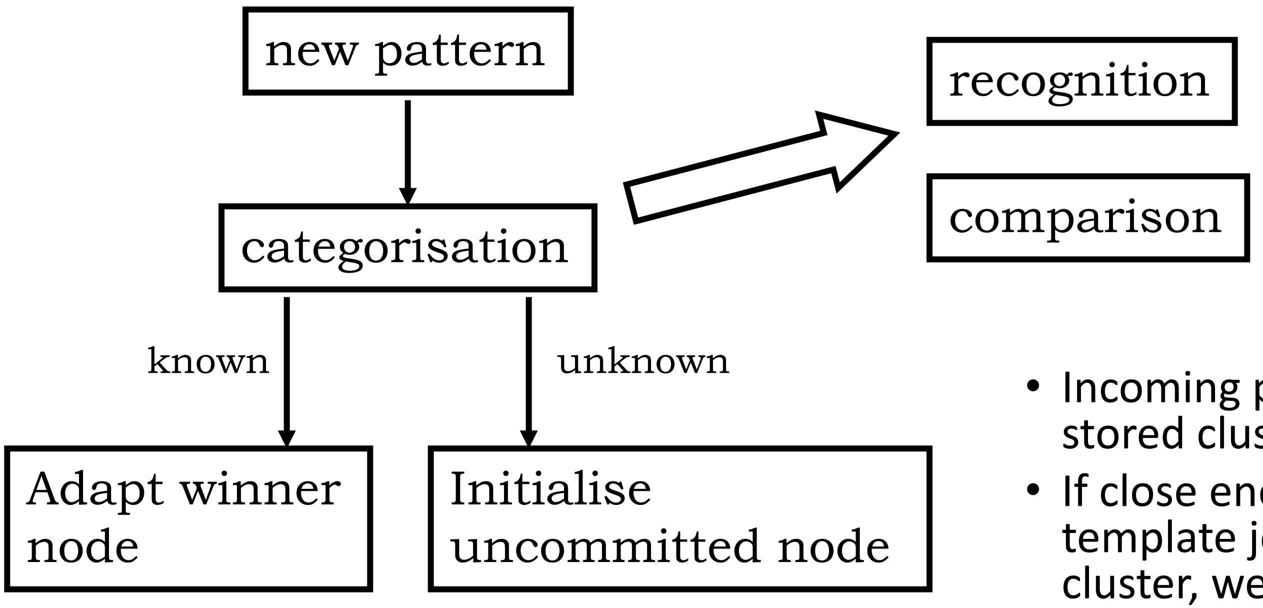


Figure: Schematic representation of ART1 network for clustering

ART Algorithm



- Incoming pattern matched with stored cluster templates
- If close enough to stored template joins best matching cluster, weights adapted
- If not, a new cluster is initialised with pattern as template

Classification of Coal Seams by using Adaptive Resonance Theory

- **Program was developed in C^{++}**
- **The program was run using four variables, which are:**
  1. Moisture 2. Volatile matter 3. Ash

One of the following susceptibility indices at a time:

- **Crossing point temperature.**
- **CAB value**
- **Onset temperature of DSC thermogram.**

- **The threshold value is set at 0.45 for all the cases to obtain 4 clusters**

Results

The clustering of all the 31 samples into four clusters

Clustering of coal samples using M, VM, A and CPT

Cluster no.	Number of sample	Sample numbers
1	3	21, 23, 24
2	16	2, 4, 5, 7, 8, 10, 11, 12, 22, 25, 26, 27, 28, 29, 30
3	11	1, 3, 6, 9, 13, 14, 15, 16, 17, 18, 19, 20
4	1	31

Discussion

- **The order of cluster numbers does not necessarily represent the susceptibility of the samples.**
- **Only describes the similarity in the spontaneous heating characteristics in a single cluster.**

The degree of spont. heating susceptibility of each cluster to be decided

To be verified from the observations of actual characteristics and occurrence of fire in mines

A review of the status of fire in the field indicates:

- **The lignite of Neyveli occurs in aquifers and it catches fire within a very short time**

Can be termed as very highly susceptible.

Discussion Contd…

- Seams with sample nos. 24, 25, 26 and 30 are known for their high susceptibility
- Take more time to catch fire than Neyveli lignite
- Placed along with some samples in cluster no. 2

May be termed as highly susceptible.

- Sample nos. 21 and 23 are placed in cluster 3
- Field experience indicate the least susceptible

Termed as poorly susceptible.

- Occasional fires in seams with sample nos. 6 and 17 (cluster no. 1)

May be termed as moderately susceptible.

Conclusion

Knowing the susceptibility of a few samples in each cluster and applying ART
the coal seams have been categorized into four classes

Class No.	Category	Cluster No.	Sample No.
1	Very highly susceptible	4	31
2	Highly susceptible	2	2, 4, 5, 7, 8, 10, 11, 12, 22, 24, 25, 26, 27, 28, 29, 30
3	Moderately susceptible	1	1, 3, 6, 9, 13, 14, 15, 16, 17, 18, 19, 20
4	Poorly susceptible	3	21, 23

Conclusion

There is no change in sample nos. in different clusters,

Confirms the consistency and authenticity of the total classification system.

Any new coal seam can be categorised

by knowing the constituents of proximate analysis

any one of the susceptibility indices in the laboratory.

Simple, easy to implement

Has the flexibility in allowing the user to identify the required number of clusters in advance, or consider it as a dependent variable.

THANK YOU