RRC-31
February 1979

Government of India
ATOMIC ENERGY COMMISSION

Techniques for Extinguishing Sodium Fires

Chander Raju and R. D. Kale

Reactor Research Centre
Kalpakkam 603 102 Tamil Nadu, India

RRC-34
1979

GOVERNMENT OF INDIA

ATOMIC ENERGY COMMISSION

TECHNIQUES FOR EXTINGUISHING SODIUM FIRES

Chander Raju & R.D. Kale

REACTOR RESEARCH CENTRE
KALPAKKAM 603 102
TAMILNADU, INDIA

ABSTRACT

This report describes the experimental work done to evaluate the performance of commercially available fire extinguishants and powders for sodium fires. Dry chemical powder with sodium bicarbonate base was found very effective. Another effective method of extinguishing fire by using perforated covered tray is also discussed.

TECHNIQUES FOR EXTINGUISHING SODIUM FIRES

Chander Raju and R.D. Kale

1. INTRODUCTION

The Reactor Engineering Laboratory has been operating liquid sodium test loops to develop sodium technology for the Fast Breeder Reactor programme. The use of high temperature sodium in the systems involves problems of sodium fire and its control in the case of eventual leaks. It was considered essential to gain familiarity with various aspects of sodium fire and its control. A short programme was therefore, initiated as described below.

1. General study of sodium fires
2. Evaluation of locally available extinguishants
3. Fire fighting techniques and protection from fire
4. Other methods of extinguishing fire.

Several experimental fires ranging from about 100 g. of sodium to 10 kg. were conducted. The report discusses experience gained in the course of the experimental study.

2. SPECIAL CHARACTERISTICS OF SODIUM FIRE

Oxidation of a material can be termed as fire when it is accompanied by evolution of large amount of heat. Sodium fire is no exception to this rule. Sodium when left open to atmosphere is oxidized spontaneously with evolution of heat at room temperature. But this cannot be termed as fire since oxidation rate is very low and the heat evolved is also very less. However, as sodium temperature is increased the rate of oxidation is also increased resulting in sodium catching fire which is characterised by incandescent spots with low flames. Sodium combustion is also very conspicuous by the large amount of white smoke evolved.

Sodium fire depends on many factors of which the important ones are listed below :

1. Temperature of sodium
2. The oxygen and moisture content of atmosphere
3. Form of molten sodium, whether pool or spray
4. Velocity of air
5. Surface area of the sodium pool
6. Depth of pool

2.1 Ignition Temperature

Ignition temperature of sodium depends on various parameters, but none can be exactly correlated. Many approximate value of ignition temperature have been reported. Newman & Bayne[1] have reported a set of values for different conditions which are given in Table - 1.

Ignition temperatures recorded in our experiments are given in Table - 2.

From these values it can be observed that ignition temperature increases with relative humidity. This may be due to the formation of the protective layer of NaOH (s), which covers the sodium pool.

Table - 1

IGNITION TEMPERATURE OF SODIUM POOLS

Temperature	Remarks
300 - 320°C	Static in Air Surface protection by NaOH (s)
140°C	Stirred in Air Protective layer is broken
200°C	Static in dry O_2 Surface protection by Na_2O_2 (s)
200 - 320°C	Static in dry air

Table - 2

IGNITION TEMPERATURE OF SODIUM POOL AS A FUNCTION OF RELATIVE HUMIDITY AND WIND VELOCITY

Temperature (° C)	Relative humidity %	Wind velocity (kmph)	Remarks
220	52	25.2	Sodium Pool fire
275	58	30.0	
310	71	17.5	
320	69	10.0	
380	71	20.8	

2.2 Visual Observation of a pool fire

When a sodium brick is heated in a tray by direct oxy-acetylene flame, it starts melting and the oil coating on the surface burns with long flames around 180°C. On further heating a liquid sodium pool is formed with a white crust of oxide layer on it and this layer turns greyish-yellow with black patches just before igniting. Suddenly some congregation of particles occur and these start emerging as nodules at different points on the pool surface and starts burning. A burning nodule is characterised by a bright incandescent spot with low golden yellow flame. The fire can be approached closely and examined without any fear, provided the person is fully covered up with a safety suit as shown in Fig. 1.

Nodules in the burning pool tend to move towards the sides of the container thereby leaving a hollow region in the centre or at one end. The movements of nodules seems to be independent of wind direction, since two trays of identical size placed side by side in the open area showed that the nodules had accumulated in different directions at the end of the experiment.

The abated fire leaves behind a hard porous mass of granules, yellow and greenish-yellow in colour. These granules turn into a viscous cream coloured semi-solid, when left exposed.

Presence of sodium in granules is indicated by the explosions resulting from sodium-water reaction during disposal with water.

2.3 Temperature distribution in and above sodium pool

The temperature distribution is of importance in developing extinguishing methods and in design of components from safety considerations.

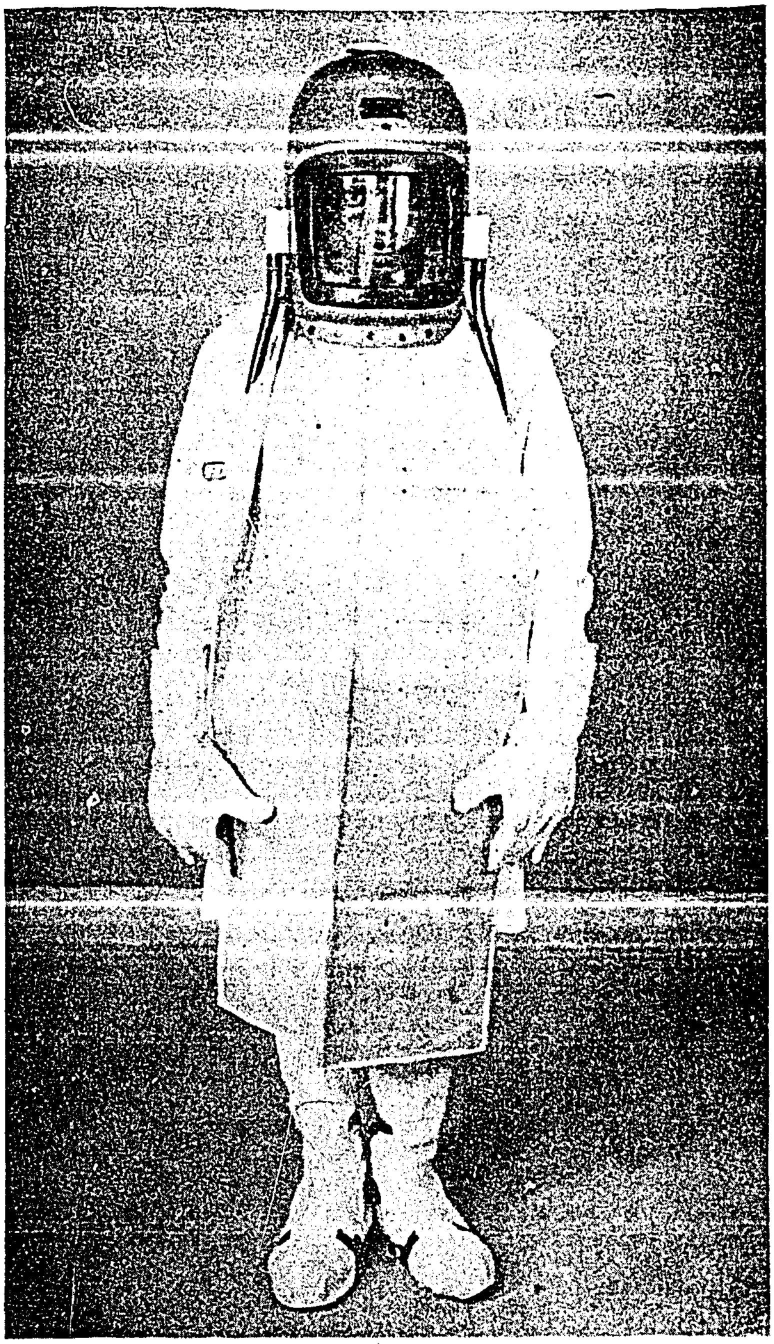

Fig. 1. Safety suit to handle Sodium Fires

A 30 mm deep molten sodium pool was formed in a small tray. Thermocouples were provided to measure temperatures from 2 mm. above the bottom of tray to 240 mm. above it. The general arrangement is shown in Fig. 2.

Fig. 4 shows the temperature profile as a function of distance from the bottom of the tray.

It can be concluded from this that the combustion occurs about 10 mm above the surface of the pool. The temperature falls very rapidly at points away from the surface, indicating that heat effects of the fire are relatively small. The burning pool can therefore be approached closely without much difficulty. As time passes the pool temperature decreases and the combustion zone also moves closer to the surface probably due to less evaporation of liquid sodium.

3. CHARACTERISTICS OF A GOOD EXTINGUISHANT

A primary objective of the fire studies was to select a suitable fire extinguishant from materials available locally. Based on the observations and available information hitherto the following requirements are considered necessary for a good extinguishant.

i) It should be neither a combustible material nor a supporter of combustion

ii) Its density should be less than 0.8 g cm^{-3}

iii) It should be stable and non-hygroscopic

iv) It should be free-flowing and compatible with liquid sodium

v) Ratio of quantity of powder required to quantity of sodium should be small

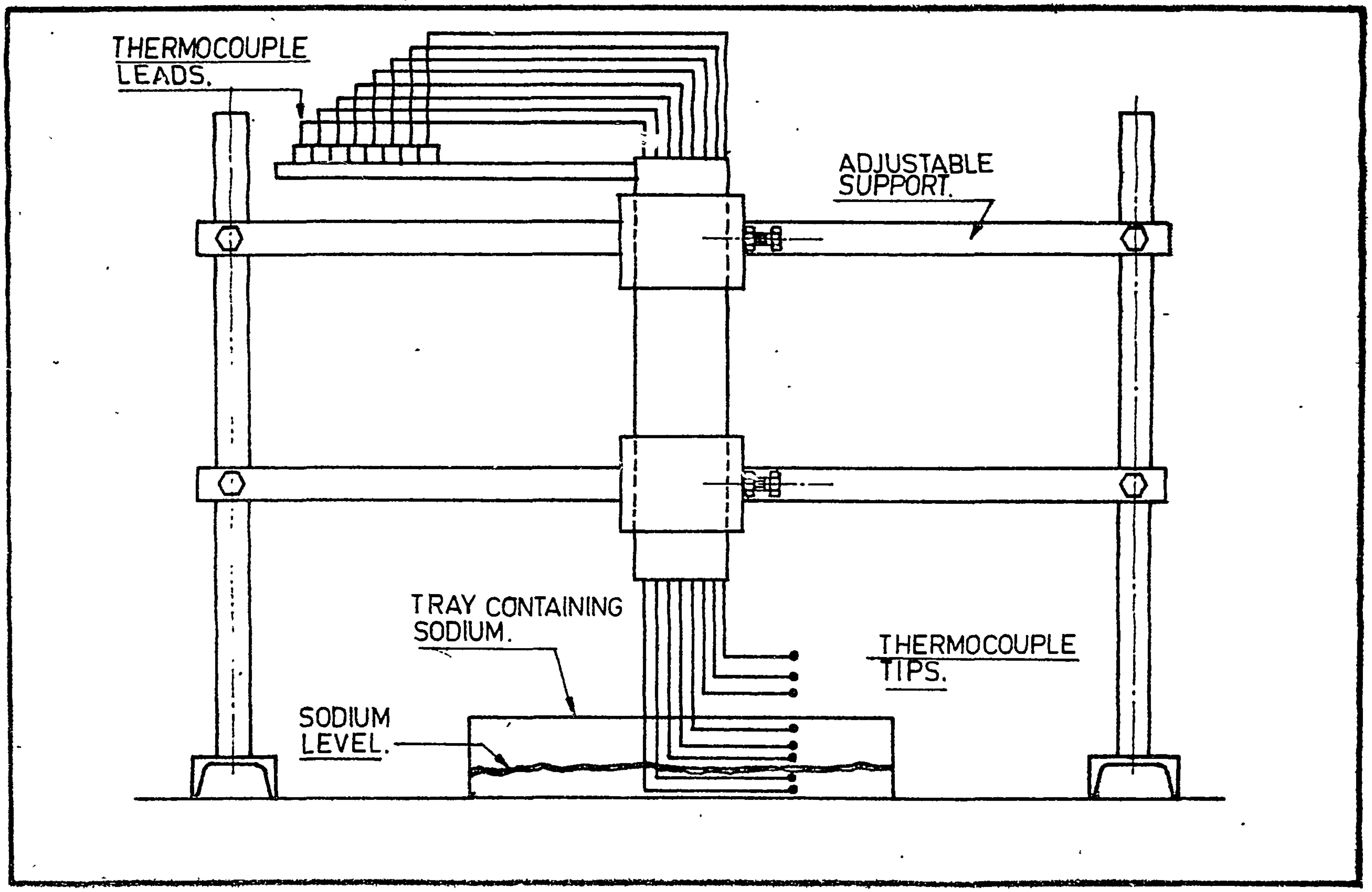

Fig. 2. Set-up for measuring Temperature distribution

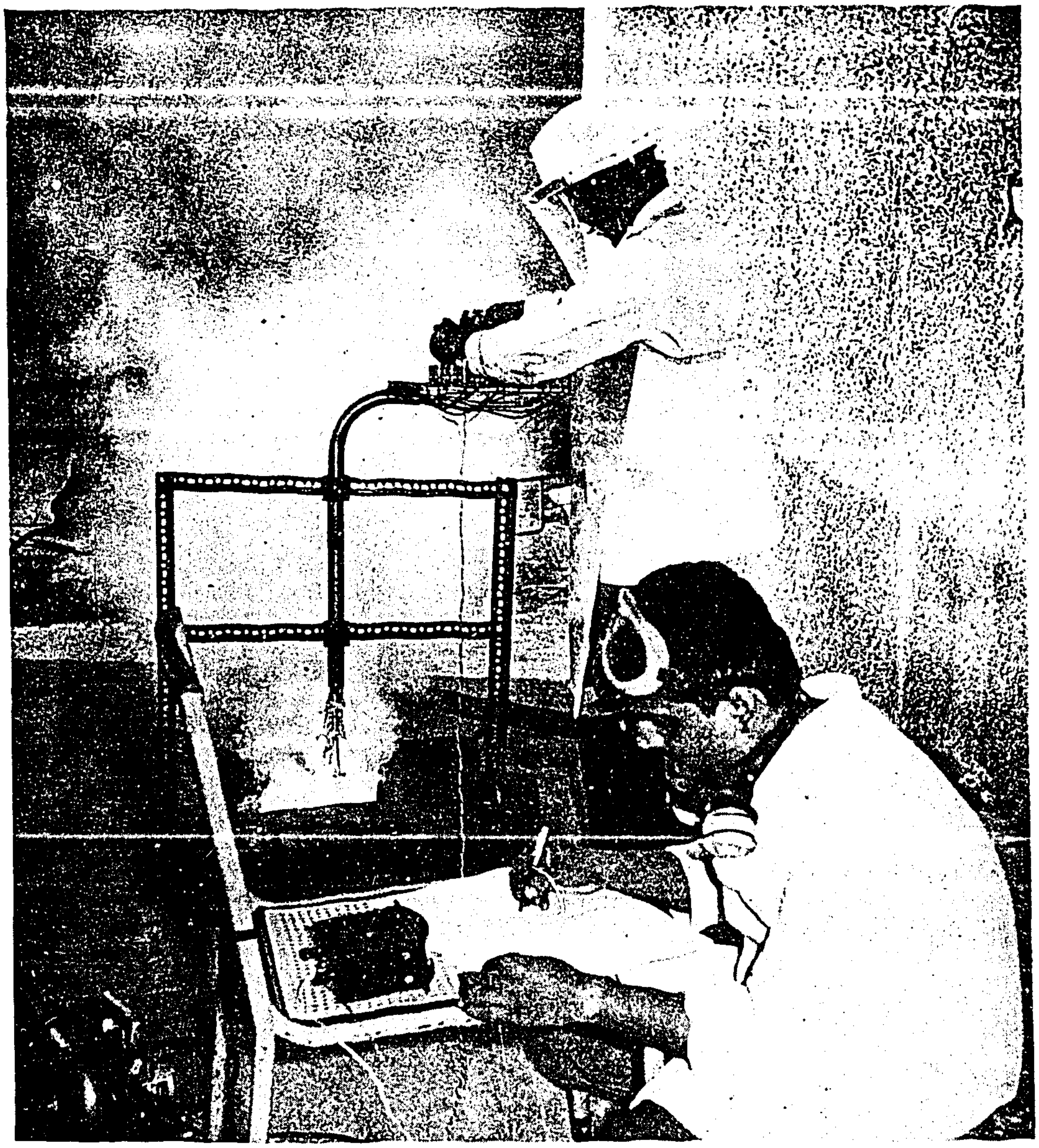

Fig. 3. Set-up to measure Temperature distribution on Sodium Fire

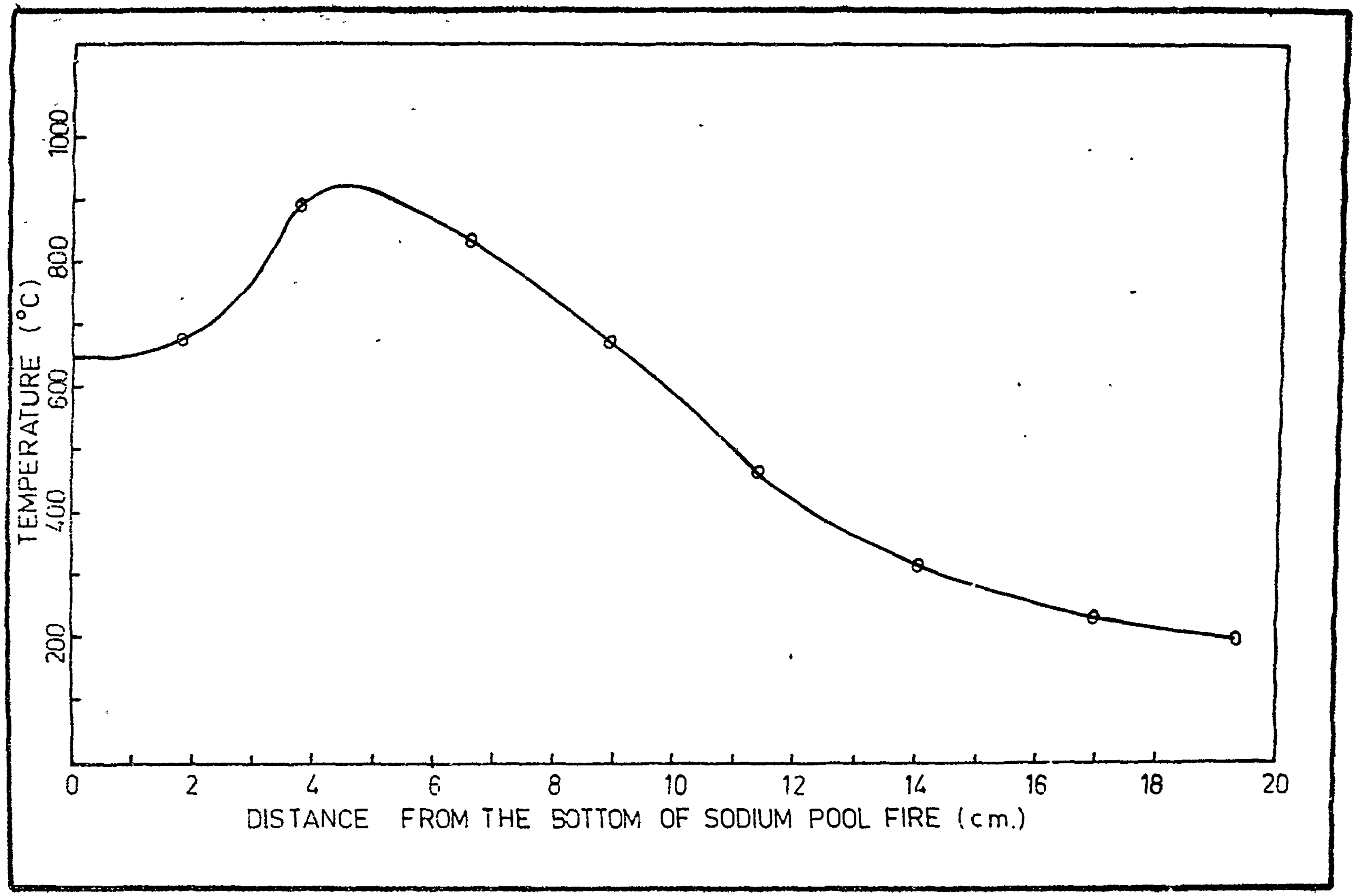

Fig. 4. Sodium fire temperature distribution versus distance

vi) It should rapidly cool the metal in order to reduce the possibility of reignition

vii) It should be easy to dispose of with water

viii) The reaction with sodium if any must neither be exothermic nor violent

ix) It should be inexpensive and freely available.

4. EXTINGUISHANTS USED IN THIS STUDY

Various extinguishants were selected on the basis of the above requirements for further investigation on sodium fires.

These were :

i)	Sodium bicarbonate	(dry chemical powder)
ii)	Sodium carbonate	(technical grade)
iii)	Calcium carbonate	(technical grade)
iv)	Vermiculite	
v)	Sand	
vi)	Alumite	
vii)	Ternary Eutectic Chloride (TEC)	

The properties of these are given in Table - 3.

Table - 3

PROPERTIES OF EXTINGUISHANTS

S.No.	Powder Extinguishant	Density (g cm^{-3})	Percentage moisture content	Remarks
1.	Alumite	1.149	2.3	Free flowing
2.	Sand	1.562	0.0002	Not free flowing
3.	Sodium carbonate (Technical grade)	0.89	22.0	Not free flowing
4.	Sodium bicarbonate (Dry chemical powder)	0.709	1.0	Free flowing
5.	Vermiculite (small size)	0.833	6.8	Not free flowing
6.	Vermiculite (big size)	0.118	5.0	Not free flowing
7.	Calcium carbonate (Technical grade)	0.4739	1.3	Not free flowing
8.	Ternary Eutectic Chloride (TEC)	1.5	1.0	Free flowing, but cakes on heating

5. BEHAVIOUR OF POWDER EXTINGUISHANTS ON FIRE

Sodium fire experiments were conducted on various scales to observe the performance of different powder extinguishants. Important parameters like ratio of quantity of powder to quantity of sodium, cooling rate, compatibility with fire, ease of disposal with water etc., were recorded.

The performance of each extinguishant is dealt with in the following paragraphs.

5.1 Sodium Carbonate (Technical Grade)

Commercial sodium carbonate of technical grade was used in all experiments. Since this contains upto 22% moisture, it was decided to use only dried powder for fire extinguishing. The dried powder was packed in sealed polythene bags. The powder contained a lot of lumps even after drying.

Table - 4 gives brief details of experiments conducted with sodium carbonate. In all the experiments the following observations were made :

i) Due to sputtering a lot of burning sodium nodules were thrown out

ii) The powder sank into the pool and did not cover the pool readily

iii) Large quantity of powder was required to extinguish the fire, hence the time taken to extinguish the fire was also long

iv) The temperature decay was slow.

Table - 4

EXPERIMENTAL OBSERVATION OF SODIUM CARBONATE EXTINGUISHANT

Exp. No.	Weight of Sodium (kg)	Ratio of quantity of extinguishant to quantity of Sodium	Remarks
1.	0.63	0.92	Conducted in beaker. The powder sank into the pool throughout up to a depth of a few centimetres from the top surface. Sinking of powder in this case was more predominant than with sodium bicarbonate. Reaction at the interface was prominent. Fig. 5 gives the temperature decay.
2.	5.25	5.41	Conducted by heating sodium in a tray in open space. The powder sank into the pool and almost a homogeneous mass of sodium carbonate formed before the fire was extinguished.
3.	8.75	2.60 of Na_2CO_3 and 0.96 of $NaHCO_3$	Conducted in a large tray by pouring burning sodium into the tray. Available dry sodium carbonate was insufficient so the fire was finally extinguished by application of sodium bicarbonate. It can be seen that even the effect of Sodium carbonate is lost due to presence of sodium carbonate. Fig. 6 gives the temperature decay.

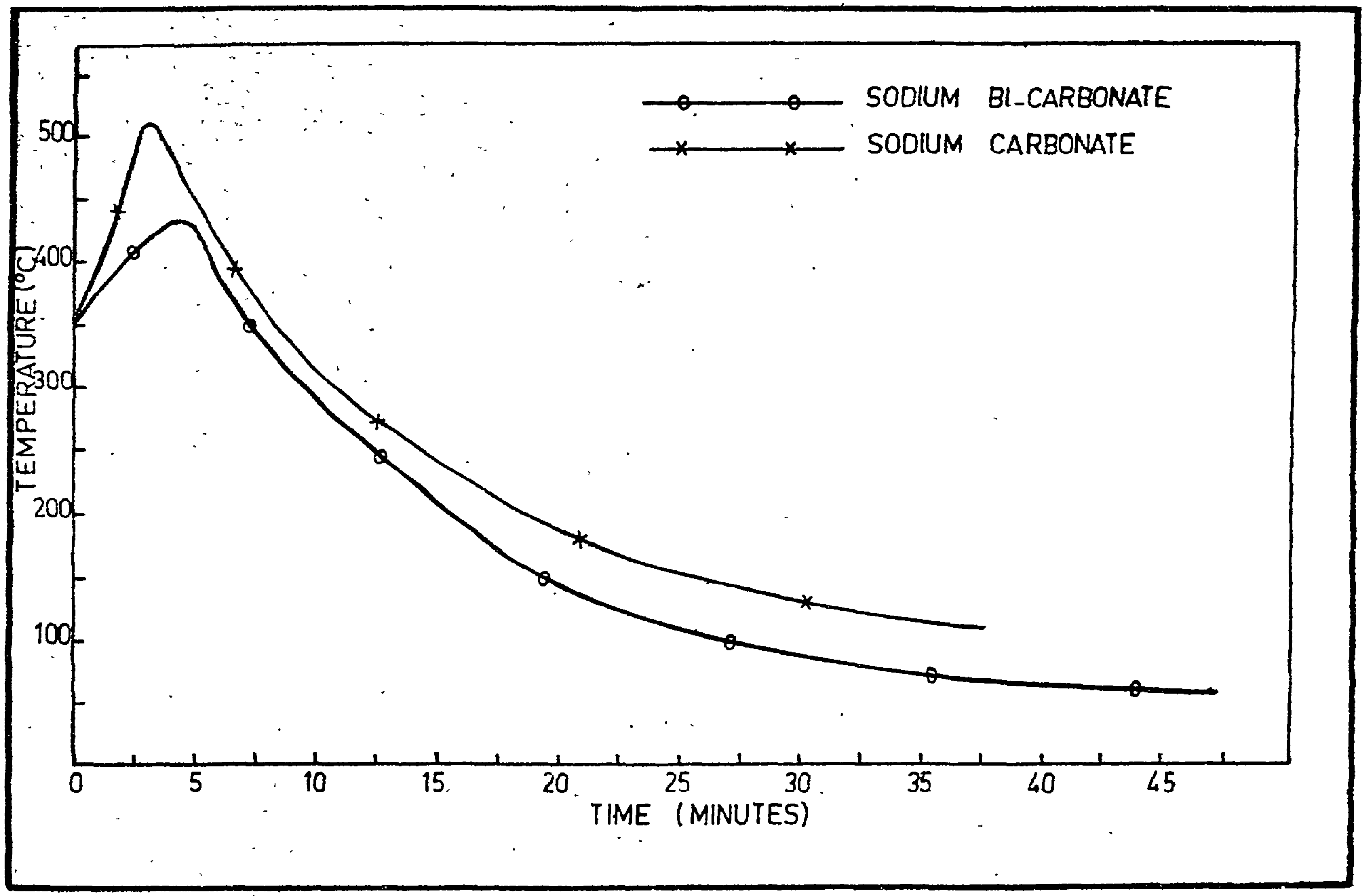

Fig. 5. Beaker experiment to test Sodium carbonate and Sodium-bi-carbonate

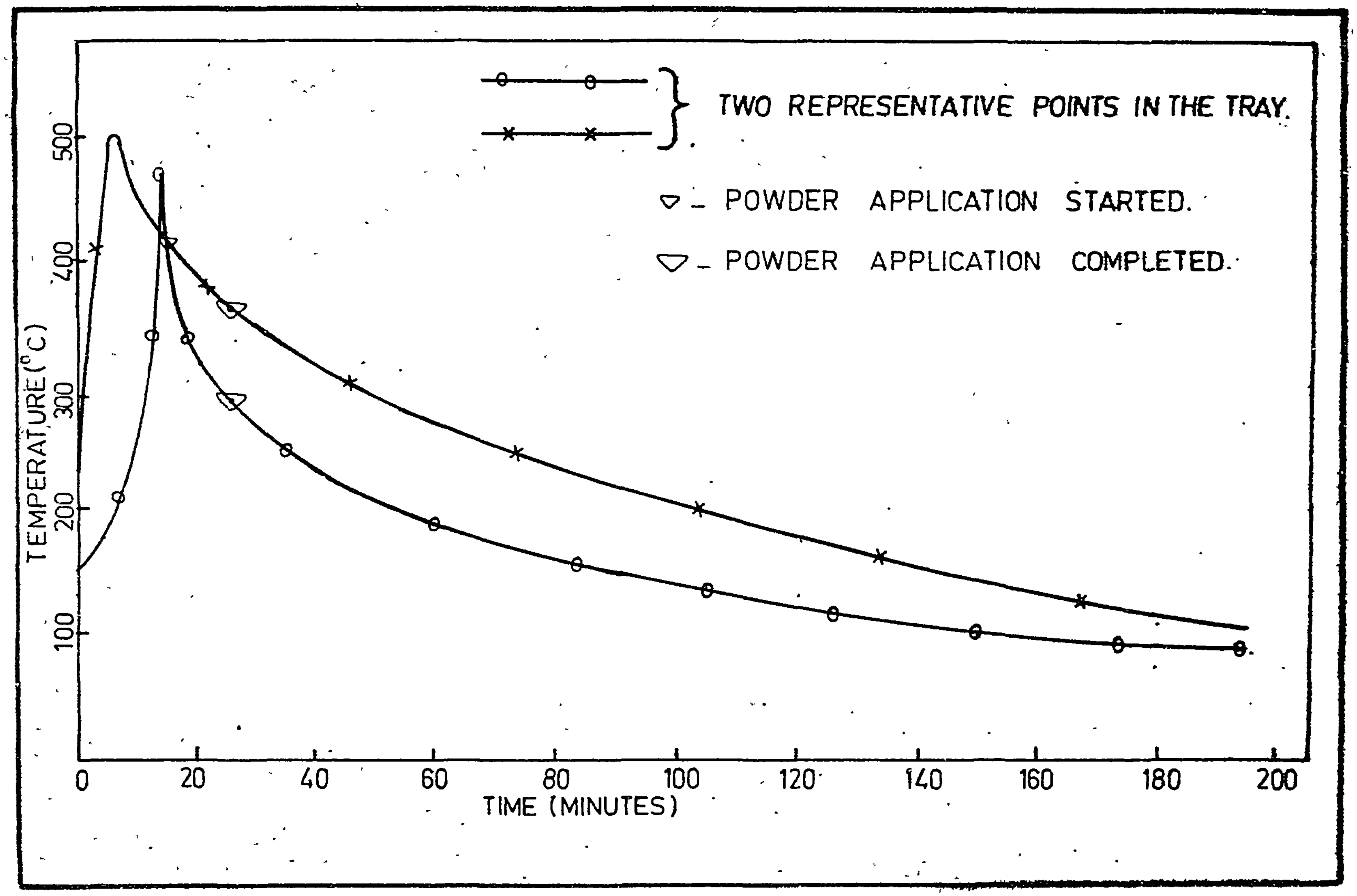

Fig. 6. Large scale fire to test Sodium Carbonate powder

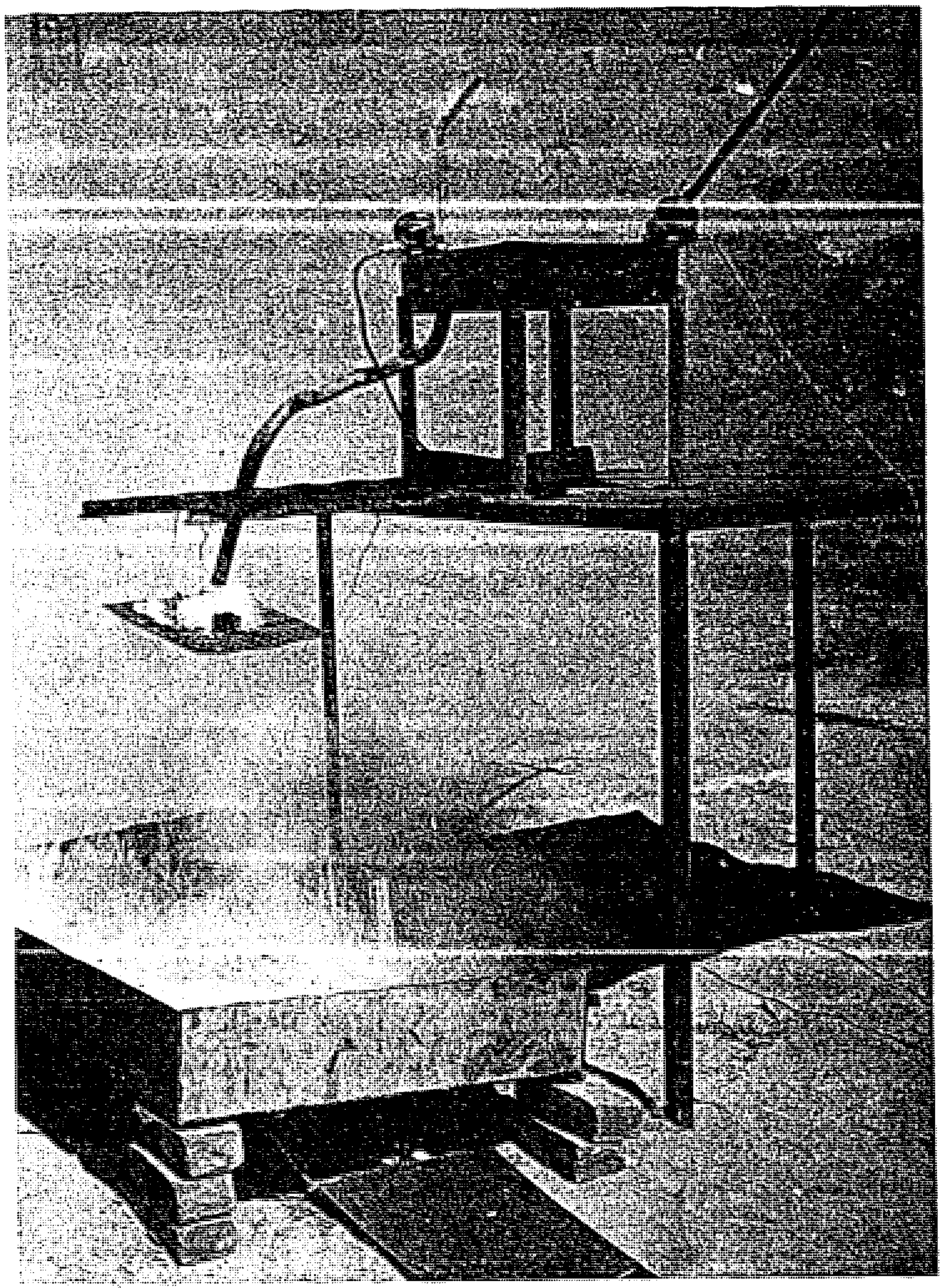

Fig. 7. Large scale Sodium fire test set-up

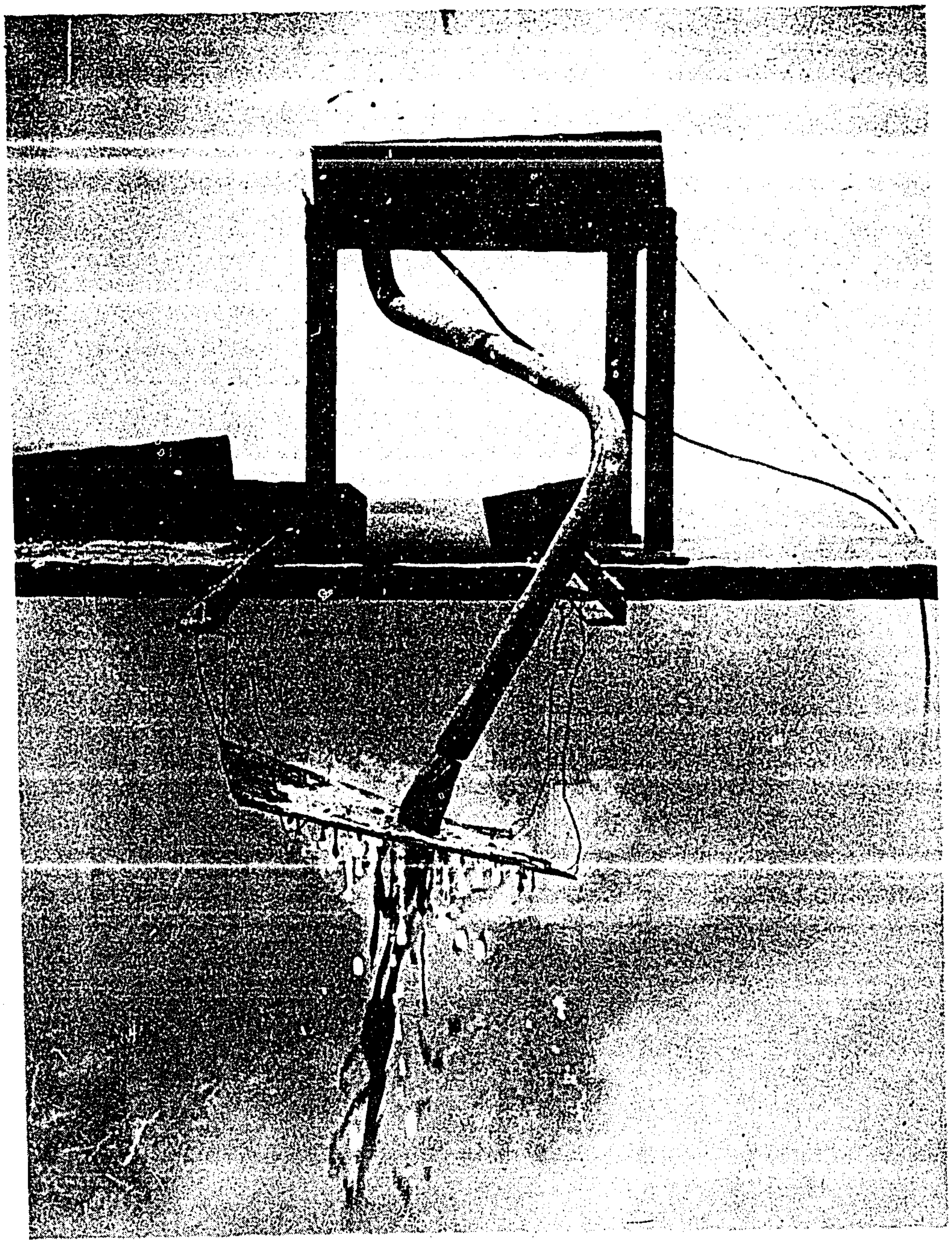

Fig. 8. Burning nodules in a large scale fire

5.2 Sodium bicarbonate (Dry Chemical Powder)

Sodium bicarbonate is available as Dry Chemical Powder (DCP). In experiments it was found that the oven dried DCP and DCP as available commercially did not show any significant difference in their extinguishing capabilities. Sodium bi carbonate as Dry Chemical Powder can be used in any standard Dry Chemical Powder fire extinguishers.

Experimental observation of this powder on sodium fire is given in Table - 5.

The general observations from these experiments are:

i) No sputtering

ii) The powder floated on top and covered the surface of burning pool very well.

iii) No substantial reaction was observed at the interface. When the top surface was scrubbed, clean liquid metal surface was observed beneath

iv) Only small quantity of powder was required and hence fire was extinguished pretty fast

v) Temperature decay is shown in Fig. 5, 9, 10 and 11

vi) The powder neither dissolves in water nor permits easy contact between water and sodium making disposal of residues a pain-staking job.

Table - 5

EXPERIMENTAL OBSERVATION OF SODIUM BICARBONATE AS EXTINGUISHANT

Exp. No.	Weight of sodium (kg)	Ratio of weight of powder to weight of sodium	Remarks
1.	0.67	0.31	Conducted in beaker. Experiment indicated that only very little powder sank into the pool and by much lower extent than Sodium Carbonate. There was some reaction at the interface. The temperature decay is shown in Fig. 5.
2.	5.25	0.5	Conducted by heating sodium in a tray in open atmosphere The powder applied on the surface remained at top surface and covered the pool well. Fig. 9 shows the temperature decay.
3.	5.25	0.73	Conducted as in experiment No. 2. This confirmed the results of experiment no. 2. Temperature decay is shown in Fig. 9.
4.	8.75	1.15	Conducted in a large tray by pouring burning sodium into it. Sodium bicarbonate was applied by showels. Fig. 10 shows temperature decay at some representative points.
5.	8.75	1.03	Conducted in a similar manner to experiment No. 4. A different brand of powder was used. Temperature decay is shown in Fig. 11.

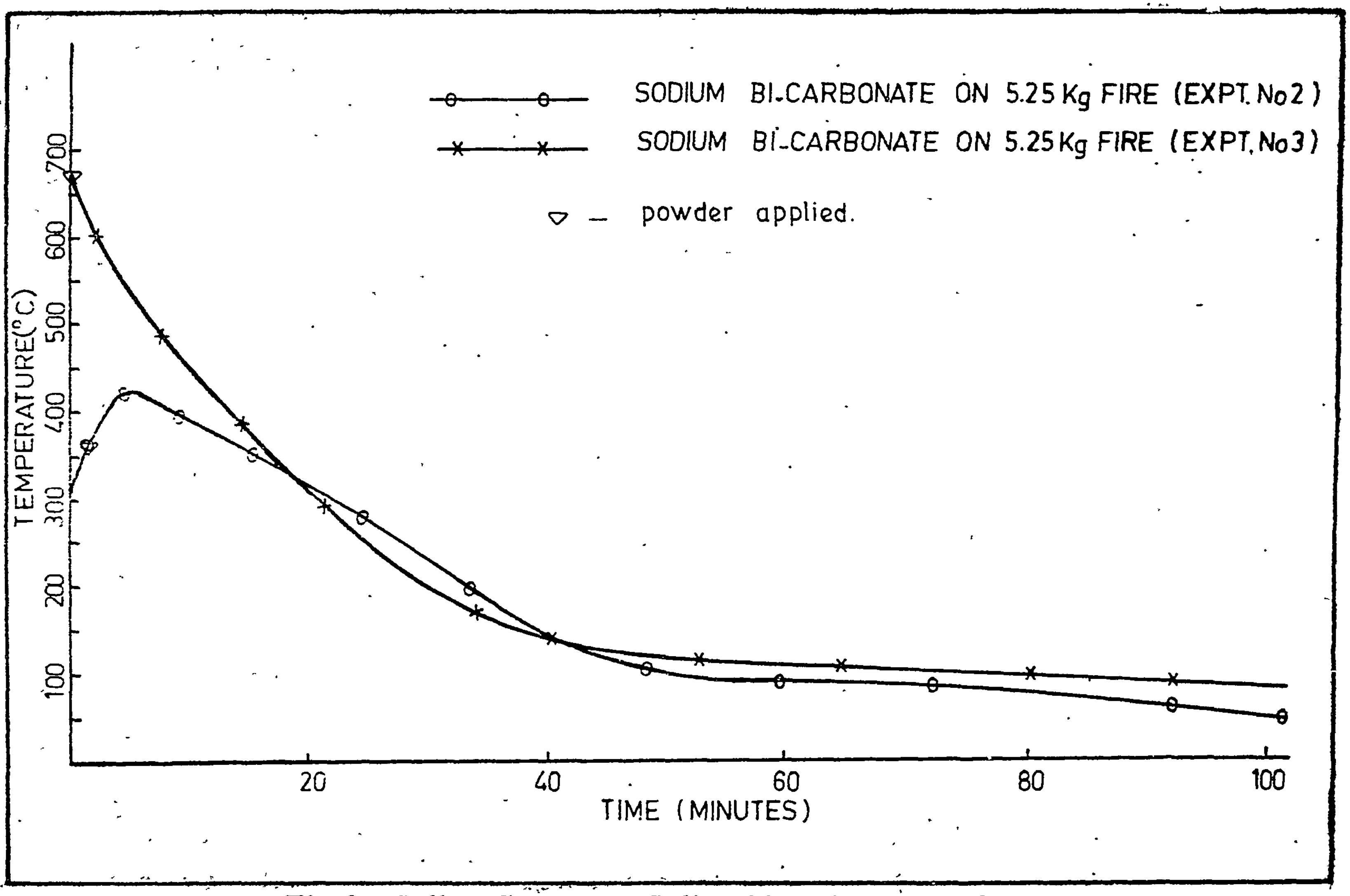

Fig. 9. Sodium fire to test Sodium bi-carbonate powder

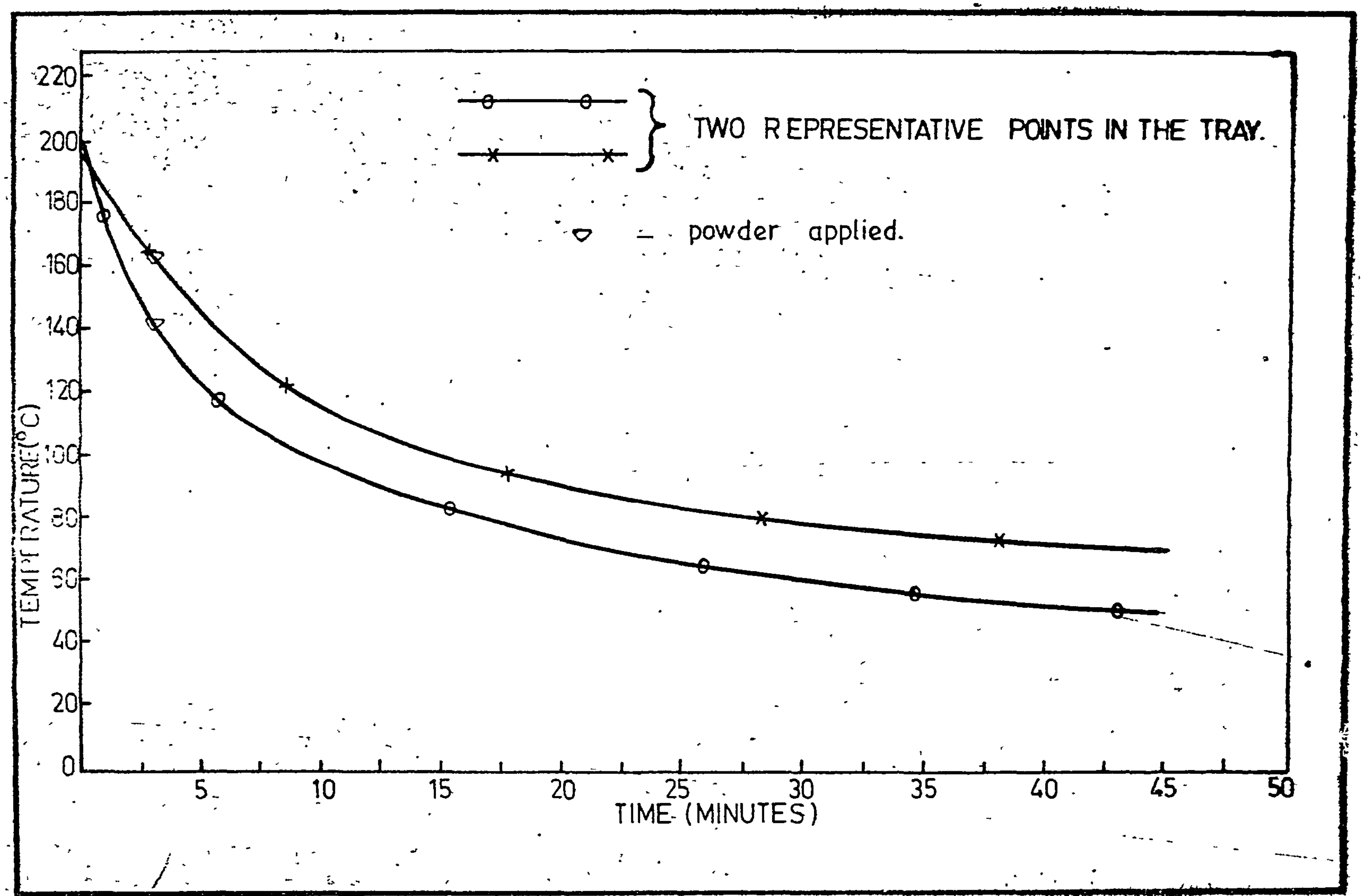

Fig. 10. First large scale fire to test Sodium-bi-carbonate powder

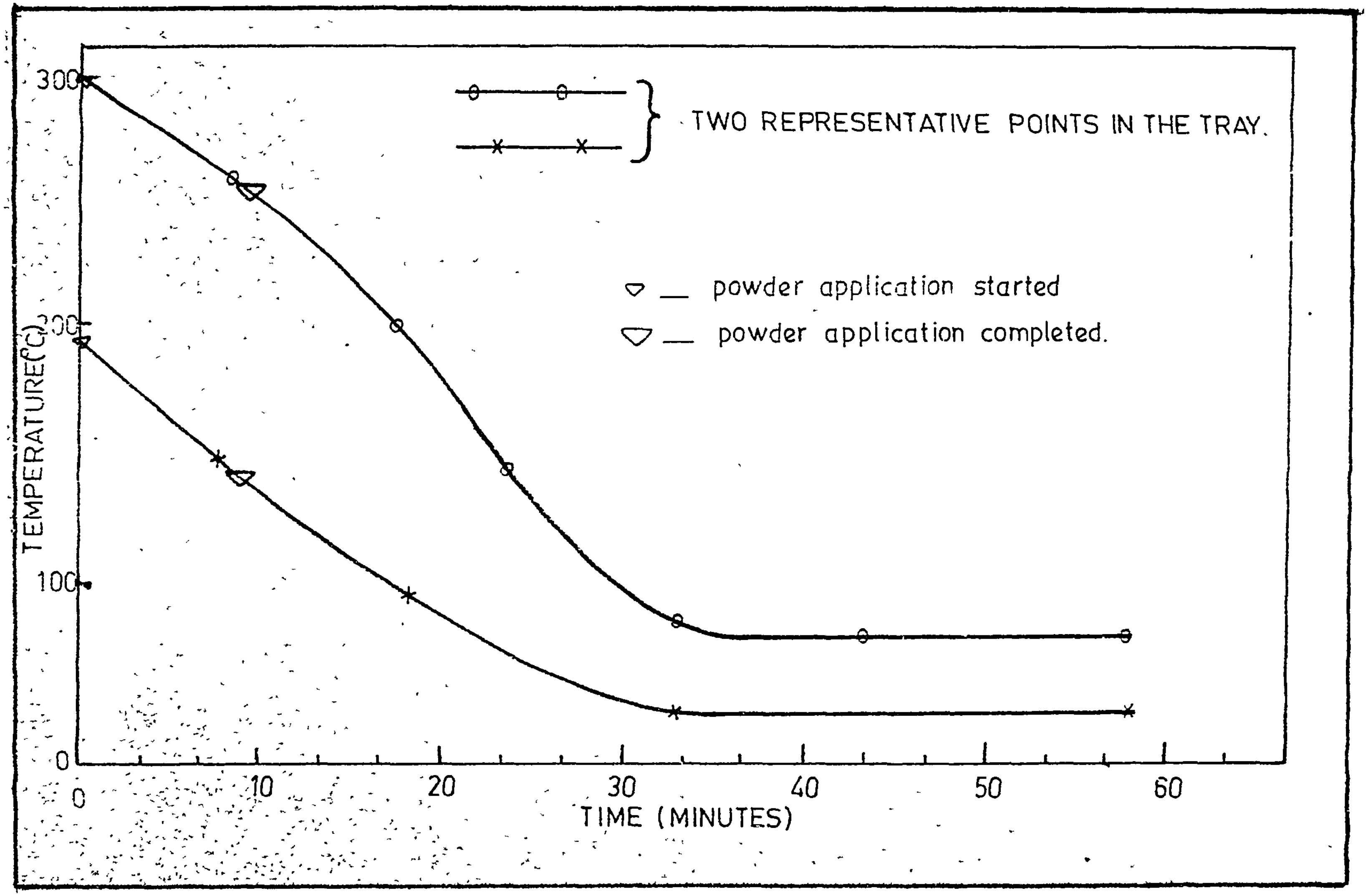

Fig. 11. Second large scale fire to test Sodium-bi-carbonate powder

5.3 Vermiculite

Vermiculite is a naturally available mineral and has mica like appearance. Its approximate composition is SiO_2 - 39% Al_2O_3 - 12%, MgO - 23%. It is very light and has very low thermal conductivity (0.064 W/m ^{o}C). Large particle size vermiculite is found to be advantageous due to its lower density. The effect of particle size on fire extinguishing capability is given in Table - 6. It has been found from our experiments that there is not much difference between dried and as available vermiculite in their extinguishing capabilities.

Table - 7 gives experimental observations using vermiculite as extinguishant. In all the experiments the following were observed.

i) Long flames resulted when the vermiculite was applied on the burning metal. These flames obstructed further application of powder to some extent.

ii) Vermiculite can be applied by showels only.

iii) Temperature decay was very slow and when the pool was disturbed, uncovered sodium started burning.

iv) The unreacted sodium chemical powder could be disposed without much difficulty.

Table - 6

EFFECT OF PARTICLE SIZE FOR VERMICULITE

Exp. No.	Particulars			Weight of sodium in (kg).	Ratio of weight of powder to weight of sodium
	Small size Vermiculite				
	Particle size ASTM	mm	Percentage		
1.	16-30	1.2 - .6	69.0	0.5	0.5
	30-50	0.6 - .3	29.0		
	50-100	0.3 - .15	1.5		
	100 and above	0.15	0.5		
2.	- as above -			1.3	1.1
3.	- as above -			0.325	1.18
	Large size Vermiculite				
	Particle size ASTM	mm	Percentage		
4.	4 and less	4.8	1.4	3.5	0.41
	4-8	4.8 - 2.4	52.0		
	8-16	2.4 - 1.2	25.2		
	16-30	1.2 - .6	11.9		
	30-50	0.6 - .3	5.2		
	50-100	0.3 - .15	2.9		
	100 and above	0.15	1.4		
5.	- as above -			9.0	0.8

Table - 7

EXPERIMENTAL OBSERVATION ON VERMICULITE AS EXTINGUISHANT

Exp. No.	Sodium Weight (kg.)	Ratio of weight of powder to weight of sodium	Remarks
1.	0.5	2.4	Small size vermiculite, Conducted in open atmosphere. The powder floats and covers the fire well. Slight flaming was observed, when the powder was applied. The temperature decay is shown in Fig. 12.
2.	1.3	1.1	Small size vermiculite. Conducted in open atmosphere. Powder covered the surface well. The time-temperature curve is shown in Fig. 12.
3.	3.6	0.41	Conducted in open atmosphere. Large size vermiculite was used. The powder floats and covers the fire well. Flaming was observed at the instant when the powder is applied. The temperature decay is shown in Fig. 13.
4.	8.75	0.8	Conducted in a large tray by pouring burning sodium into it. Large size vermiculite was used. Vermiculite was applied by showel. A representative point temperature decay is shown in Fig. 14.

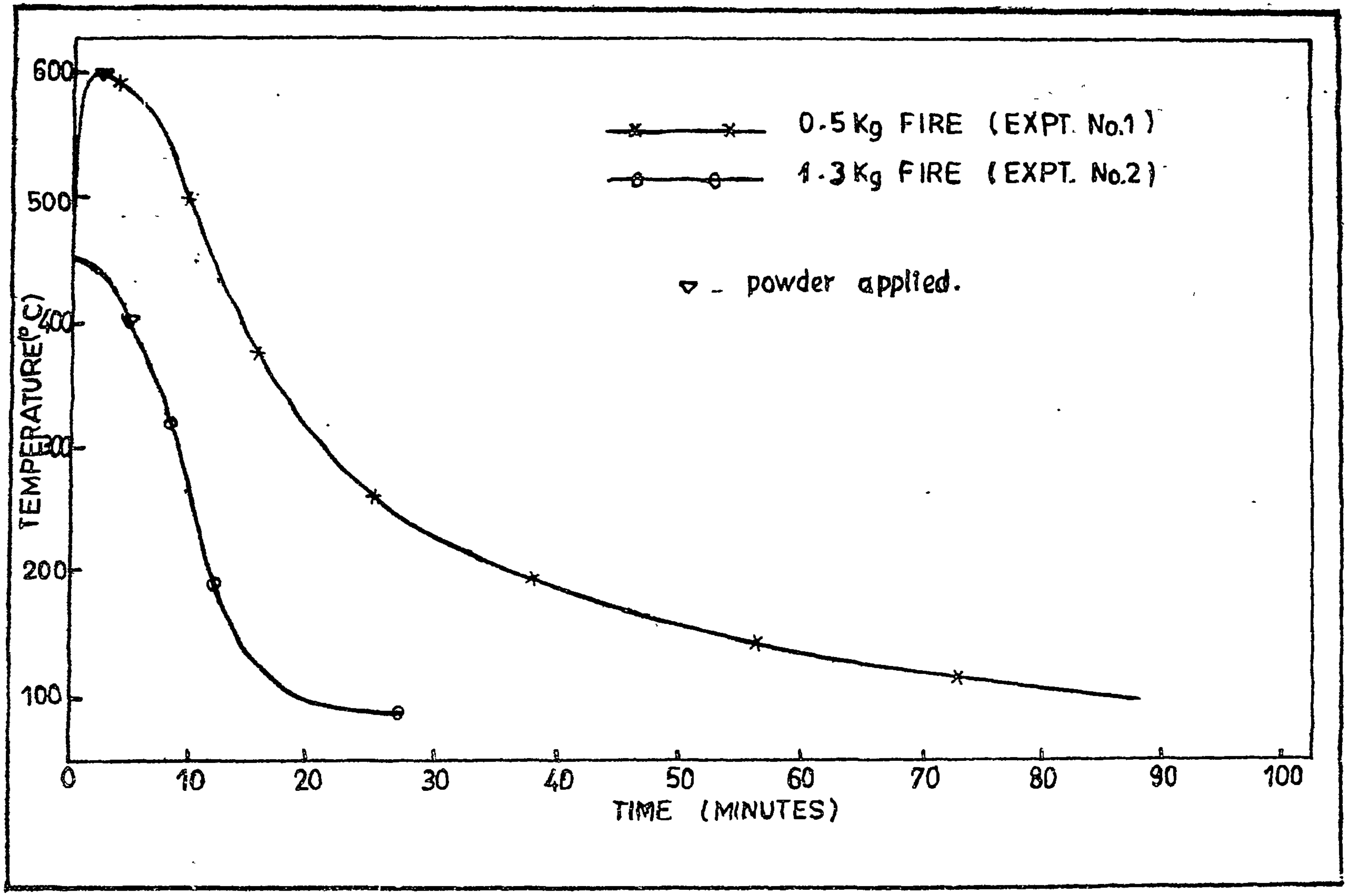

Fig. 12. Small scale fire to test small size Vermiculite

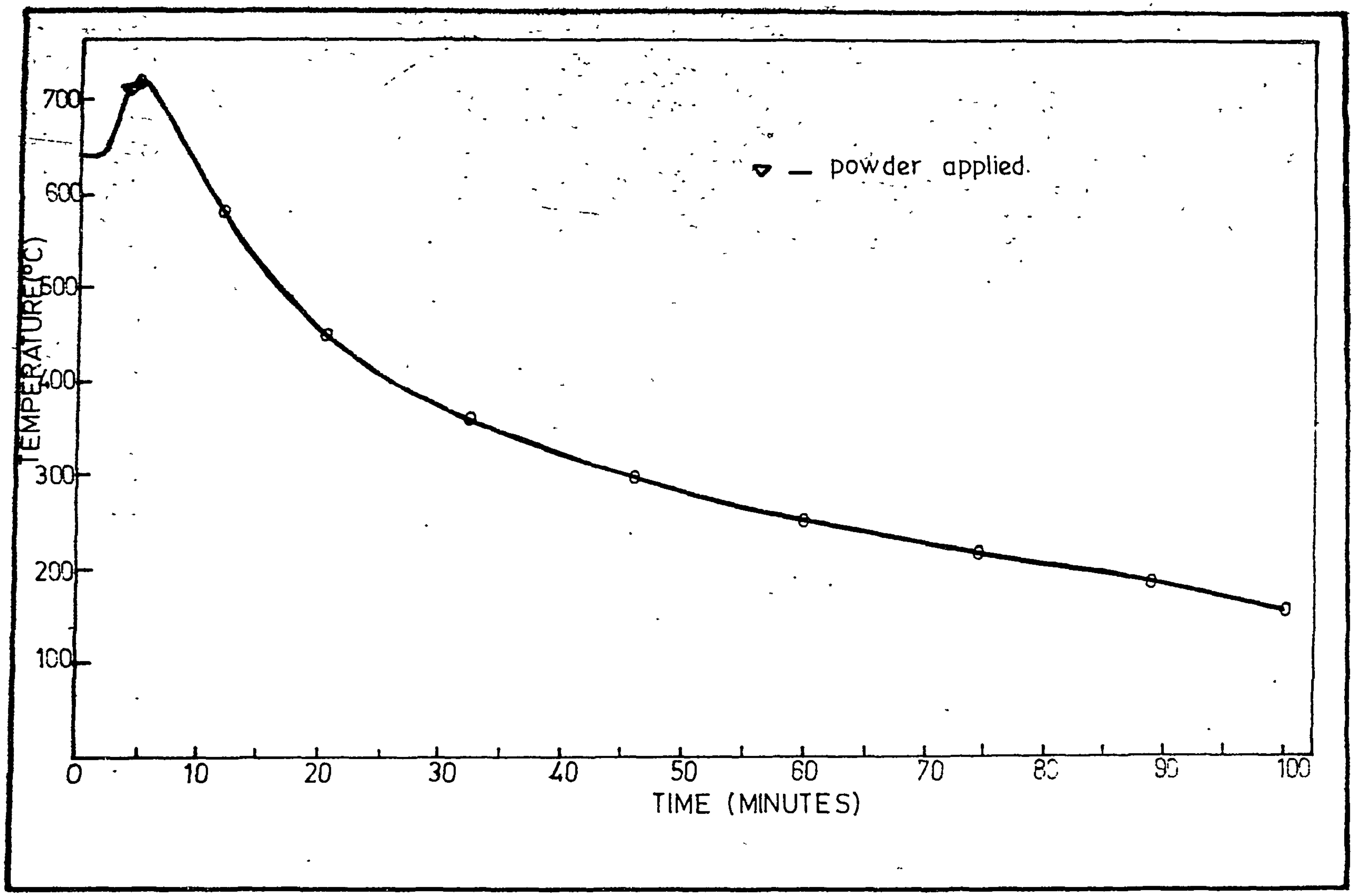

Fig. 13. Sodium fire to test large size Vermiculite

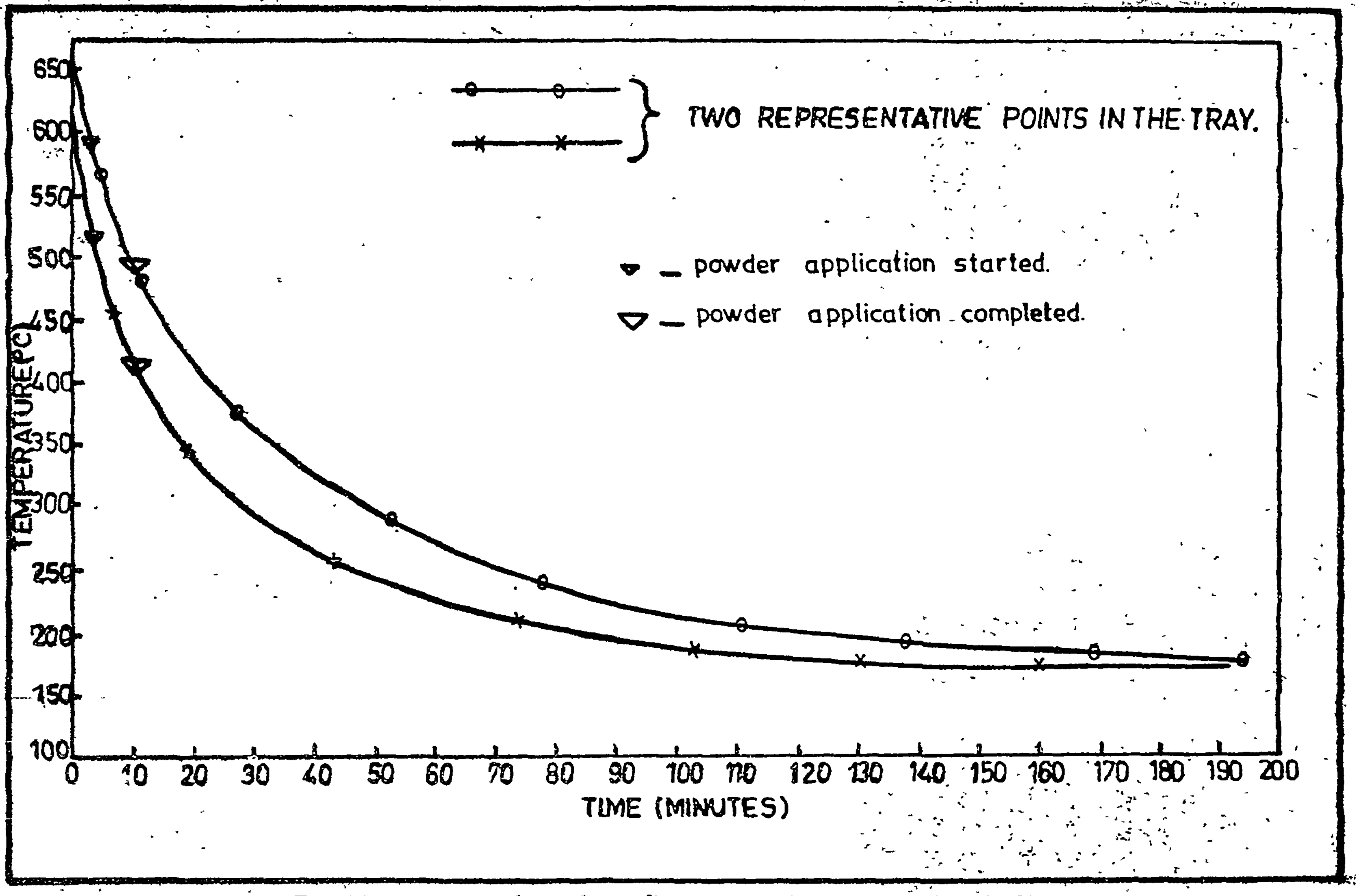

Fig. 14 Large scale sodium fire to test large size Vermiculite

5.4 Calcium Carbonate (Technical Grade)

Calcium carbonate powder is available freely in technical grade in a fine particle size. It cannot, however, be used in standard fire extinguishers since it is not free flowing.

Experimental data are given in Table - 8.

The general observations in our experiments are :

i) Very little sputtering

ii) Long sustained yellow flames were produced hindering further application of powder. This delayed the extinguishing process

iii) Powder sank a little, but covered the surface fairly well

iv) The temperature decay was relatively slow. Fig. 15 shows the temperature decay

v) Powder reacted with sodium and formed a lump, but there was no problem in disposal since this readily dissolved in water.

Table - 8

EXPERIMENTAL OBSERVATION OF CALCIUM CARBONATE AS EXTINGUISHANT

Exp. No.	Weight of sodium (kg)	Ratio of weight of powder to weight of sodium	Remarks
1.	0.450	2.83	Conducted in atmosphere. Substantial quantity sank into the pool. No problem while disposal. Fig. 15 shows the temperature decay.
2.	5.4	1.17	Conducted in atmosphere. Long flames were observed which hindered further application of extinguishant Fig. 15 shows the temperature decay.

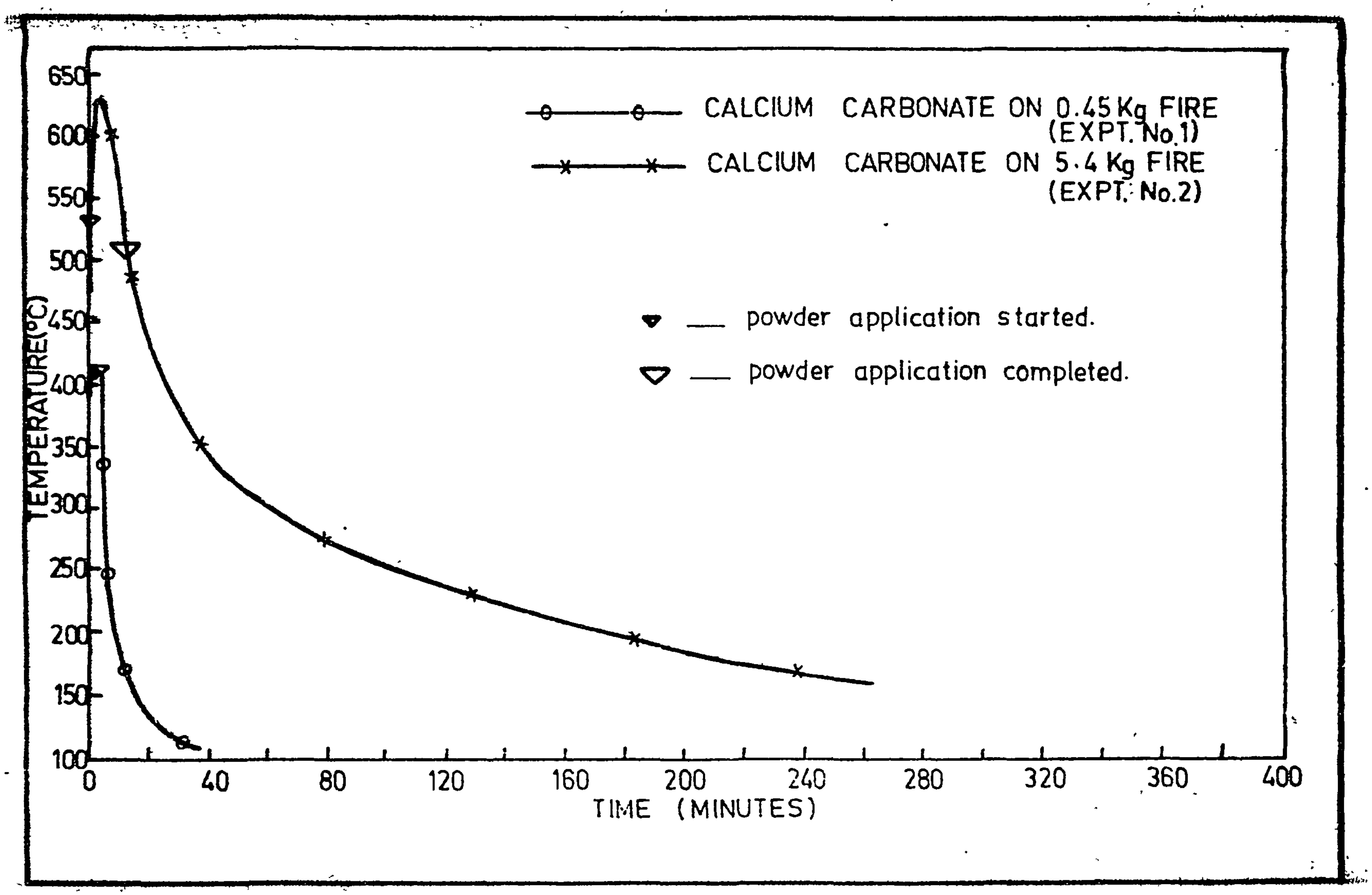

Fig. 15 Sodium fire to test Calcium Carbonate powder

5.5 Behaviour of Other Extinguishants

5.5.1 Sand: A small scale trial revealed that it causes a lot of flaming and charring. A lot of sand is required to cover the fire. Sand sinks in the pool. Table - 9 gives the experimental observations. Fig. 16 gives the temperature decay.

5.5.2 Ternary Eutectic Chloride : A small scale fire experiment revealed that it causes little flaming. Charring of powder however occurs as in the case of sand. Temperature reduction was very rapid as shown in Fig. 16. However, when left to atmosphere it absorbs substantial quantity of moisture. Table - 9 gives the general experimental observations.

5.5.3 Alumite : This powder is a mixture of SiO_2, Al_2O_3, K_2O, Na_2O etc. It produces flames which are short lived, but they char the powder through which molten metal comes out and reignites. Hence, additional powder is required from time to time. Some sputtering was also observed. Temperature decay is shown in Fig. 16. Table - 9 gives the general experimental observations.

Table - 9

EXPERIMENTAL OBSERVATION OF SOME OTHER EXTINGUISHANTS

Exp. No.	Particulars	Weight of sodium (kg.)	Ratio weight of powder to weight of sodium	Remarks
1.	Sand	0.500	7.0	Conducted in open atmosphere. Flaming and sputtering was observed.
2.	Alumite	1.00	-	Conducted in open atmosphere. Sputtering and flaming was observed.
3.	Ternary Eutectic Chloride	0.855	2.87	Conducted in open atmosphere. Little flaming occured. Temperature decay was very rapid.

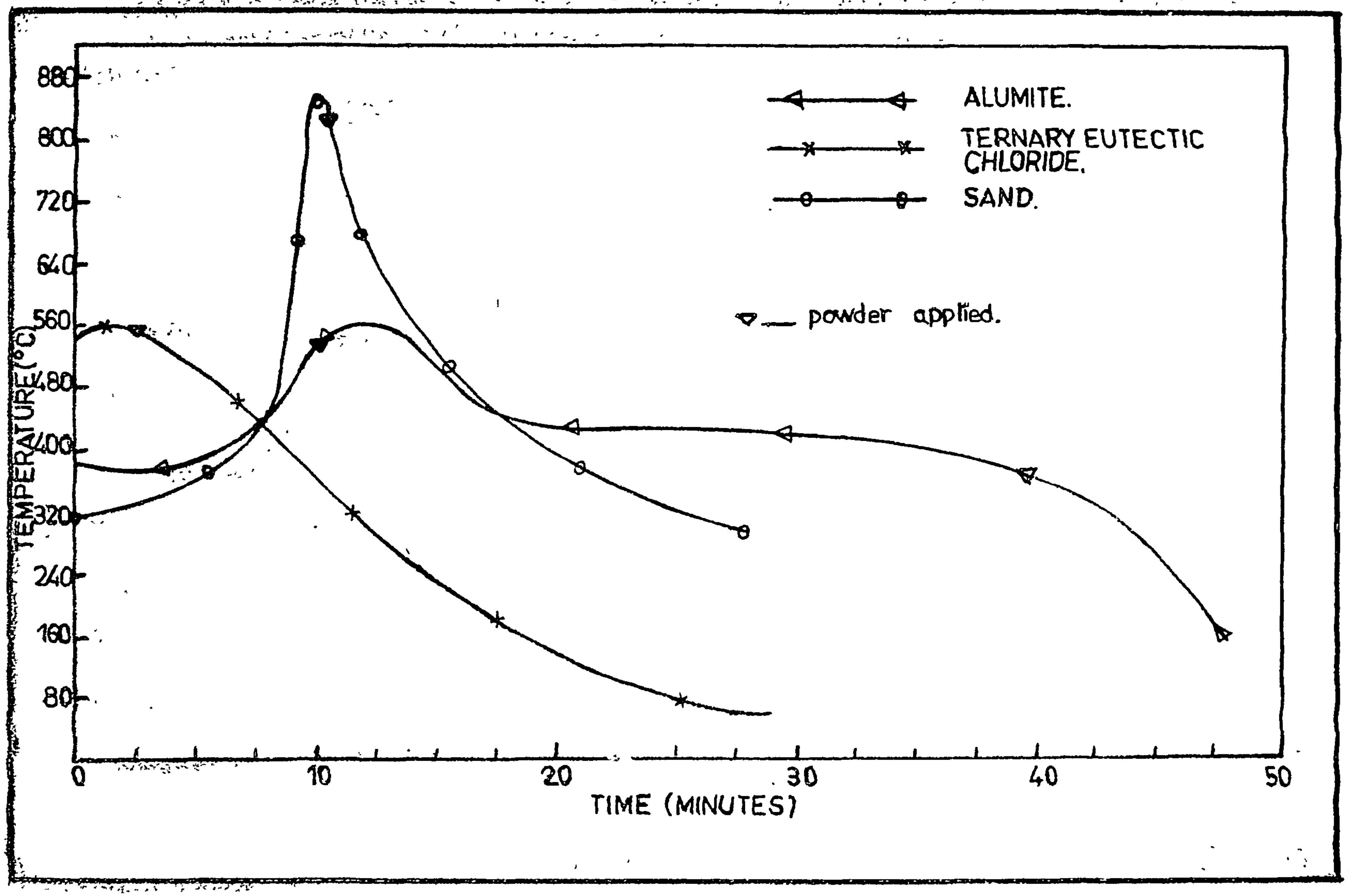

Fig. 16 Sodium fire to test Sand, Alumite and Ternary Eutectic Chloride

6. COMPARATIVE STUDY OF EXTINGUISHANTS

The various extinguishants tested were evaluated relative to each other to find the most suitable powder extinguishant. For evaluation purposes the following important parameters are compared.

i) The ratio of weight of powder to weight of sodium to extinguish the fire

ii) Ease and mode of application

iii) Availability and cost

iv) Cooling rate

v) Ease of disposal

vi) Ease of storage

Table - 10 gives the general comparative results of some of the prospective extinguishants.

It is found that sodium bicarbonate (DCP) is the best available powder, inspite of the difficulty while disposal. The ratio of weight of powder to weight of sodium is extremely small. It can be applied by standard extinguishers. It rapidly cools the burning metal. Next to this ranks vermiculite which is cheap and easy to store, but cannot be used in standard extinguishers. The cooling rate is also slow, since it only covers the fire but does not stop combustion completely. Calcium carbonate can be ranked number three. It is cheap and available freely but due to the difficulty while application it cannot be ranked higher.

Sand, Alumite and Ternary Eutectic Chloride are not suitable for extinguishing large sodium fires as these give rise to flaming and sputtering is also observed. Ternary Eutectic Chloride is found to absorb moisture on exposure to atmosphere.

Table - 10

COMPARATIVE STUDY OF EXTINGUISHANTS

No.	1	2	3		4	5	6	7
Particulars	Sodium Carbonate	Sodium bi Carbonate	Vermiculite		Calcium Carbonate	Sand	Ternary Eutectic Chloride	Alumite
			Large	Small				
Average ratio of* weight of powder to weight of sodium	5.5	1.1	0.8	1.1	1.2	7	2.9	-
Average rate ** of cooling (°C/min)	2	10	3	16	1.5	-	18.5	18.5
Availability and cost	Available and cheap. But drying is essential	Available but costly. No drying required	Available and cheap. Drying not necessary		Available and cheap	Available and cheap	Not available in India	Not available in India
Mode of application	Showel only	By showel and standard extinguishers	By showel only		By showel only	By showel only	By showel and extinguishers	By showel and extinguishers
Storage	To be stored in polythene bags.	Can be stored in air tight containers	In any container		In air tight containers	In any container	In air tight containers	In air tight containers
Disposability	Easy	Difficult	Easy		Easy	Easy	Easy	Easy
Remarks			Tested on small scales only, with small size vermiculite			Tested on small scales only	Tested on small scales only	Temperature drop in large scale fire could not be monitored

* Please note that this is only a representative number. Exact figures are available elsewhere in the report.

** Rate of temperature decay is only suggestive. For actual values corresponding graphs must be referred.

7. OTHER FORMS OF EXTINGUISHANTS

7.1 Carbon-di-oxide :

This controls the fire when applied on it directly, but fire restarts as soon as it is removed. However, there is always the danger of moisture condensing with carbon-di-oxide which can cause an explosion. Hence, carbon-di-oxide should not be used on sodium fires.

7.2 Inert Gases :

These gases are good to extinguish fire in an enclosed space but of little use in an open area.

7.3 Thermofluids :

These oils are good for small fires in a container. There is however, a danger of the thermofluids catching fire when used in very small quantity and hence these cannot be generally considered for use on sodium fires.

8. OTHER EXTINGUISHMENT TECHNIQUES

Oxygen starvation principle was used in some experiments to extinguish sodium fires created in trays. In the earlier experiments perforated flat sheets were used to cover the trays containing burning sodium. This, though slowed down the burning rate, did not extinguish the fire. It was decided to reduce the area of the perforations and carry out more trials. In the later experiments the area of perforation or openings was reduced by the use of corrugated sheets with holes. Fig. 17 shows the exact arrangement of corrugated sheets with holes. Several tests were conducted on various scales in which burning sodium was poured on the top cover containing perforations. Fig. 17 shows the general arrangement of the experimental set-up. The results are tabulated in Table - 11. It is found that the extinguishing capability in this method is a very strong function of area of opening which in turn controls the oxygen concentration inside the tray. Experiments have confirmed that area of openings should be less than 0.5% of covered area as reported[3]. It was also observed that the above area of opening was sufficient to allow all the burning sodium to enter the tray in a very short period. This arrangement extinguished the fire very effectively. Experiments are being planned to study the exact effect of area of opening.

Table - 11

RESULTS OF EXPERIMENTS CONDUCTED WITH COVERED TRAYS

Experiment No.	Weight of Sodium in kg	Percentage area of opening	Number of holes	Rate of temperature decrease(^{o} C/min)	Remarks
1.	1.8	0.826	4 double corrugation	0.67	Burning sodium entered the tray fast and very little was left on surface to burn. Since gaskets were not provided in the sides, fumes were seen coming through it. Fig. 18 shows the temperature versus time.
2.	1.8	0.826	4 double corrugation	0.65	Experiment No. 1 was repeated. The temperature-time curve is shown in Fig. 18
3.	1.8	0.4131	2 single corrugation	100.0	Similar to set-up of experiment nos. 1 and 2 but only with 2 holes on the corrugated sheet. Gaskets were provided on both the sides. The temperature drop was very rapid. Amount of sodium left on top of the corrugated sheet was more than that in experiment no.1 and 2.

Experiment No.	Weight of Sodium in kg	Percentage area of opening	Number of holes	Rate of temperature decrease (° C/min)	Remarks
4.	1.8	0.826	4 double corrugation	1.0	Set up of exp. No. 1 was used with gaskets on sides to check whether it had any pronounced effect. It can be seen from Fig. 19 that it is not so.
5.	[illegible]	0.4131	2 single corrugation	2.19	Set up of experiment No. 3 was used with a different arrangement for pouring sodium. Fig. 18 shows the temperature versus time curve. Amount of sodium left on the top of the corrugated sheet was more than that of experiment 1 & 2.
6.	8.75	0.432	4 double corrugation	1.99	Set up as shown in Fig. 17 was made such that there was better sealing on all four sides. Most of the sodium poured entered the tray. Temperature-time curve is shown in Fig. 19.
7.	8.75	0.200	4 double corrugation	3.15	Hole size was reduced in the set up used in experiment No. 6 Sodium was extinguished at a faster rate as shown in Fig. 19 but the same quantity of sodium remained on top of the corrugate sheet.

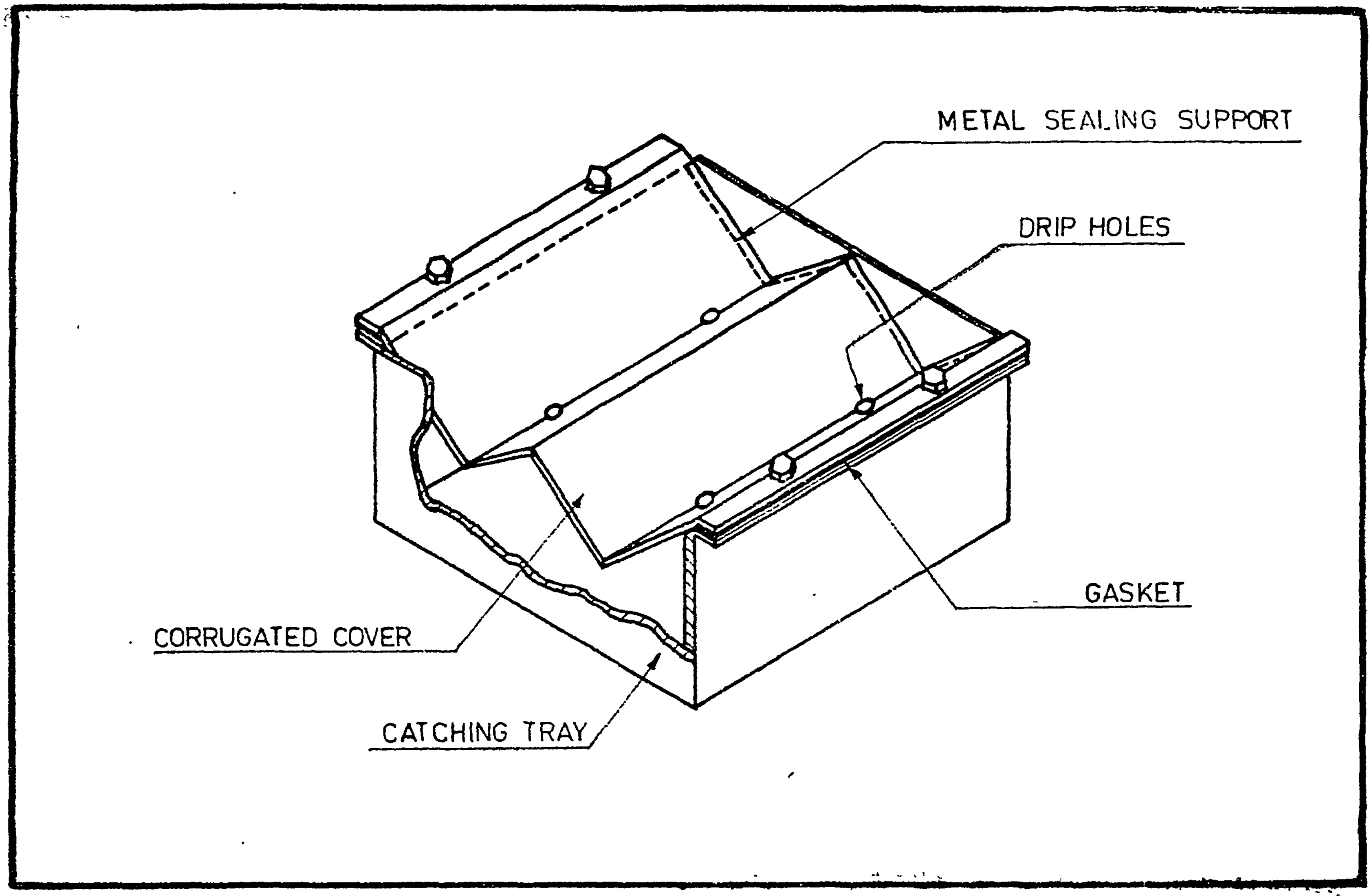

Fig. 17 General arrangement of covered trays

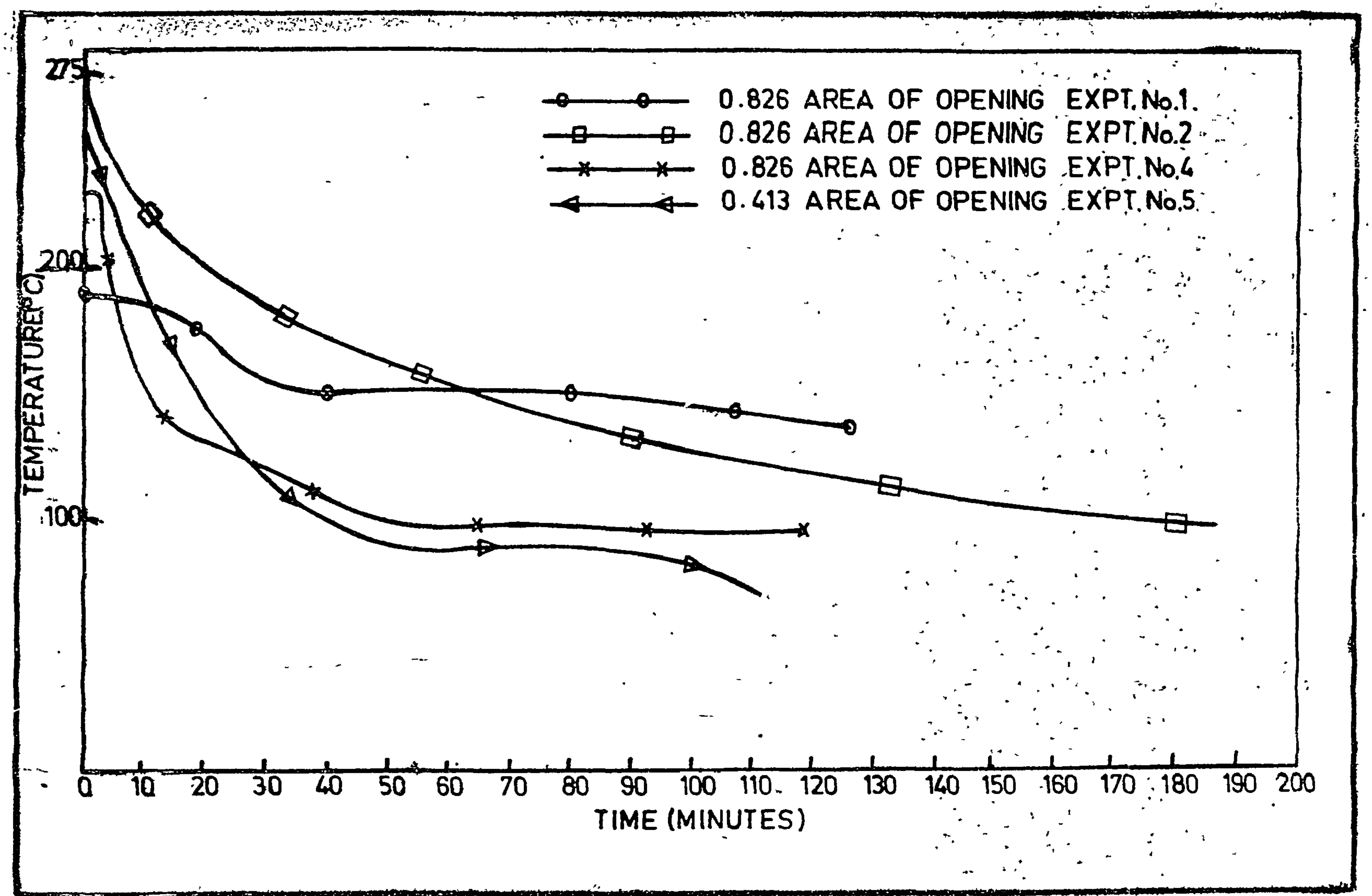

Fig. 18 Sodium fire to test the efficacy of Covered trays

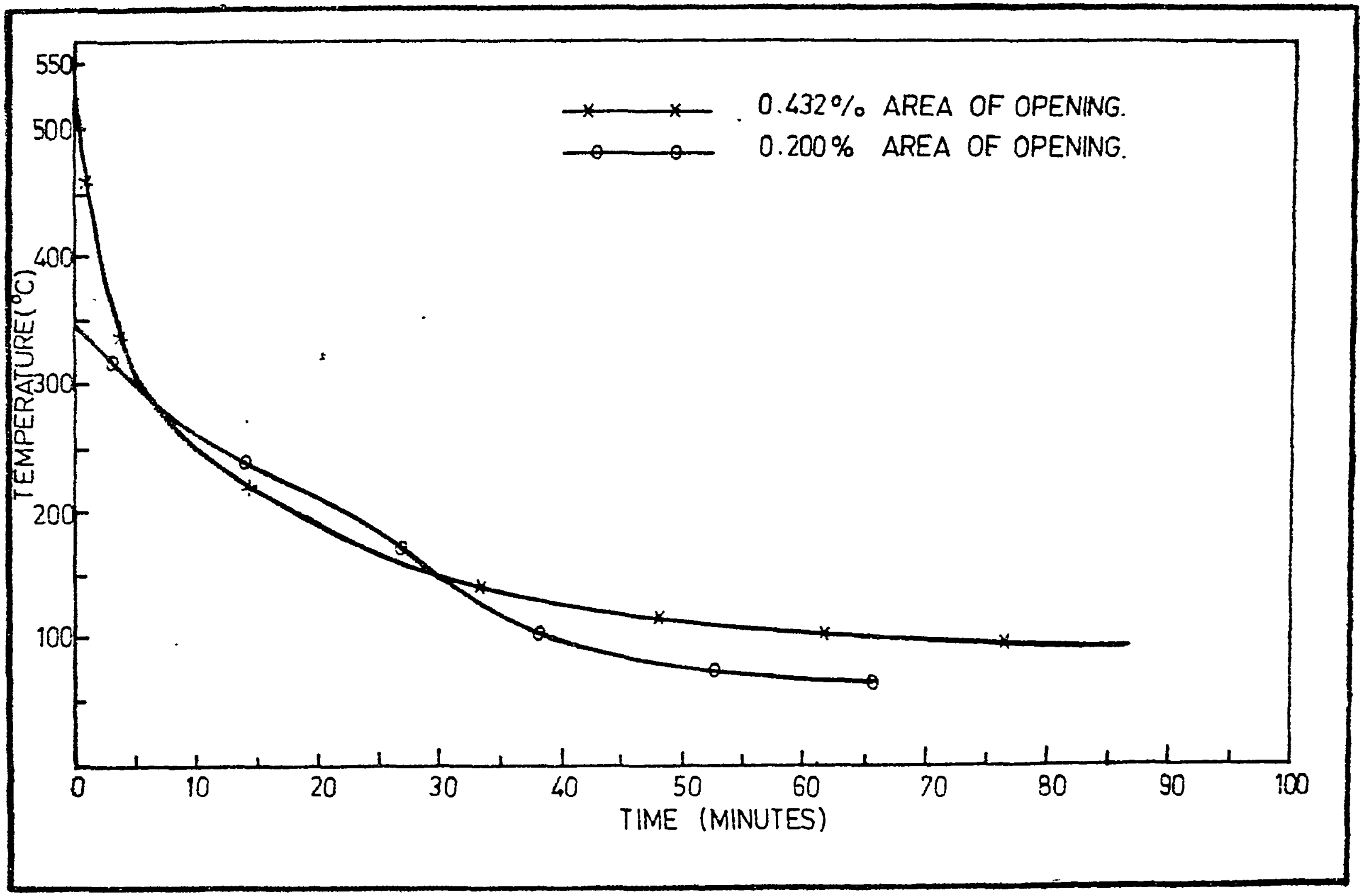

Fig. 19. Large fire to test the efficacy of Covered tray

9. FIRE FIGHTING TECHNIQUES AND SAFEGUARDS

Sodium is a highly reactive metal and hence, it should be handled with extreme care. In case of an accident involving sodium leak, a fire can result. In these situations exact knowledge of fire extinguishing procedure is essential. The personnel engaged in fire fighting are advised to proceed as follows :

i) Alertness : This is of great importance in any fire accident but more so in the case of sodium fire, since the large quantity of smoke released can reduce the visibility rapidly. With sodium burning at a rate of 0.2 kg/sec in a hall of 16 x 16 x 45 meters., the visibility can become zero in about 20 secs. and in 5 secs. an operator located at the centre of hall may not be able to identify the exit.[4] The personnel must also be aware of the following.[5]

a) Location of emergency dump switch

b) Location of safety items

c) Location of extinguishants and extinguishers.

ii) Take immediate action to contain the sodium. This is done by dumping the loop sodium or any other suitable action. Stop water circulation. Switch off electrical supply in the area.

iii) Protect yourself with protective dress and gas masks as shown in Fig. 1.

iv) Watch the fire carefully and plan your action from a distance. Quick action on the part of the fire fighter is essential.

v) Apply powder extinguishant by suitable means such as shovel, cartridge type or other standard dry chemical powder. extinguishers. While using pressurised extinguishers, care must be taken to avoid splashing. For this it is advised that the nozzle should be directed towards the fire such that, the powder does not impinge the pool with much velocity.

10. FURTHER EXPERIMENTS IN THE FIELD

Many other important characteristics of sodium fire that are required to be studied are listed below. It is felt that information on these would be of use in safe handling of sodium.

i) Visibility through the fumes of different concentrations of sodium-oxide aerosol.

ii) Corrosive action of these fumes on the permanent structures.

iii) Development of lighter and better safety dress.

iv) Correlation of the experimental and analytical study results in oxygen starvation method of controlling the fire.

v) Quantity of carbon monoxide evolved when sodium bicarbonate powder is applied on large sodium fires.

11. CONCLUSIONS

i) Confidence in handling sodium fires was gained during the experiments. Operators are now expected to be in a position to fight sodium fires with confidence using correct approach. Disposal and clean up procedures are also well understood.

ii) Sodium bicarbonate seems to be the most suitable extinguishant among those available locally for use in all sodium fires in the laboratory. Vermiculite and calcium carbonate can also be used as extinguishants in small sodium fires.

iii) Efficacy of covered tray with perforations has been ascertained. This method can be used in a loop area wherever an accident involving sodium spillage is considered.

ACKNOWLEDGEMENT

The authors thank Shri S.R. Paranjpe, Principal Design Engineer for providing the required facilities. Authors also thank Shri S. Muthuvel and Shri M. Gopalakrishnan for their assistance in conducting the experiments.

REFERENCES

1. R.N. Newman and J.F.B. Bayne, The burning and smoke release rates of sodium pool fires, CEGB report RD/N3853 (Oct. 1976).

2. J.D. Gracie and J.J. Droher, A study of sodium fires, Atomics International, N.A.A.-SR-4383 (15th Oct. 1960).

3. F. Huber, P. Menzenhauer, W. Peppler and W. Till, Behaviour of sodium area conflagration and suitable protecting systems, Fast reactor safety meeting (April 2 1974).

4. P.C.C. Yates, Fire Hazards and Fire Precautions, UKAEA report AHSB (S) R188, (1970).

5. R.D. Kale and R. Selvaraj, Recommended Practice For Safe Handling of Sodium and NaK, Reactor Research Centre, RRC/REL/00020/RDK/77/1.