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SUBJECT: AN INVESTIGATION INTO THE IMPROVEMENT OF COAL IGNITION IN CHAIN GRATE STOKER FIRED BOILERS

AFDELING:
DIVISION: ENGINEERING

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AN INVESTIGATION INTO THE IMPROVEMENT OF COAL IGNITION IN CHAIN GRATE STOKER FIRED BOILERS

1. INTRODUCTION AND SYNOPSIS

The changeover from pea sized coal (25 mm - 6 mm) to smalls (25 mm - 0), together with deterioration in coal quality have created acute problems in the operation of South African chain grate stoker fired boilers. Size segregation in coal handling systems, exaggerated by the wider size range, has led to uneven changing of the grate, which has in turn resulted in loss of efficiency due to uneven ash burn-out and the formation of blow holes in the fuel bed. Various anti-segregation devices have been used to partly alleviate this problem. A further effect, loss of ignition, is primarily due to the lower coal quality. In this case, the reflected radiation from the already burning coal via the ignition arch is insufficient to sustain ignition of the green coal. The effect is that the fire front literally runs away from the guillotine door. This phenomenon causes loss of both efficiency and output.

During the current investigation, three methods of preheating the green coal in the guillotine door area of the stoker have been tried. One of these has proved successful.

In addition, a series of preliminary laboratory tests have been carried out in order to investigate the volatile release rates of two coals, each at two different heating rates. The results are discussed and suggestions are made for further work of this type.

The investigation has been carried out in association with the Transvaal Coal Owners' Association (TCOA).

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2. THE TEST BOILER

The test boiler in which the present work has been carried out is an Adamson Triple Pass unit, fitted with a Bennis Chain Grate Stoker. The rated output of the boiler at sea level is 1 800 kg/h of dry saturated steam at a pressure of 690 kpa. The grate has an area of 1,85 m^2 (length 2,44 m x breadth 0,76 m). The boiler is manually operated.

3. THE COALS TESTED

Analyses of all coals tested are presented in the Appendix.

4. THE PROBLEM

The failure of coal to ignite at the guillotine door of a chain grate stoker in normal operation can be caused by one or more of the following interrelated factors:

(i) Too fast a grate speed, and hence an insufficient coal residence time in the ignition region.

(ii) An incorrectly set fuel bed thickness.

(iii) Insufficient heat generation from already burning coal, which reduces radiation to the ignition arch and consequently re-radiation from the ignition arch down to the green coal.

(iv) An inadequate arch provision (i.e. an insufficient or badly directed re-radiation area).

In all the above circumstances, the necessary ignition equilibrium is lost, and the fire front runs away from the guillotine door. In most cases, the boiler has been proved adequate for the good quality peas for which it was originally designed. It is essentially since the advent of coals of wider size range and lower quality, (higher ash, lower volatile matter), that the problem has become acute.

In order to avoid loss of ignition, more heat must be supplied to the incoming green coal. This could be achieved by a number of potential techniques:

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(i) Improved design of the ignition arch.[1,2] (This technique has been tried out at the Institute, but was not successful, possibly due to the impracticability of altering the ignition arch of the particular boiler to the necessary extent).

(ii) By the provision of small oil or gas burners at appropriate positions.

(iii) By the addition of oil or tar to the coal.

(iv) By recycling hot gas from the combustion chamber of the boiler to the green coal area.

(v) By sucking hot gas from the ignition area through the firebed (i.e. a local downdraught system). This could be realised by:
a) utilizing the suction at the front base of the boiler;[3,4]

b) utilizing the suction of the I.D. fan of the boiler, and

c) employing an external suction device.[2]

(vi) By fitting a small heat exchanger in the combustion chamber of the boiler, fed by a small air blower. The resultant hot air would then be passed to the green coal area.

Some of the above methods have been tried in the present work. Accent has been placed on techniques which would be as independent as possible of the operators skill, and those which would avoid both smoke emission into the boiler house and have the possibility of causing long term damage.

5. PREHEATING OF THE GREEN COAL USING A HEAT EXCHANGER IN THE COMBUSTION CHAMBER OF THE BOILER - LANDAU PEAS

A diagram of the system used is given in Figure 1. It should be noted that the hot air was introduced to tne green coal about 10 cms above the guillotine door.

Initially, without the use of hot air, the boiler was operated using Landau peas over a wide range of conditions - grate speeds 3,7 - 5,5 m/h and fuel bed thicknesses 100 - 150 mm. In all cases, loss of ignition occurred within 5 - 20 minutes.

For the trials using hot air, the boiler was started up with a small positive pressure at the front of the furnace. This rather uncomfortable procedure which resulted in the emission of smoke into the boiler house, was necessary in order to ensure ignition, and to establish an ex heat exchanger air temperature of the required order. Before hot air was diverted to the green coal, the boiler was put back to its normal slight negative pressure at the front of the furnace. From this point on, using a hot air temperature of 300°C, despite prolonged operation, no loss of ignition occurred.

At this stage, due to a request for work on behalf of the Transvaal Coal Owners Association (see Section 6), work on the heat exchanger had to be curtailed. Further intended investigation was as follows:

(i) the construction of a semi-permanent heat exchanger;

(ii) the establishment of minimum green coal heat requirements for various low grade smalls and peas, and

(iii) the execution of parallel fuel efficiency tests.

6. WORK ON WATERPAN SMALLS

In recognition of the fact that a part of the problem associated with the combustion of smalls is created by its wide size range in comparison to peas, TCOA asked the Institute to investigate the improvement that might occur as a result of reduction of the top size of the fuel (possibly to 15 mm). It was discovered, however, that loss of ignition occurred as a matter of course, despite the apparently reasonable volatile matter content of the coal. Hence, it was decided to recommence the loss of ignition investigation on slightly different lines. Waterpan smalls were used throughout this section of the investigation, and an analysis is given in the Appendix.

Discussions with TCOA elicited the opinion that although they accepted the effectiveness of the use of a heat exchanger, they considered that a number of other techniques, which might be less costly to apply, should also be looked at. The methods are described below.

(i) <u>The recirculation of gases from the front box of the boiler</u>

This modification (Figure 2), was accomplished by making a connection between the front box and the guillotine door area of the boiler, using a small blower to deliver hot gas to the green coal. The technique was not effective. Despite very careful lagging of the connection, it was found that the front base gas temperature of 350°C was reduced to 120°C on delivery. In order to increase the delivery temperature, the volume of gas was increased. This action, however, caused the emission of smoke into the boiler house, and appeared to blow away the flames. (The recirculation of hotter gases from the combustion chamber (900 - 1 000°C), might have been more effective, but would have involved extremely stringent blower requirements).

(ii) <u>The sucking of hot gases from the boiler ignition area through the green coal (downdraught system)</u>

This system is not original, and has been used in the past as a means of promoting the ignition of coke breeze on chain grate stokers,(2) utilizing a small fan beneath the grate so that hot gases were drawn downwards through the firebed and delivered to various boiler locations. The various suction and delivery points are shown in Figure 3.

Referring to Figure 3, position 2 was found to be impracticable due to blockage of the suction connection by fine coal. Position 3 did not have this problem, but was found to interfere with coal delivery to the grate. Position 4 was not used, due to the complicated stoker modifications which would have been required.(4) Performance in this position was, however, observed by Institute personnel on a John Thompson boiler installed at the premises of S.A. Oil Mills (Pty) Ltd. In this example hot gas delivery was to the front box of the boiler without using a fan. The technique was reported as ineffective due to blockage by fines and low volumetric delivery. Position 1 was found to be the most practical as it suffered from no apparent defects, it was accordingly used for all subsequent experiments.

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The first experiment did not use a fan, and hot gas was delivered to the front box of the boiler, utilizing the difference in pressure between this point and the ignition area. This pressure differential ($\pm$ 50 mm wg) was found to be insufficient to deliver an adequate volume of gas. The next attempt used the boiler's own induced draught fan as a direct suction source. This again was ineffective, despite an increased pressure differential ($\pm$ 100 mm wg). Another system involving a steam ejector was also ineffective ($\pm$ 120 mm wg). In summary, the main stumbling block was the high fuel bed resistance and thus the low volume of gases delivered.

As a result of not being able to utilize the boiler's own resources to achieve sufficient hot gas flow, a relatively larger external fan was used in order to determine the minimum gas flow required to prevent loss of ignition. During this exercise, the gas was not returned to the boiler. The minimum vacuum required was found to be 250 mm wg, but the system proved unstable. It was not practicable to achieve the required fire control of the gas flow so that on one hand, loss of ignition did not occur, and the other hand, the front hopper did not catch fire. After a number of trials the method was abandoned as too unreliable.

(iii) Further work using a heat exchanger in the combustion chamber of the boiler

After a minor adjustment to the position of the heat exchanger in order to minimise interference with gas flow, this technique was again used successfully in the combustion of Waterpan smalls. The minimum hot air temperature was established as 300°C, and for this size of boiler, the optimum air flow rate was $\pm$ 60 m^{3}/h. Lower flows did not allow the temperature of 300°C to be achieved due to heat losses, and higher flows tended to blow away the flames.

7. LABORATORY INVESTIGATIONS

(i) Experimentation and results

In parallel with the boiler investigations which have been described, it was decided to attempt a preliminary investigation into the comparative volatile release rates and the quantitative overall vola-

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tile release of different coals. Two coals were chosen - Waterpan smalls and Phoenix peas (a coal which operates satisfactorily in the Institute test boiler). This work was carried out with the co-operation of the Institute's Chemistry Division. Determinations were carried out using a Du Pont Thermograimetric Analyser with nitrogen flow. The coal samples were heated at two different rates, 10^{o}C/min and 50^{o}C/min. The results are presented in Figures 4 - 9 and in Table 1.

TABLE 1

SUMMARISED RESULTS OF COAL DISTILLATION TESTS

Coal	Rate of heating (^{o}C/min)	Volatile matter content of sample (%)	Weight loss 100 - 800^{o}C (%)	Temperature of maximum rate of volatile matter release (^{o}C)	Overall weight loss at point of maximum rate of volatile matter release (%)	Overall weight loss at point of maximum rate of volatile matter release. (expressed as a percentage of the total volatile matter content of the coal) (%)
Phoenix	10	27,0	25,4	465	9,50	35,18
Peas	50	27,0	25,5	507	12,28	45,48
Water-pan	10	24,3	23,2	465	7,73	31,81
Smalls	50	24,3	22,4	510	10,12	41,64

(ii) Comment

The point of maximum rate of volatile matter release is at a higher temperature for the higher rate of heating. However, at the same rates of heating, there is little difference in this temperature between the two coals tested. The results appear to shed little light on the reason for the difference in behaviour of the two coals.

This work is probably to be extended to include analysis of the released volatile matter.

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8. CONCLUSIONS

It has been shown that, by the use of a heat exchanger in the combustion chamber of the boiler fed by a blower operating on cold air, loss of ignition can be prevented.

Methods using the draught resources of the boiler itself have been shown to be inadequate, and a method which incorporated the minimum workable fuel bed downdraught has been shown to be unreliable.

It is hoped to pursue the heat exchanger technique using the Institute's new test boiler (John Thompson Afripac Mark 2 - 3 200 kg/h saturated steam), and to extend the laboratory scale investigations.

Generally it is suggested that methods which involve discharging hot tar laden gases into the front box of the boiler should be avoided due to potential tube fouling problems.

9. BIBLIOGRAPHY

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4. John Thompson Triumph Chain Grate Stoker Manual - Issue No. 1. Appendix C.

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APPENDIX

ANALYSIS OF COALS TESTED

(i) PROXIMATE ANALYSIS (Air dried basis)

Coal		Phoenix Peas	Landau Peas	Waterpan Smalls
Moisture	%	2,9	2,2	2,9
Volatile Matter	%	27,0	23,0	24,3
Ash	%	14,7	14,5	19,5
Fixed Carbon	%	55,4	60,3	53,3
Total	%	100,0	100,0	100,0
Calorific Value	MJ/kg	27,2	27,7	25,3

(ii) SIZE ANALYSIS

Coal		Phoenix Peas	Landau Peas	Waterpan Smalls
>19,1 mm	%	13,4	2,5	18,8
19,1 - 12,7 mm	%	33,3	19,1	20,6
12,7 - 6,3 mm	%	42,8	55,8	27,8
6,3 - 3,2 mm	%	6,4	17,0	12,0
3,2 - 1,6 mm	%	0,8	1,8	8,4
<1,6 mm	%	3,3	3,8	12,4
T O T A L	%	100,0	100,0	100,0

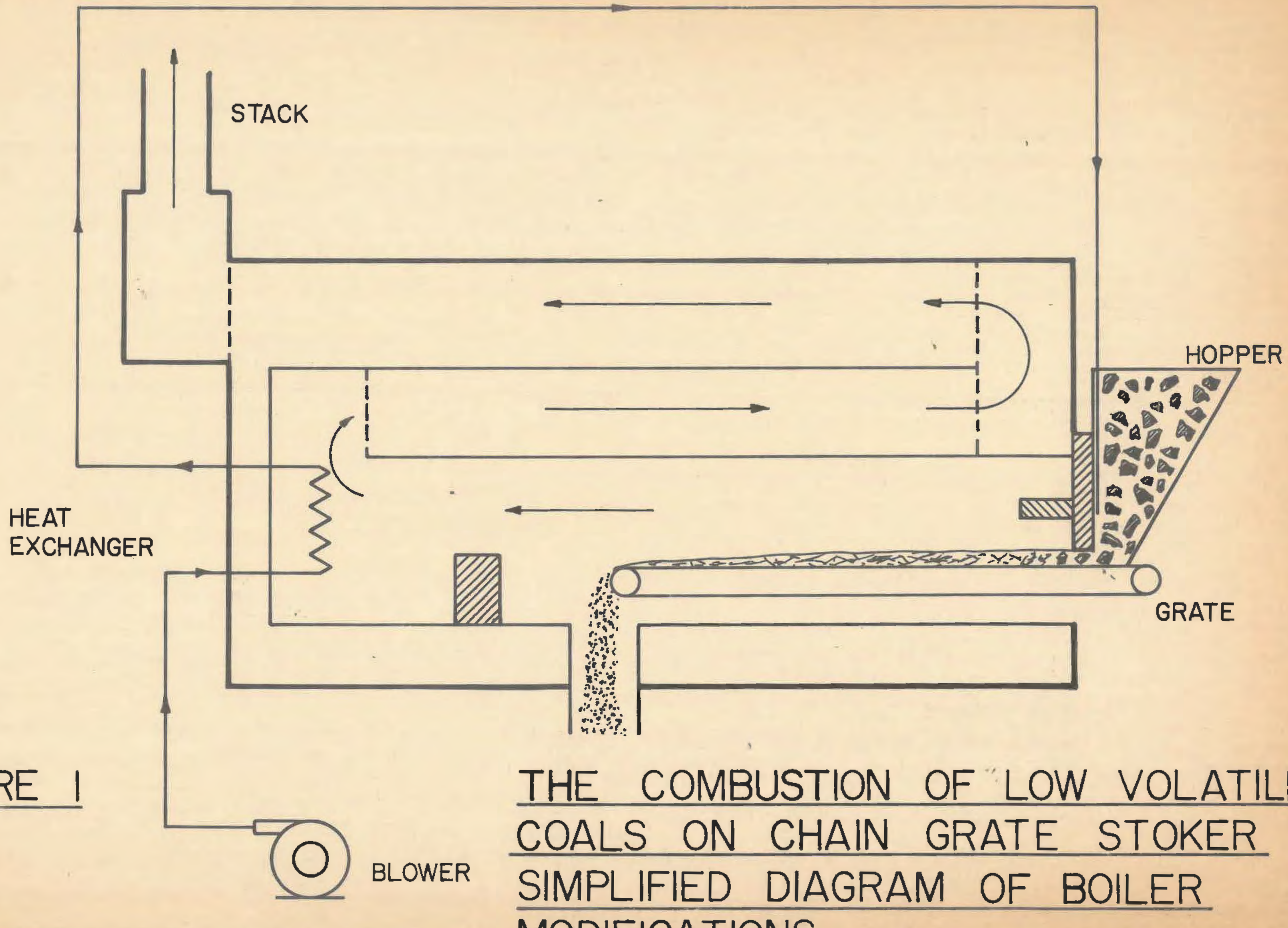

FIGURE I

THE COMBUSTION OF LOW VOLATILE COALS ON CHAIN GRATE STOKER
SIMPLIFIED DIAGRAM OF BOILER MODIFICATIONS

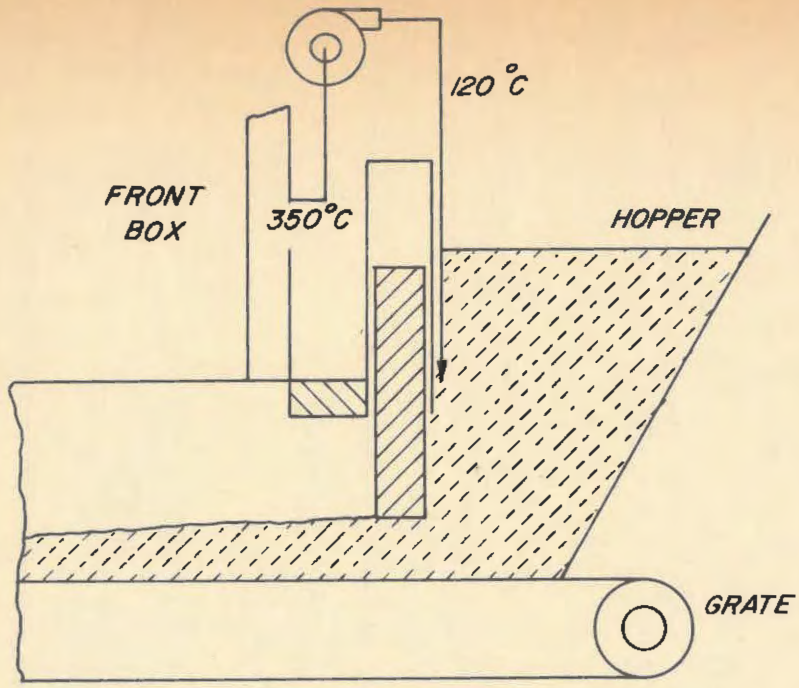

FIGURE 2

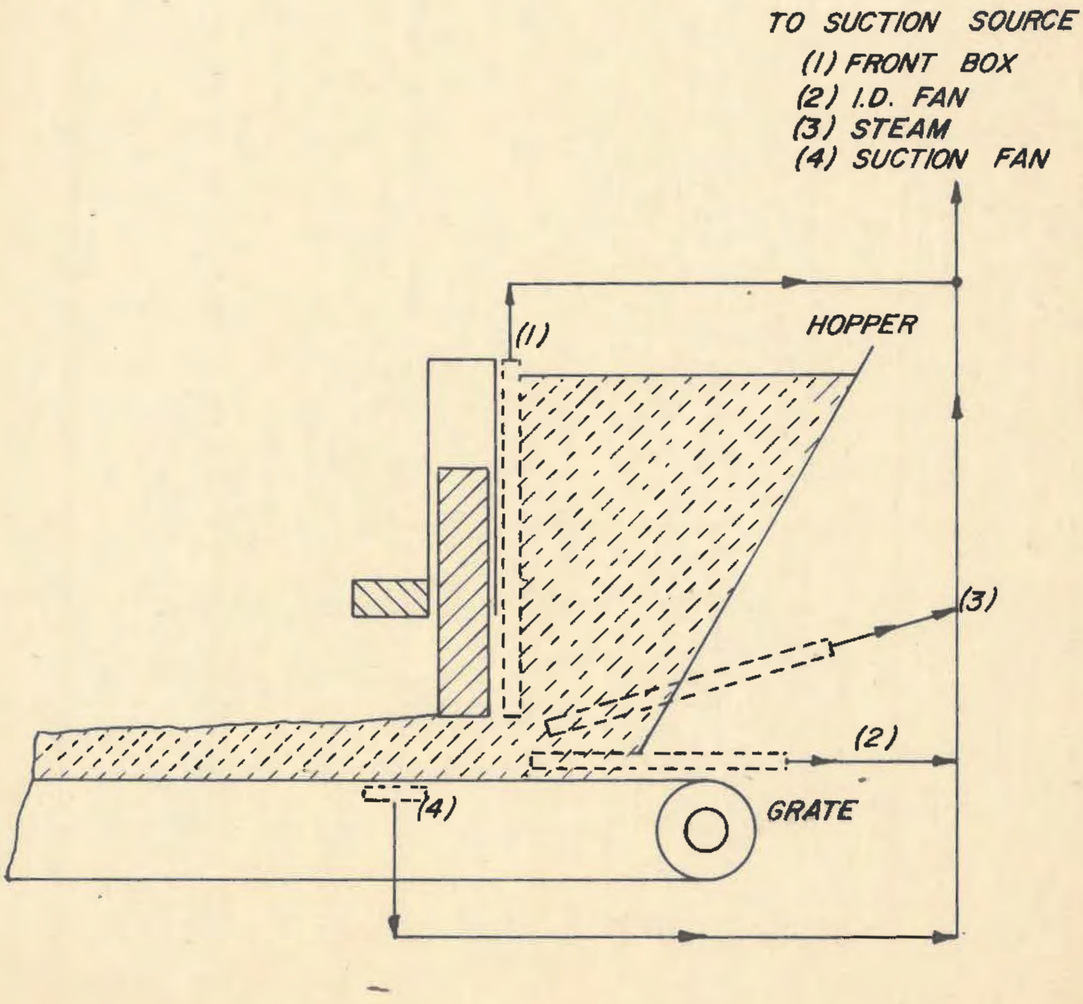

FIGURE 3

FIGURE 4

RATE OF HEATING - 10 °C / MIN

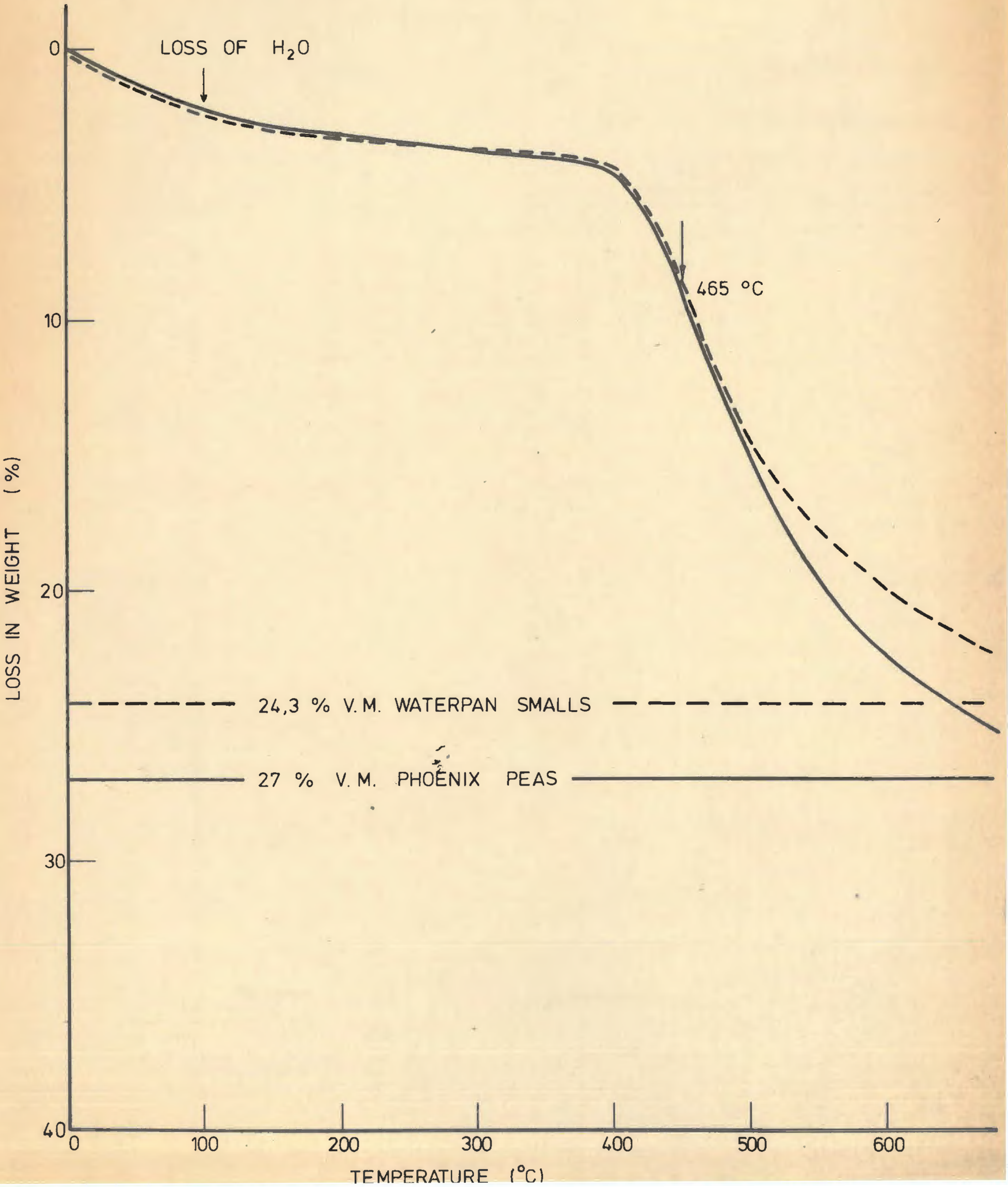

FIGURE 5

RATE OF HEATING – 50 °C / MIN

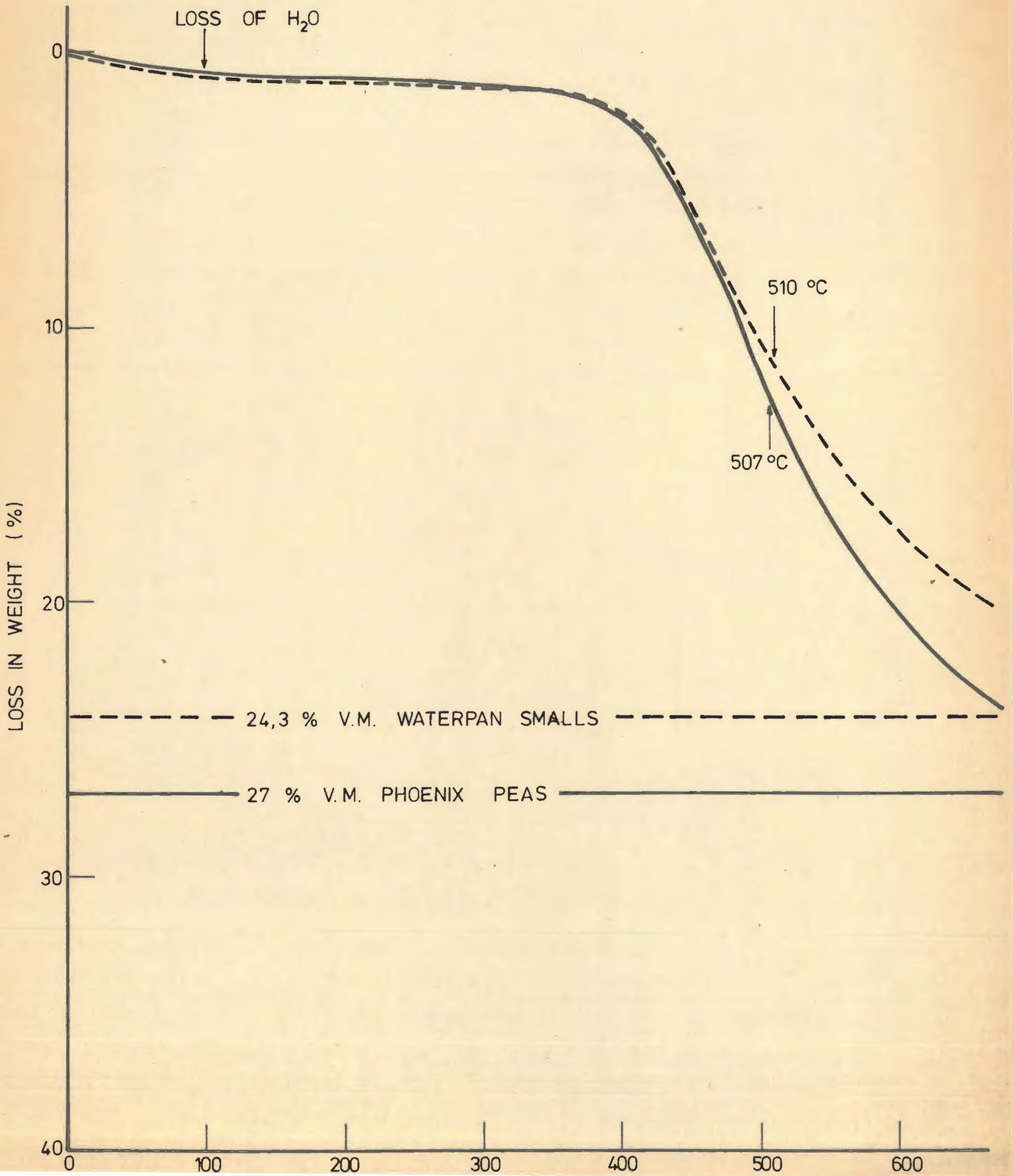

FIGURE 6

RATE OF HEATING 10 °C / MIN

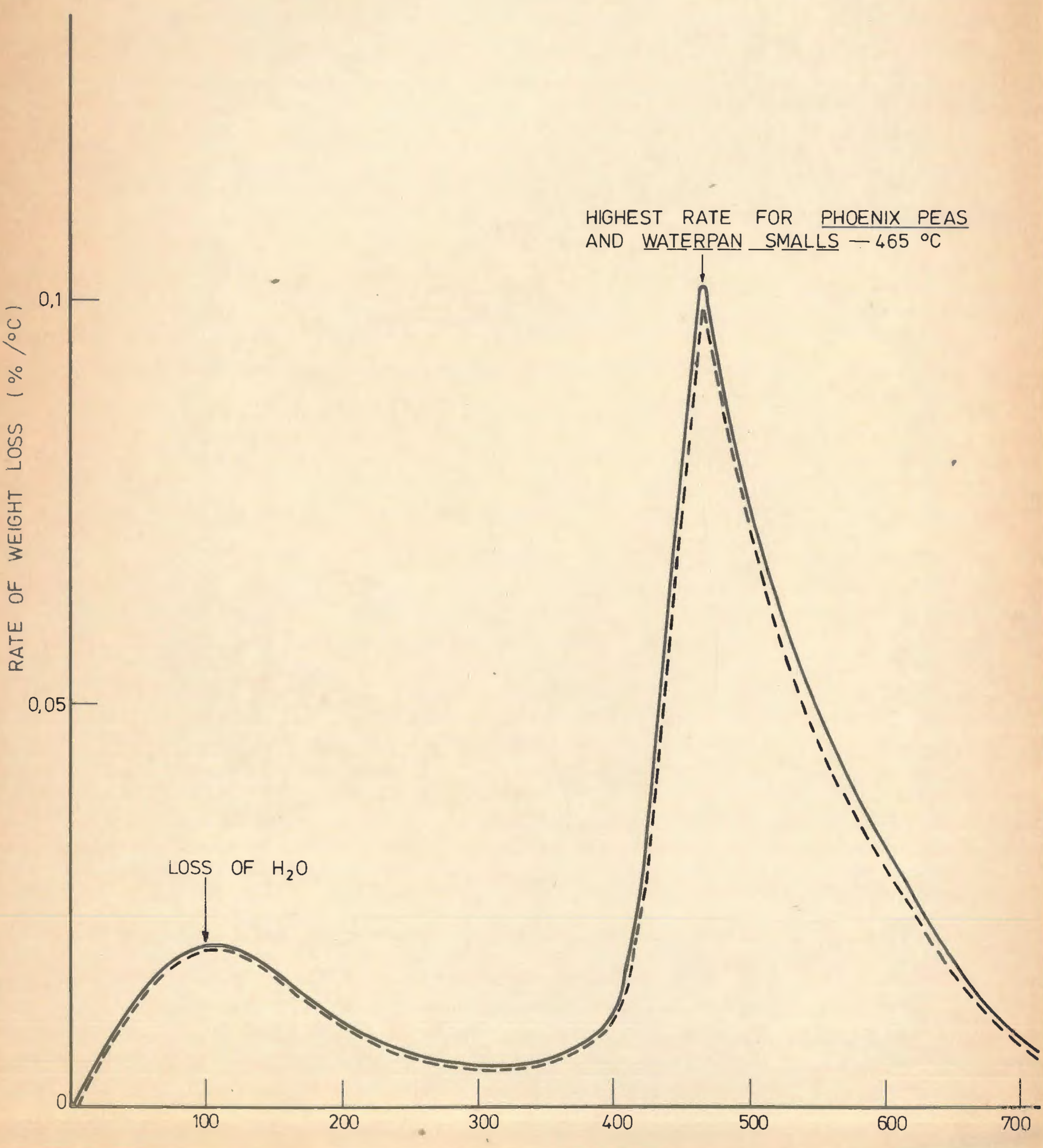

FIGURE 7

RATE OF HEATING – 50 °C / MIN.

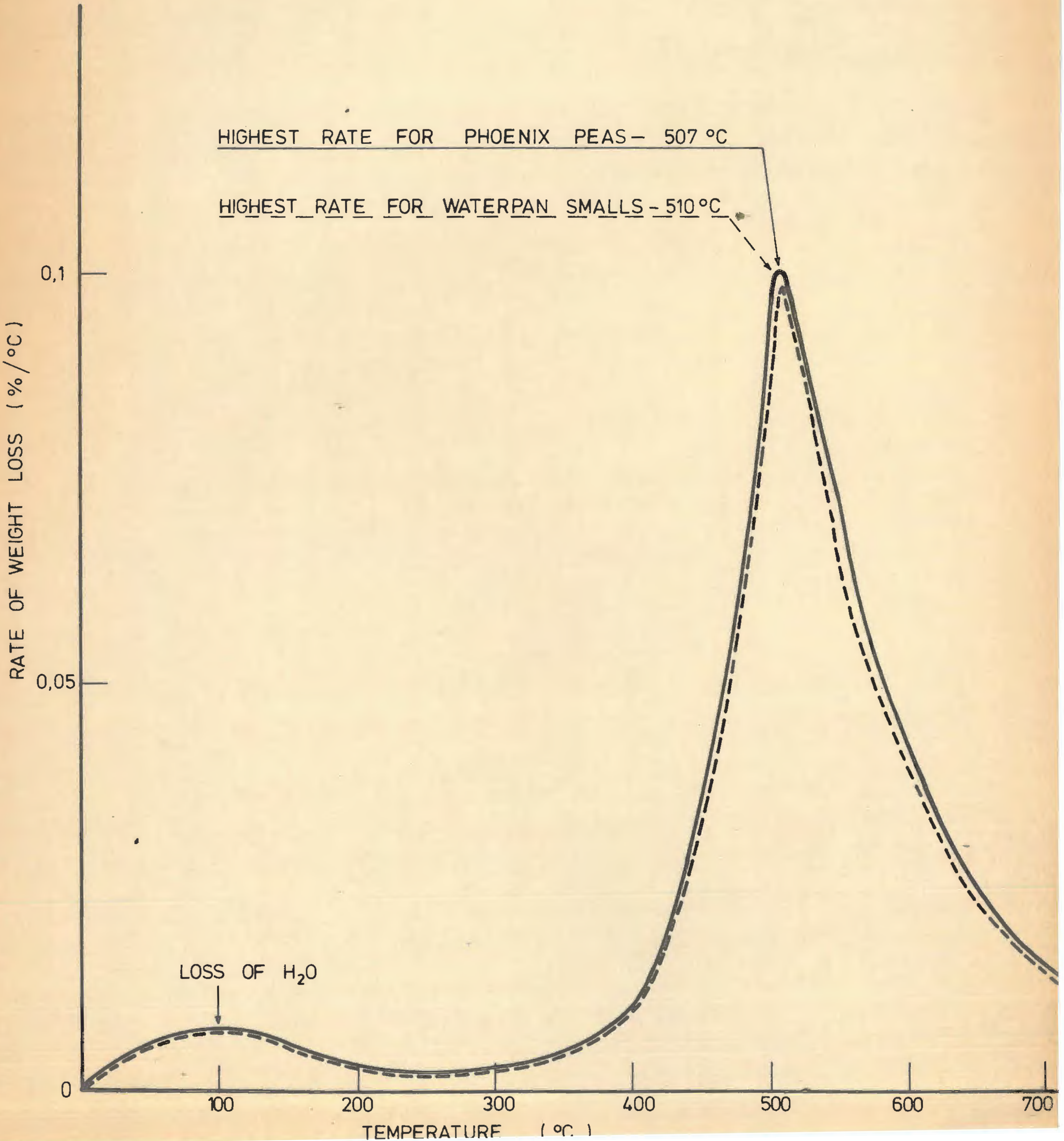

FIGURE 8
PHOENIX PEAS

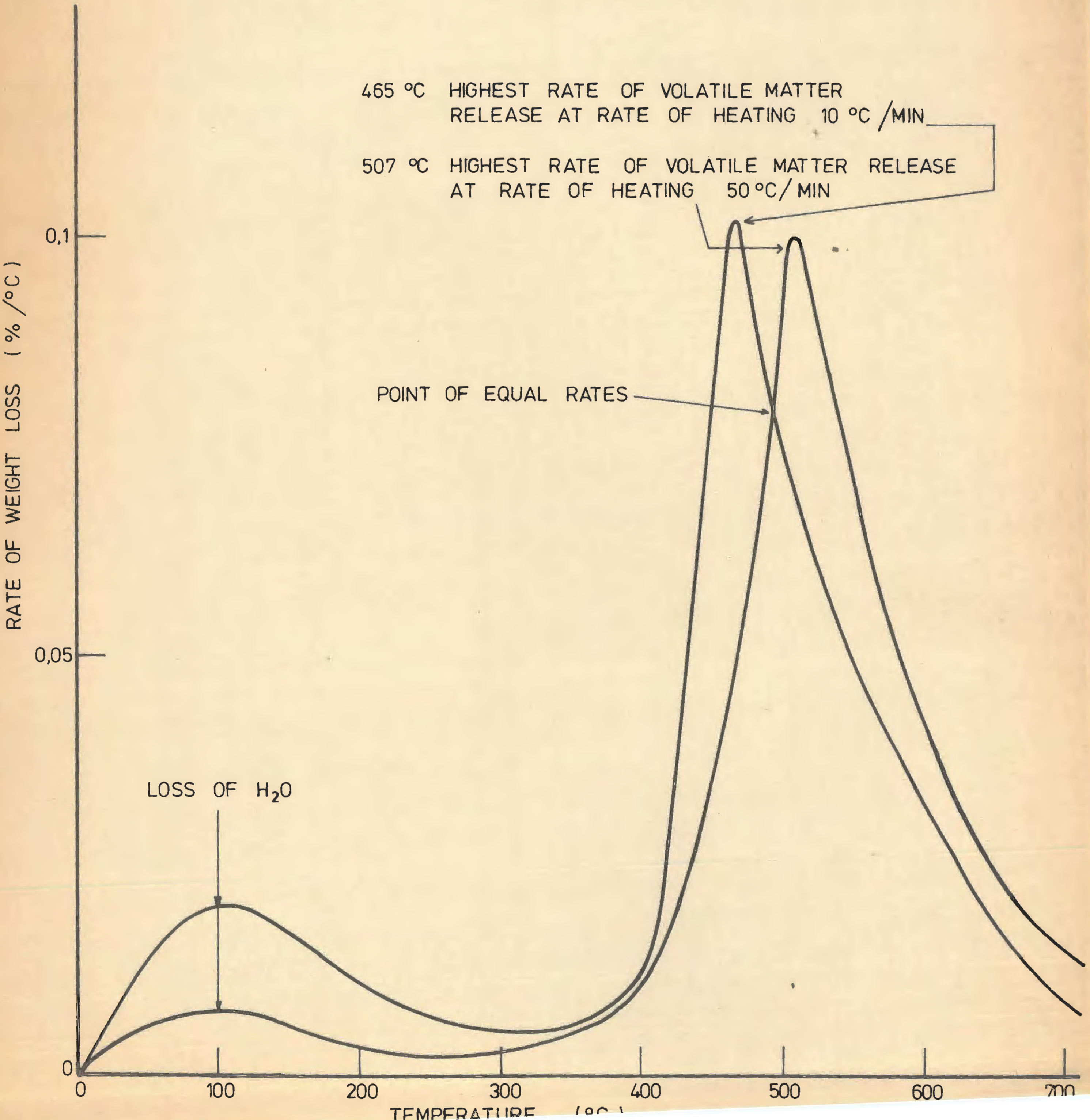

FIGURE 9
WATERPAN SMALLS