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A Study of the Evaporation of Petroleum Oils

by

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ABSTRACT

The evaporation behaviours of eight oils were examined under a variety of conditions. Data from laboratory and field experiments showed that the effect of oil layer thickness on evaporation was adequately compensated for by the evaporative exposure concept. However, two oils studied showed signs of inhibited evaporation as thickness increased. The cause of this is likely the formation of waxy crusts which inhibit evaporation of the underlying oil.

Estimates of evaporation based upon the evaporative exposure equation of Stiver and Mackay (1984) were compared to experimental data. The accuracy of the estimate depends upon the oil. The equation provides a good fit to the evaporation behaviour of typical crude oils as defined by Stiver and Mackay. This was expected since the constants used in the equation are based upon data collected from typical oils. The rate of evaporation of not-so typical oils tend to be over-estimated by this method. Significant improvements in prediction occurred when oil specific constants were determined and used.

The second part of this report describes a study that evaluated methods of accelerating oil evaporation. Three techniques were evaluated and compared to the presently used laboratory method of air stripping. The most promising technique identified which could be applied to large oil samples (1 litre) was the use of a rotary evaporator. Results obtained from experiments using a small-scale rotary evaporator compared favourably to other methods of oil evaporation in terms of the rate and extent.

RESUME

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION AND REPORT FORMAT

Evaporation is one of the dominant weathering process that affects the behaviour of oil released into the marine environment. Characterization of evaporation is therefore of key importance to the testing of oils for environmental purposes. The objectives of this study were: to collect comprehensive data on the evaporation behaviour of various oils as a function of oil thickness; and to develop a rapid means to weather oil samples for testing purposes.

The first of section of the report, Evaporation Experiments, examines the evaporation behaviour of eight oils exposed to different conditions. The second section, Methods of Accelerating Evaporation, describes an investigation into potential laboratory techniques for accelerating oil evaporation.

2.0 EVAPORATION EXPERIMENTS

2.1 INTRODUCTION

Evaporation is one of the most significant weathering processes that act upon spilled oils. The rate of evaporation of any oil depends upon the composition and physical state of the slick, and upon prevailing climatic conditions. Typically when oil is spilled on open water, evaporation and spreading are the dominant initial processes. Most of the volatile fraction, considered to be C_{10} and lower molecular weight compounds, rapidly evaporate. Following this initial rapid loss, evaporation continues as a slow but progressive loss of components.

Evaporation has a profound effect on the persistence and fate of oil in the environment. Depending upon the specific conditions, evaporation can remove a significant portion of the oil from the water surface. In addition, evaporation modifies the physical, chemical and toxicological properties of the oil remaining on the water.

This section of the report presents the results of a study which examined in detail the evaporation behaviour of selected oils. Included are data from laboratory and field experiments using different exposure conditions and oil thicknesses.

2.2 LITERATURE REVIEW

The rate of evaporation from a given volume of oil depends on a number of factors: thickness, vapour pressure and the mass transfer coefficient which are in turn functions of oil composition, wind velocity, and temperature. Numerous laboratory and field experiments have been conducted, and various theories and models of evaporation have been proposed. Interested readers can refer to the bibliography at the end of this report for information on these.

A comprehensive review of laboratory and field studies dealing with oil evaporation was compiled by McAuliffe (1989). A comparison of field and laboratory data showed that results have not been consistent. The difficulties of predicting and measuring field evaporation are explained in McAuliffe's review. It is concluded that evaporation during actual spills is more rapid than would be indicated by most studies. Most laboratory studies have used slick thicknesses that are many times greater than would be realistically found during a spill. Field studies are expected to provide a better indication of evaporation, but the tendency to sample from thicker proportions of the slick may bias the data and underestimate the overall evaporation. It is stated that most crude oils attain an average thickness of about 0.1 millimetre in the thick areas within an hour or two of being spilled. This value is believed to be relatively independent of the spill size.

Jordan and Payne (1980) present a comprehensive summary of studies conducted prior to 1979. A synopsis of petroleum evaporation is also presented in the NRC report "Oil in the Sea".

Attempts to predict evaporation rates have been reported by a number of researchers. Huang (1983) in his review of oil spill fate and behaviour models evaluated the state-of-the-art evaporation models used then. A more recent review of the evaporation modelling is presented by Spaulding (1986).

Recently, four models were reviewed by Coons and Knoke (1990). The evaporation component of COZOIL Model (Coastal Zone Oil Spill) calculates the mass transfer rates for up to 15 constituents of oil in a thick slick using standard vapour transfer equations. Thin slicks are ignored by the COZOIL Model. The Oil Weathering Model (Science Applications International Corporation) uses a pseudo-component characterization based upon boiling temperature. The model assumes the oil is well mixed, or that evaporative loss is independent of slick thickness. Coons and Knoke cite this as the model's prime over-simplification.

There are two basic approaches to modelling the evaporation of oil, these being the pseudo-component approach and the analytical approach. The pseudo-component approach characterizes the oil by dividing it into discrete fractions. This grouping can be either by carbon number (Spaulding et al. 1988) or by boiling point cut. Characterization by boiling point cut is the more widely used method (Johansen, 1991; Kirstein et al., 1983; Payne et al., 1988, 1991; Spaulding et al., 1991; Quinn et al., 1990). For each component, properties are assigned and the evaporation rate of each is given by:

$$dM_i/dt = K_p A X_i P_i / R T$$

where:
M_i is the number of moles of component i in the slick
i is the component number
K_p is the mass transfer coefficient
A is the slick area
X_i is the mole fraction of i in slick
P_i is vapour pressure of i
R is the universal gas constant
T is the absolute temperature

The analytical approach predicts the volume fraction evaporated based on the evaporative exposure concept (Mackay et al. 1980). The fraction of oil evaporated is given by:

$$F = [\ln(P_o) + \ln(C*E) + 1/P_o]/C$$

where:
P_o is the initial vapour pressure
C is a constant dependent upon temperature
E is the evaporative exposure

Refinements to the evaporative exposure concept have been performed by Stiver (1984), Stiver and Mackay (1984), and Stiver, Shiu and Mackay (1989). Dimensionless evaporative exposure is given by:

$\theta = K A t / V$

where: K is the air-side mass transfer coefficient
A is the slick area
t is time
V is volume of oil spilled

The evaporative exposure approach has been adapted for modelling evaporation of oil beneath snow (Ross and Dickens, 1988), oil in leads and pack ice (Buist et al., 1987; Ross and Dickins, 1987), and waxy oils that form crusts or that solidify (Ross and Mackay, 1988).

Results from experimental and actual oil spills have been compared to the predictions of various models. Predicted results from the Oil Weathering Model were recently compared to parameters observed following the Exxon Valdez oil spill of North Slope crude (Payne et al., 1991). It is claimed that excellent agreement was obtained between predicted and observed evaporation data. A few caveats are noted with respect to the model. The model assumes the oil spreads instantly to a uniform thickness. An initial thickness of 1 cm was used to generate the model output. Runs of the model using thinner thicknesses predicted evaporation in excess of that measured in the field. Observations on the extreme heterogeneity of actual slick thickness 10 days after the spill were noted. Wind-driven slicks were fluid and formed windrows 0.05 to 0.2 microns thick while in protected areas, the oil slicks were 100 to 5000 microns thick.

Predicted results obtained using algorithms from the Warren Spring Laboratory model were compared to actual measured data points from 16 experimental oil spills (Buchanan, 1985). The model generally gives a good fit to the data but tends to over-estimate the initial evaporation rate. The model assumes that the oil spreads to a thin layer, this can lead to problems with oils of high pour points that do not do not spread. The recommended solution to correct this is to adjust the mass transfer coefficient to reflect the reduction in mobility of the volatiles. It was also realized that when applied to large spills, the model may have to take into account spreading time.

Comparison of computed evaporation data from the SINTEF-IKU model to results from an experimental spill of 30 tonnes of Osberg crude was performed by Johansen (1991). When corrections were applied for the initial film thickness and subsequent spreading, the predicted evaporation behaviour was comparable to the observed loss.

Field spills of oil in pack ice (Ross and Dickins, 1987) and oil in ice leads (Buist et al. 1987) showed that the evaporative exposure model of Mackay and Stiver (1983) provided a satisfactory prediction of the observed results.

2.3 EXPERIMENTAL SECTION

Eight oils supplied by the Emergencies Science Division were used.

Table 1: Oils used in study and selected physical properties.

Oil	Density (g/mL) (15°C)	Viscosity (cp) (15°C)	Asphaltene Content (wt%)	Wax Content (wt%)
Adgo Crude	0.9530	61.6	0.2	0.2
Alberta Sweet Mixed Blend Crude (ASMB)	0.8390	9.2	2.0	6.9
Amauligak Crude	0.8896	14.0	0.1	0.8
Bent Horn Crude	0.8181	24.0	0.1	7.4
Diesel Fuel	0.827	2.7	0	0.6
Endicott Crude	0.9149	84	3.7	8.1
North Slope Crude	0.8936	23	2.1	6.7
Panuke Crude	0.7757	1.1	0	1.8

Pyrex petri dish bottoms were used as the exposure vessels. In some experiments, oil layers less than 0.5 millimetres in thickness were also exposed on 15 centimetres by 15 centimetres glass sheets. Mass loss was measured using a Mettler Model PM1200 balance.

Indoor experiments were performed in a laboratory fume-hood. The gas phase mass transfer coefficient was determined by measuring the evaporation rates of decane, toluene, and octane. For each series of oil samples evaporated, the mass transfer coefficient was measured at the beginning and at the end of the exposure period. The induced air velocity within the fume-hood was measured using an electronic manometer. The air velocity at oil level was 1.16 m/s (2.26 knots).

Outdoor experiments were conducted on the roof of Environment Canada's River Road facilities. An elevated canopy shielded the samples from sunlight. Wind speed, air temperature, and vessel temperature were monitored during the experiments.

Air stripping was performed using the methods described by Stiver (1984). A 1 litre graduated cylinder was used as the stripping vessel. The cumulative air volume was measured using a Precision Wet Test Meter. The air supplied was of dry, breathable quality. The flow rate used varied from approximately 0.2 to 1.0 L/min depending upon the viscosity of the oil.

Distillation curves were determined from the method described by Bobra and Callaghan (1989). 200 millilitres of oil were distilled. The volume of condensate was monitored as a function of both boiling liquid temperature and vapour temperature. The weathering equation of Striver and Mackay (1984) uses information provided by the modified distillation curve (volume fraction distilled versus boiling liquid temperature).

2.4 RESULTS AND DISCUSSION

Figures 1 to 8 show the evaporation behaviour of the oils as a function of time. These curves illustrate the importance of thickness on the rate of evaporation. For the length of time over which the experiments were conducted, curves for each individual thickness appear to approach different asymptotic end-point values. When the percentage of oil evaporated is expressed as a function of θ (theta) dimensionless evaporative exposure, the data points follow near logarithmic behaviour. Figures 9 to 16 show that for most oils, the effect of thickness on evaporation is adequately accounted for in the θ calculation. Endicott and Bent Horn crude oils show the largest variance of evaporation between different oil layer thicknesses at the same θ values. The data indicate that above θ values of 10,000, the thinner oil layers experience a higher degree of evaporation than thicker oil layers. For Endicott crude at a θ value of 100,000, the difference between the weight percent lost between the thickest oil layer and the thinnest layer is less than 2%. This difference in evaporation for different oil thicknesses is less for Bent Horn. This effect of thickness on evaporation is opposite to that observed by Ross and Mackay (1988); they noted that for a waxy oil, the thicker slicks experienced a higher degree of evaporation than thinner slicks at the same θ values. It is difficult to make comparisons between the results of these experiment and those of Ross and Mackay since their experiments were conducted under with higher wind velocities and at lower temperatures. Regardless, under the wind and temperature conditions used in our experiments, the effect is not highly significant. The cause of these deviations is likely the same, a resistance in the liquid phase diffusivity resulting from waxy crust formations. Insufficient data exists to postulate how exposure conditions affect the rate of formation and resistivity of these crusts, and in turn how this affects mass transfer.

Figure 1: Evaporation curves for Adgo (Weight % versus time)

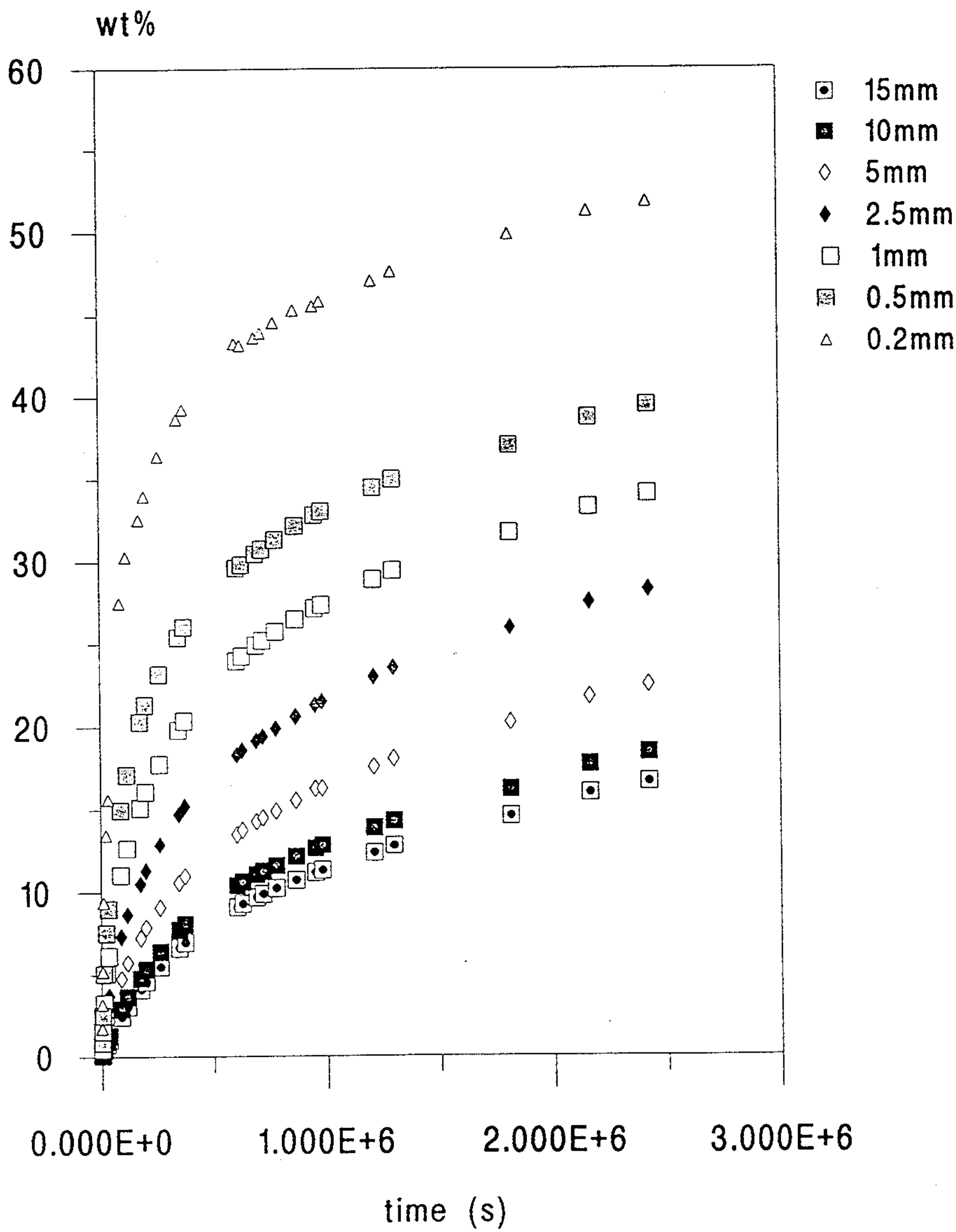


Figure 2: Evaporation curves for ASMB (Weight % versus time)

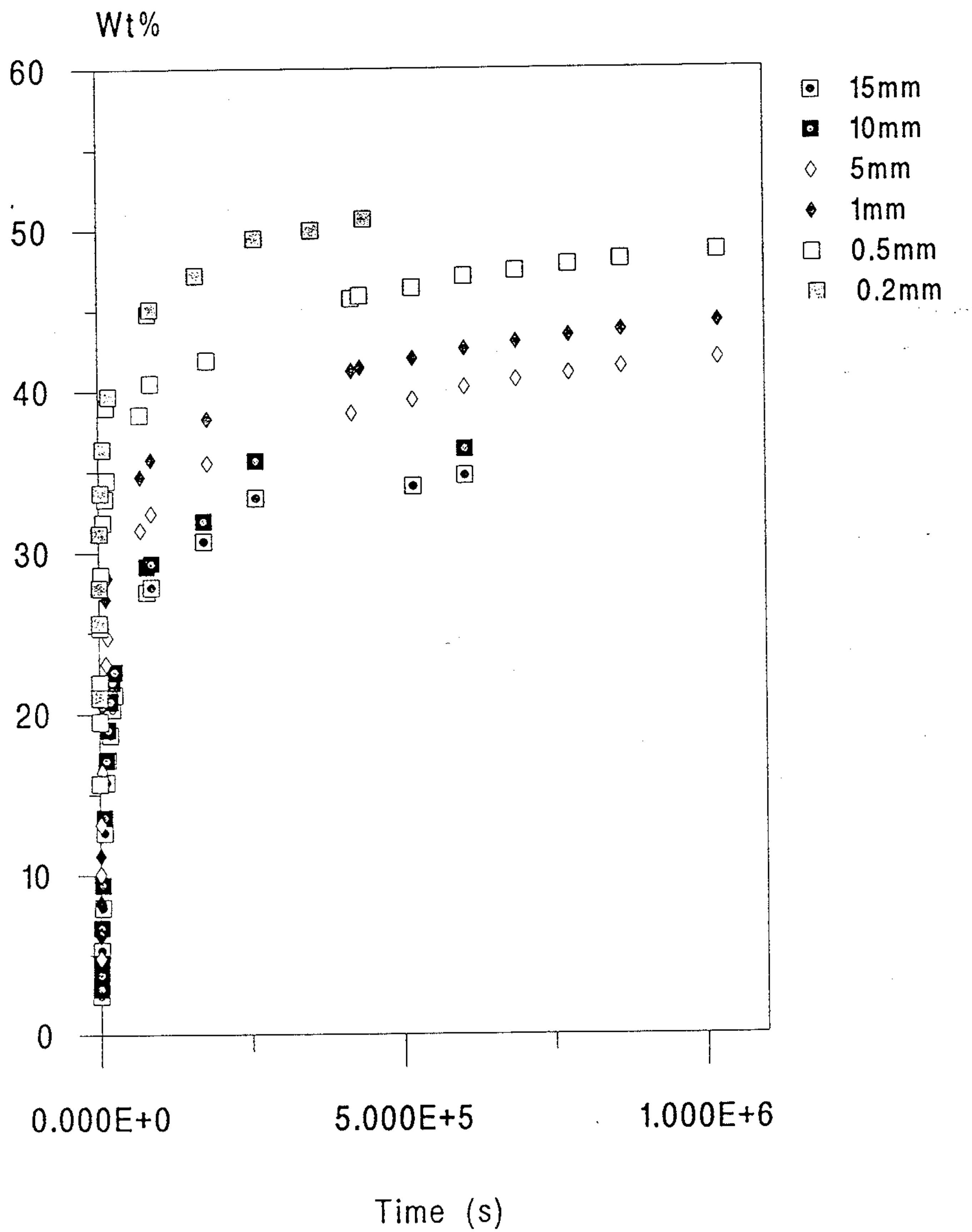


Figure 3: Evaporation curves for Amauligak (Weight % versus time)

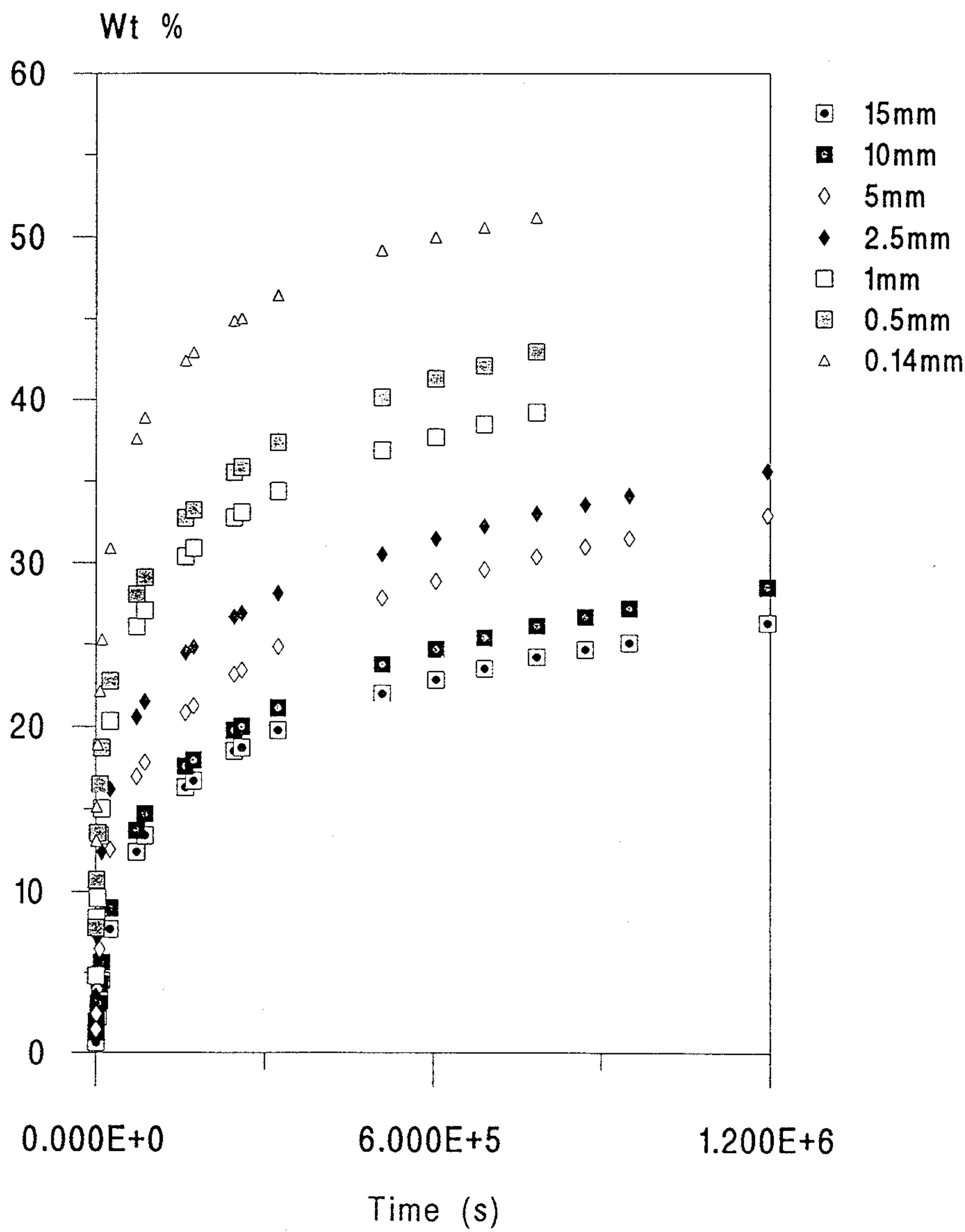


Figure 4: Evaporation curves for Bent Horn (Weight % versus time)

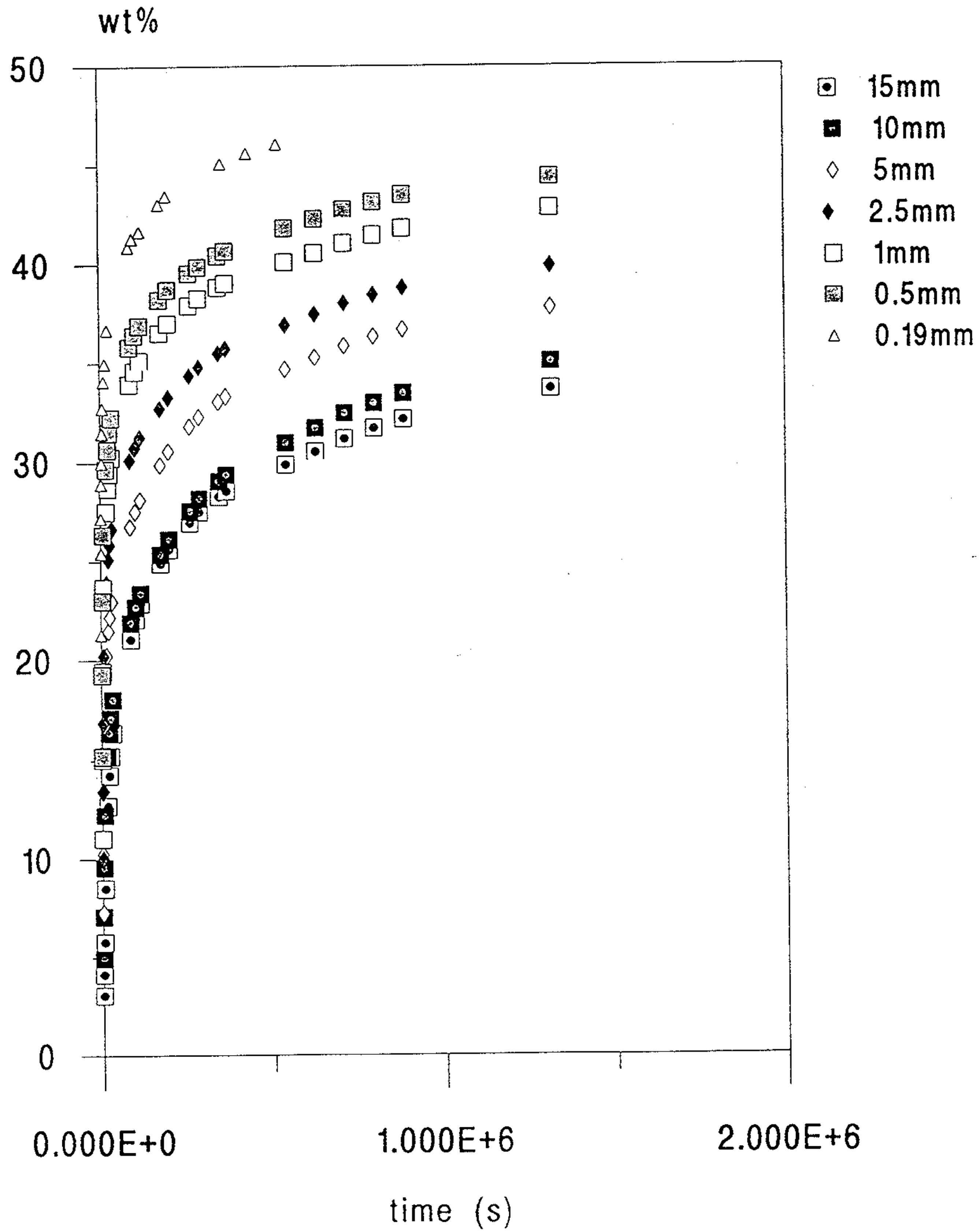


Figure 5: Evaporation curves for Diesel (Weight % versus time)

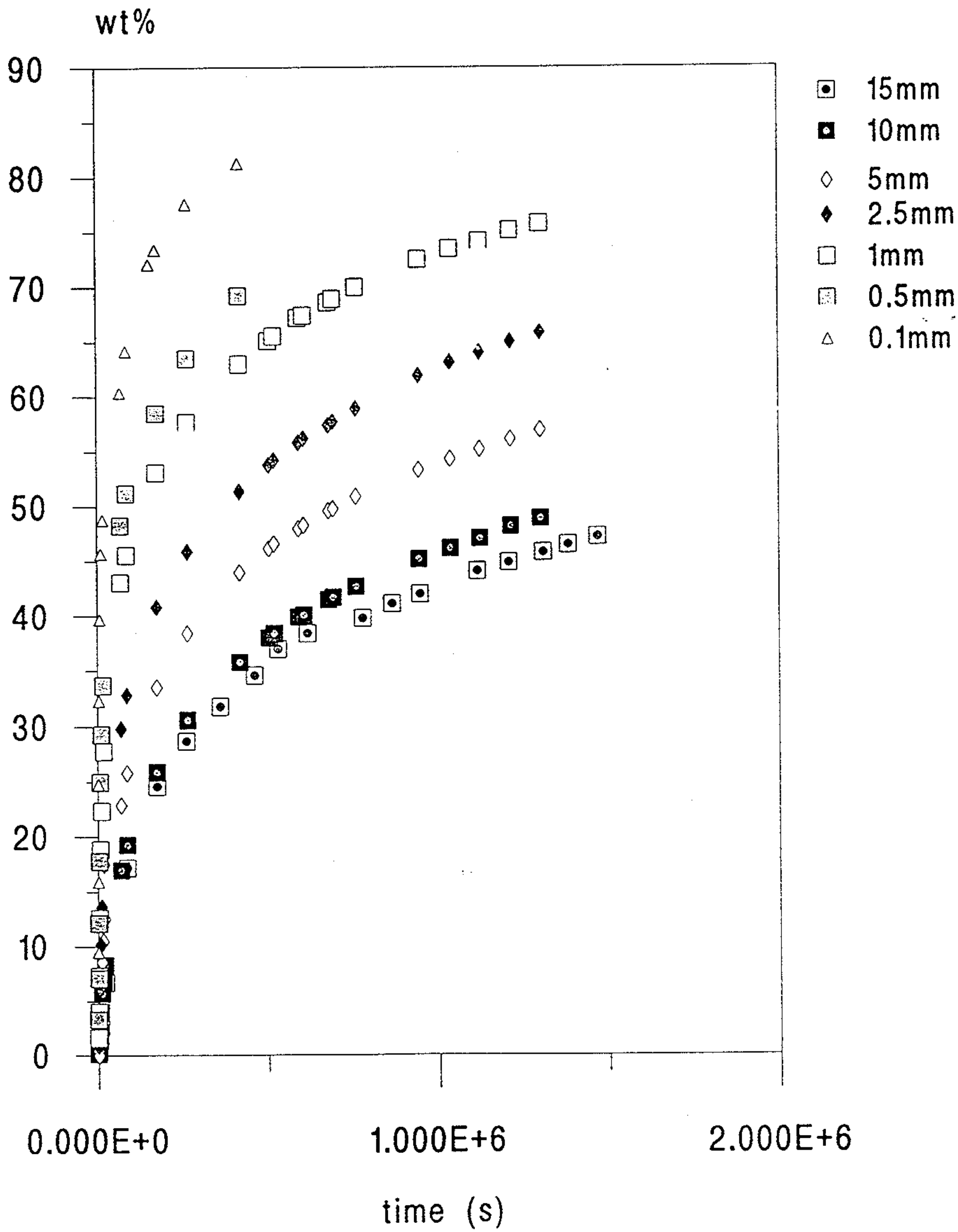


Figure 6: **Evaporation curves for Endicott (Weight % versus time)**

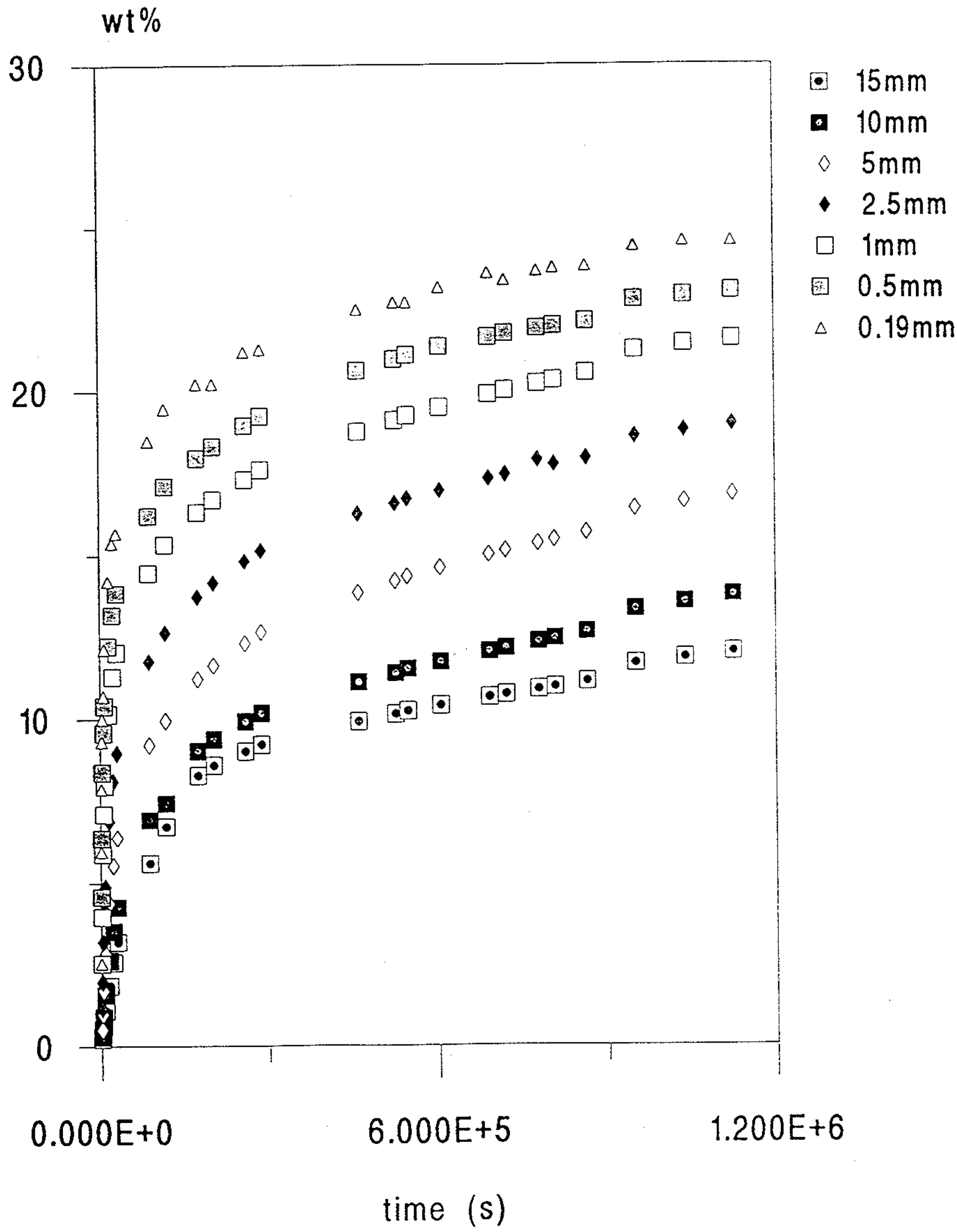


Figure 7: **Evaporation curves for North Slope (Weight % versus time)**

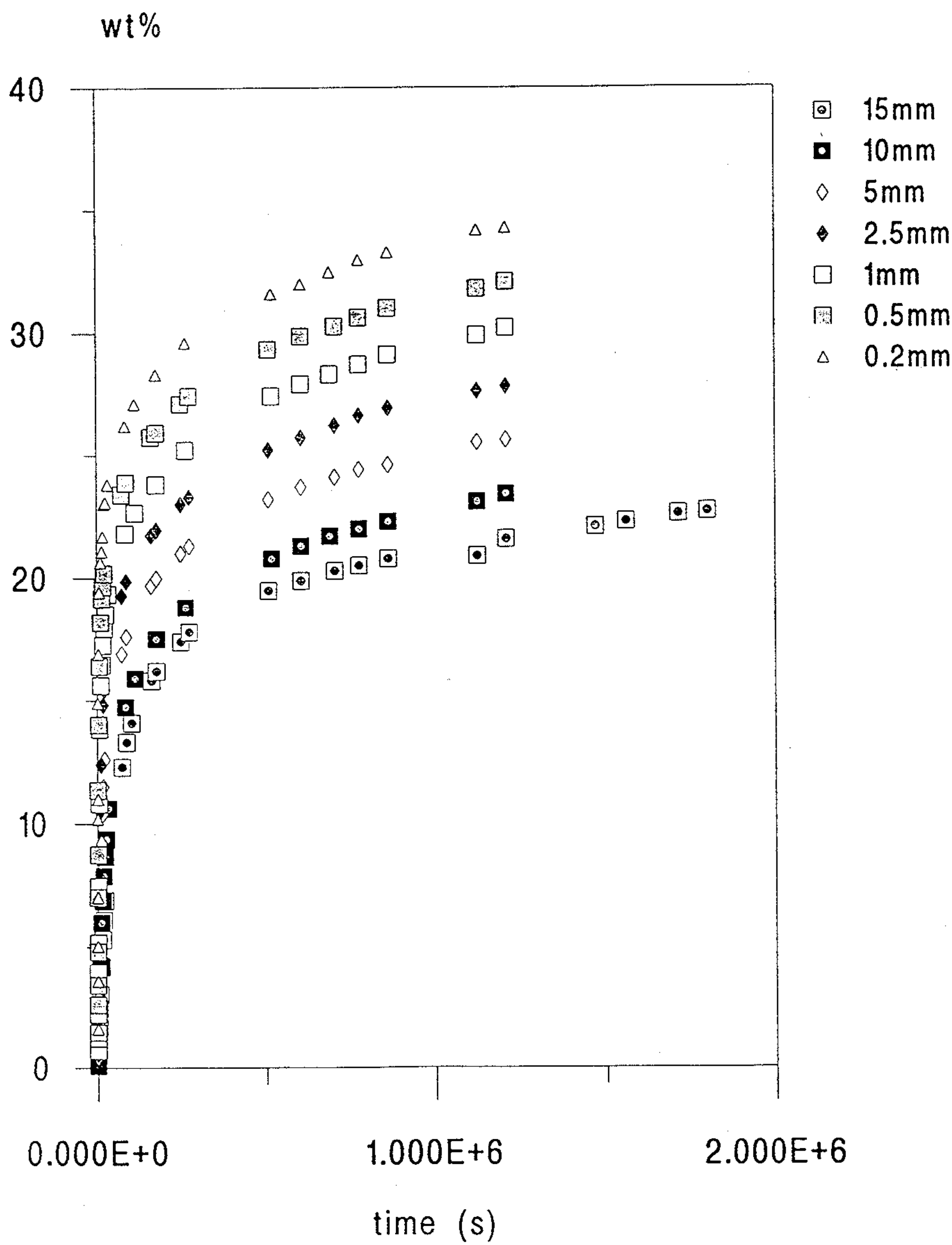


Figure 8: Evaporation curves for Panuke (Weight % versus time)

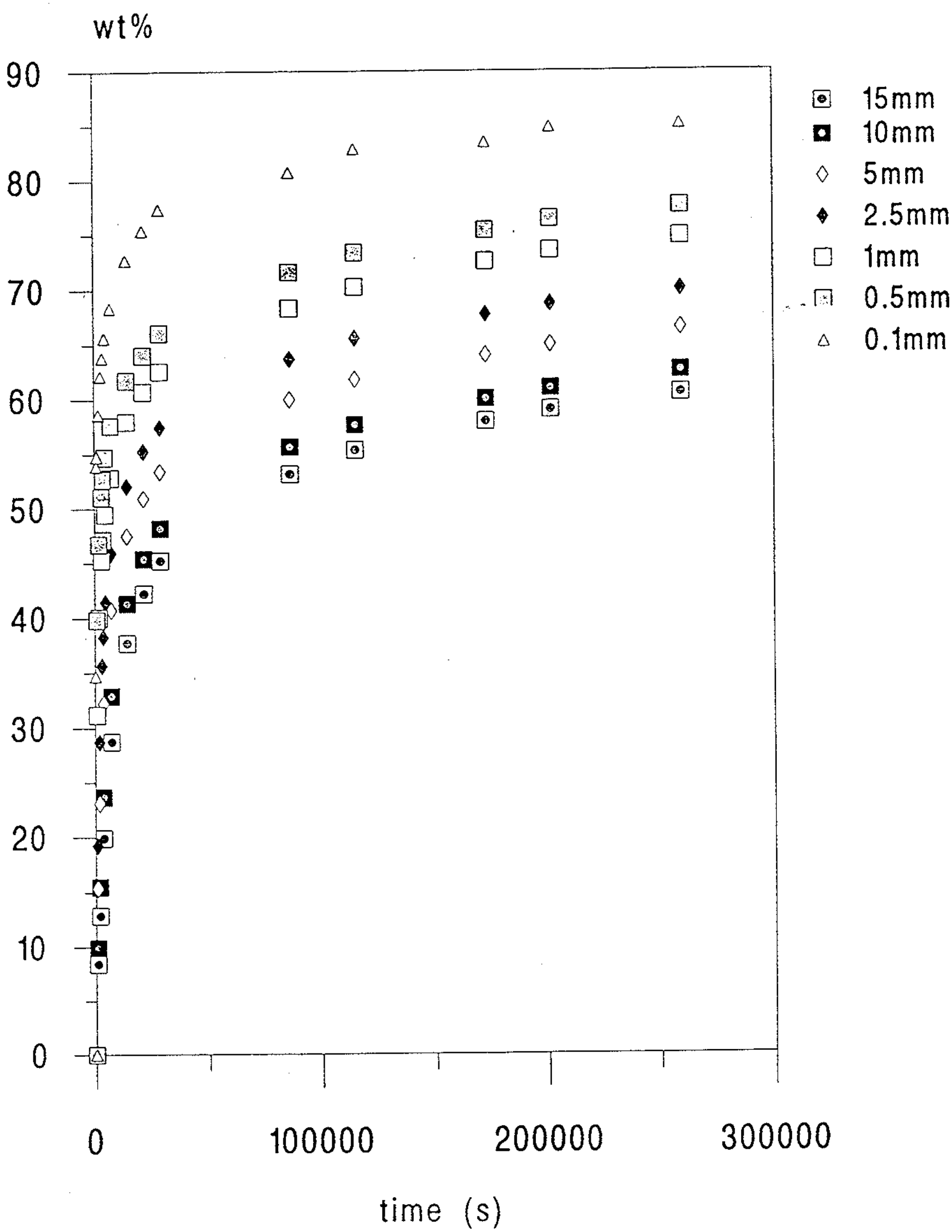


Figure 9: Evaporation curves for Adgo (Weight % versus θ)

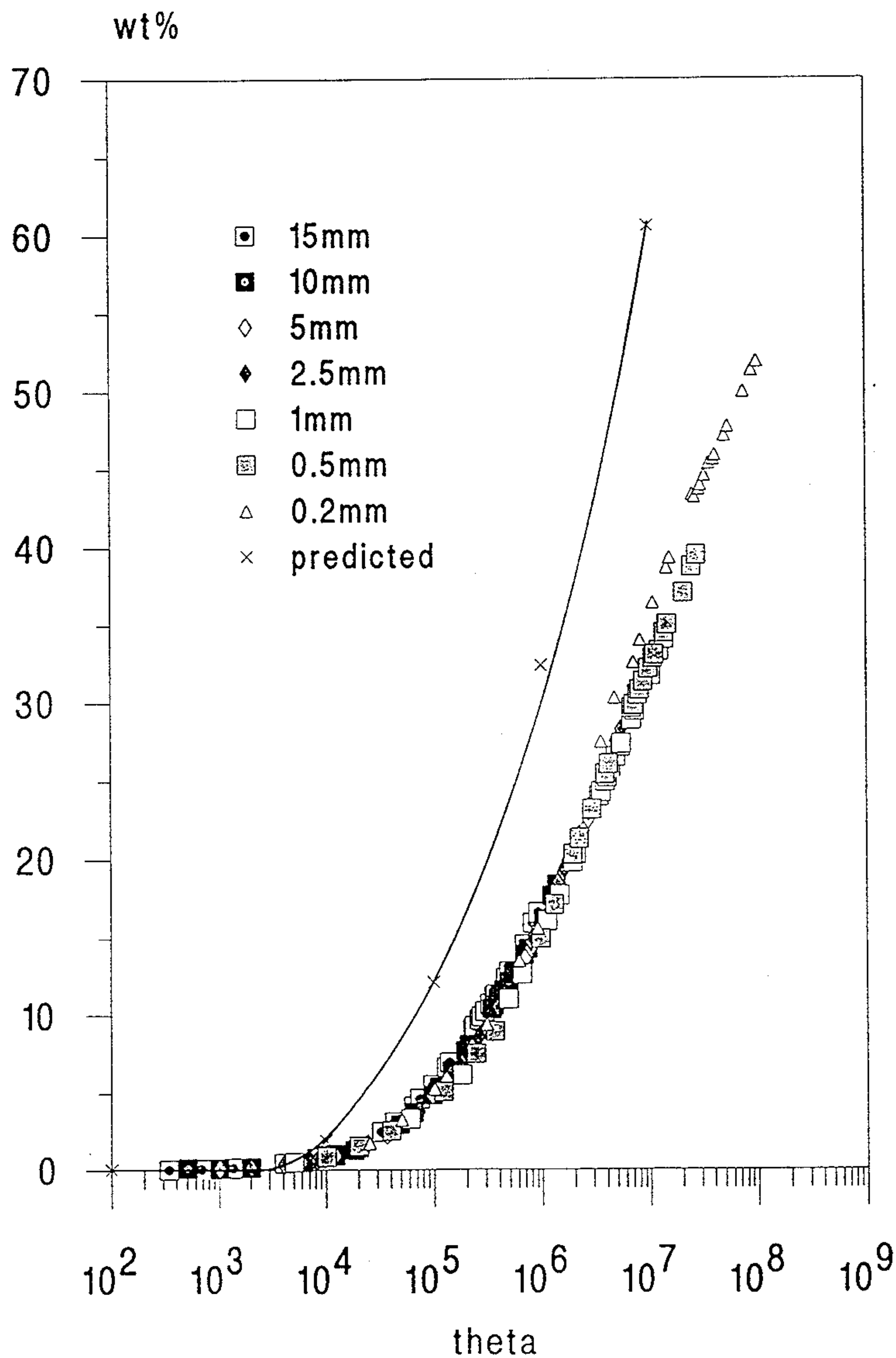


Figure 10: Evaporation curves for ASMB (Weight % versus θ)

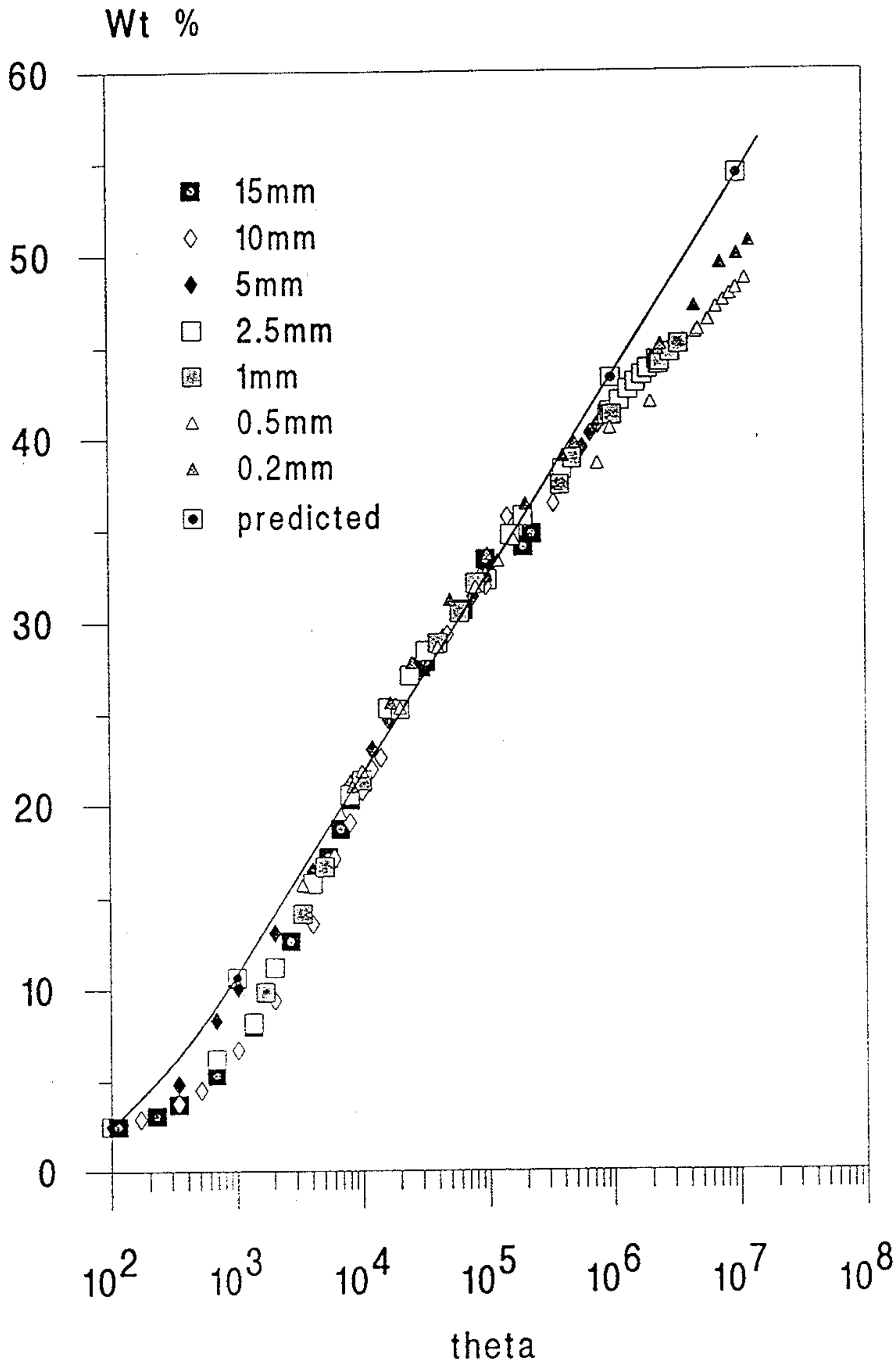


Figure 11: Evaporation curves for Amauligak (Weight % versus Θ)

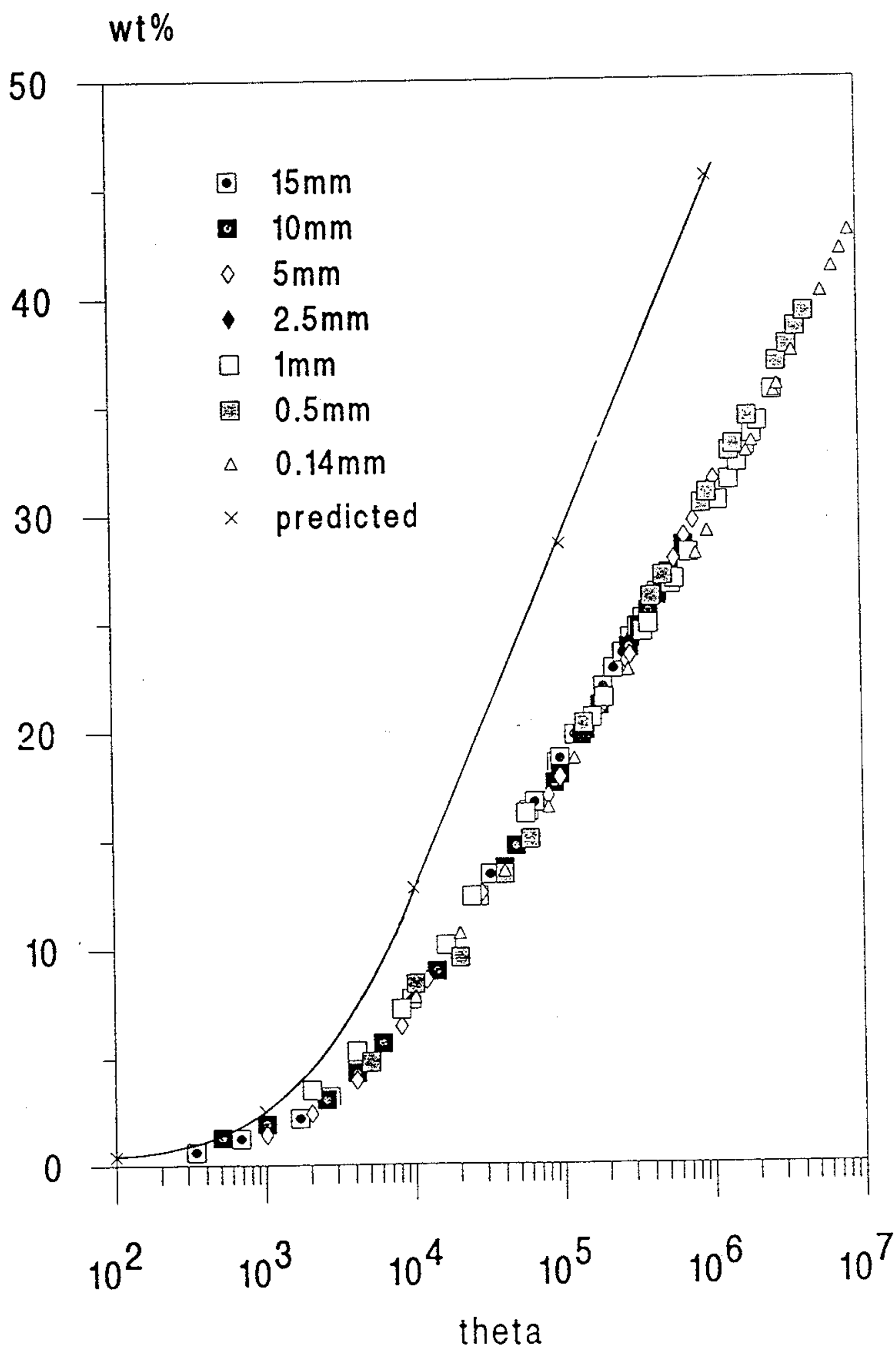


Figure 12: Evaporation curves for Bent Horn (Weight % versus θ)

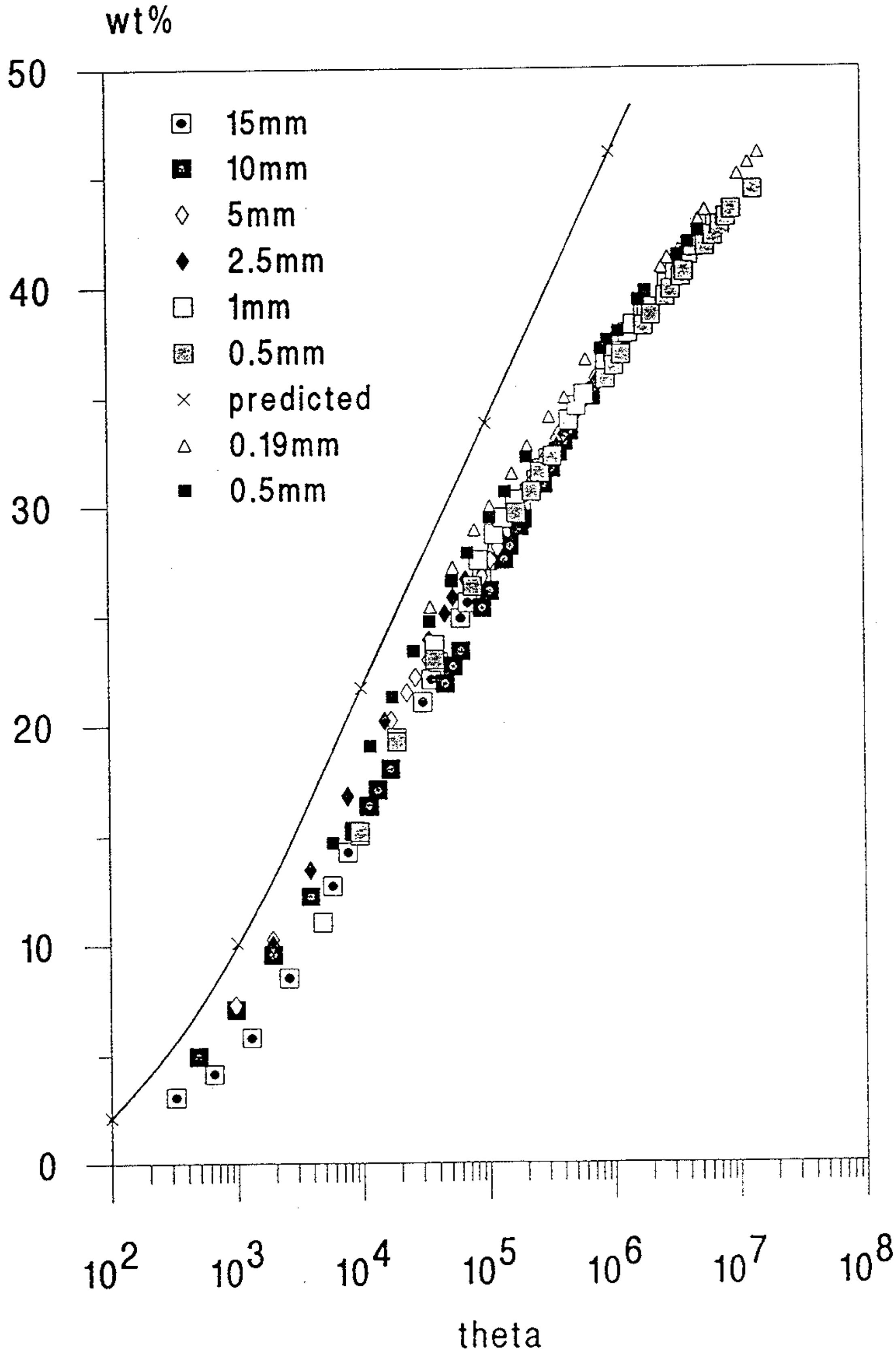


Figure 13: Evaporation curves for Diesel (Weight % versus ϴ)

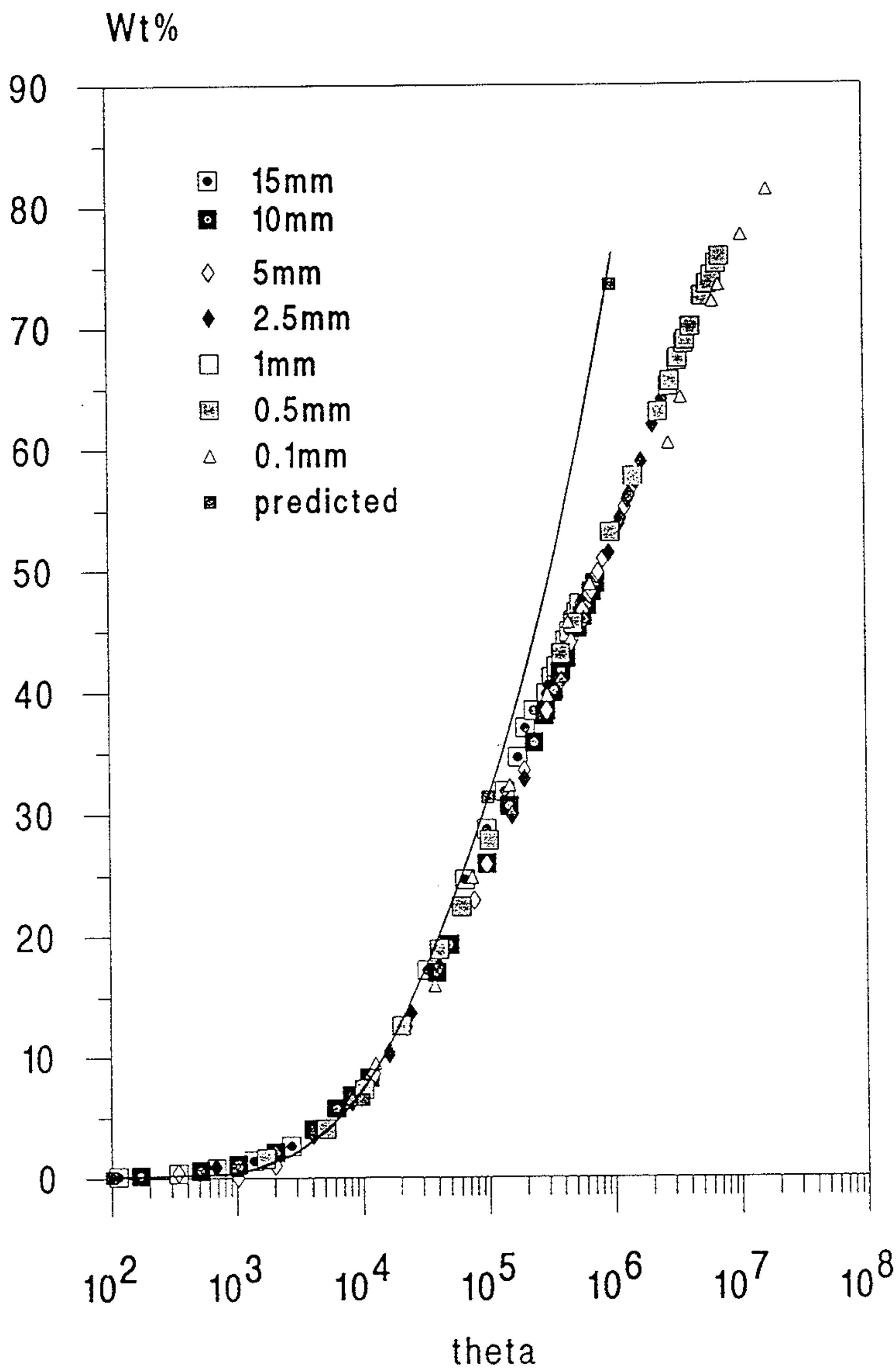


Figure 14: Evaporation curves for Endicott (Weight % versus θ)

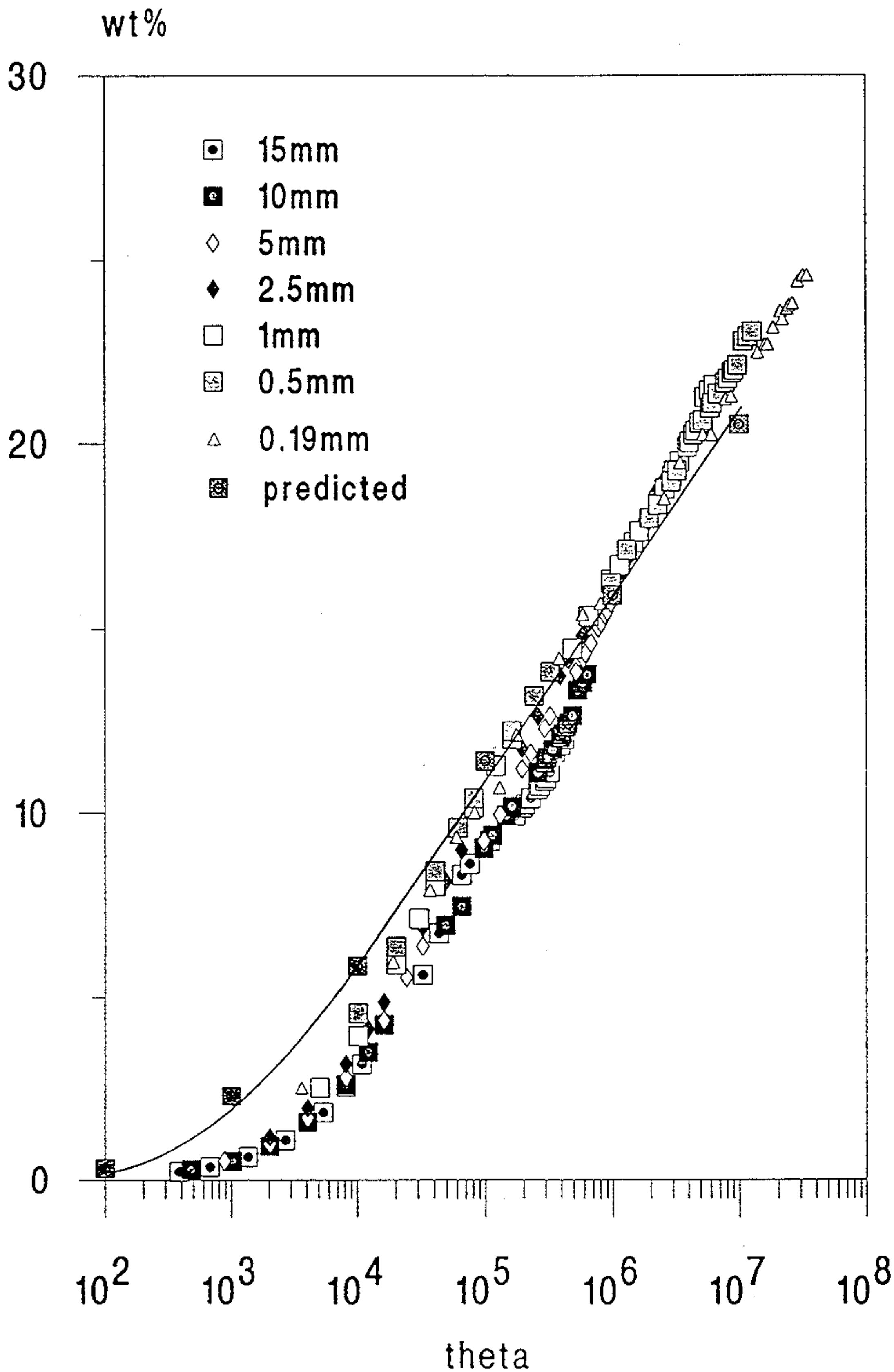


Figure 15: Evaporation curves for North Slope (Weight % versus θ)

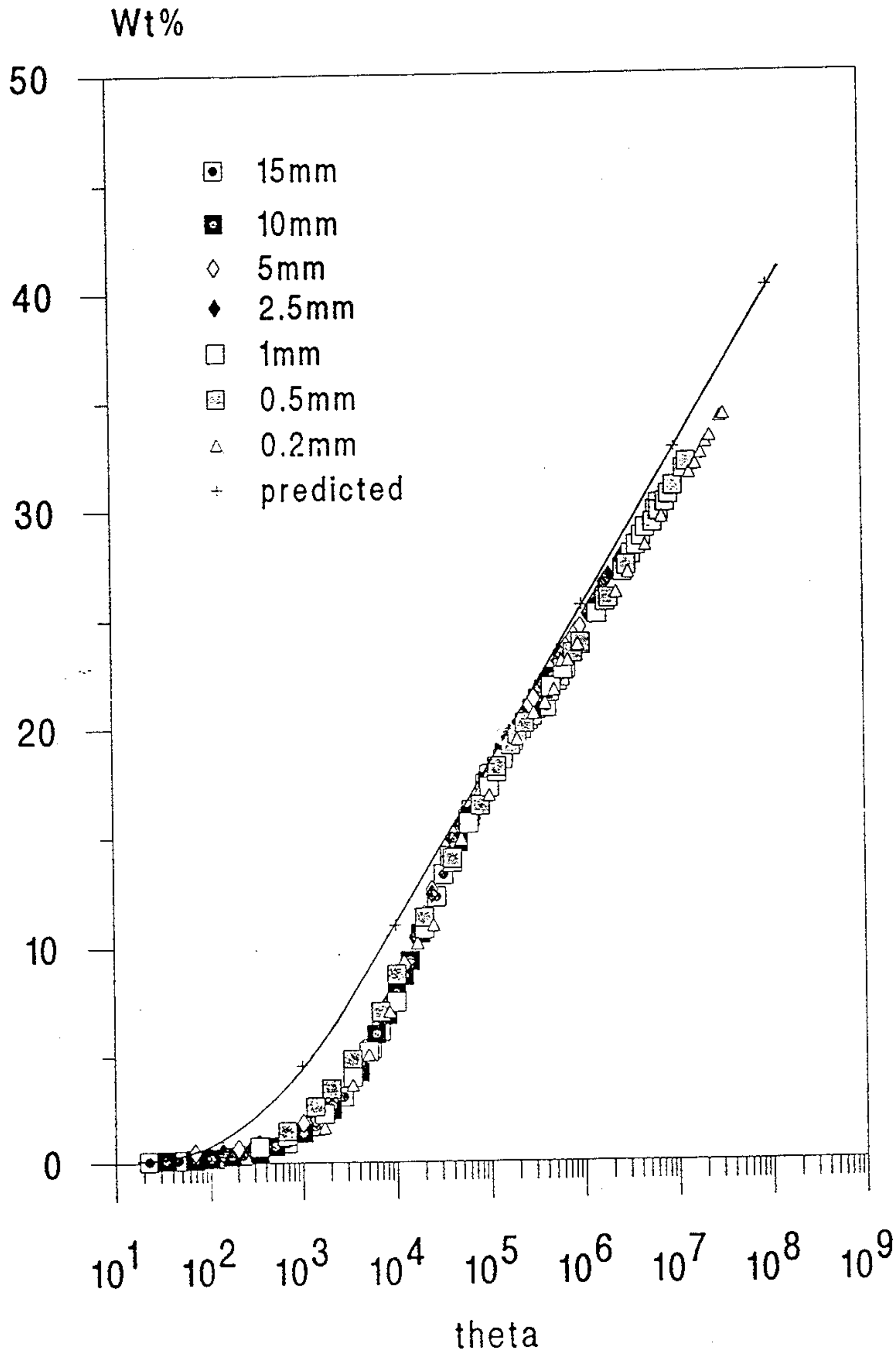
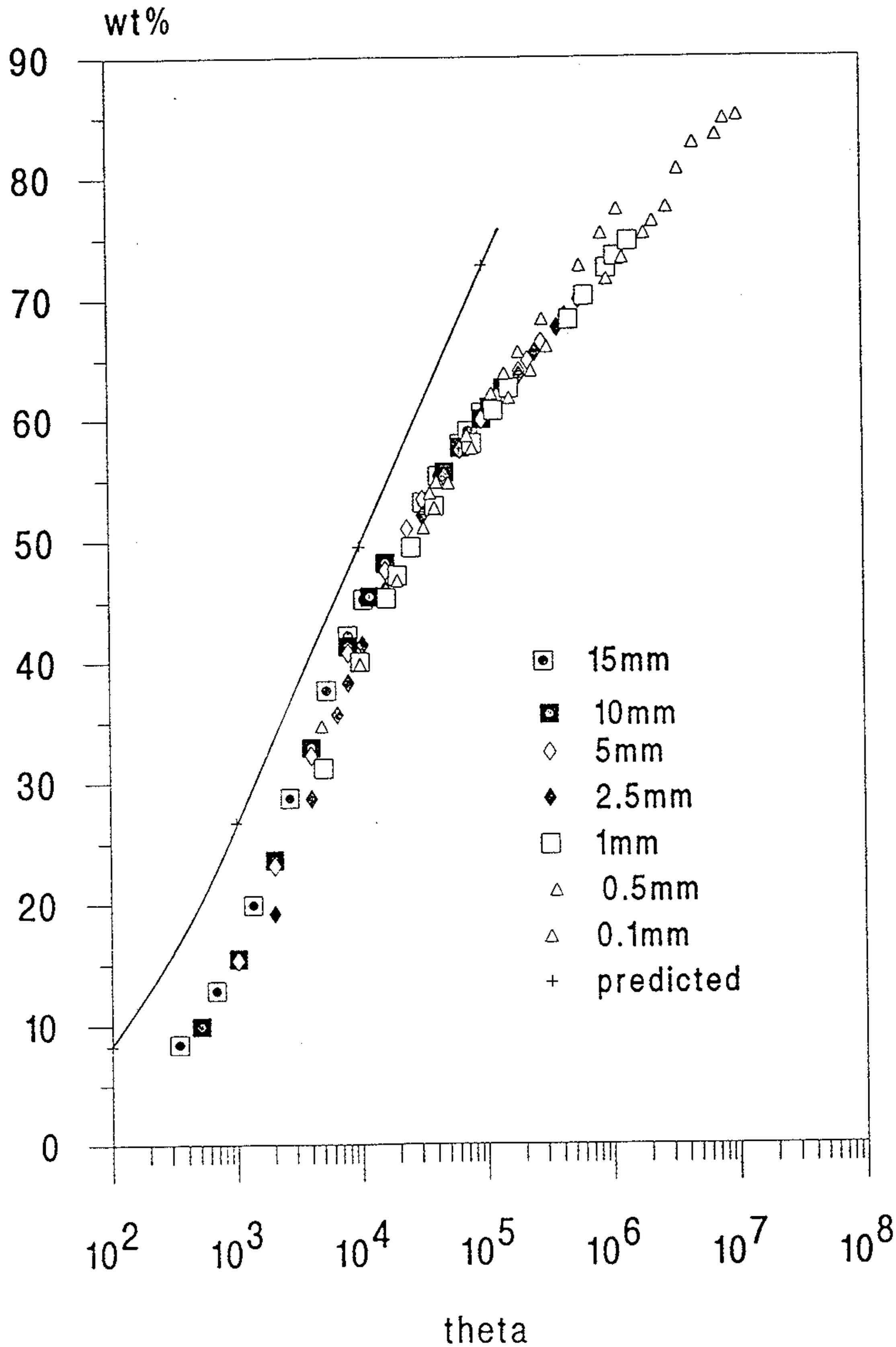


Figure 16: Evaporation curves for Panuke (Weight % versus θ)



Also, shown on Figures 9 to 16 are the predicted evaporation curves based upon the evaporative exposure model derived by Stiver (1984). The equation is given as:

$$F_v = \ln[1 + B(T_G/T)\,\theta\,\exp(A - B\,T_o/T)]\,[T/BT_G]$$

where: T_G is the gradient of the modified distillation curve
T_o is the initial boiling point of the modified distillation curve
A and B are dimensionless constants
for "typical" crudes A = 6.3 and B = 10.3.
Typical is undefined.

This equation provides a good estimate of evaporation as a function of θ for ASMB, Endicott, North Slope and Diesel. For Adgo, Amauligak, Bent Horn and Panuke, the predicted evaporation curve has the correct general form but tends to over-estimate evaporation. This is particularly true for Adgo and Amauligak. New values of A and B were determined for each oil using the method outlined by Stiver and Mackay (1983) for determining Henry's Law constant (H). See Appendix A for plots used to determined A and B. Derived values of A and B are given in Table 2. Predicted evaporation curves using the new constants are shown in Figures 17 to 24. The predicted behaviour using these derived constants provide a good fit to the data.

Table 2: Values for T_o, T_G, A and B.

Oil	T_o	T_G	A	B
Adgo	551.0	195.4	24.3	20.5
ASMB	397.0	539.1	8.1	11.6
Amauligak	471.0	370.0	12.1	14.5
Bent Horn	406.0	484.0	11.4	13.8
Diesel	517.0	139.8	20.3	18.1
Endicott	453.7	1400.0	-0.8	7.1
North Slope	430.6	722.0	4.5	10.1
Panuke	268.1	367.8	7.2	11.4

Figure 17: **Evaporation curves for Adgo (Weight % versus θ) Prediction using derived A and B constants.**

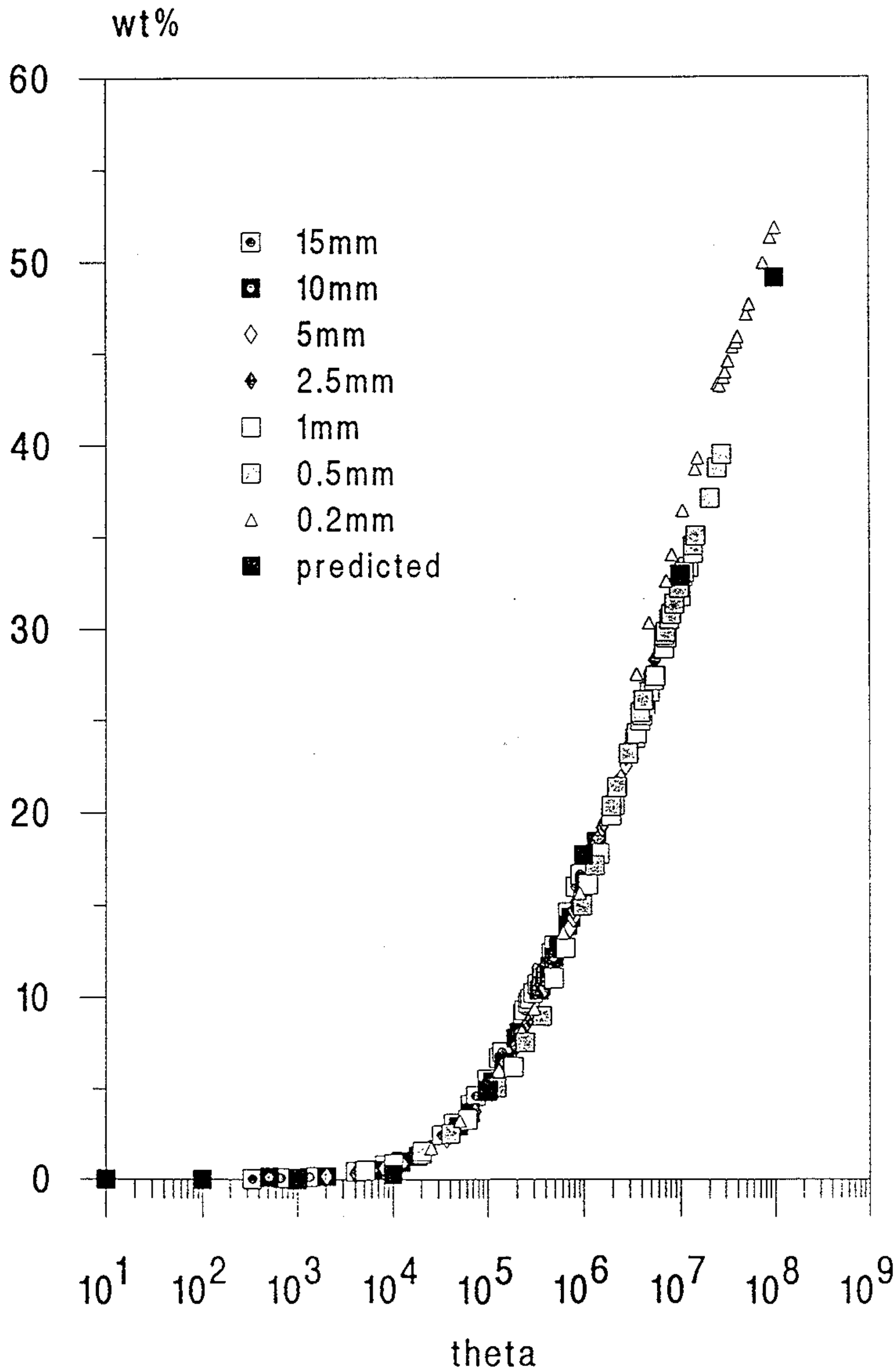


Figure 18: Evaporation curves for ASMB (Weight % versus ϴ) Prediction using derived A and B constants.

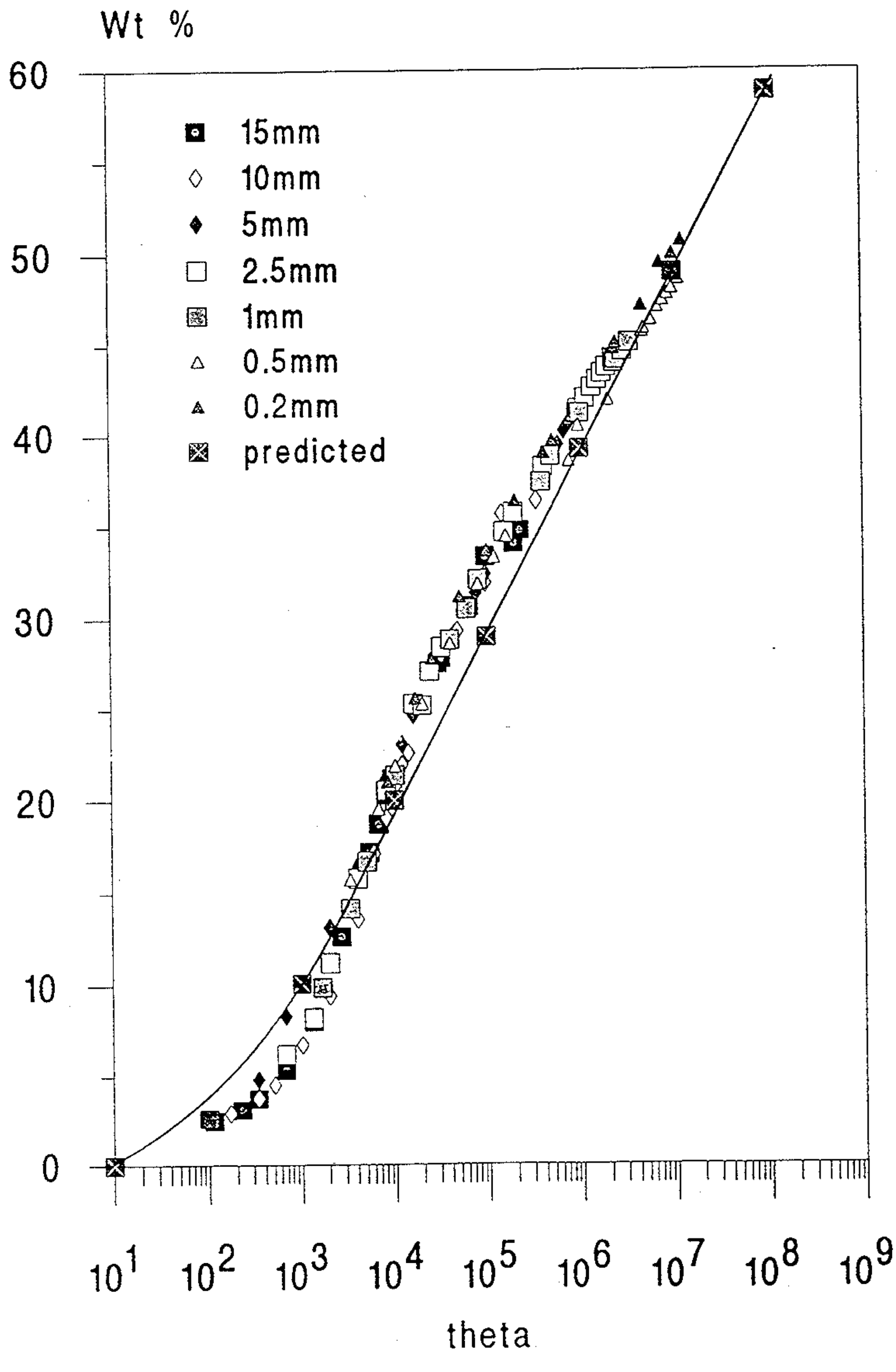


Figure 19: Evaporation curves for Amauligak (Weight % versus ϴ) Prediction using derived A and B constants.

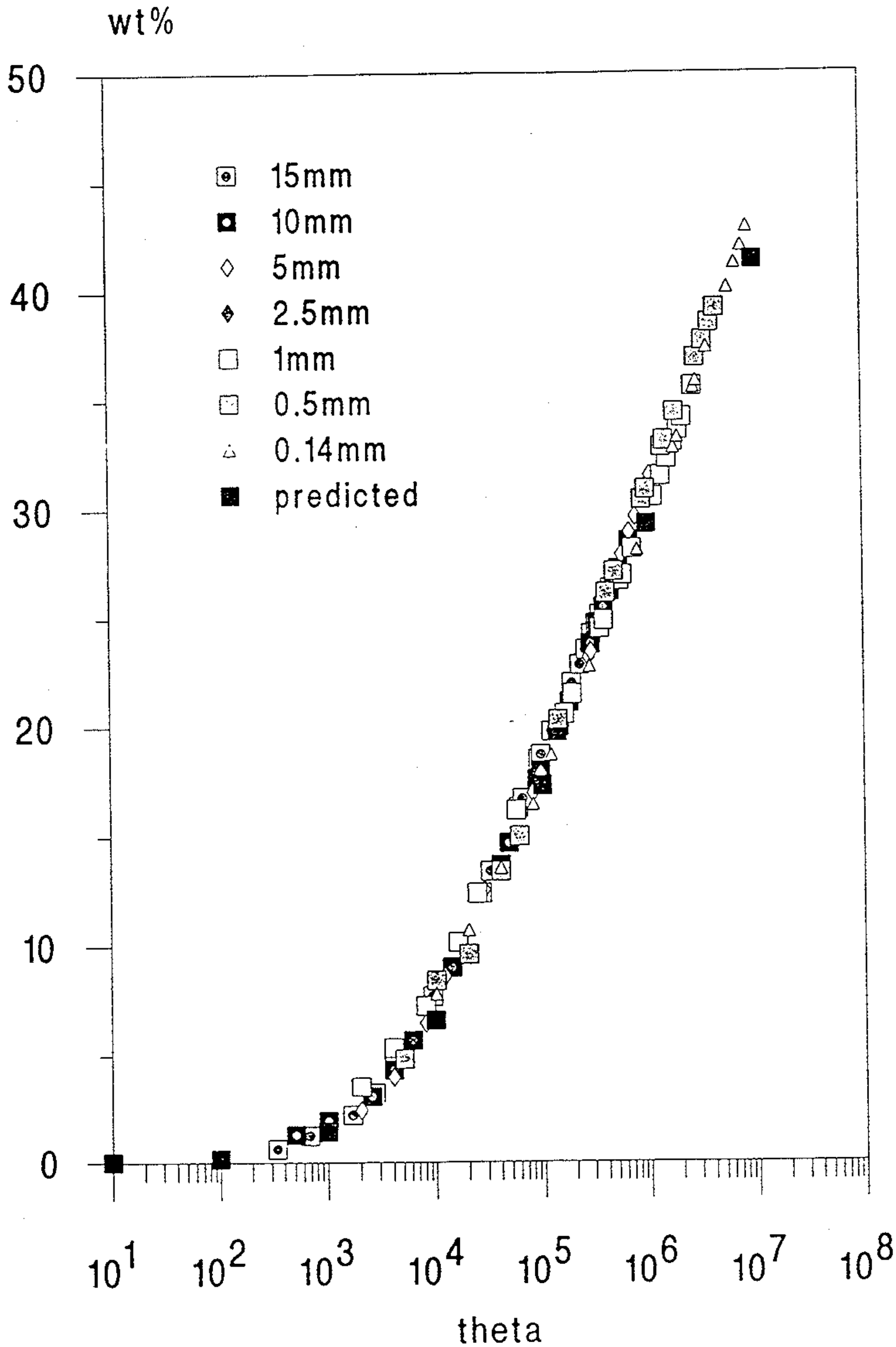


Figure 20: **Evaporation curves for Bent Horn (Weight % versus ϴ) Prediction using derived A and B constants.**

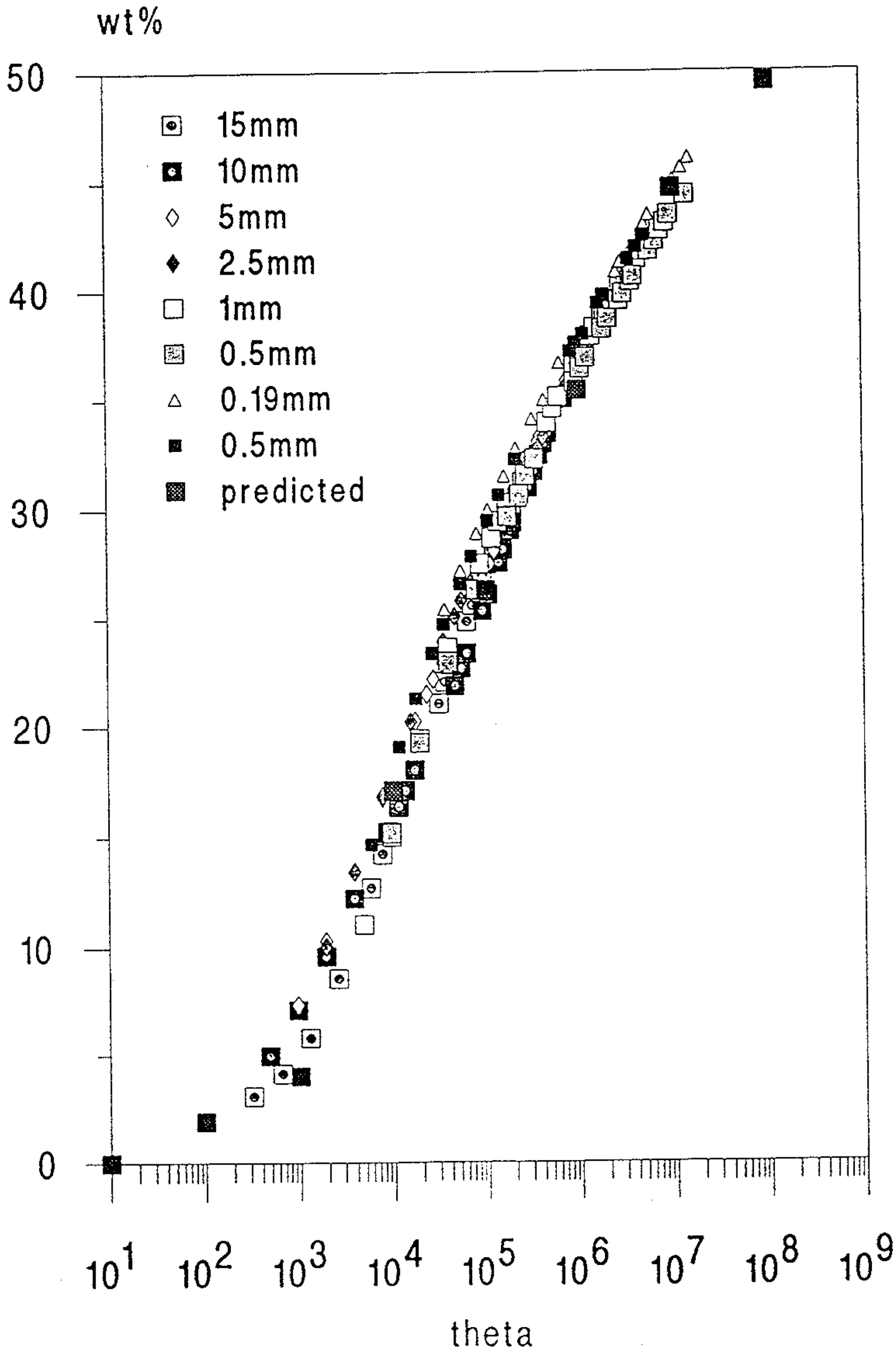


Figure 21: Evaporation curves for Diesel (Weight % versus ϴ) Prediction using derived A and B constants.

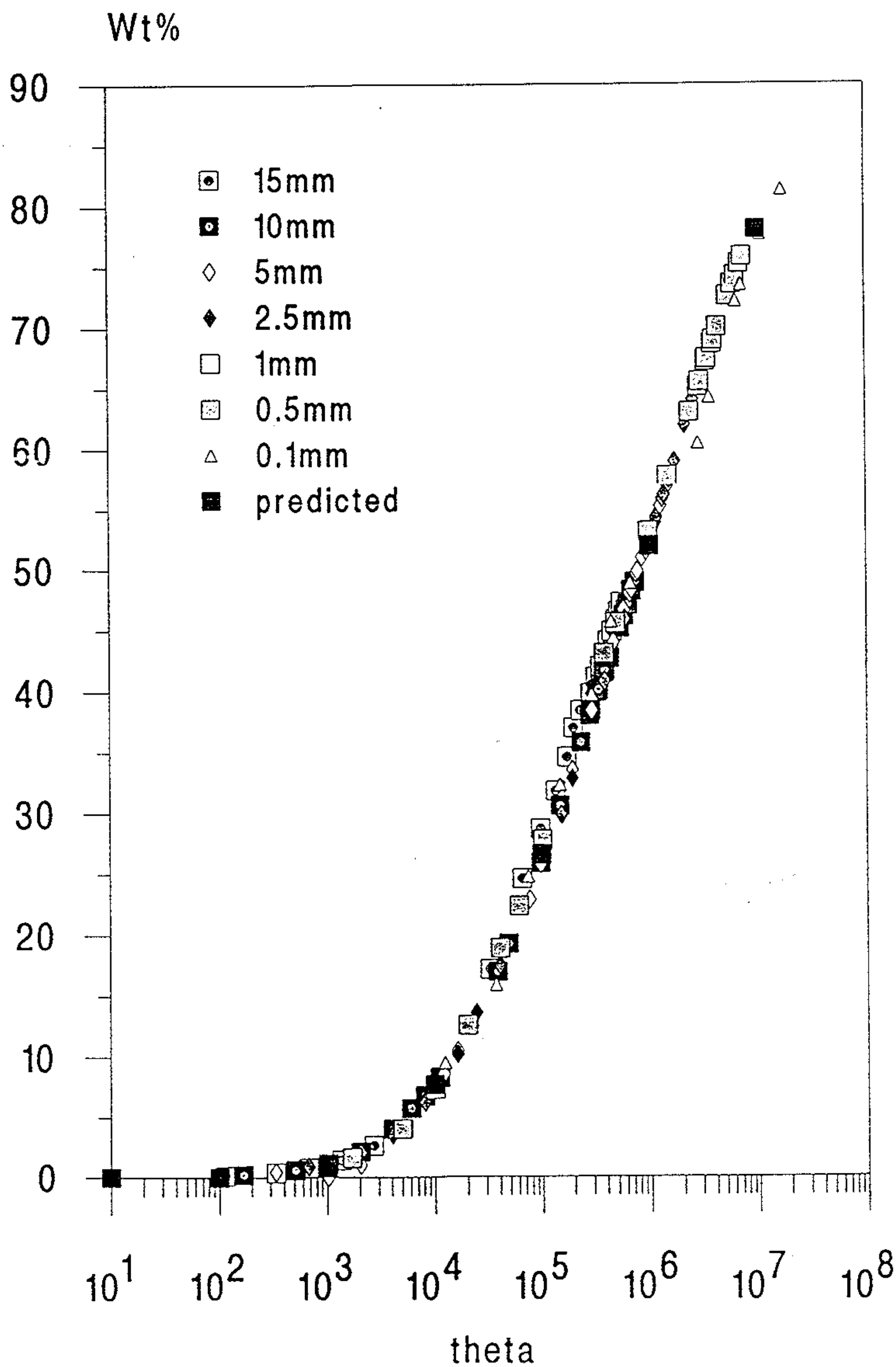


Figure 22: **Evaporation curves for Endicott (Weight % versus θ) Prediction using derived A and B constants.**

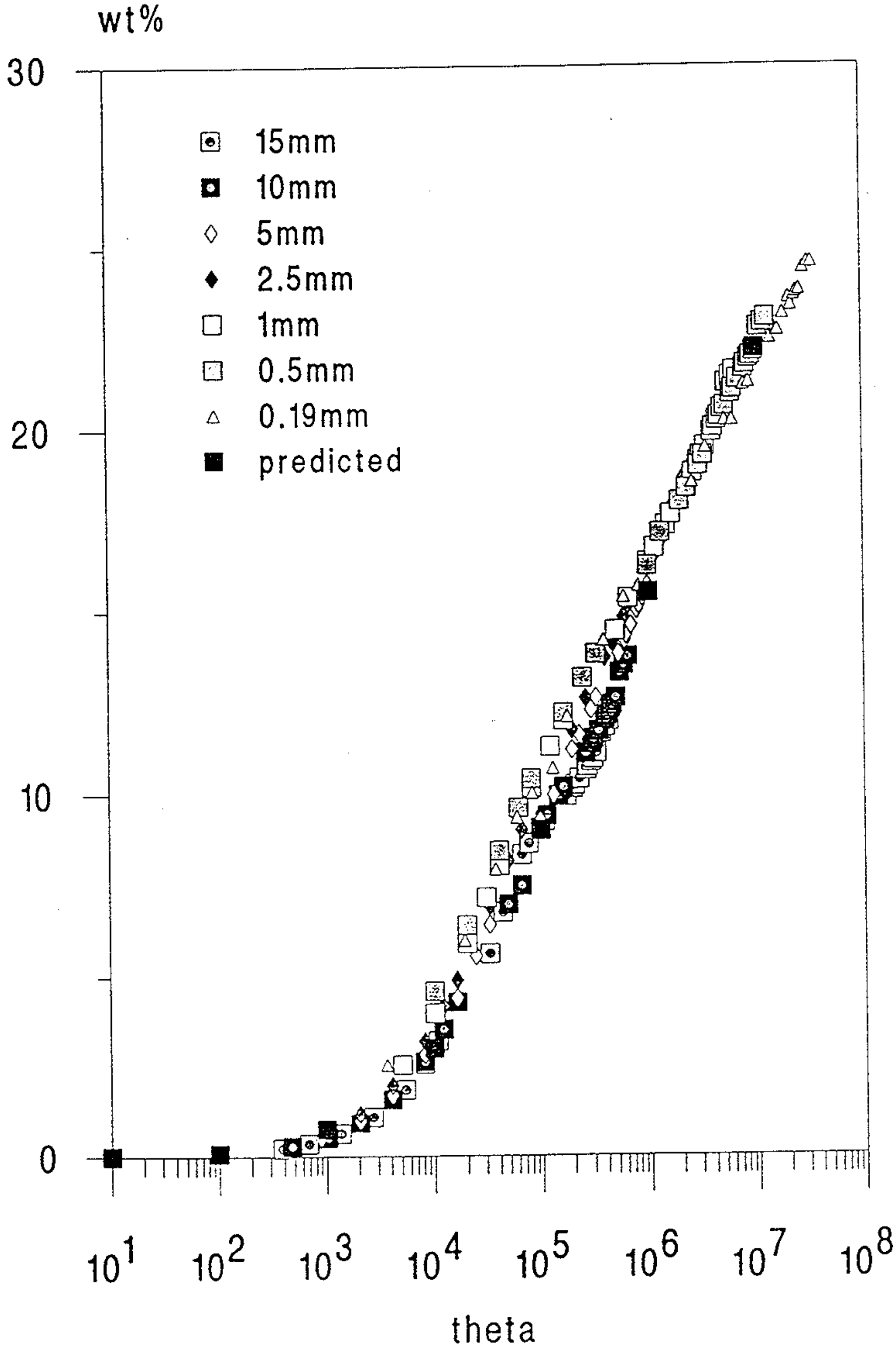


Figure 23: **Evaporation curves for North Slope (Weight % versus θ) Prediction using derived A and B constants.**

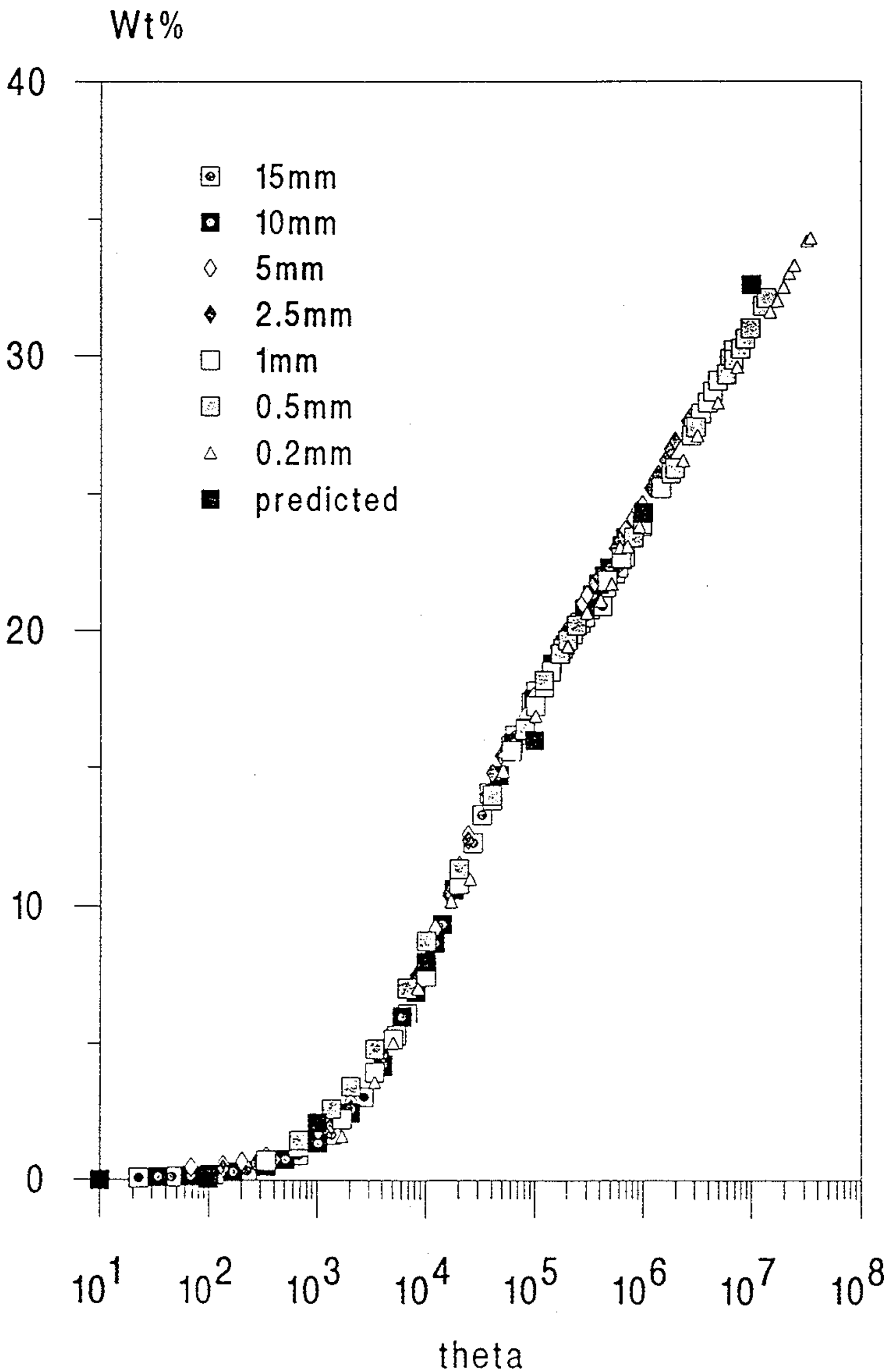
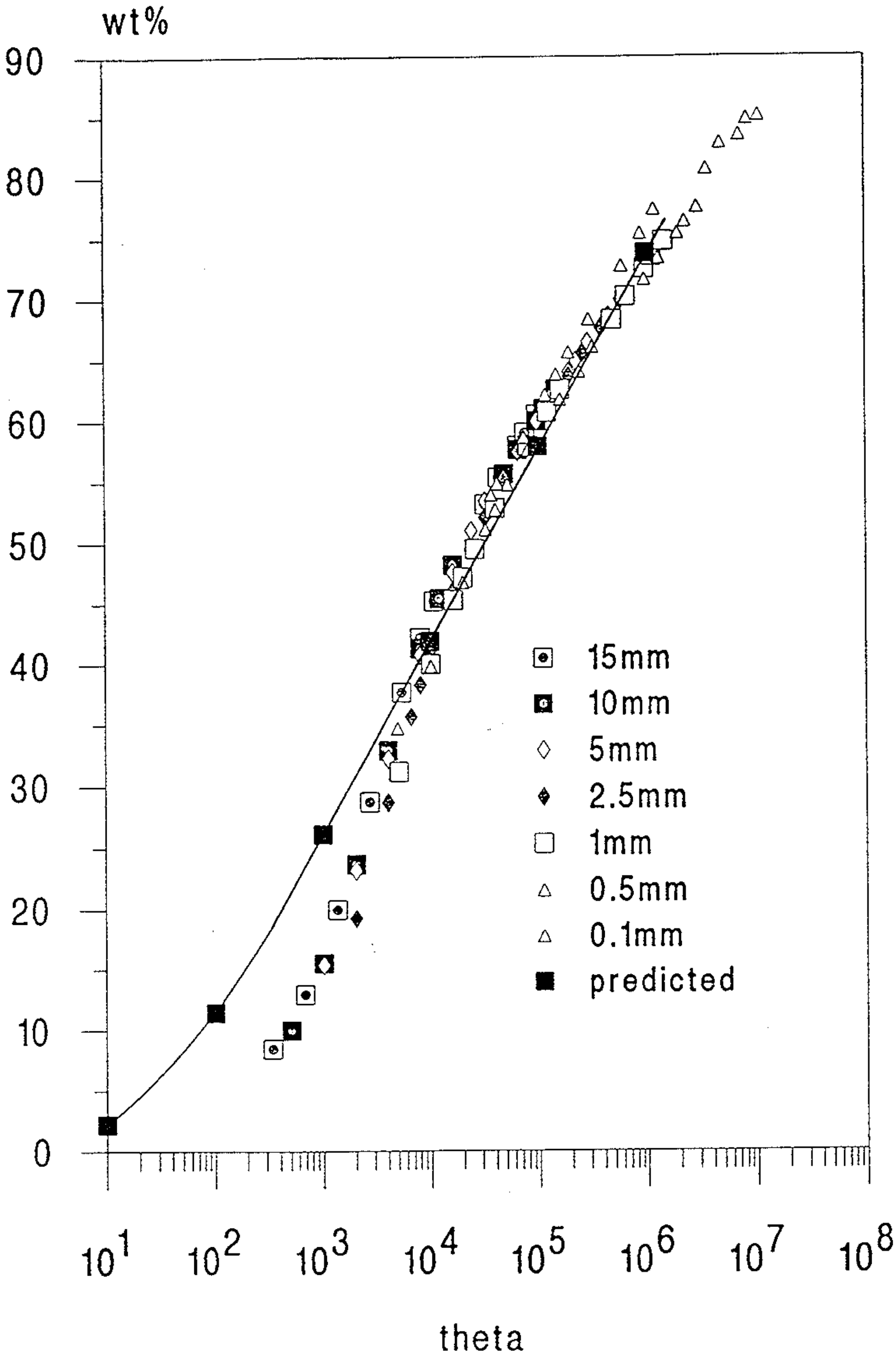


Figure 24: **Evaporation curves for Panuke (Weight % versus θ) Prediction using derived A and B constants.**



Figures 25 to 32 compare evaporation curves obtained from experiments using petri dishes and air stripping. For nearly all the oils, data from the tray evaporation experiments lags behind the air stripping method. At the same θ value, air stripping appears to be slightly more effective in evaporating oil. Similar behaviour has been noted by Stiver and Mackay (1983). This effect may be caused by one or more of the following: oil phase resistance, evaporative cooling, or a diffusivity effect on the mass transfer coefficient. Predictions for the evaporation curves are also shown in Figures 25 to 32. Overall, equations using values of A and B derived for specific oils provide a better estimate of evaporation than equations using A and B values of 6.3 and 10.3 respectively.

Figure 25: **Evaporation curves for Adgo (Weight % versus θ) Comparison of air stripping and dish evaporation.**

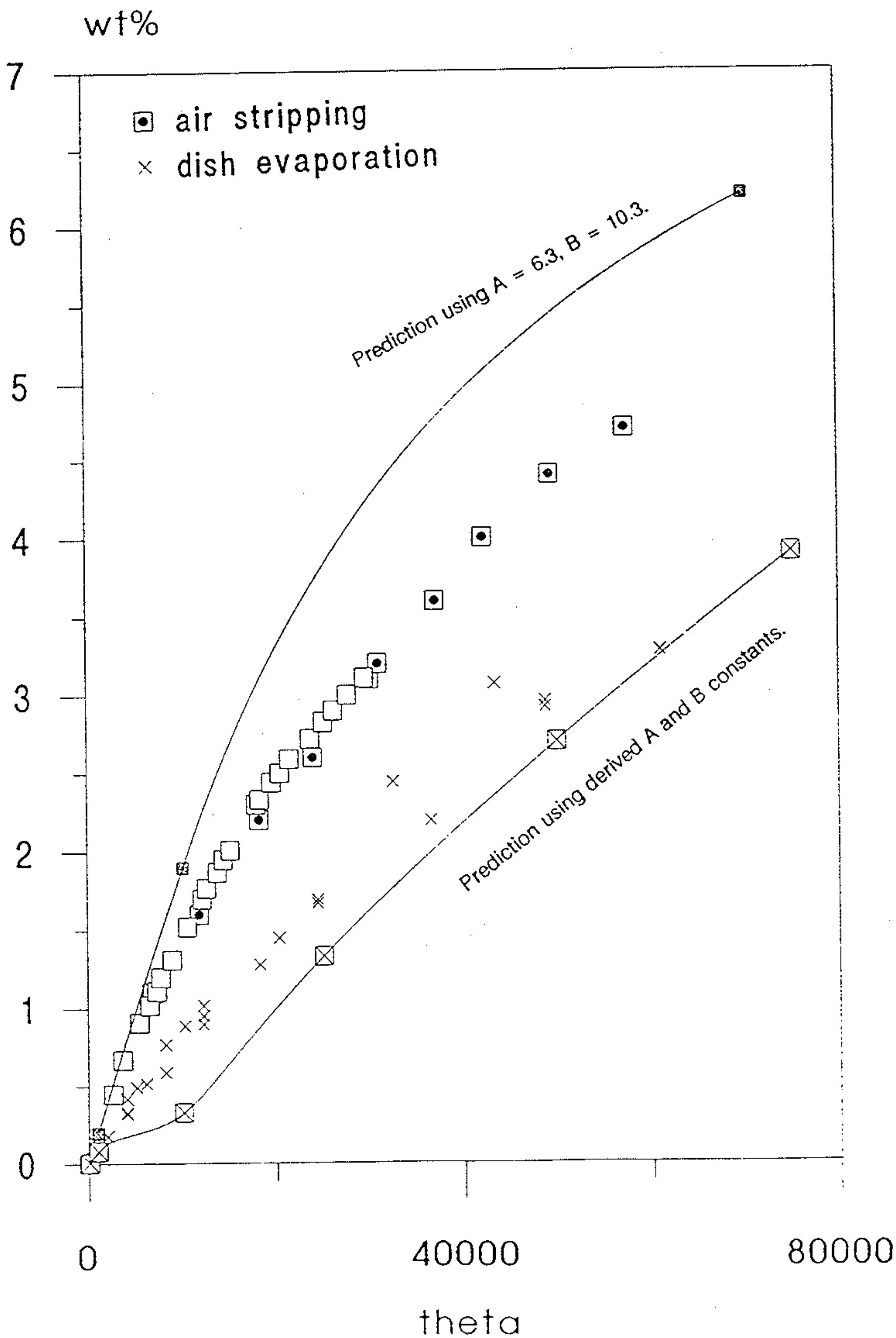


Figure 26: Evaporation curves for ASMB (Weight % versus θ) Comparison of air stripping and dish evaporation.

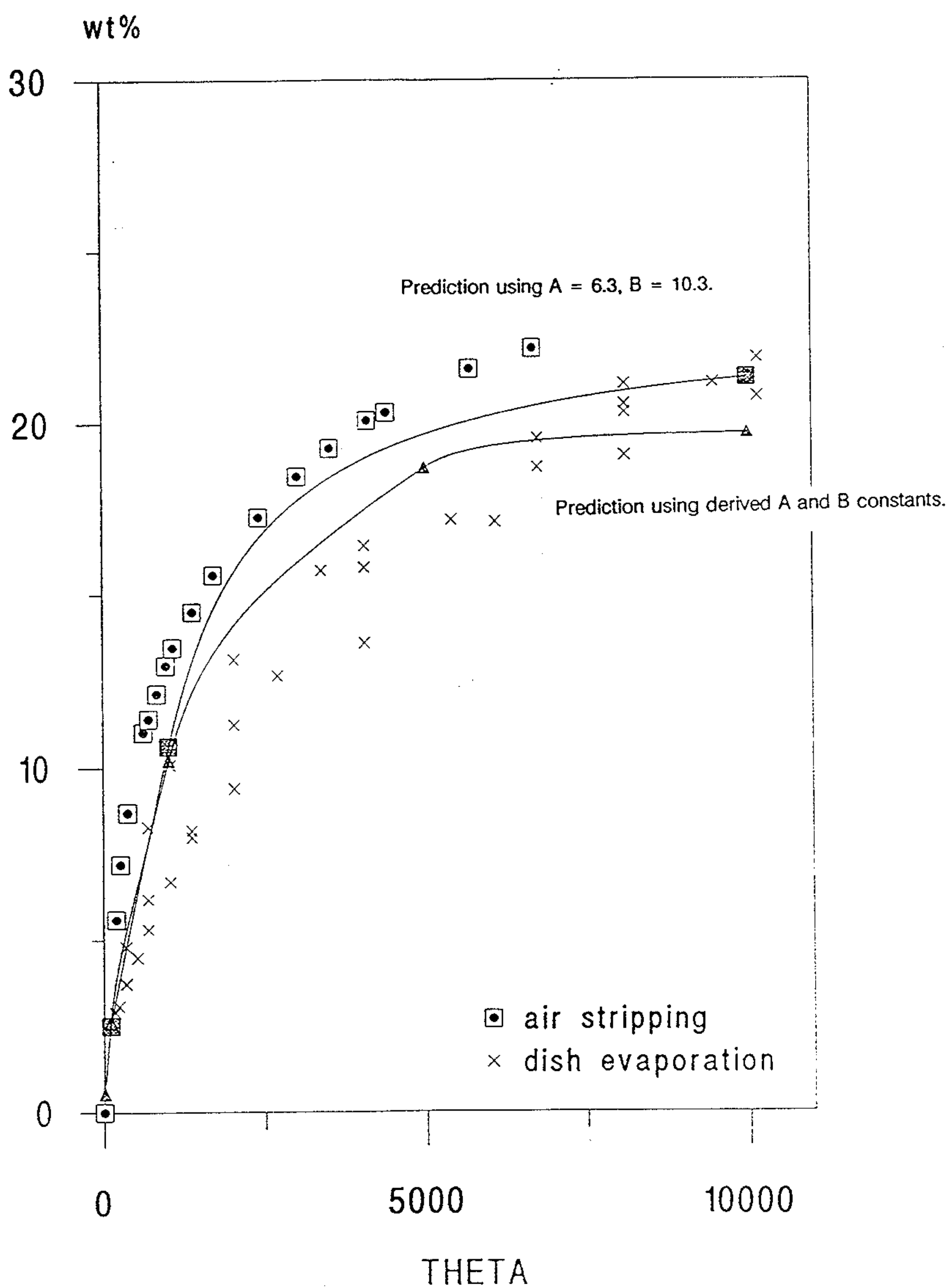


Figure 27: **Evaporation curves for Amauligak (Weight % versus Θ) Comparison of air stripping and dish evaporation.**

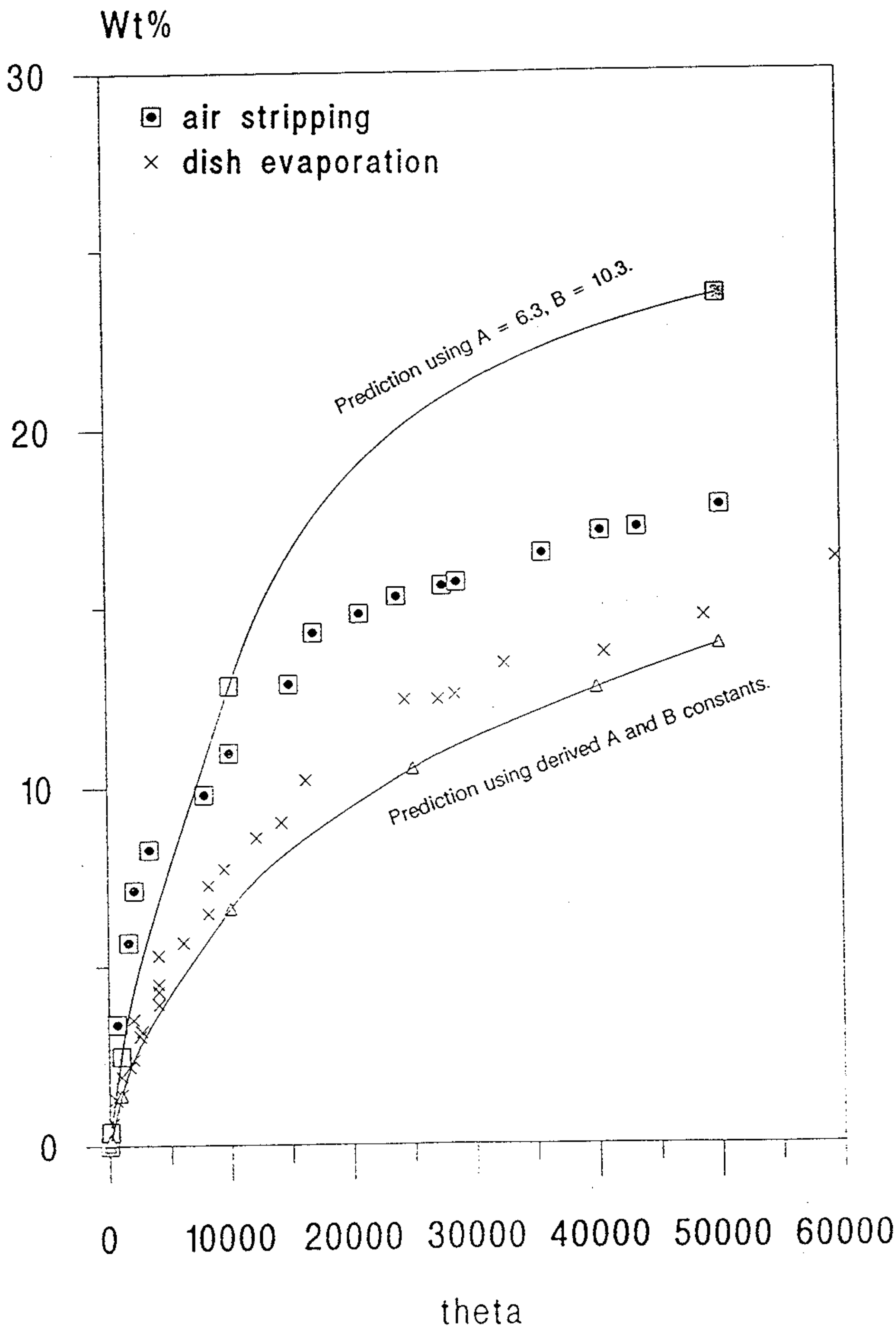


Figure 28: **Evaporation curves for Bent Horn (Weight % versus ϴ) Comparison of air stripping and dish evaporation.**

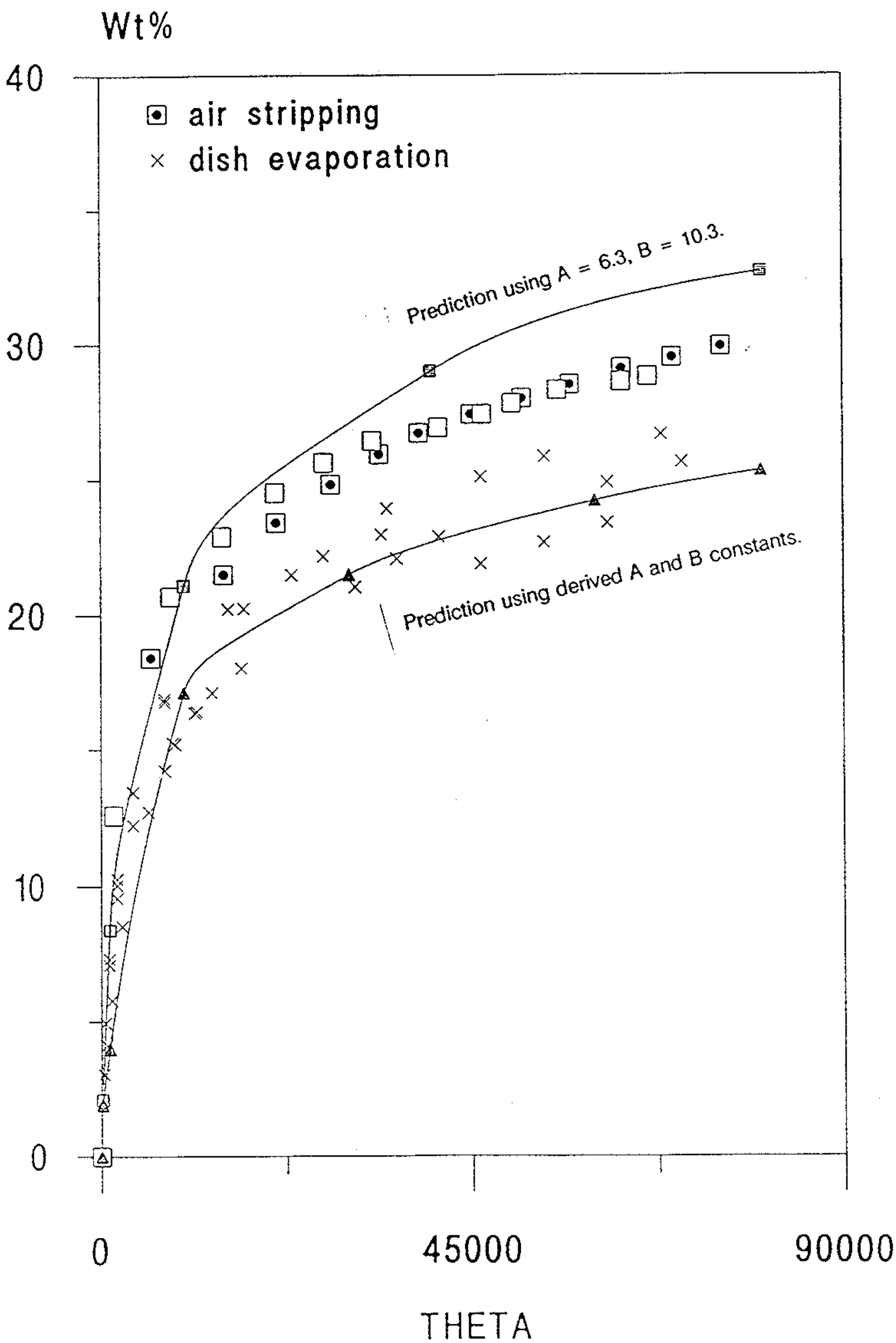


Figure 29: Evaporation curves for Diesel (Weight % versus Θ) Comparison of air stripping and dish evaporation.

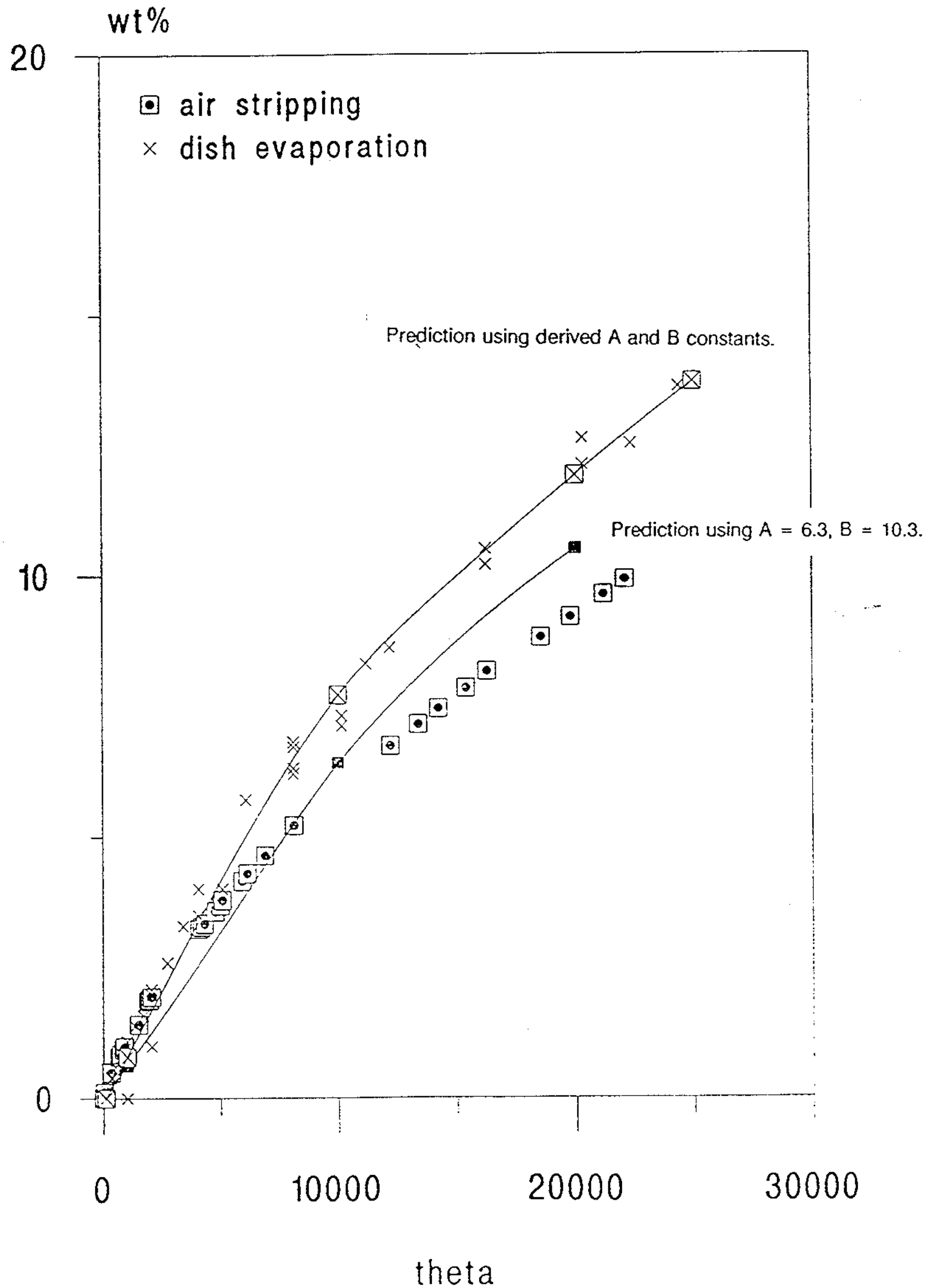


Figure 30: Evaporation curves for Endicott (Weight % versus Θ) Comparison of air stripping and dish evaporation.

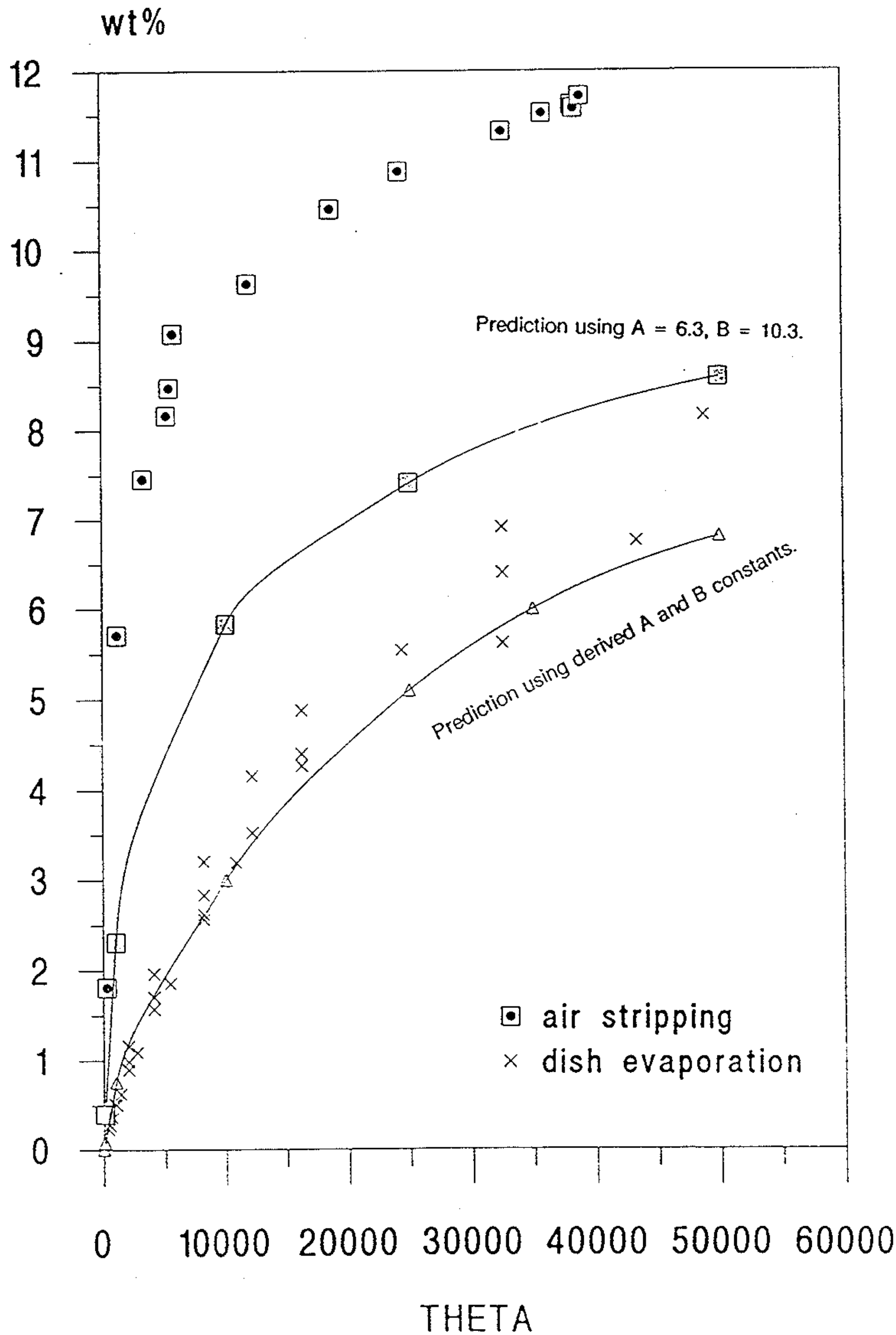


Figure 31: Evaporation curves for North Slope (Weight % versus θ) Comparison of air stripping and dish evaporation.

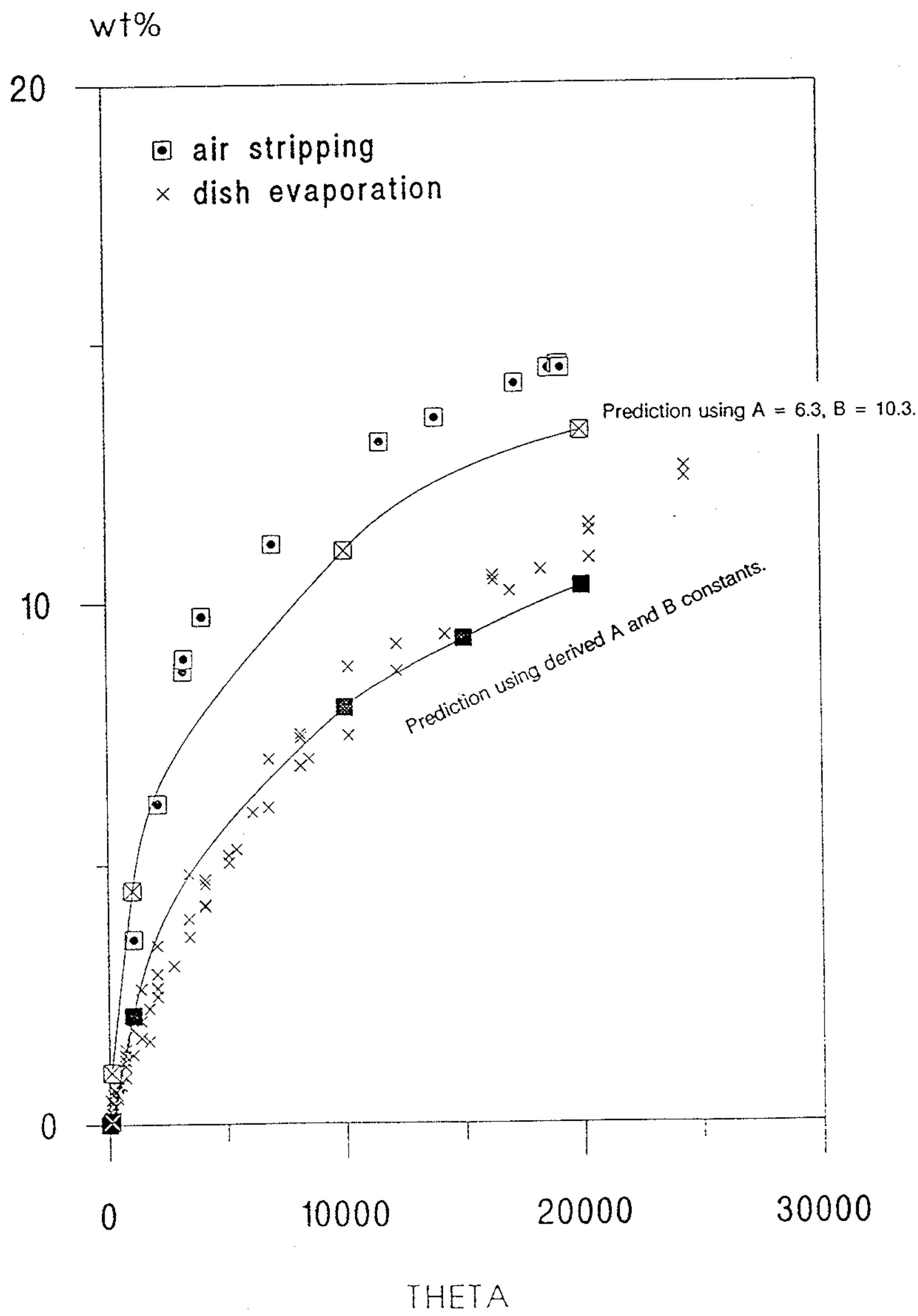
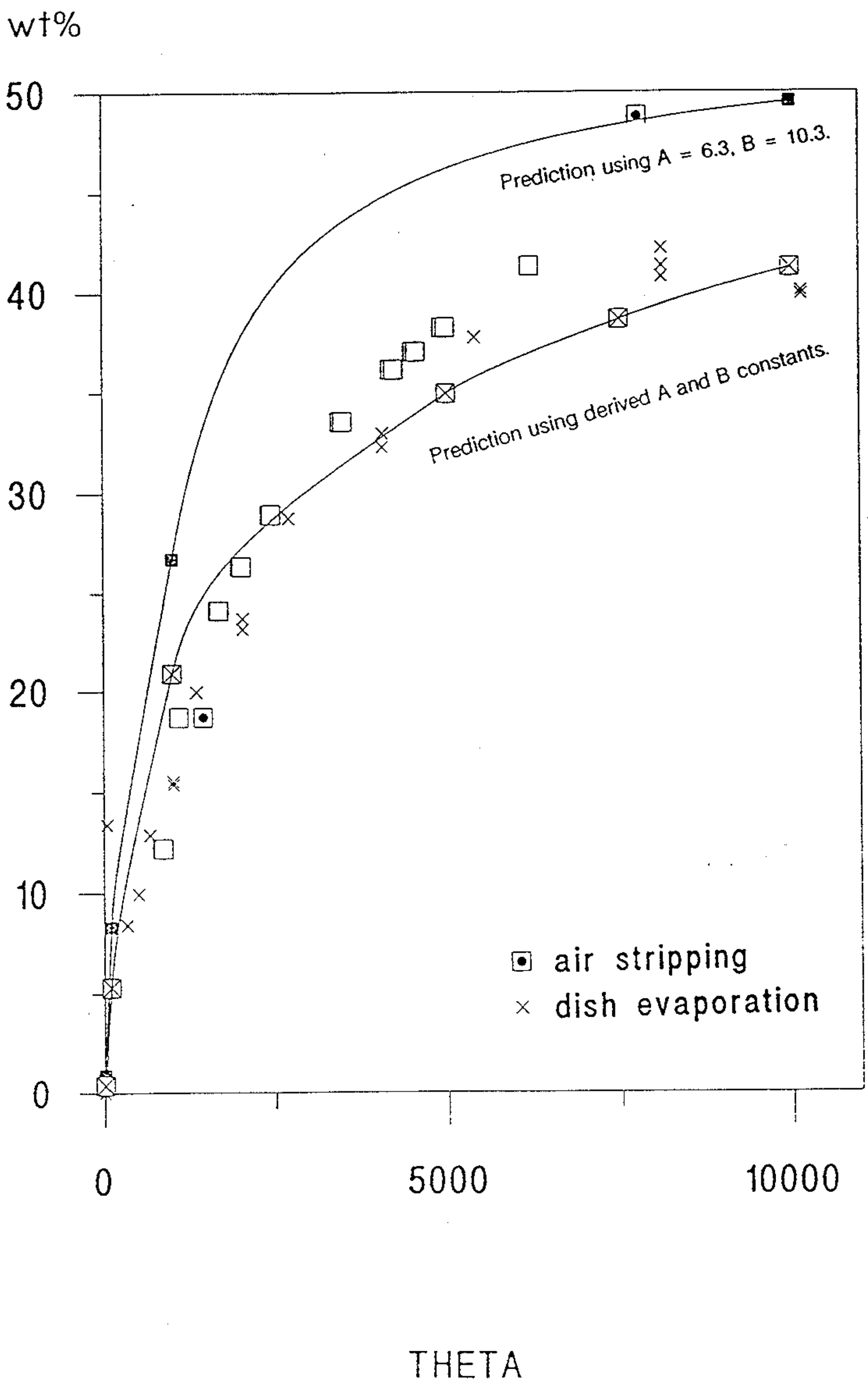


Figure 32: Evaporation curves for Panuke (Weight % versus θ) Comparison of air stripping and dish evaporation.



Results from experiments performed outdoors under varying conditions are presented in Figures 33 to 40. Although the variance is greater than in the data obtained under controlled indoor conditions, the results are similar. The evaporative exposure concept accounts for the effect of thickness on evaporation. Predicted evaporation curves using the derived constants A and B in the evaporative exposure equation provide a reasonable fit.

Tables of data are contained in the Appendix.

Figure 33: Evaporation curves for Adgo (Volume % versus Θ) Experiments performed outdoors.

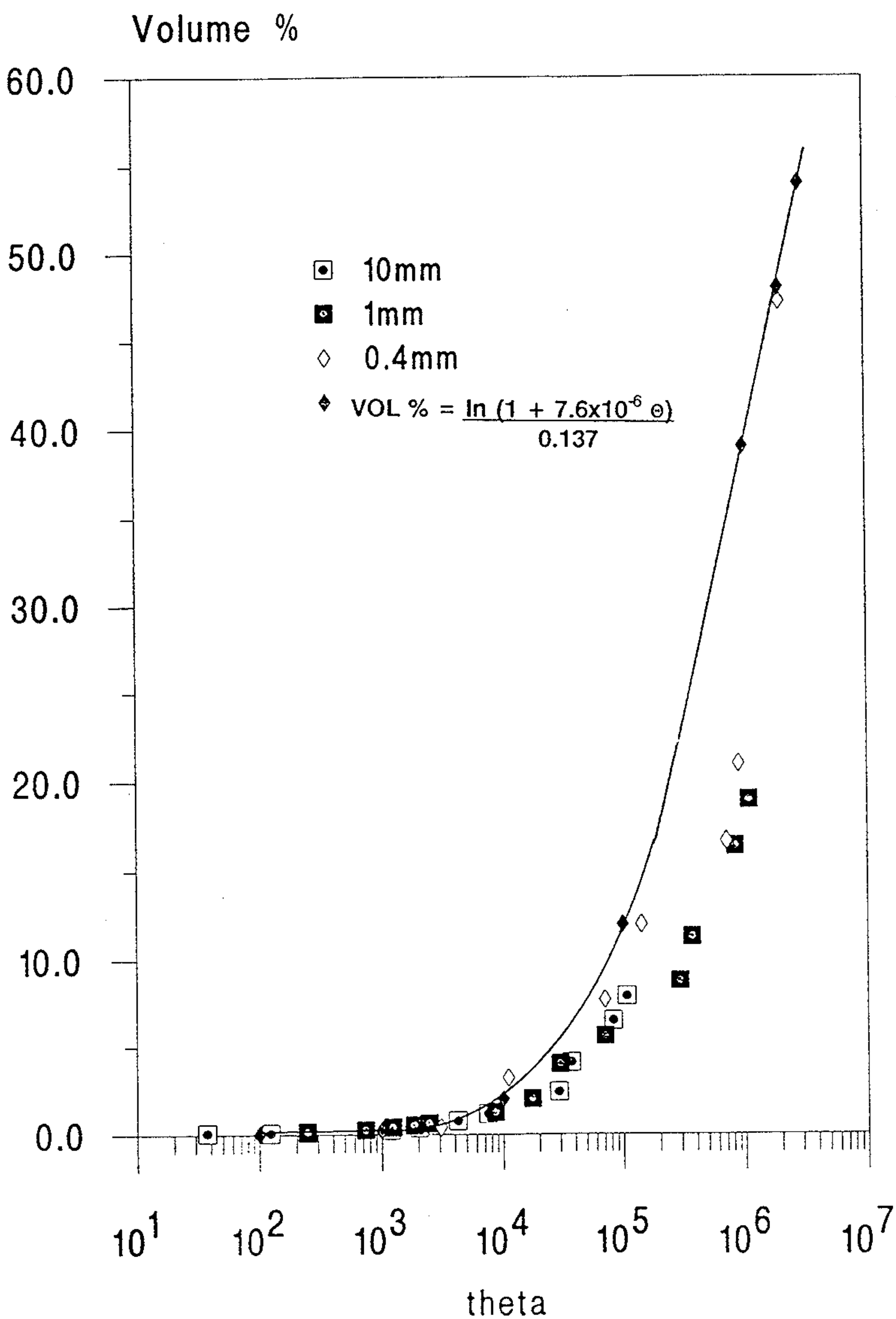


Figure 34: Evaporation curves for ASMB (Volume % versus Θ) Experiments performed outdoors.

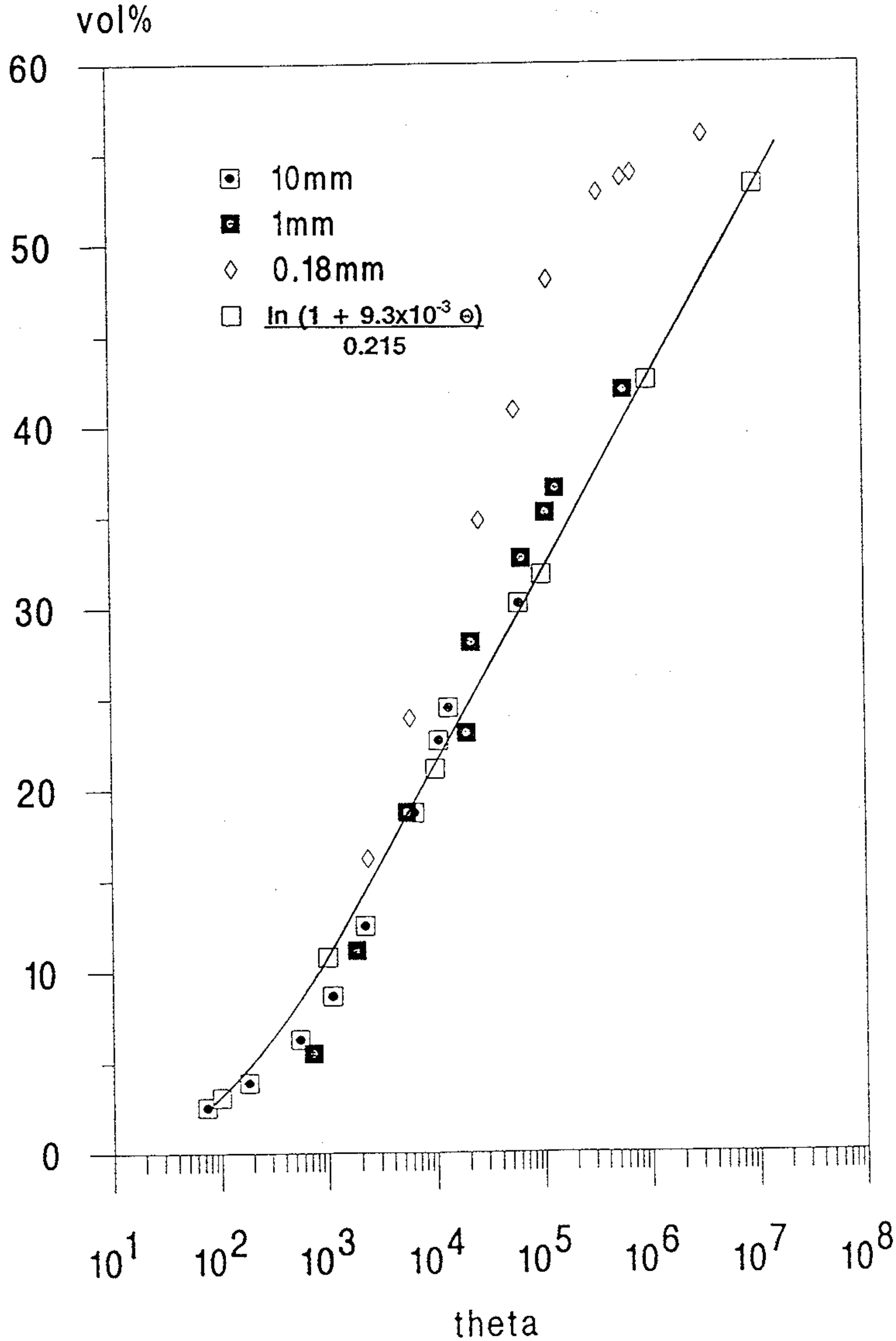


Figure 35: Evaporation curves for Amauligak (Volume % versus θ) Experiments performed outdoors.

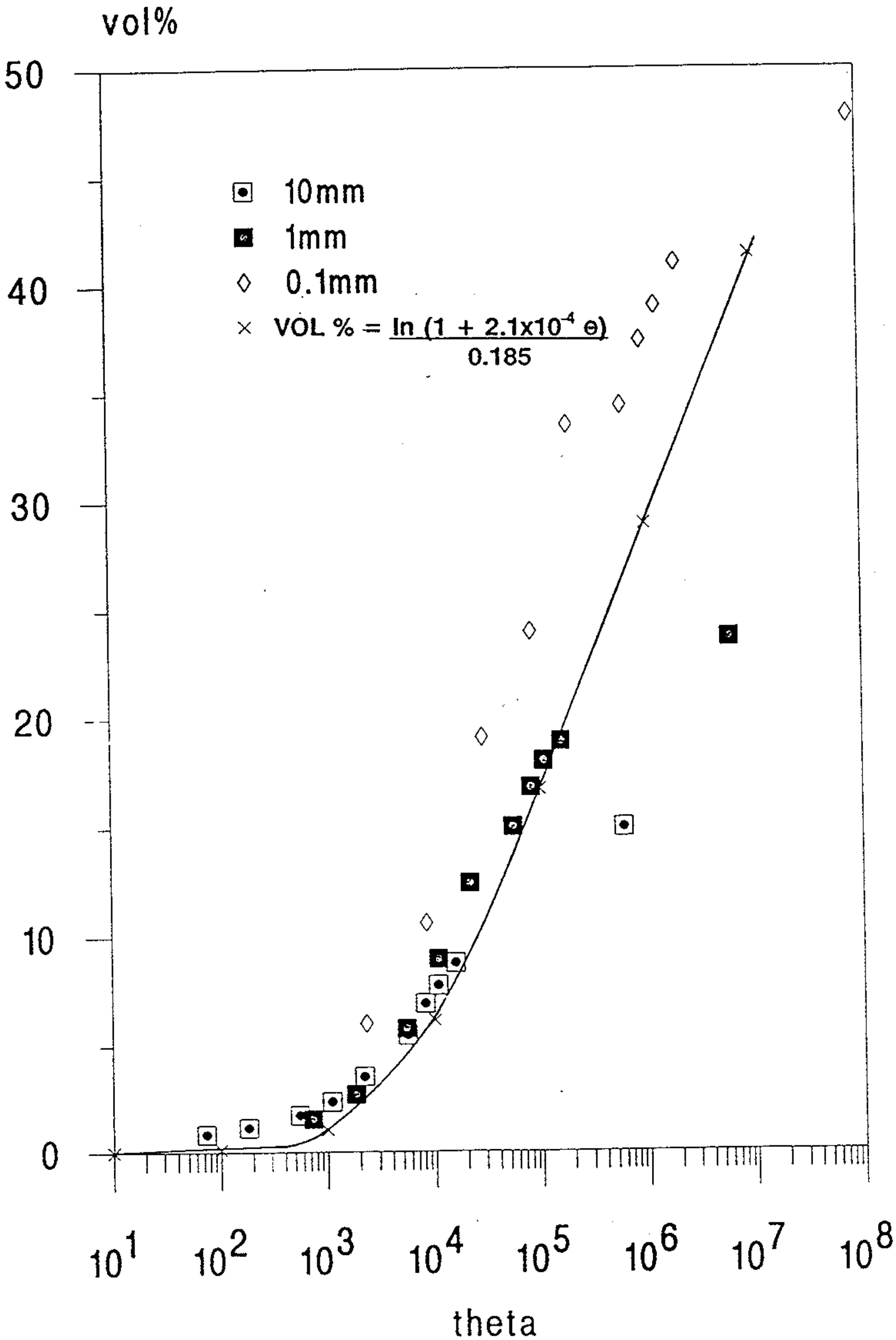


Figure 36: Evaporation curves for Bent Horn (Volume % versus Θ)
Experiments performed outdoors.

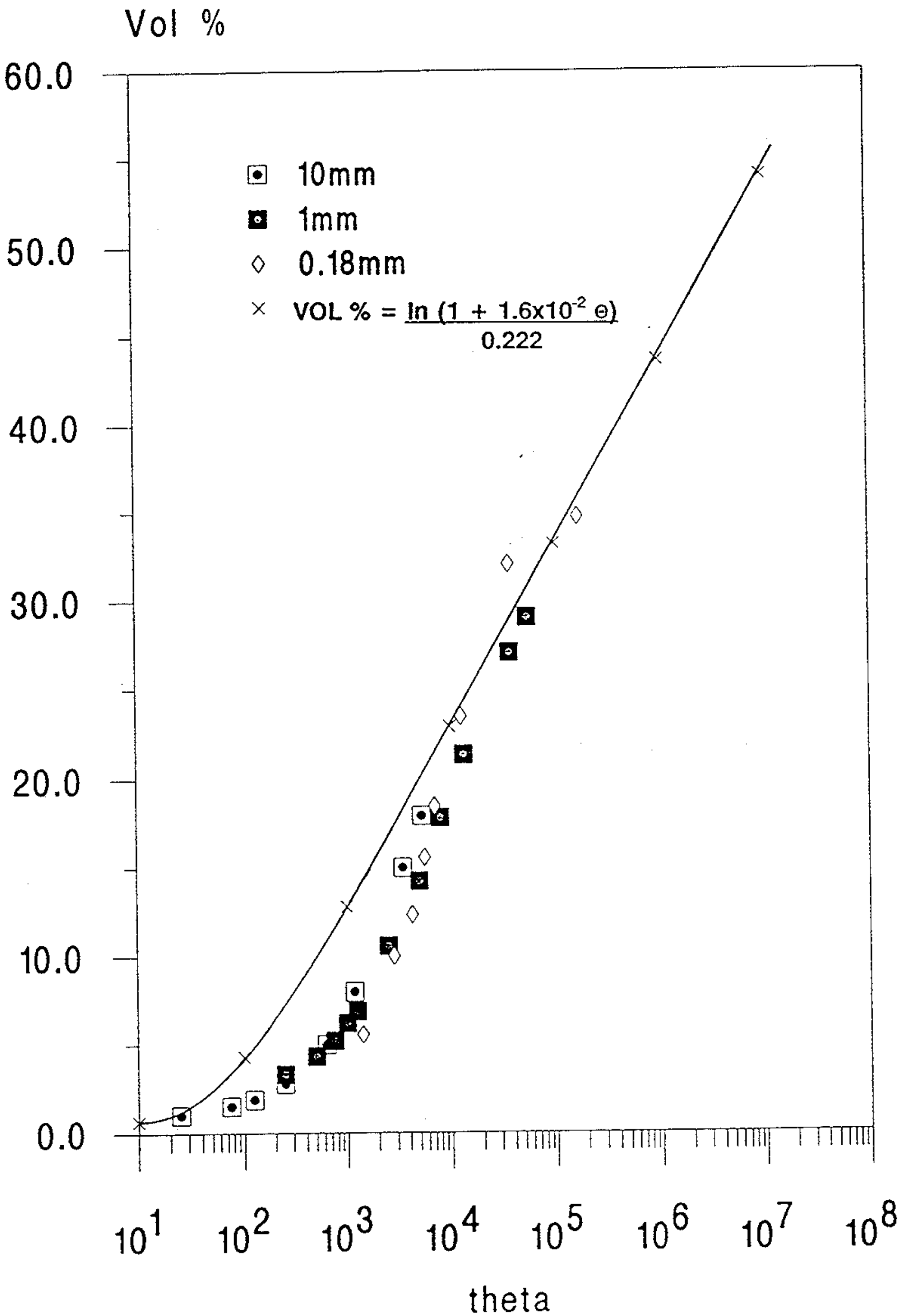


Figure 37: Evaporation curves for Diesel (Volume % versus Θ) Experiments performed outdoors.

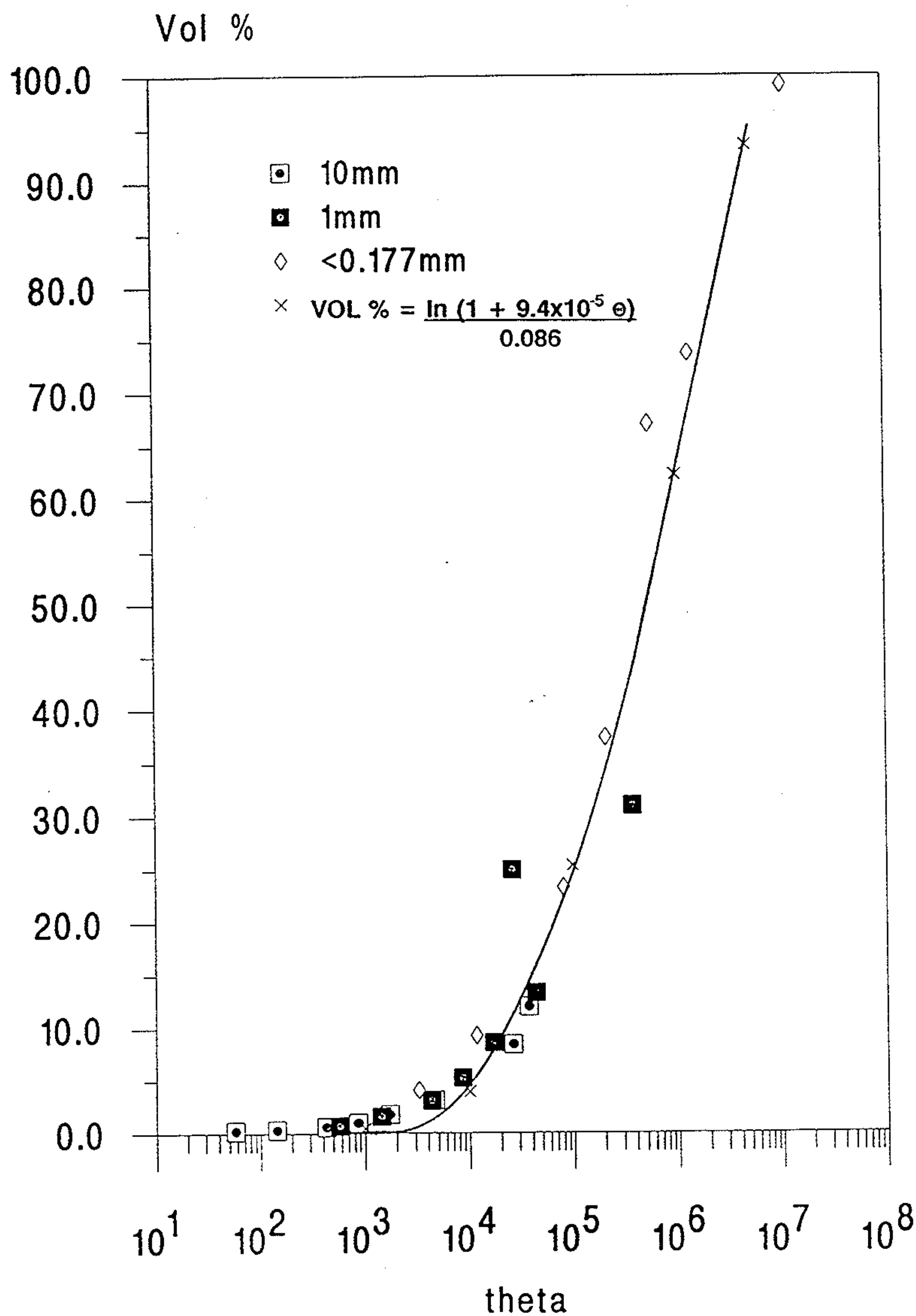


Figure 38: **Evaporation curves for Endicott (Volume % versus ϴ) Experiments performed outdoors.**

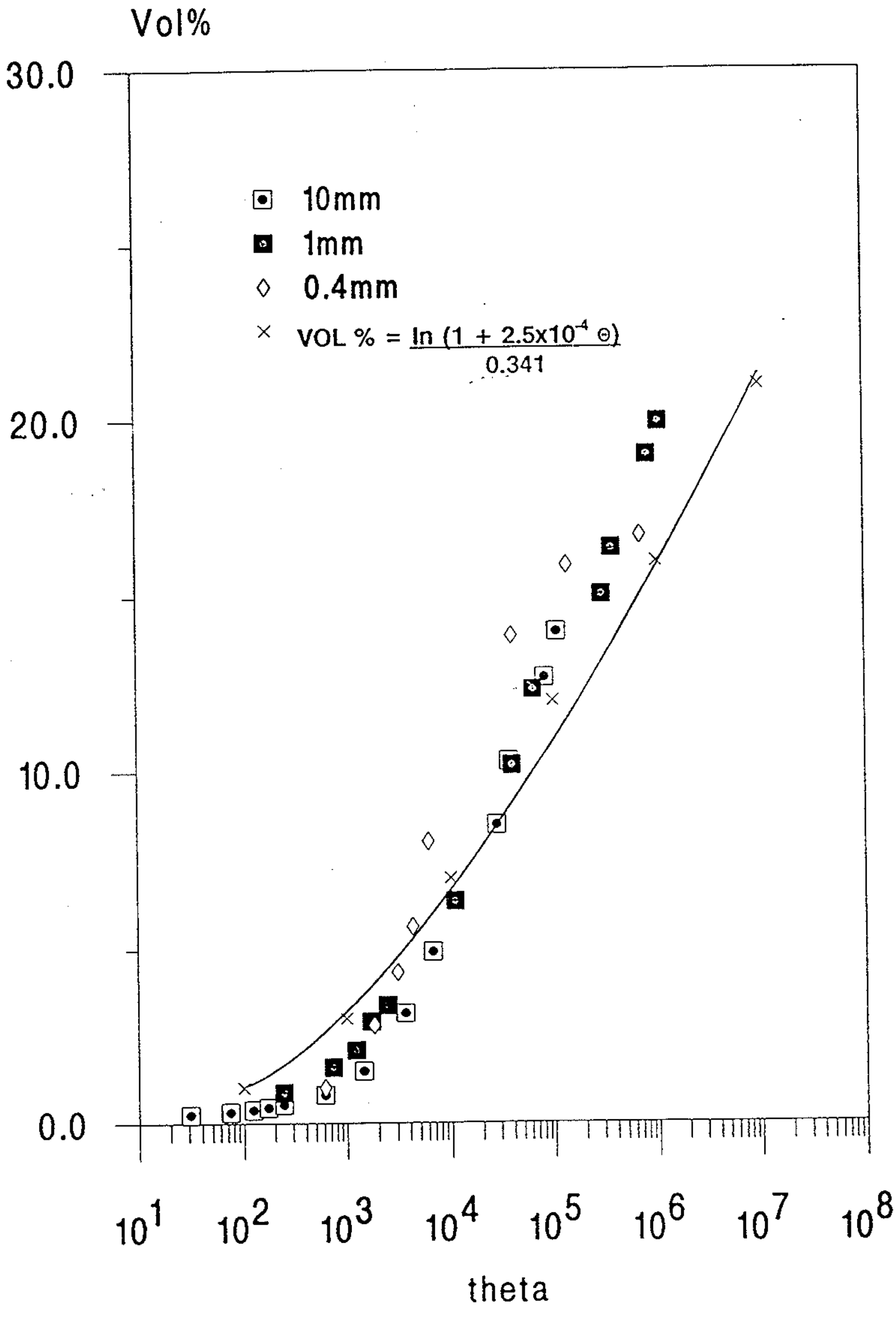


Figure 39: Evaporation curves for North Slope (Volume % versus ϴ) Experiments performed outdoors.

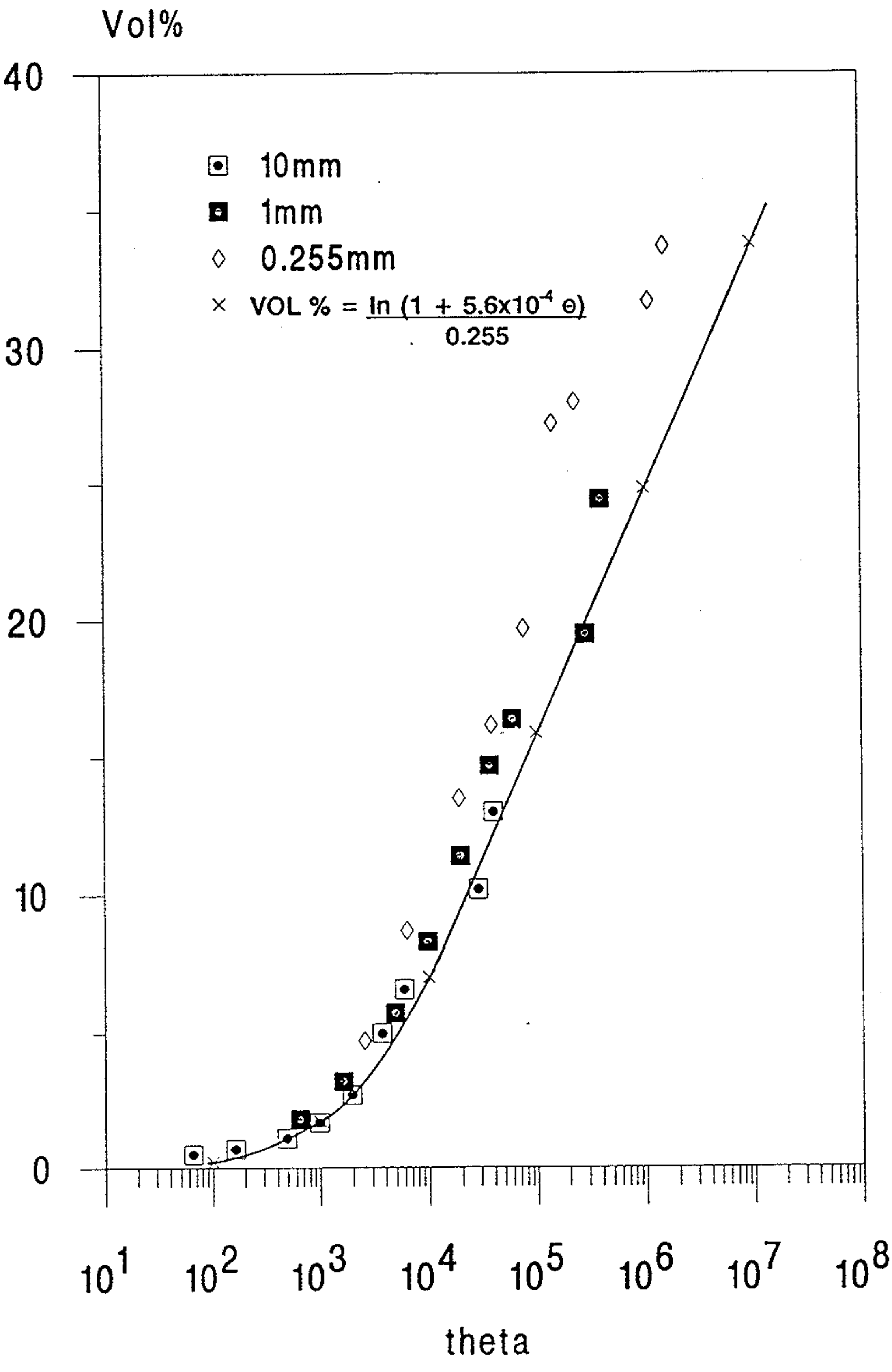
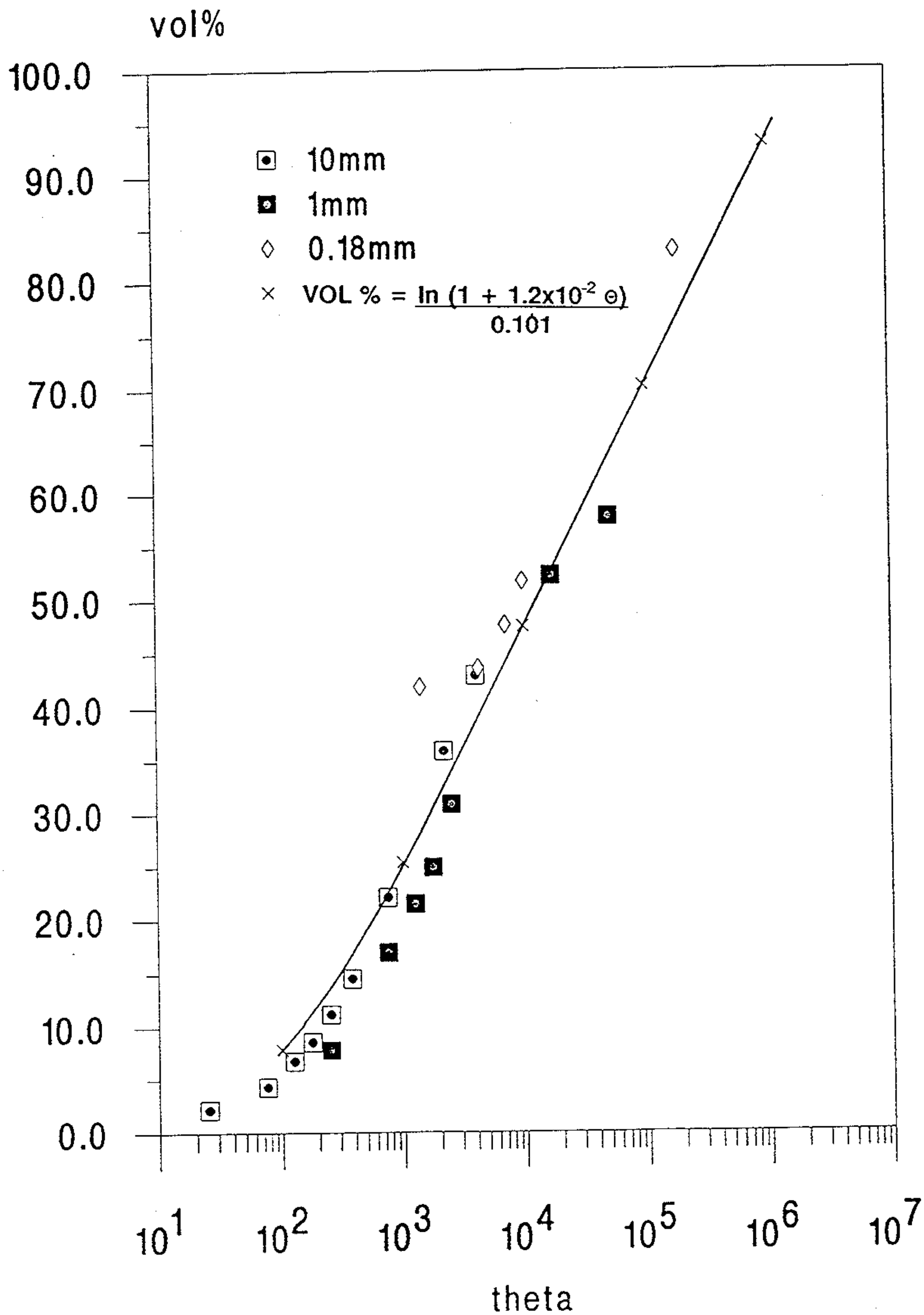


Figure 40: Evaporation curves for Panuke (Volume % versus Θ) Experiments performed outdoors.



2.5 CONCLUSIONS

Evaporation experiments were conducted on 8 oils. The effect of oil layer thickness on evaporation was studied in detail. Under the exposure conditions used in this study, the evaporative exposure method adequately compensated for the effect of slick thickness on evaporation. Two oils of high wax content showed slight increases in resistance to evaporation as oil layer thickness was increased. Thicker oil layers therefore experienced slightly lower evaporation rates at high evaporative exposure values, θ, than thin oil layers. The likely cause of this phenomenon is the formation of waxy crusts which cause an oil phase resistance. These observations are in contrast to results previously reported by Ross and Mackay (1988).

Estimates of evaporation based on the equation developed by Stiver and Mackay (1984) were compared to the experimental data. Accuracy of this equation was found to be dependent upon the oil. The equation provided a good fit to the data for what would be considered typical oils since the constants used in the equation are based upon data obtained from typical oils. It was shown that improved predictions could be obtained if the constants used were determined for the each individual oil.

3.0 METHODS OF ACCELERATING EVAPORATION

3.1 INTRODUCTION

The three techniques that are commonly used to artificially weather oils for testing purposes are: gas stripping, thin-film tray evaporation, and distillation. Details regarding the use of each technique are given by Stiver (1984). As will be discussed, each method has its advantages and disadvantages. The objective of this part of the project was to investigate new methods of quickly evaporating oil samples to degrees of weathering which are representative of environmental exposure conditions.

Gas stripping, or more commonly referred to as air bubbling, involves slowly bubbling gas, usually air, through a column of oil. Gas stripping is presently the method employed for the weathering of oil samples during the routine testing of oil properties by the Emergencies Science Division. The flow-rate of air is maintained at a low level that assumes the emerging air is saturated with volatile hydrocarbons. Accurate evaporation curves as a function of evaporative exposure can be obtained using this method. Gas stripping is well suited for weathering of large samples of oil, such as the 1 L samples needed for the testing of physical properties (Bobra and Callaghan, 1990). The main drawbacks of gas stripping are that it is a relatively slow process and the degree of evaporation achieved is far less than that normally experienced in the environment. For practical purposes, the technique is limited to evaporative exposure values of less than 100,000. It takes several weeks of stripping to approach this value. In the natural environment, a 1 millimetre thick slick exposed to a wind of 10 m/s experiences this same exposure in slightly over 2 hours. Therefore, samples weathered by gas stripping are representative of oil which has, experienced only a few hours of weathering in a real spill situation.

Thin-film tray evaporation more closely simulates environmental situations. The technique involves passing air over a film of oil of a few millimetres in thickness. Unfortunately, this technique normally requires the use of a wind tunnel which is not readily amendable to all laboratory settings. The procedure also requires a relatively large exposed surface area for a given volume of oil.

Distillation can be used to "top" oil to provide simulated samples of weathered oils for property measurements. Distillation can quickly provide large samples of oil which are believed to have approximately the same composition as naturally weathered oil. However, the thermal effects of distillation on oil properties have not been clearly established in comparison to oil evaporated under isothermal conditions.

The purpose of this part of the study was to identify and test new techniques of evaporation which could be applied to oil on a laboratory size scale. The final objective was to select a method that would either replace or augment the presently used air stripping technique. Ideally for oil testing purposes, the technique chosen should weather 1 litre samples of oil to high values of θ (10^6-10^7) within a short period of time.

3.2 GAS STRIPPING AT ELEVATED TEMPERATURES

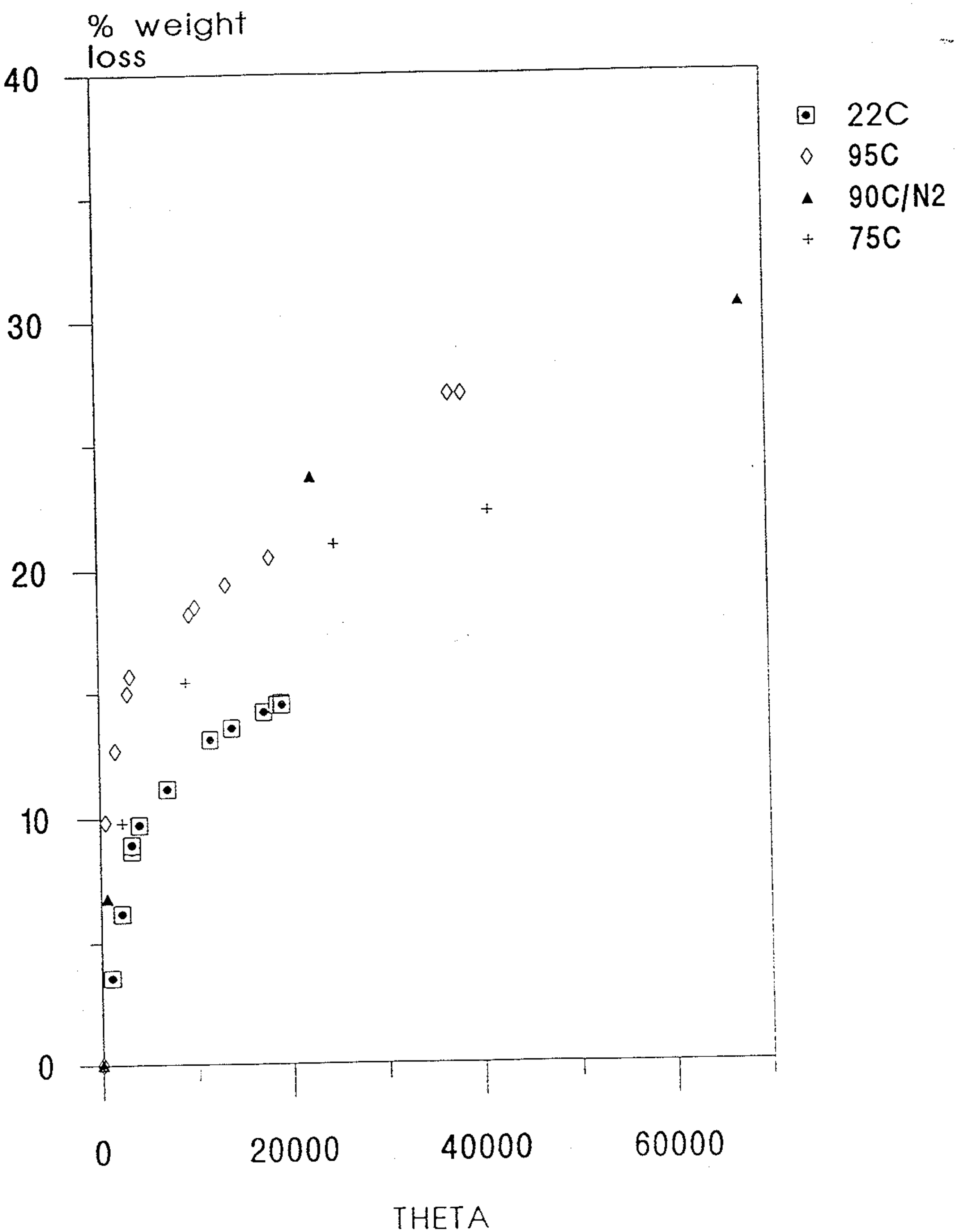
3.2.1 Experimental Section

A 100 millilitres gas stripping apparatus was used to evaporate North Slope Crude oil. The procedure followed is that described by Stiver and Mackay (1983). Gas stripping at elevated temperatures was performed by immersing the graduated cylinder in a silicone oil bath. Unless it is otherwise noted, air was the stripping gas. Nitrogen (N_2) was used in one experiment.

3.2.2 Results and Discussion

Figure 41 shows the evaporation curves using air stripping at 22°C, 75°C and 90°C, and at 95°C using nitrogen stripping. As anticipated elevated temperatures accelerated the rate of evaporation. However, this increased rate of evaporation was marginal and was far short of the desired rate. It was noted that above 75°C, there were obvious signs of thermal degradation of the samples after several days. This degradation was seen in samples stripped with both air and nitrogen. This phenomenon alone makes this method unsuitable for producing artificially weathered samples for the testing of properties.

Figure 41: Gas stripping of North Slope Crude Oil.



3.3 EVAPORATION USING A TURBOVAP 500 CONCENTRATOR

3.3.1 Experimental Section

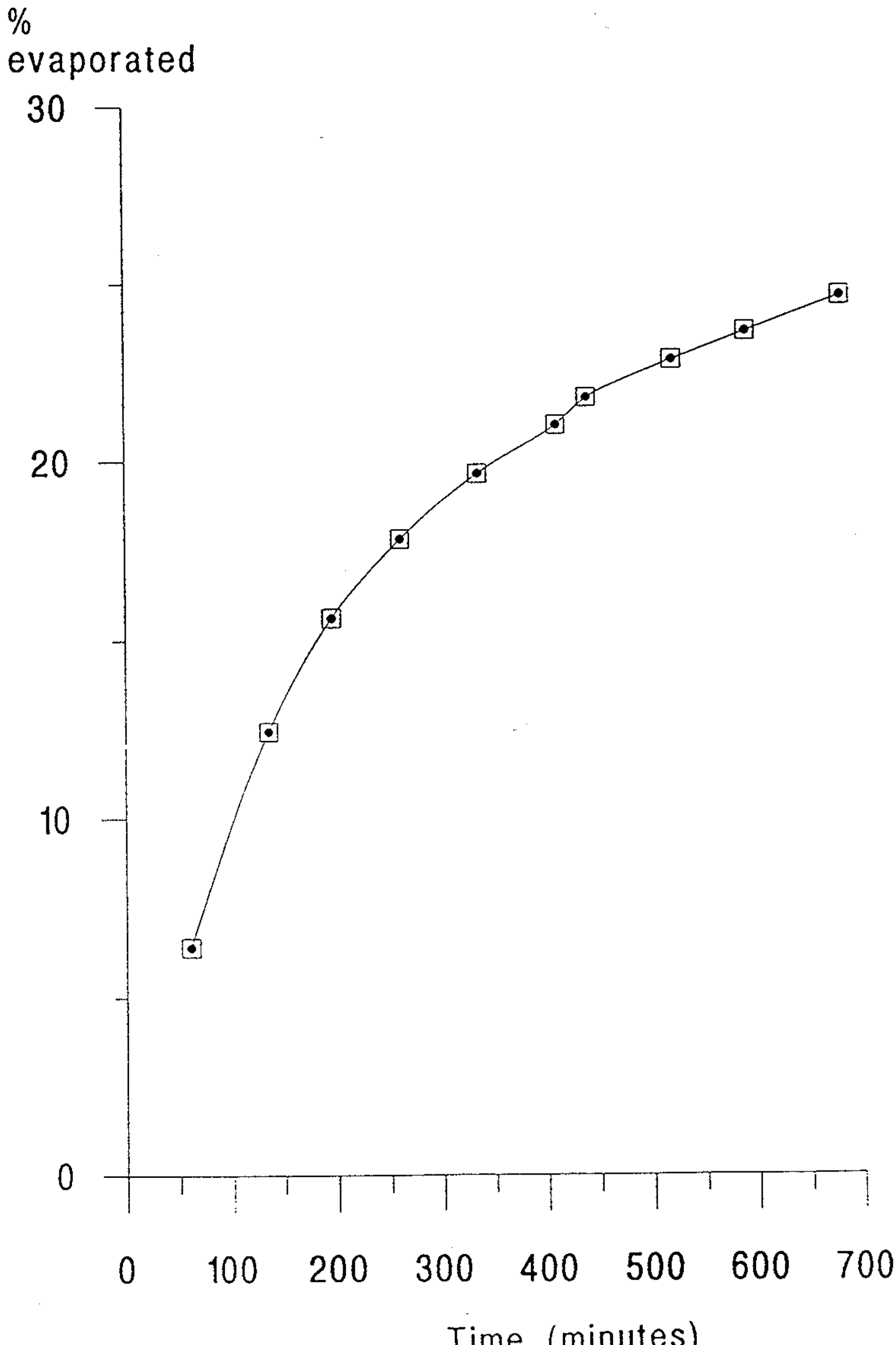
A Zymark Turbovap 500 Closed Cell Concentrator (Zymark Corporation, Hopkinton, MA) was tested using ASMB crude oil. The Concentrator uses a high speed fan to create a "gas vortex shearing" action at the surface of the sample. The Concentrator is marketed as an alternative to traditional rotary evaporators for extract concentration.

3.3.2 Results and Discussion

After preliminary testing, it was determined that the maximum sample size that could be used without excessive splattering within the concentrator was 250 millilitres. Any oil that splatters is lost, as a result this leads to errors in the mass balance. Preliminary tests indicated that a bath temperature of 60°C and a fan speed of 5000 rpm were optimum. The evaporation curve is shown in Figure 42. After 11 hours of operation, 24.5% was evaporated. This is approximately the same loss that can be achieved in slightly over 1 week using the 1 L gas stripping apparatus.

The relatively small sample size that can be weathered using the TurboVap means that multiple samples would have to be run in order to generate sufficient weathered sample for the testing of its properties. This instrument is designed for use with low viscosity solvents whose surfaces become highly agitated as a result of the action of the fan. Samples with higher viscosities, such as crude oils, do not experience this level of agitation. Therefore, the machine losses much of its effectiveness as the oil becomes more viscous.

Figure 42: Weight % evaporated versus time using Zymark Concentrator. ASMB.



3.4 EVAPORATION USING A ROTARY EVAPORATOR

3.4.1 Experimental section

The roto-evaporator used was a Buchi Rotovapor Model RE121. In all experiments the evaporation vessel was a 500 millilitres round bottom flask. The evaporator was operated in two different configurations: the inlet feed line was left open which allowed a continuous stream of air to pass through the system at a flow rate of approximately 24 L/s; or the inlet feed line was closed thus creating a constant vacuum of 650 millilitres Hg. The evaporation flask was operated at a rotation speed of 220 rpm. Experiments were performed with bath temperatures of 80°C, 60°C, 40°C and 20°C. The weight change of the oil sample was measured as a function of time.

3.4.2 Results and Discussion

The results of experiments using North Slope Crude Oil are presented in Figures 43 to 49. Figure 43 shows the weight percent evaporated from North Slope Crude Oil as a function of time with the Rotovapor operated with the inlet feed line open. Figure 44 shows the weight percent evaporated as a function of time with the Rotovapor operated with the inlet feed line closed. Clearly, significantly higher degrees of evaporation are obtained when the system is operated in the configuration where the inlet feed line is open.

Figure 43: Weight % evaporated as a function of time in rotary evaporator. North Slope.

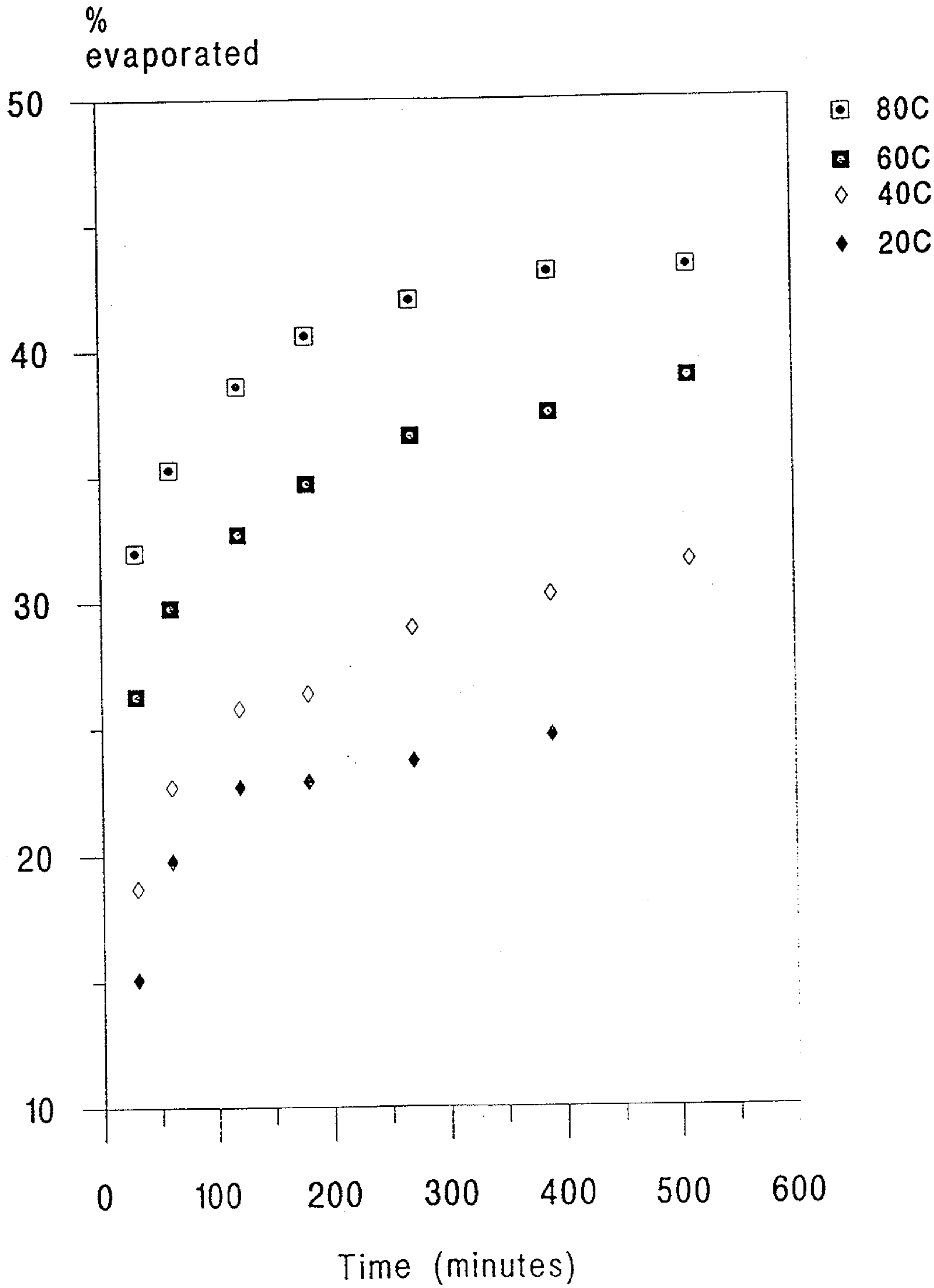


Figure 44: **Weight % evaporated as a function of time in rotary evaporator. Roto-evaporator under vacuum. North Slope.**

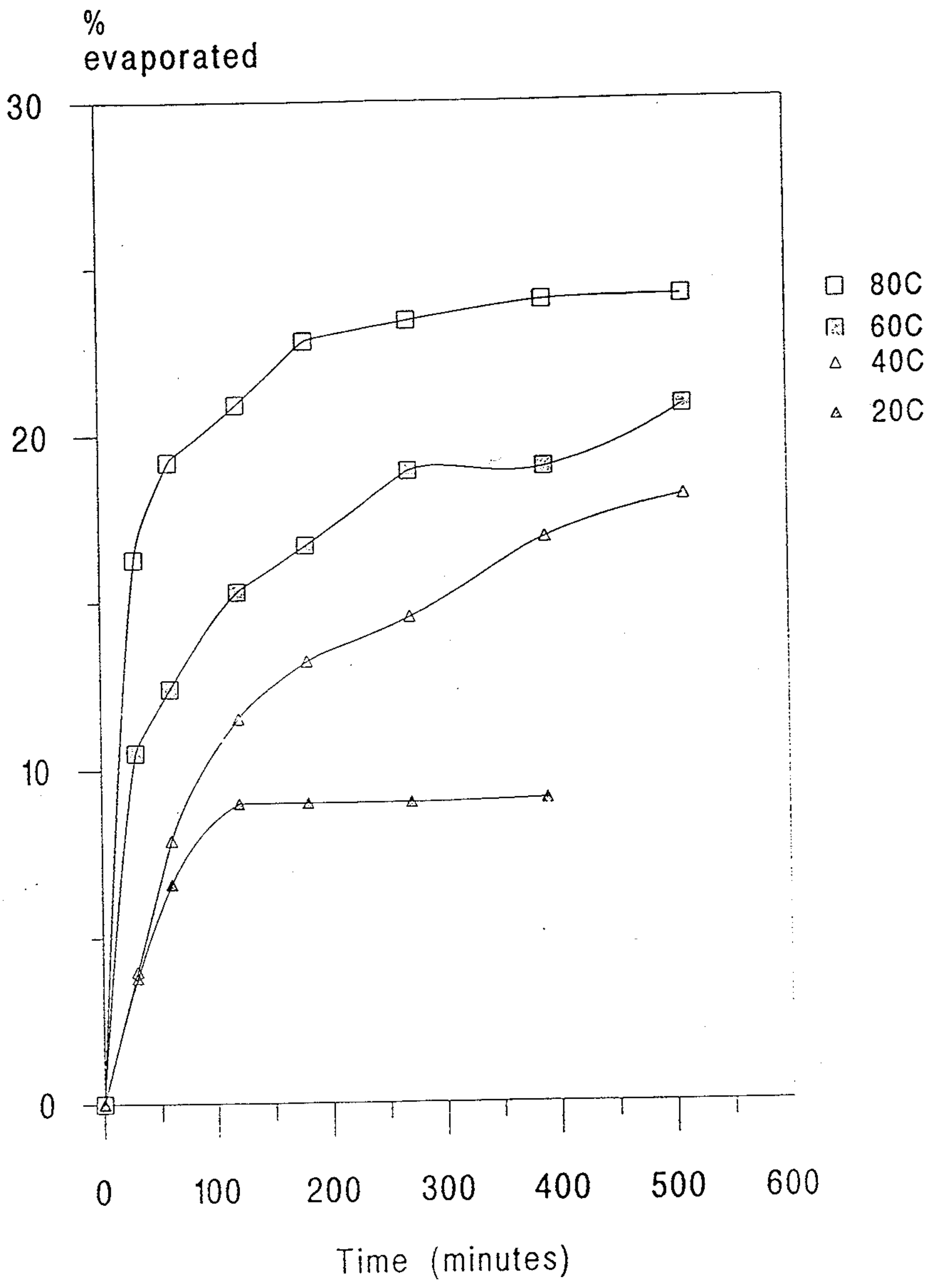


Figure 45: Time versus equivalent topping temperature for Bureau of Mines Distillation. North Slope.

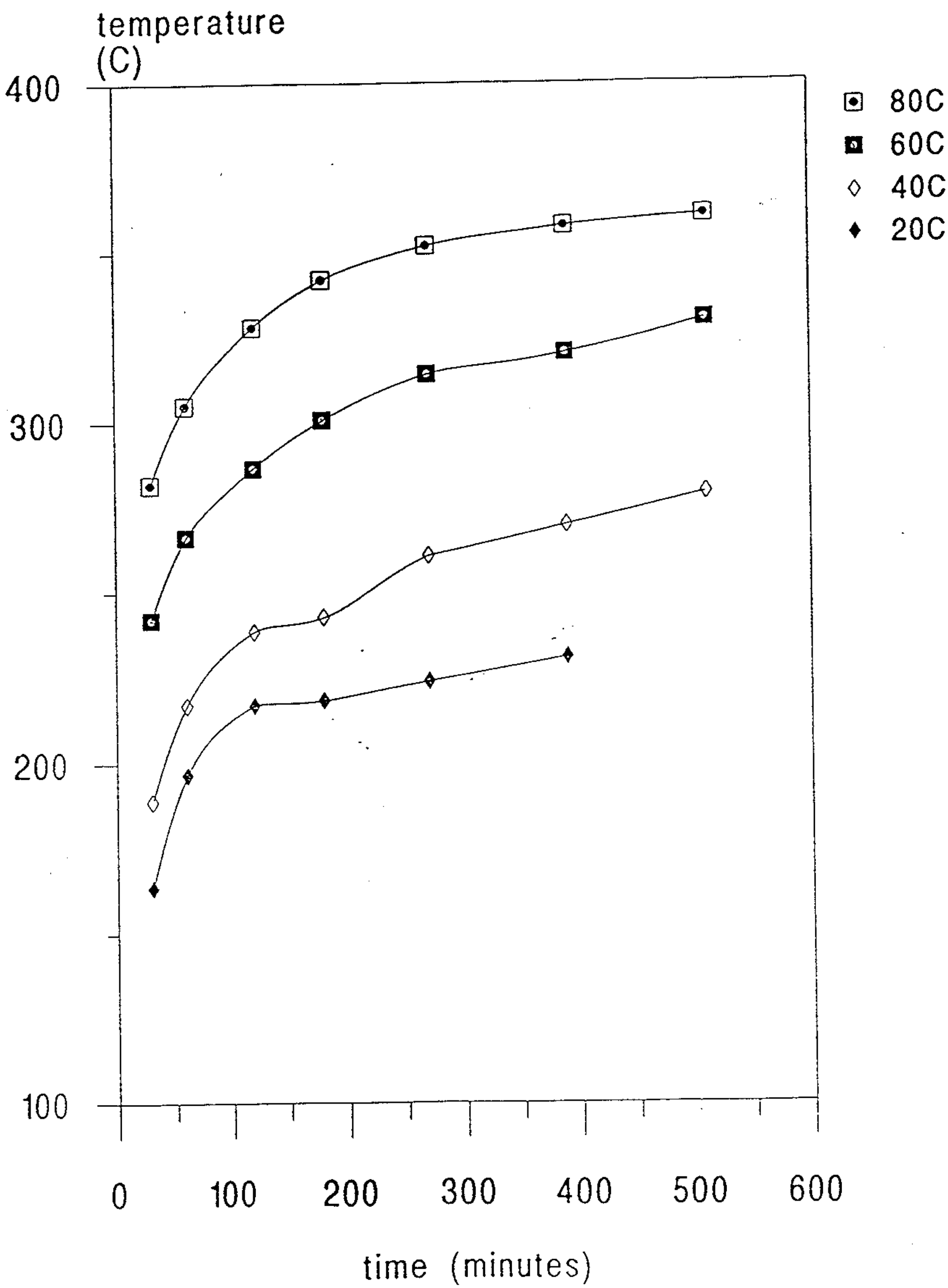


Figure 46: **Time versus equivalent topping tempersture for Aalund's Assay Distillation. North Slope.**

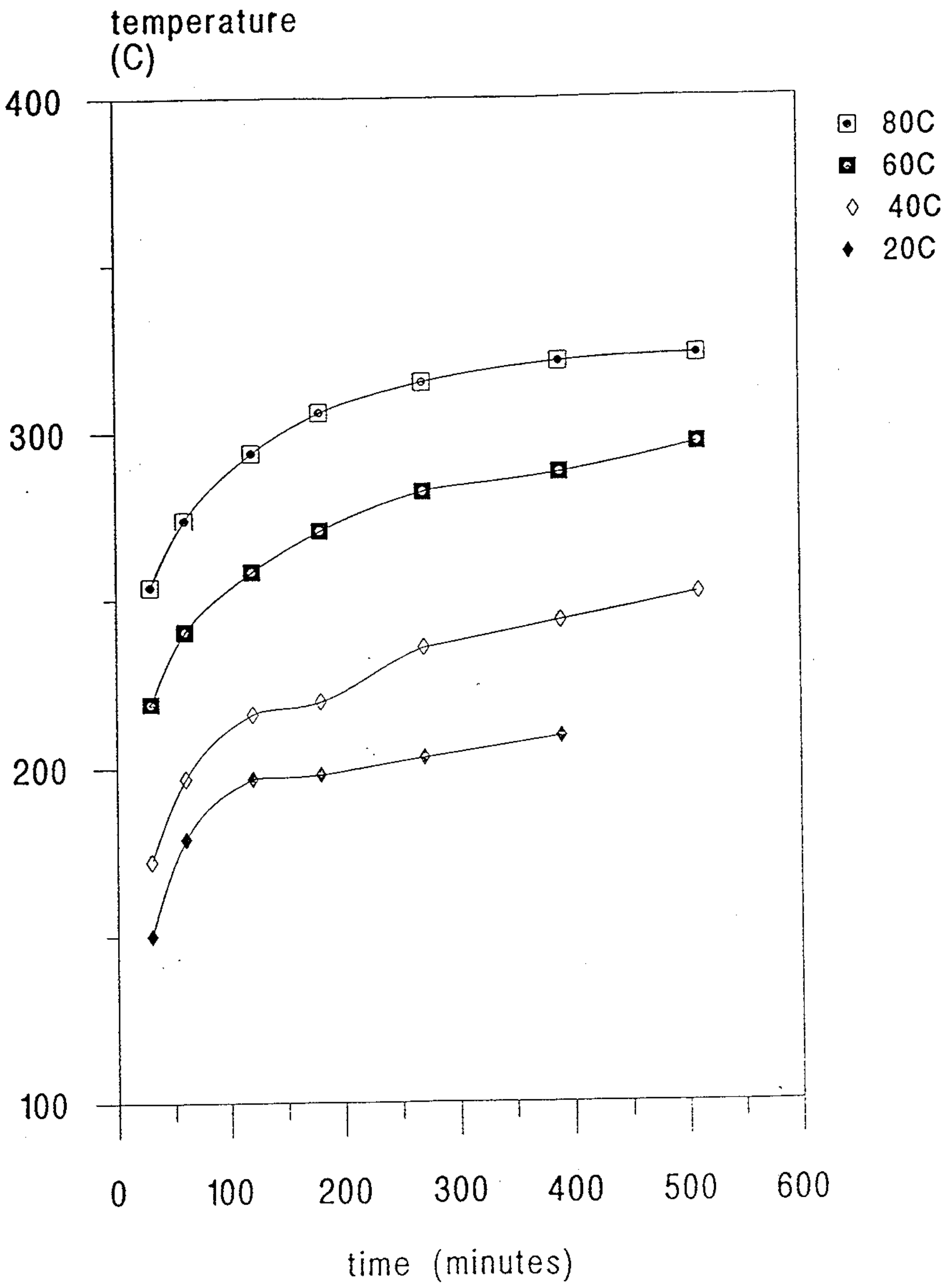


Figure 47: **Time versus equivalent topping temperature ESD distillation measuring liquid temperature. North Slope.**

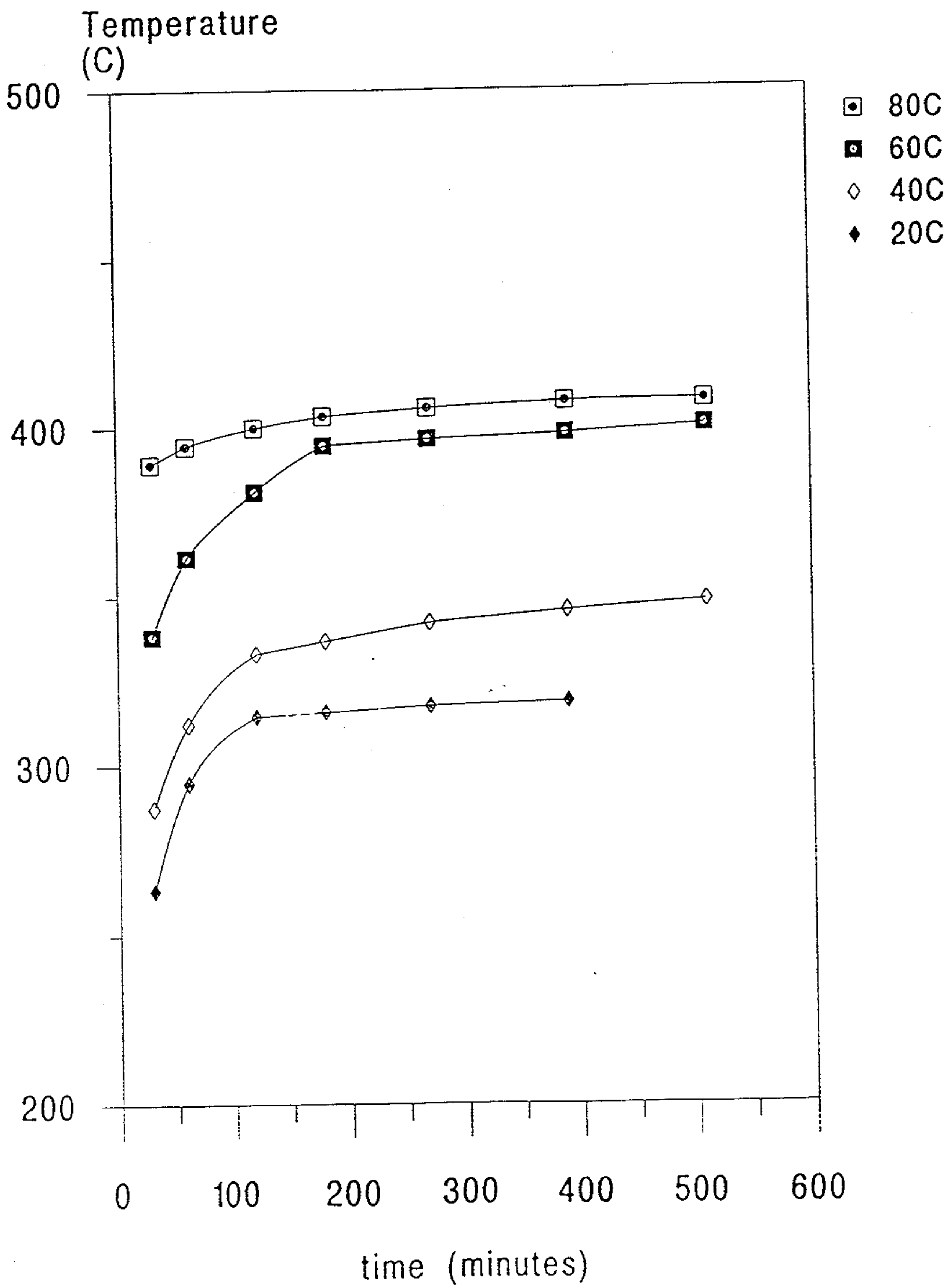
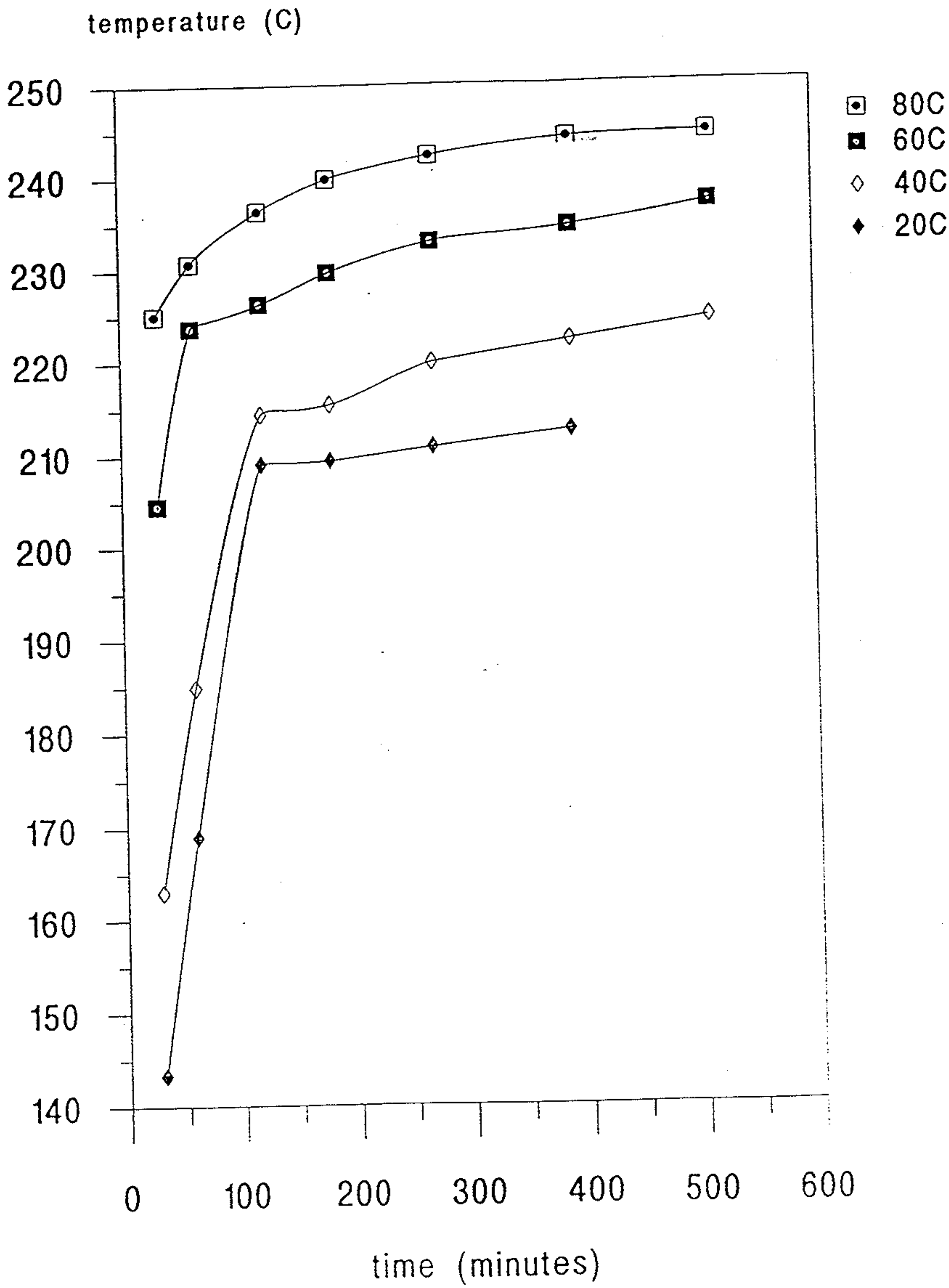


Figure 48: **Time versus equivalent topping temperature for ESD distillation measuring vapour temperature. North Slope.**



Figures 45 to 48 show correlations between the equivalent topping temperature for different methods of distillation and the length of time the oil was evaporated in the Rotovapor. At a bath temperature of 80°C, topping temperatures equal to the cut range of petroleum residuum could be reached within a couple of hours. For the Bureau of Mines distillation and Aalund's Assay distillation, residuum is considered to have boiling temperatures of 300+°C. Data for the Bureau of Mines distillation and Aalund's Assay distillation are taken from Coleman et al. (1978) and Aalund (1983), respectively.

Equivalent θ (theta) values (at 22°C) are shown in Figure 49 as a function of time in the Rotovapor at the four bath temperatures for North Slope crude oil. The equivalent θ values are taken from the evaporation experiments conducted in the first section of this report. With the Rotovapor operating at 80°C, equivalent θ values in the order of 10^8 can be obtained within two hours. At 60°C, θ values of 10^7 to 10^8 are reached. At 40°C, θ values in the range of 10^6 to 10^7 are achieved. At 20°C, a theta value of 10^6 can be obtained. Table 3 shows the approximate time it would take for 3 slicks of different thickness to reach θ values of 10^5 to 10^8 when exposed to a wind with a velocity of 5 m/s.

Table 3: Approximate time to reach specified θ values as a function of slick thickness. Assumes a wind velocity of 5 m/s.

slick thickness	$\theta = 10^5$	$\theta = 10^6$	$\theta = 10^7$	$\theta = 10^8$
1mm	4 hours	1.5 days	2.5 weeks	5.5 months
0.1mm	23 minutes	4 hours	1.5 days	2.5 weeks
0.01mm	140 seconds	23 minutes	4 hours	1.5 days

Results similar to those obtained with North Slope were achieved with ASMB crude, as is shown in Figures 50 and 51.

Figure 49: Theta equivalent as a function of time and temperature. North Slope.

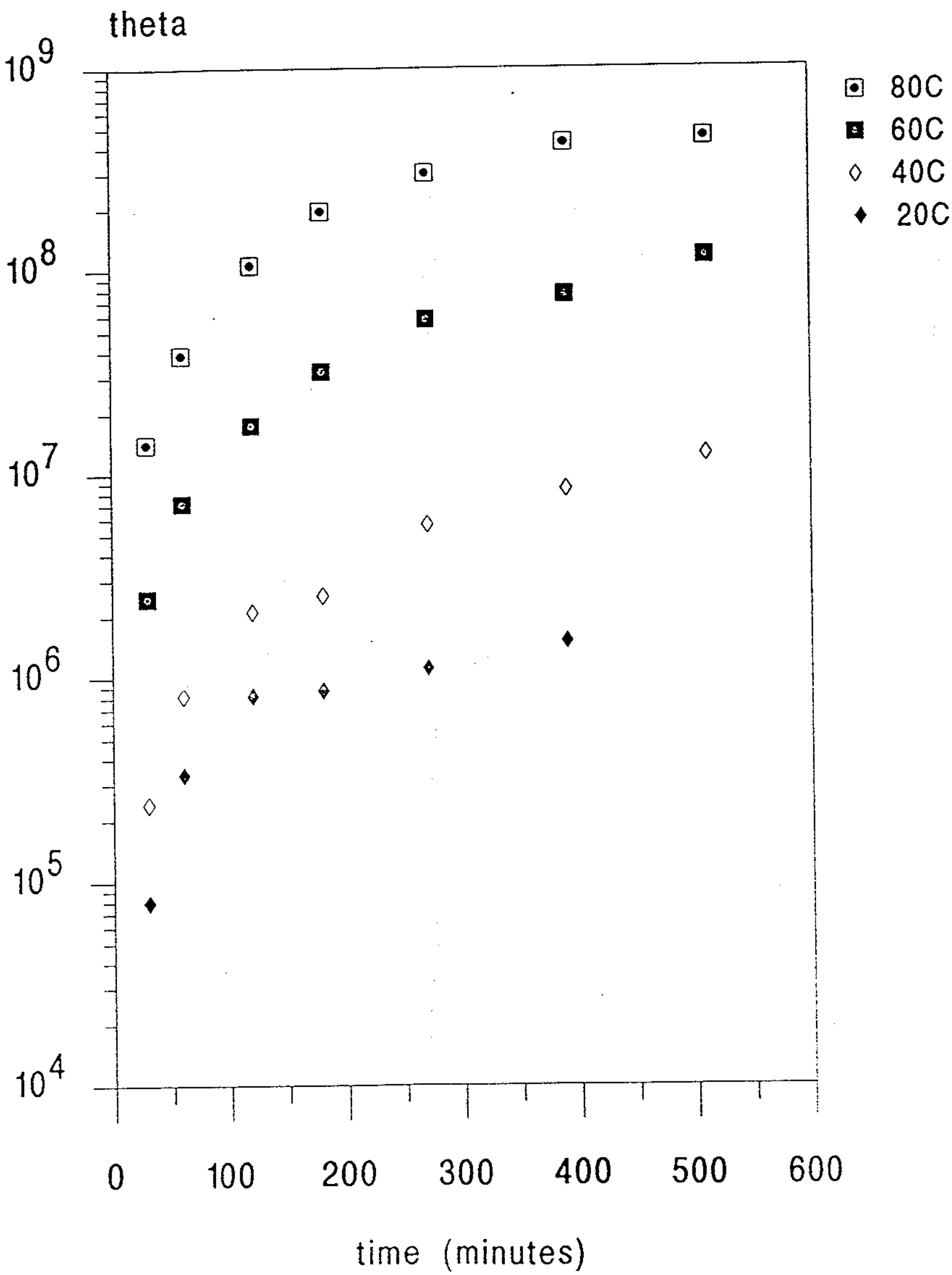


Figure 50: **Weight % evaporated as a function of time. ASMB.**

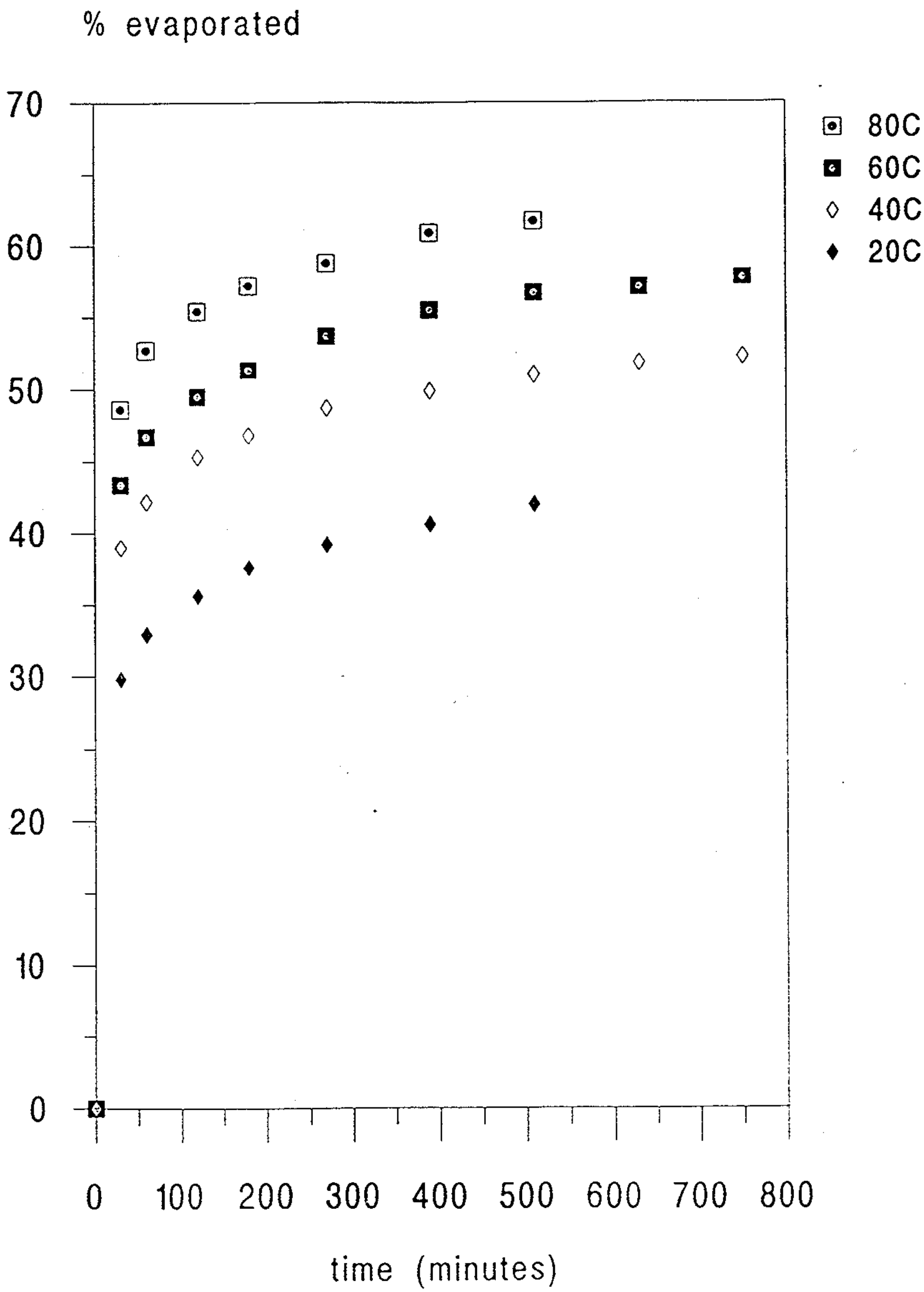
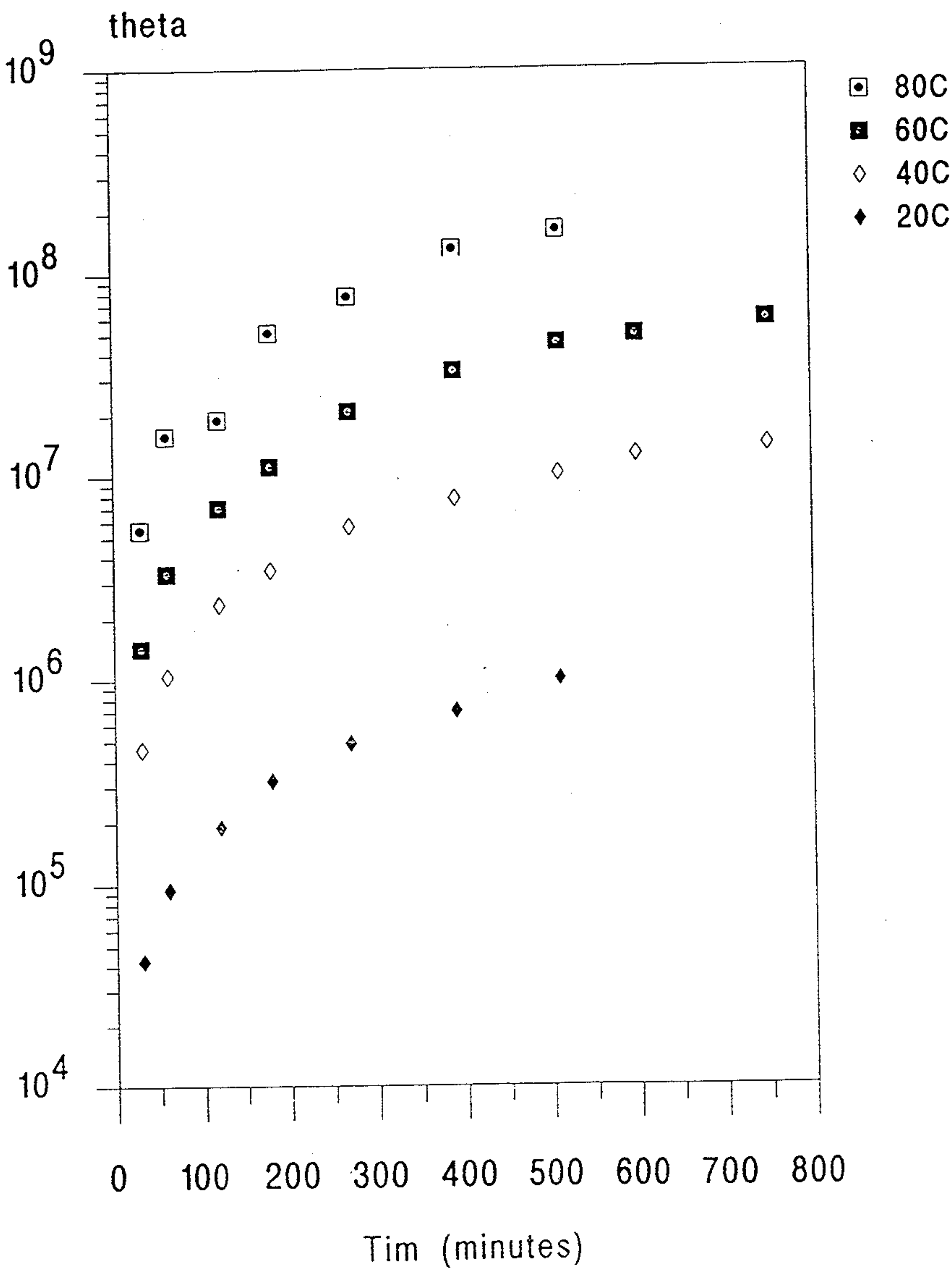


Figure 51: Theta equivalent as a function of time and temperature. ASMB.



3.5 CONCLUSIONS

Three techniques were evaluated as potential methods for rapidly weathering oil. The performance of each technique was compared to the presently used method of air stripping at room temperature. The criteria used were: the technique could be used on sufficiently large samples (1 litre) to allow for the testing of physical properties; the exposure be close to that experienced in spill situations; and the technique reach this state of evaporation within a specified time period.

Gas stripping at elevated temperatures did not provide the desired accelerated rate of evaporation and samples exhibited signs of thermal degradation. Therefore, this technique is unsatisfactory.

Testing of the Zymark Turbovap 500 Concentrator showed that the viscosity of the oil is higher than the design limits of the apparatus. Therefore, the state of evaporation that can be achieved is limited.

Evaporation experiments using a small-scale rotary evaporator indicate that rapid rates of evaporation can be achieved. Time and temperature can be controlled to yield exposures that equate those found in environmental situations. It is anticipated that these results can be duplicated with larger scale rotary evaporators. Tests with a 10 litre bench top Wheaton rotary evaporator are pending its arrival.

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APPENDIX

Tables of Experimental Data

Figure 52: Plot of natural log of H versus $T_B/295$. Adgo Crude Oil.

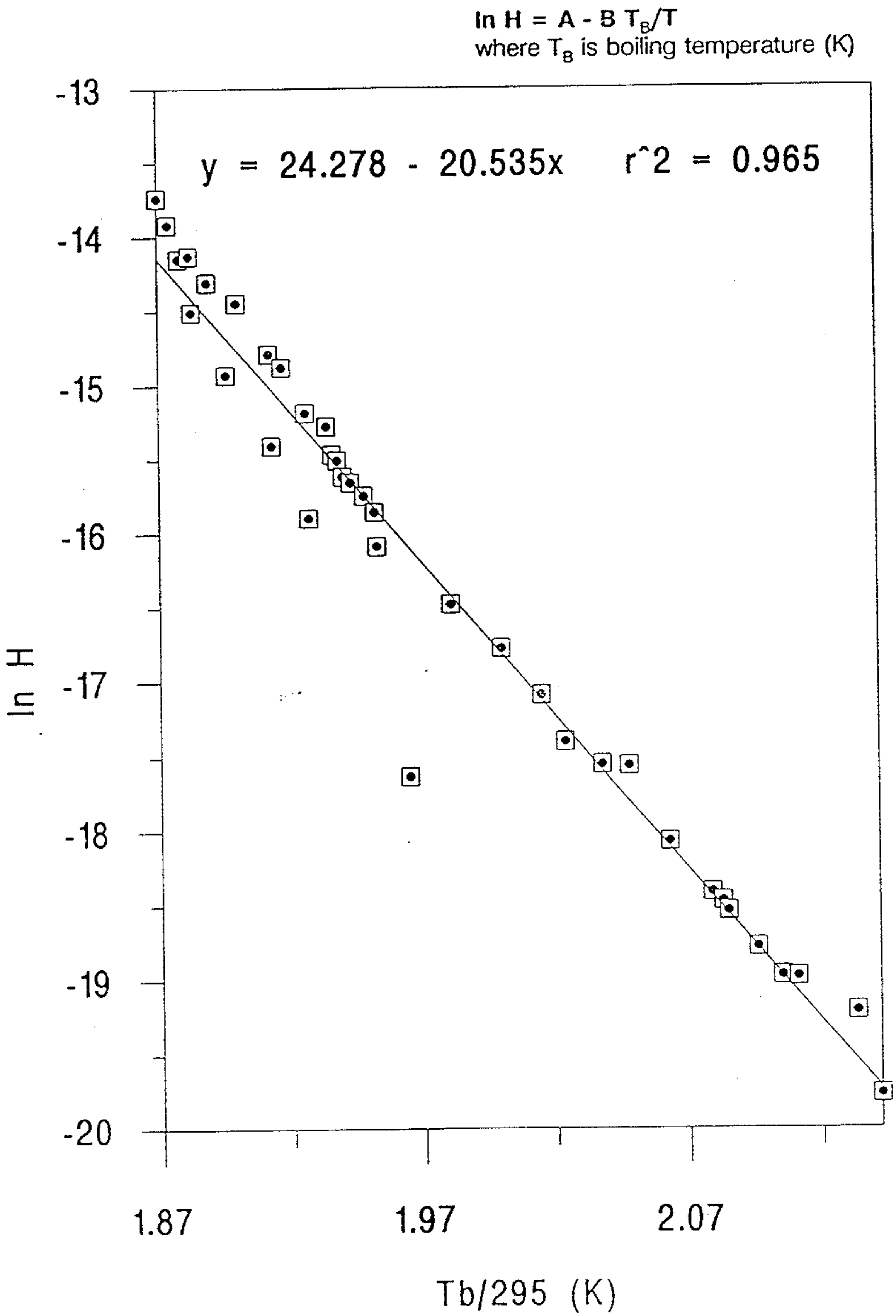


Figure 53: Plot of natural log of H versus $T_B/295$. ASMB Crude Oil.

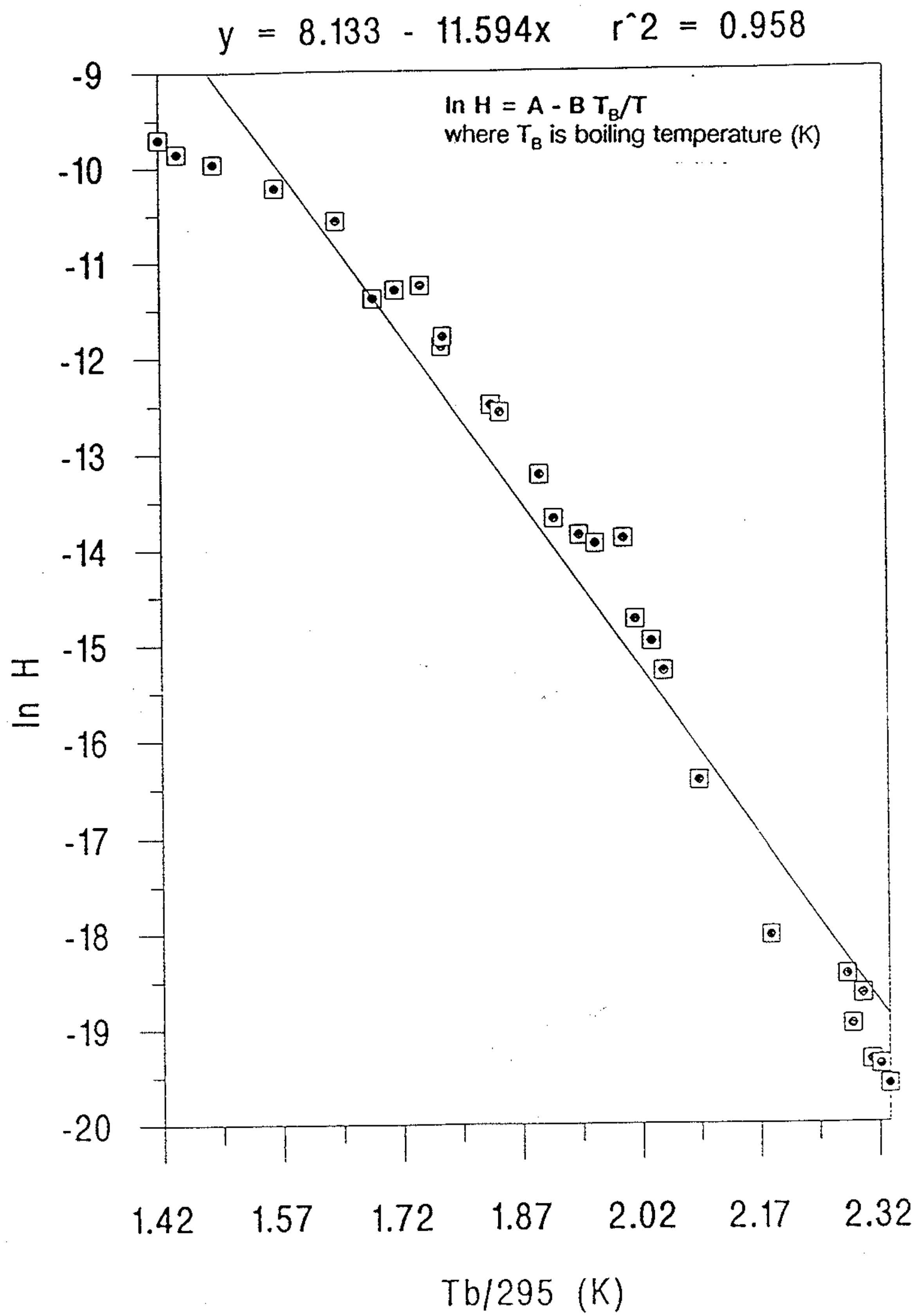


Figure 54: Plot of natural log of H versus T_B/295. Amauligak Crude Oil.

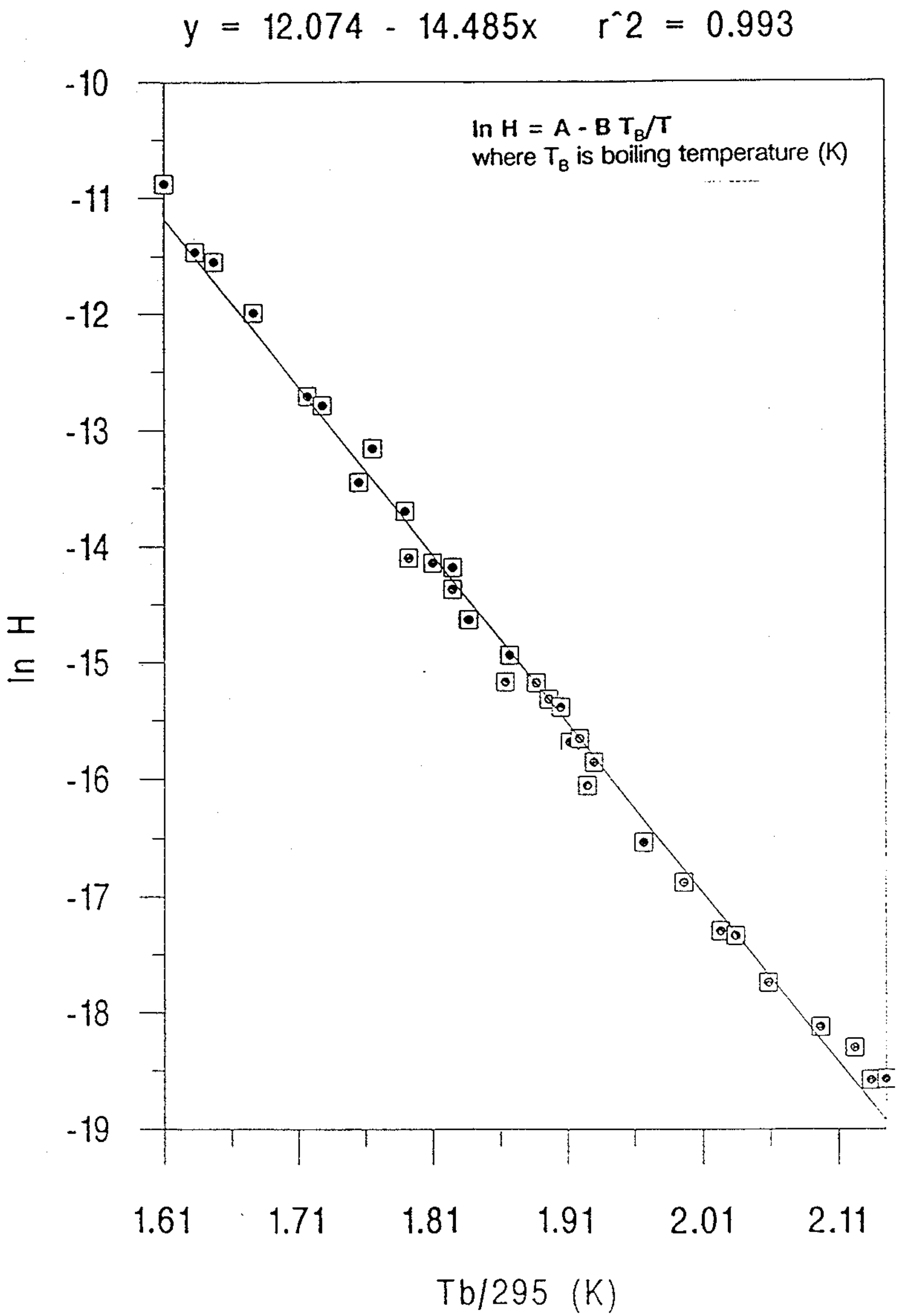


Figure 55: Plot of natural log of H versus $T_B/295$. Bent Horn Crude Oil.

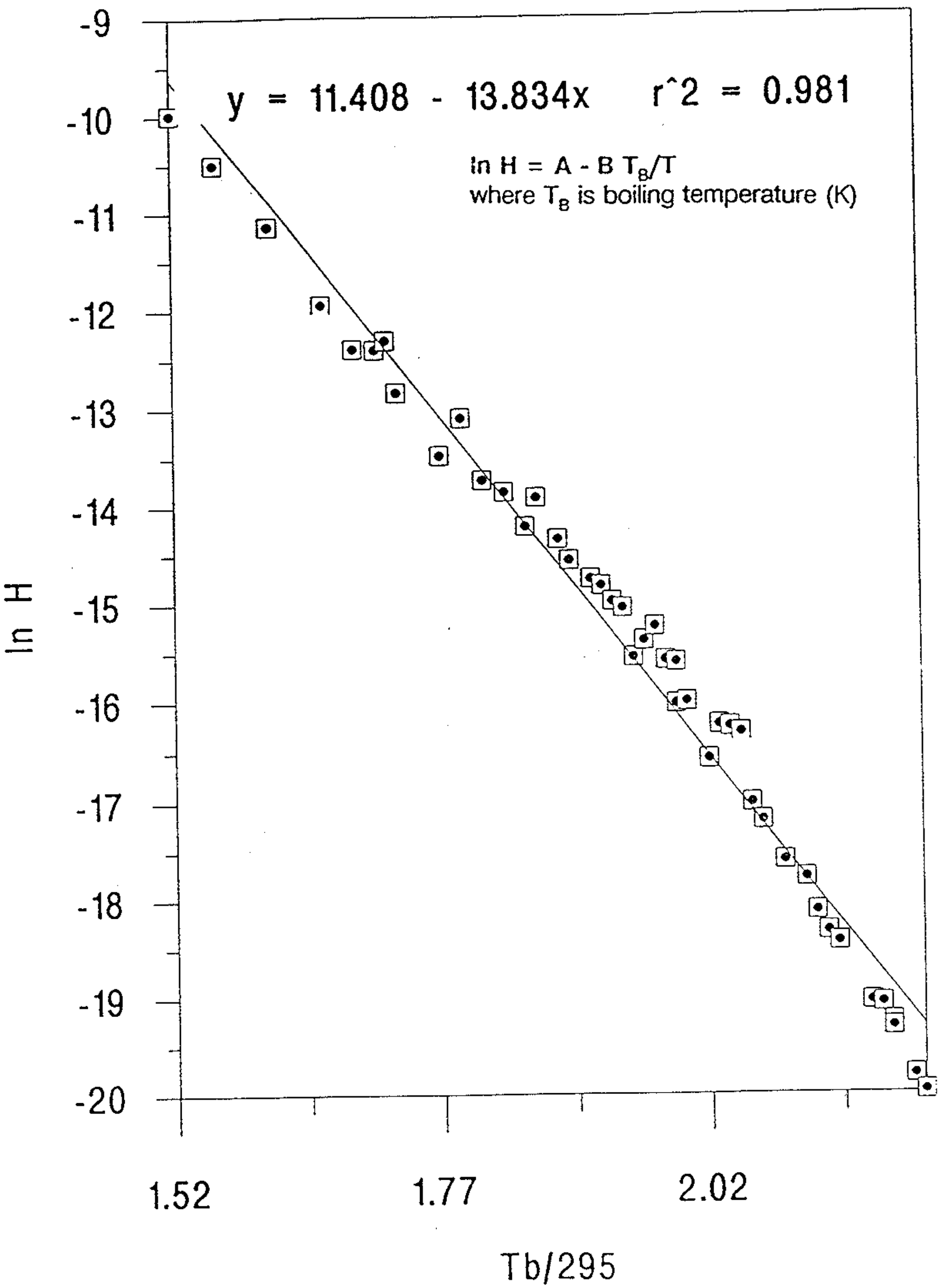


Figure 56: **Plot of natural log of H versus $T_B/295$. Diesel.**

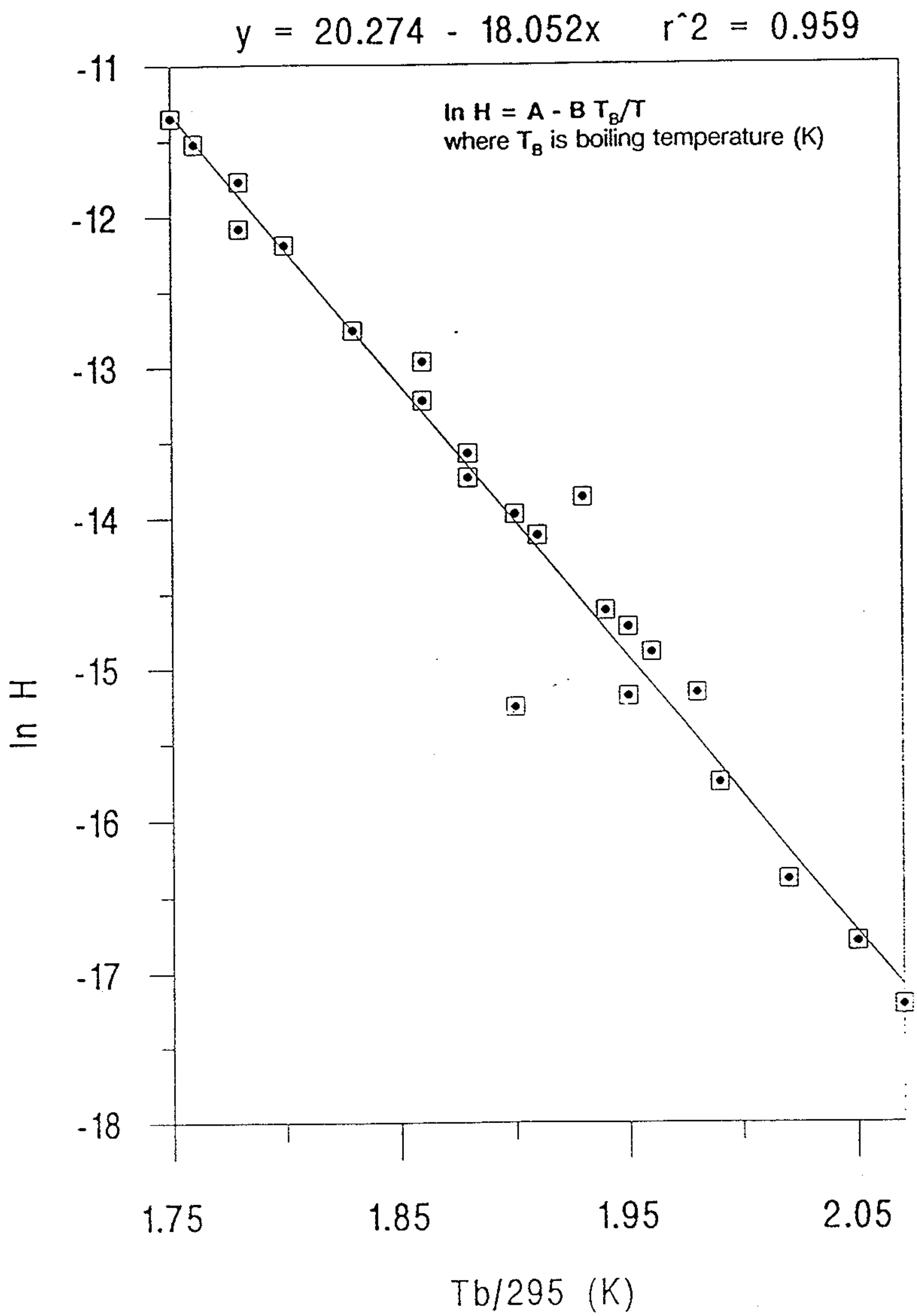


Figure 57: Plot of natural log of H versus T_B/295. Endicott Crude Oil.

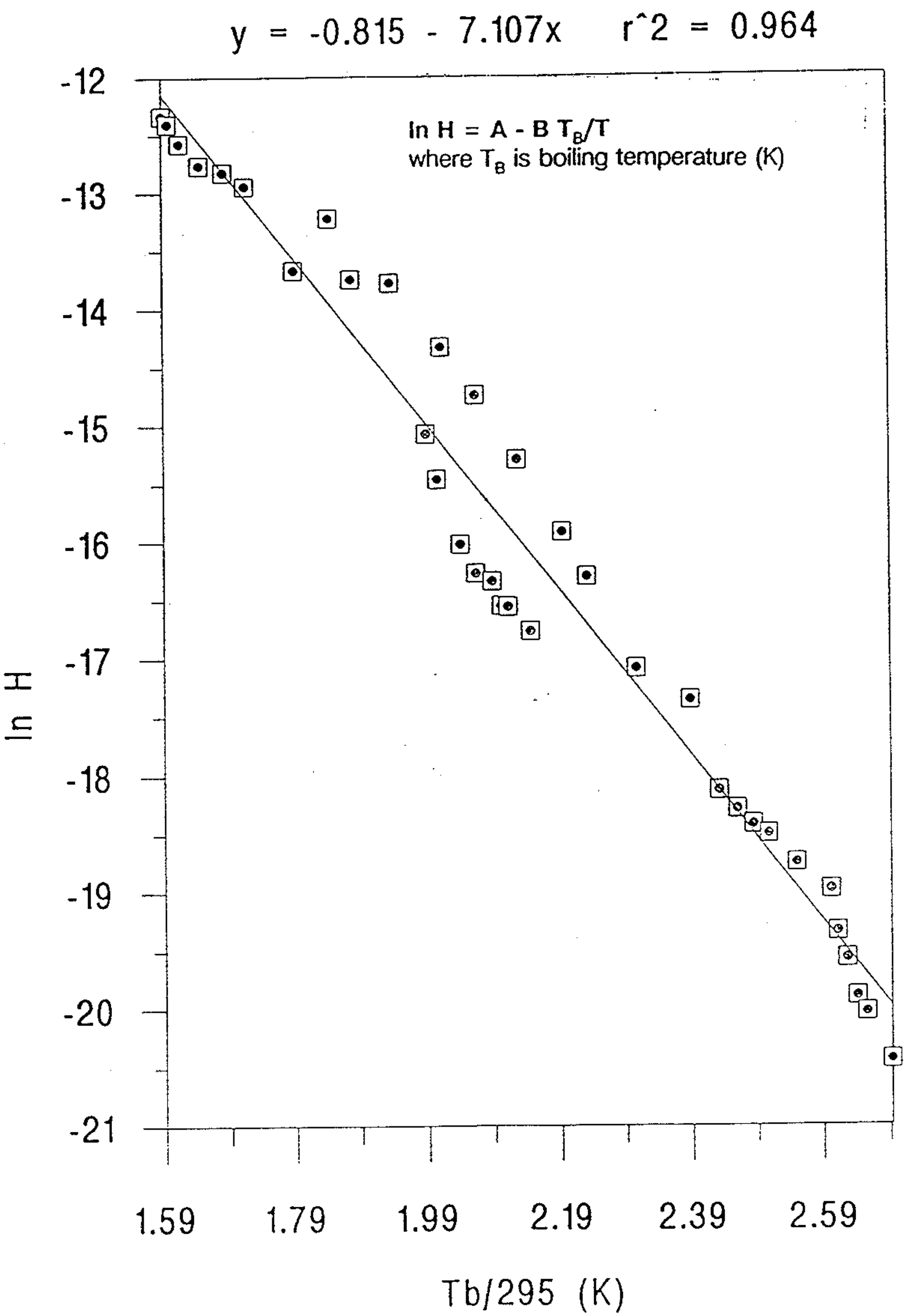


Figure 58: Plot of natural log of H versus $T_B/295$. North Slope Crude Oil.

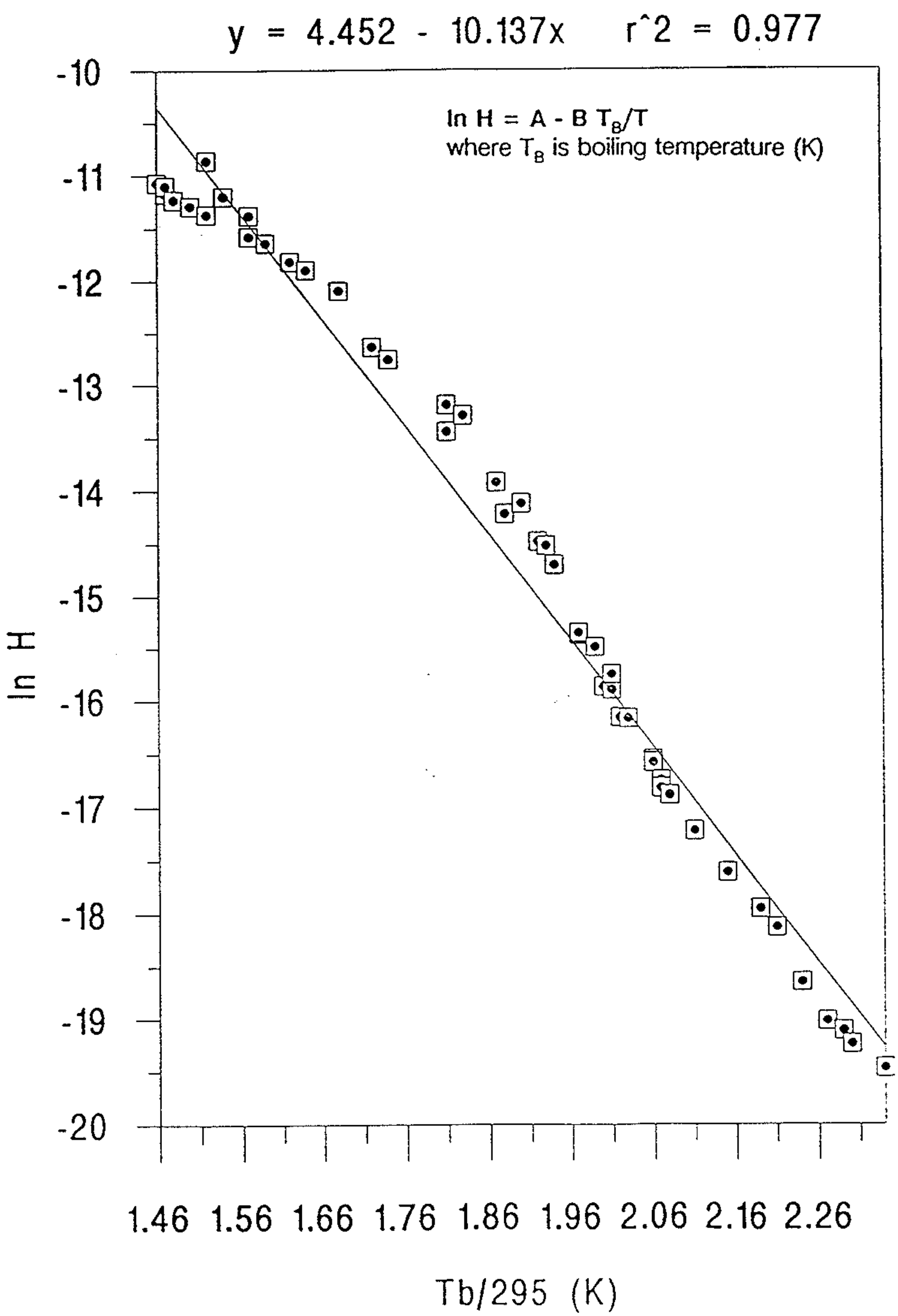
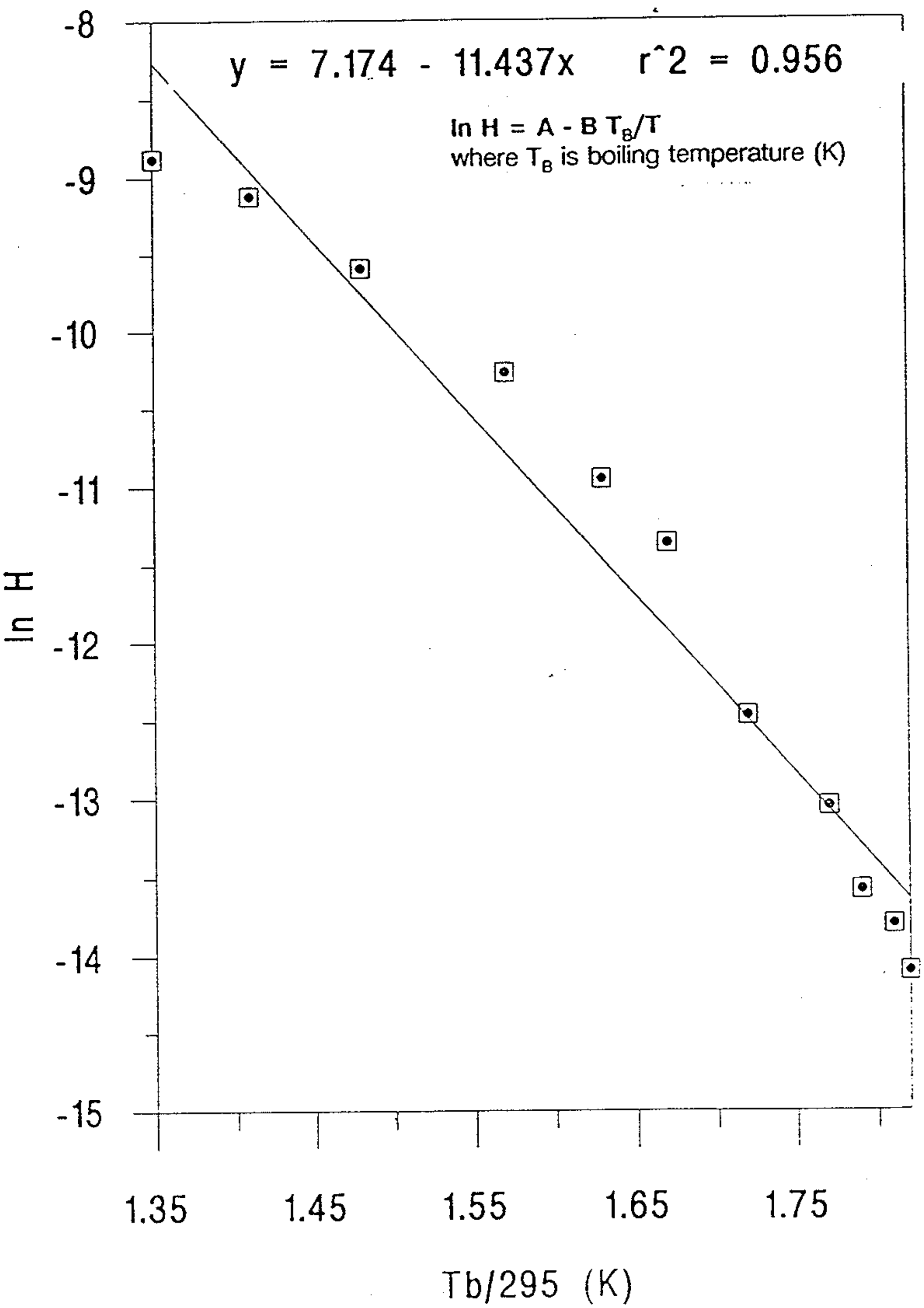


Figure 59: Plot of natural log of H versus $T_B/295$. Panuke Crude Oil.



Weather conditions during exposure of Adgo and Endicott.

Date	Hour	time (hours)	Temp (C)	Av.Temp (C)	Velocity (m/s)	Av.Vel. (m/s)
91/09/05	10	1	17.3	17.30	2.50	2.50
	11	2	18.6	17.95	1.95	2.22
	12	3	21.1	19.00	1.67	2.04
	13	4	21.7	19.68	5.28	2.85
	14	5	22.9	20.32	3.06	2.89
	15	6	22.1	20.62	1.11	2.59
	16	7	22.6	20.90	3.61	2.74
	17	8	22.8	21.14	1.67	2.61
	18	9	22.1	21.24	1.95	2.53
	19	10	21.4	21.26	0.00	2.28
	20	11	19.8	21.13	1.11	2.17
	21	12	19.8	21.02	1.11	2.09
	22	13	18.5	20.82	1.67	2.05
	23	14	16.8	20.54	0.00	1.91
	24	15	16.2	20.25	1.11	1.85
91/09/06	1	16	16.2	19.99	1.11	1.81
	2	17	15.5	19.73	0.00	1.70
	3	18	14.7	19.45	0.00	1.61
	4	19	13.4	19.13	1.11	1.58
	5	20	12.4	18.80	0.00	1.50
	6	21	12.3	18.49	0.00	1.43
	7	22	12.5	18.21	1.11	1.42
	8	23	13.8	18.02	3.06	1.49
	9	24	15.3	17.91	2.50	1.53
	10	25	18	17.91	2.50	1.57
	11	26	20.4	18.01	1.95	1.58
	12	27	22.1	18.16	1.67	1.59
	13	28	22.6	18.32	1.11	1.57
	14	29	24.4	18.53	1.11	1.55
	15	30	25.1	18.75	2.50	1.58
	16	31	25.3	18.96	1.67	1.59
	17	32	25.4	19.16	1.67	1.59
	18	33	24.7	19.33	2.50	1.62
	19	34	23.2	19.44	1.67	1.62
	20	35	21.7	19.51	2.50	1.64
	21	36	19.4	19.50	1.95	1.65
	22	37	20	19.52	2.50	1.68
	23	38	18.7	19.49	1.11	1.66
	24	39	18	19.46	1.11	1.65
91/09/07	1	40	18.2	19.43	1.67	1.65
	2	41	18	19.39	1.95	1.65
	3	42	17.3	19.34	1.95	1.66
	4	43	16.2	19.27	1.95	1.67
	5	44	15.1	19.17	1.95	1.67
	6	45	13.8	19.05	1.95	1.68
	7	46	13.2	18.93	1.95	1.69
	8	47	14.2	18.83	1.67	1.69
	9	48	17.5	18.80	3.06	1.71
	10	49	19	18.80	4.73	1.78

	11	50	20.8	18.84	5.28	1.85
	12	51	22.7	18.92	4.17	1.89
	13	52	22.9	18.99	3.61	1.92
	14	53	23.3	19.08	3.61	1.96
	15	54	22.2	19.13	2.50	1.97
	16	55	21.2	19.17	2.50	1.98
	17	56	22.1	19.22	1.67	1.97
	18	57	21.9	19.27	1.11	1.96
	19	58	21	19.30	1.11	1.94
	20	59	19.6	19.31	0.00	1.91
	21	60	19.1	19.30	0.00	1.88
	22	61	18.1	19.28	0.00	1.85
	23	62	17.2	19.25	1.11	1.83
	24	63	16.8	19.21	0.00	1.80
91/09/08	1	64	15.5	19.15	0.00	1.78
	2	65	14.8	19.08	0.00	1.75
	3	66	14.8	19.02	0.00	1.72
	4	67	13.9	18.94	0.00	1.70
	5	68	12.7	18.85	0.00	1.67
	6	69	12.7	18.76	1.67	1.67
	7	70	13.3	18.68	1.11	1.66
	8	71	14.1	18.62	1.11	1.66
	9	72	17.2	18.60	1.67	1.66
	10	73	19.9	18.62	1.11	1.65
	11	74	22.5	18.67	1.95	1.65
	12	75	23.7	18.74	1.95	1.66
	13	76	24.8	18.82	3.06	1.68
	14	77	24.7	18.89	2.50	1.69
	15	78	25.4	18.98	1.95	1.69
	16	79	25.2	19.06	3.06	1.71
	17	80	26	19.14	3.06	1.72
	18	81	25.4	19.22	5.28	1.77
	19	82	23.1	19.27	4.73	1.80
	20	83	20.5	19.28	3.06	1.82
	21	84	18.3	19.27	3.61	1.84
	22	85	17.9	19.25	3.06	1.85
	23	86	16.5	19.22	3.06	1.87
	24	87	16.4	19.19	1.67	1.87
91/09/09	1	88	15.2	19.14	1.11	1.86
	2	89	14.1	19.09	1.95	1.86
	3	90	13.1	19.02	2.50	1.87
	4	91	12.8	18.95	3.61	1.88
	5	92	11.9	18.88	4.17	1.91
	6	93	11	18.79	4.17	1.93
	7	94	10.2	18.70	5.28	1.97
	8	95	10.4	18.61	4.17	1.99
	9	96	12.4	18.55	4.17	2.02
	10	97	14.5	18.51	4.17	2.04
	11	98	16.1	18.48	4.17	2.06
	12	99	18.6	18.48	3.34	2.07
	13	100	20.5	18.50	4.17	2.09
	14	101	20.1	18.52	4.17	2.11
	15	102	20.6	18.54	4.17	2.13
	16	103	21.8	18.57	5.28	2.16
	17	104	21.8	18.60	4.73	2.19
	18	105	20.6	18.62	4.17	2.21

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	19	106	19.2	18.63	4.17	2.23
	20	107	17.6	18.62	1.39	2.22
	21	108	16.3	18.60	1.95	2.22
	22	109	15.4	18.57	3.06	2.22
	23	110	15.1	18.53	2.50	2.23
	24	111	14.9	18.50	1.95	2.22
91/09/10	1	112	14.1	18.46	1.95	2.22
	2	113	13.8	18.42	1.95	2.22
	3	114	13.8	18.38	1.11	2.21
	4	115	14.7	18.35	0.00	2.19
	5	116	18.3	18.35	3.06	2.20
	6	117	19.6	18.36	3.61	2.21
	7	118	19.2	18.37	1.95	2.21
	8	119	19.4	18.37	3.61	2.22
	9	120	20.2	18.39	3.61	2.23
	10	121	22.5	18.42	5.28	2.26

	Weather conditions during exposure of Diesel and North Slope.							
Date	Hour	Time (hrs)	Temp (C)	Av. Temp.	Vel (km/h	Av. Vel.	Vel. (m/s)	Av. Vel.
		(hours)	(C)	(C)	(km/hr)	(km/hr)	(m/s)	(m/s)
91/10/23	14	1	14.9	14.90	13	13.00	3.614	3.61
	15	2	17.1	16.00	11	12.00	3.058	3.34
	16	3	18.2	16.73	13	12.33	3.614	3.43
	17	4	20.6	17.70	13	12.50	3.614	3.48
	18	5	19.2	18.00	17	13.40	4.726	3.73
	19	6	17.7	17.95	7	12.33	1.946	3.43
	20	7	12.4	17.16	9	11.86	2.502	3.30
	21	8	11.5	16.45	11	11.75	3.058	3.27
	22	9	9.5	15.68	11	11.67	3.058	3.24
	23	10	8.2	14.93	9	11.40	2.502	3.17
	24	11	8.5	14.35	7	11.00	1.946	3.06
91/10/24	1	12	6.9	13.73	9	10.83	2.502	3.01
	2	13	6.5	13.17	7	10.54	1.946	2.93
	3	14	6.3	12.68	9	10.43	2.502	2.90
	4	15	5.7	12.21	7	10.20	1.946	2.84
	5	16	5.8	11.81	6	9.94	1.668	2.76
	6	17	6.2	11.48	6	9.71	1.668	2.70
	7	18	6.8	11.22	6	9.50	1.668	2.64
	8	19	7	11.00	4	9.21	1.112	2.56
	9	20	7.9	10.85	4	8.95	1.112	2.49
	10	21	11.7	10.89	0	8.52	0	2.37
	11	22	17.9	11.20	15	8.82	4.17	2.45
	12	23	19.7	11.57	26	9.57	7.228	2.66
	13	24	20.1	11.93	19	9.96	5.282	2.77
	14	25	20	12.25	19	10.32	5.282	2.87
	15	26	20.5	12.57	19	10.65	5.282	2.96

Weather conditions during exposure of ASMB and Amauligak.

Date	Hour	Time (hrs) (hours)	Temp (C) (C)	Av. Temp. (C)	Vel (km/h (km/hr)	Av. Vel. (km/hr)	Vel. (m/s) (m/s)	Av. Vel. (m/s)
91/10/24	11	1	17.9	17.90	15	15.00	4.17	4.17
	12	2	19.7	18.80	26	20.50	7.228	5.70
	13	3	20.1	19.23	19	20.00	5.282	5.56
	14	4	20	19.43	19	19.75	5.282	5.49
	15	5	20.5	19.64	19	19.60	5.282	5.45
	16	6	20.3	19.75	17	19.17	4.726	5.33
	17	7	19.8	19.76	17	18.86	4.726	5.24
	18	8	19.5	19.73	17	18.63	4.726	5.18
	19	9	18.4	19.58	7	17.33	1.946	4.82
	20	10	16.6	19.28	7	16.30	1.946	4.53
	21	11	16.7	19.05	13	16.00	3.614	4.45
	22	12	16.8	18.86	15	15.92	4.17	4.42
	23	13	16.9	18.71	11	15.54	3.058	4.32
	24	14	15.7	18.49	7	14.93	1.946	4.15
91/10/25	1	15	15.8	18.31	11	14.67	3.058	4.08
	2	16	15.9	18.16	15	14.69	4.17	4.08
	3	17	16	18.04	17	14.82	4.726	4.12
	4	18	16.3	17.94	22	15.22	6.116	4.23
	5	19	16.2	17.85	13	15.11	3.614	4.20
	6	20	15.6	17.74	17	15.20	4.726	4.23
	7	21	15.9	17.65	17	15.29	4.726	4.25
	8	22	15.5	17.55	15	15.27	4.17	4.25
	9	23	15.5	17.46	11	15.09	3.058	4.19
	10	24	16.2	17.41	17	15.17	4.726	4.22
	11	25	17.7	17.42	19	15.32	5.282	4.26
	12	26	19.4	17.50	22	15.58	6.116	4.33
	13	27	20	17.59	20	15.74	5.56	4.38
	14	28	21	17.71	24	16.04	6.672	4.46

	Weather conditions during exposure of Bent Horn and Panuk.					
Date	Hour	time (hours)	Temp (C)	Av.Temp (C)	Velocity (m/s)	Av.Vel. (m/s)
91/09/03	13	0	28	28.00	2.50	2.50
	14	1	28.4	28.20	3.10	2.80
	15	2	28.7	28.37	2.50	2.70
	16	3	28.6	28.43	2.30	2.60
	17	4	28.3	28.40	2.60	2.60

Adgo Crude Oil Evaporation Indoors

time (m) 15mm	time (s) 15mm	theta 15mm	wt (g) 15mm	loss (g) 15mm	wt % 15mm	time (s) 10mm	theta 10mm	wt (g) 10mm	loss (g) 10mm
15	900	338.76	304.538	0.091	0.04	900	508.14	208.17	0.21
30	1800	677.52	304.47	0.159	0.07	1800	1016.28	208.256	0.124
60	3600	1355.04	304.334	0.295	0.14	3600	2032.56	208.129	0.251
180	10800	4065.12	303.732	0.897	0.42	10800	6097.68	207.651	0.729
360	21600	8130.24	302.983	1.646	0.77	21600	12195.36	207.043	1.337
540	32400	12195.36	302.448	2.181	1.02	32400	18293.04	206.585	1.795
1440	86400	32520.96	299.407	5.222	2.44	86400	48781.44	204.273	4.107
1920	115200	43361.28	298.052	6.577	3.07	115200	65041.92	203.218	5.162
2880	172800	65041.92	295.821	8.808	4.11	172800	97562.88	201.609	6.771
3300	198000	74527.2	294.814	9.815	4.59	198000	111790.8	200.832	7.548
4320	259200	97562.88	292.883	11.746	5.49	259200	146344.3	199.355	9.025
5760	345600	130083.8	290.38	14.249	6.66	345600	195125.8	197.507	10.873
6180	370800	139569.1	289.709	14.92	6.97	370800	209353.7	197.013	11.367
10080	604800	227646.7	285.163	19.466	9.09	604800	341470.1	193.728	14.652
10500	630000	237132	284.716	19.913	9.30	630000	355698	193.418	14.962
11520	691200	260167.7	283.826	20.803	9.72	691200	390251.5	192.79	15.59
12000	720000	271008	283.416	21.213	9.91	720000	406512	192.5	15.88
12960	777600	292688.6	282.687	21.942	10.25	777600	439033	192.029	16.351
14400	864000	325209.6	281.638	22.991	10.74	864000	487814.4	191.261	17.119
15840	950400	357730.6	280.676	23.953	11.19	950400	536595.8	190.546	17.834
16320	979200	368570.9	280.354	24.275	11.34	979200	552856.3	190.32	18.06
20160	1209600	455293.4	278.074	26.555	12.41	1209600	682940.2	188.828	19.552
21600	1296000	487814.4	277.19	27.439	12.82	1296000	731721.6	188.23	20.15
30240	1814400	682940.2	273.367	31.262	14.60	1814400	1024410	185.59	22.79
36000	2160000	813024	270.44	34.189	15.97	2160000	1219536	183.499	24.881
40320	2419200	910586.9	269.002	35.627	16.64	2419200	1365880	182.505	25.875

Adgo Crude Oil Evaporation Indoors

wt % 10mm	time (s) 5mm	theta 5mm	wt (g) 5mm	loss (g) 5mm	wt % 5mm	time (s) 2.5mm	theta 2.5mm	wt (g) 2.5mm	loss (g) 2.5mm
0.15	900	1016.28	159.815	0.059	0.08	900	2032.2	110.773	0.063
0.09	1800	2032.56	159.749	0.125	0.18	1800	4064.4	110.718	0.118
0.18	3600	4065.12	159.65	0.224	0.32	3600	8128.8	110.627	0.209
0.52	10800	12195.36	159.248	0.626	0.90	10800	24386.4	110.236	0.6
0.95	21600	24390.72	158.711	1.163	1.67	21600	48772.8	109.786	1.05
1.28	32400	36586.08	158.346	1.528	2.19	32400	73159.2	109.51	1.326
2.92	86400	97562.88	156.543	3.331	4.78	86400	195091.2	108.23	2.606
3.67	115200	130083.8	155.858	4.016	5.77	115200	260121.6	107.769	3.067
4.82	172800	195125.8	154.827	5.047	7.25	172800	390182.4	107.108	3.728
5.37	198000	223581.6	154.383	5.491	7.89	198000	447084	106.818	4.018
6.42	259200	292688.6	153.551	6.323	9.08	259200	585273.6	106.258	4.578
7.73	345600	390251.5	152.514	7.36	10.57	345600	780364.8	105.615	5.221
8.09	370800	418707.4	152.243	7.631	10.96	370800	837266.4	105.441	5.395
10.42	604800	682940.2	150.468	9.406	13.51	604800	1365638	104.342	6.494
10.64	630000	711396	150.287	9.587	13.77	630000	1422540	104.242	6.594
11.09	691200	780503	149.918	9.956	14.30	691200	1560730	104.033	6.803
11.30	720000	813024	149.761	10.113	14.52	720000	1625760	103.943	6.893
11.63	777600	878065.9	149.488	10.386	14.91	777600	1755821	103.775	7.061
12.18	864000	975628.8	149.052	10.822	15.54	864000	1950912	103.518	7.318
12.69	950400	1073192	148.55	11.324	16.26	950400	2146003	103.278	7.558
12.85	979200	1105713	148.53	11.344	16.29	979200	2211034	103.205	7.631
13.91	1209600	1365880	147.63	12.244	17.58	1209600	2731277	102.68	8.156
14.33	1296000	1463443	147.28	12.594	18.08	1296000	2926368	102.478	8.358
16.21	1814400	2048820	145.77	14.104	20.25	1814400	4096915	101.631	9.205
17.70	2160000	2439072	144.724	15.15	21.76	2160000	4877280	101.084	9.752
18.40	2419200	2731761	144.218	15.656	22.48	2419200	5462554	100.811	10.025

Adgo Crude Oil Evaporation Indoors

wt %	time (s)	theta	wt (g)	loss (g)	wt %	time (s)	theta	wt (g)	loss (g)
2.5mm	1mm	1mm	1mm	1mm	1mm	0.5mm	0.5mm	0.5mm	0.5mm
0.18	900	5081.4	104.483	0.071	0.49	900	10162.8	95.086	0.059
0.33	1800	10162.8	104.426	0.128	0.89	1800	20325.6	95.038	0.107
0.59	3600	20325.6	104.346	0.208	1.44	3600	40651.2	94.971	0.174
1.69	10800	60976.8	104.082	0.472	3.28	10800	121953.6	94.794	0.351
2.96	21600	121953.6	103.821	0.733	5.09	21600	243907.2	94.623	0.522
3.74	32400	182930.4	103.665	0.889	6.17	32400	365860.8	94.522	0.623
7.34	86400	487814.4	102.962	1.592	11.05	86400	975628.8	94.107	1.038
8.64	115200	650419.2	102.727	1.827	12.68	115200	1300838	93.958	1.187
10.51	172800	975628.8	102.374	2.18	15.13	172800	1951258	93.736	1.409
11.32	198000	1117908	102.235	2.319	16.10	198000	2235816	93.666	1.479
12.90	259200	1463443	101.998	2.556	17.74	259200	2926886	93.539	1.606
14.71	345600	1951258	101.697	2.857	19.83	345600	3902515	93.384	1.761
15.20	370800	2093537	101.621	2.933	20.36	370800	4187074	93.34	1.805
18.30	604800	3414701	101.099	3.455	23.98	604800	6829402	93.092	2.053
18.58	630000	3556980	101.061	3.493	24.25	630000	7113960	93.078	2.067
19.17	691200	3902515	100.963	3.591	24.93	691200	7805030	93.031	2.114
19.43	720000	4065120	100.923	3.631	25.20	720000	8130240	93.011	2.134
19.90	777600	4390330	100.844	3.71	25.75	777600	8780659	92.973	2.172
20.62	864000	4878144	100.736	3.818	26.50	864000	9756288	92.914	2.231
21.30	950400	5365958	100.644	3.91	27.14	950400	10731917	92.869	2.276
21.50	979200	5528563	100.614	3.94	27.35	979200	11057126	92.853	2.292
22.98	1209600	6829402	100.392	4.162	28.89	1209600	13658803	92.754	2.391
23.55	1296000	7317216	100.312	4.242	29.45	1296000	14634432	92.717	2.428
25.94	1814400	10244102	99.984	4.57	31.72	1814400	20488205	92.576	2.569
27.48	2160000	12195360	99.758	4.796	33.29	2160000	24390720	92.46	2.685
28.25	2419200	13658803	99.645	4.909	34.08	2419200	27317606	92.409	2.736

Adgo Crude Oil Evaporation Indoors

wt % 0.5mm	time (s) 0.2mm	theta 0.2mm	wt (g) 0.2mm	loss (g) 0.2mm	wt % 0.2mm
0.85	900	25461	92.381	0.025	1.71
1.54	1800	50922	92.359	0.047	3.22
2.51	3600	101844	92.33	0.076	5.21
5.06	10800	305532	92.269	0.137	9.39
7.53	21600	611064	92.209	0.197	13.50
8.98	32400	916596	92.178	0.228	15.63
14.97	86400	3582403	92.005	0.401	27.48
17.12	115200	4776538	91.964	0.442	30.29
20.32	172800	7164806	91.931	0.475	32.56
21.33	198000	8209674	91.91	0.496	34.00
23.16	259200	10747210	91.875	0.531	36.39
25.39	345600	14329613	91.842	0.564	38.66
26.03	370800	15374480	91.833	0.573	39.27
29.60	604800	25076822	91.774	0.632	43.32
29.81	630000	26121690	91.776	0.63	43.18
30.48	691200	28659226	91.769	0.637	43.66
30.77	720000	29853360	91.765	0.641	43.93
31.32	777600	32241629	91.756	0.65	44.55
32.17	864000	35824032	91.745	0.661	45.30
32.82	950400	39406435	91.741	0.665	45.58
33.05	979200	40600570	91.737	0.669	45.85
34.48	1209600	50153645	91.719	0.687	47.09
35.01	1296000	53736048	91.711	0.695	47.64
37.04	1814400	75230467	91.678	0.728	49.90
38.72	2160000	89560080	91.658	0.748	51.27
39.45	2419200	1E+08	91.65	0.756	51.82

ASMB Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	wt (g)	loss(g)	wt%	vol%	theta
5	300	277.194	4.706	2.45	2.73	1.13E+02
10	600	276.005	5.895	3.07	3.42	2.26E+02
15	900	274.8	7.1	3.7	4.11	3.39E+02
30	1800	271.735	10.165	5.3	5.89	6.78E+02
60	3600	266.189	15.711	8.19	9.09	1.36E+03
120	7200	257.668	24.232	12.63	14.02	2.71E+03
180	10800	251.612	30.288	15.79	17.52	4.07E+03
240	14400	248.953	32.947	17.18	19.06	5.42E+03
300	18000	246.04	35.86	18.7	20.74	6.78E+03
360	21600	242.973	38.927	20.3	22.52	8.13E+03
420	25200	241.322	40.578	21.16	23.47	9.49E+03
1320	79200	229.063	52.837	27.55	30.56	2.98E+04
1440	86400	228.535	53.365	27.82	30.87	3.25E+04
2880	172800	223.093	58.807	30.66	34.01	6.50E+04
4320	259200	217.899	64.001	33.37	37.02	9.76E+04
8640	518400	216.549	65.351	34.07	37.8	1.95E+05
10080	604800	215.252	66.648	34.75	38.55	2.28E+05

10 mm

time (m)	time (s)	wt (g)	loss (g)	wt%	vol%	theta
5	300	217.527	3.813	2.89	3.21	169.38
10	600	216.403	4.937	3.74	4.15	338.76
15	900	215.418	5.922	4.48	4.98	508.14
30	1800	212.464	8.876	6.72	7.46	1016.28
60	3600	208.213	13.127	9.94	11.03	2032.56
120	7200	203.4	17.94	13.58	15.07	4065.12
180	10800	198.721	22.619	17.12	19.00	6097.68
240	14400	196.171	25.169	19.05	21.14	8130.24
300	18000	193.92	27.42	20.75	23.03	10162.80
360	21600	192.349	28.991	21.94	24.34	12195.36
420	25200	191.52	29.82	22.57	25.04	14227.92
1320	79200	182.87	38.47	29.12	32.30	44716.32
1440	86400	182.602	38.738	29.32	32.53	48781.44
2880	172800	179.152	42.188	31.93	35.42	97562.88
4320	259200	174.21	47.13	35.67	39.57	146344.32
10080	604800	173.279	48.061	36.38	40.35	341470.08

ASMB Crude Oil Evaporation Indoors

5mm

time (m)	time (s)	wt (g)	loss(g)	wt %	vol %	theta
5	300	151.07	3	4.8	5.33	338.76
10	600	148.889	5.181	8.2	9.10	677.52
15	900	147.773	6.297	10.1	11.21	1016.28
30	1800	145.877	8.193	13.1	14.54	2032.56
60	3600	143.809	10.261	16.4	18.20	4065.12
120	7200	140.865	13.205	21.1	23.41	8130.24
180	10800	139.662	14.408	23	25.52	12195.36
240	14400	138.644	15.426	24.7	27.40	16260.48
1140	68400	134.45	19.62	31.4	34.83	77237.28
1440	86400	133.797	20.273	32.4	35.94	97562.88
3000	180000	131.865	22.205	35.52	39.41	203256
6960	417600	129.939	24.131	38.60	42.82	471553.9
8640	518400	129.426	24.644	39.43	43.73	585377.3
10080	604800	128.939	25.131	40.20	44.60	682940.2
11520	691200	128.646	25.424	40.67	45.12	780503
12960	777600	128.412	25.658	41.05	45.53	878065.9
14400	864000	128.175	25.895	41.43	45.95	975628.8
17040	1022400	127.84	26.23	41.96	46.55	1154494

2.5mm

time (m)	time (s)	wt (g)	loss (g)	wt%	vol%	theta
5	300	121.959	1.896	6.2	6.88	677.4
10	600	120.921	2.516	8.3	9.21	1354.8
15	900	120.009	3.428	11.2	12.43	2032.2
30	1800	118.613	4.824	15.8	17.53	4064.4
60	3600	117.157	6.28	20.5	22.74	8128.8
120	7200	115.699	7.738	25.3	28.07	16257.6
180	10800	115.154	8.283	27.1	30.06	24386.4
240	14400	114.748	8.689	28.4	31.51	32515.2
1140	68400	112.831	10.606	34.7	38.49	154447.2
1440	86400	112.513	10.924	35.7	39.60	195091.2
3000	180000	111.741	11.696	38.25	42.43	406440
6960	417600	110.839	12.598	41.20	45.70	942940.8
7200	432000	110.779	12.658	41.40	45.92	975456
8640	518400	110.602	12.835	41.98	46.56	1170547
10080	604800	110.404	13.033	42.63	47.28	1365638
11520	691200	110.282	13.155	43.02	47.73	1560730
12960	777600	110.17	13.267	43.39	48.13	1755821
14400	864000	110.064	13.373	43.74	48.52	1950912
17040	1022400	109.909	13.528	44.24	49.08	2308579

ASMB Crude Oil Evaporation Indoors

1.0 mm

time (m)	time (s)	wt (g)	loss (g)	wt%	vol%	theta
5	300	98.776	1.245	9.86	10.94	1693.8
10	600	98.236	1.785	14.13	15.68	3387.6
15	900	97.913	2.108	16.69	18.52	5081.4
30	1800	97.323	2.698	21.36	23.70	10162.8
60	3600	96.836	3.185	25.22	27.97	20325.6
120	7200	96.378	3.643	28.84	32.00	40651.2
180	10800	96.168	3.853	30.50	33.84	60976.8
240	14400	95.966	4.055	32.10	35.61	81302.4
1140	68400	95.298	4.723	37.39	41.48	386186.4
1440	86400	95.117	4.904	38.82	43.07	487814.4
3000	180000	94.818	5.203	41.19	45.69	1016280
6960	417600	94.467	5.554	43.97	48.77	2357770
7200	432000	94.443	5.578	44.16	48.99	2439072
8640	518400	94.384	5.637	44.63	49.50	2926886
10080	604800	94.324	5.697	45.10	50.03	3414701
11520	691200	94.27	5.751	45.53	50.50	3902515
12960	777600	94.23	5.791	45.85	50.86	4390330
14400	864000	94.194	5.827	46.13	51.17	4878144
17040	1022400	94.133	5.888	46.62	51.71	5772470

0.5 mm

time (m)	time (s)	wt (g)	loss (g)	wt %	vol %	theta
5	300	89.845	0.942	15.71	17.43	3387.6
10	600	89.615	1.172	19.54	21.68	6775.2
15	900	89.475	1.312	21.87	24.27	10162.8
30	1800	89.269	1.518	25.31	28.08	20325.6
60	3600	89.07	1.717	28.63	31.76	40651.2
120	7200	88.875	1.912	31.88	35.36	81302.4
180	10800	88.788	1.999	33.33	36.97	121953.6
240	14400	88.719	2.068	34.48	38.25	162604.8
1140	68400	88.474	2.313	38.56	42.78	772372.8
1440	86400	88.358	2.429	40.50	44.92	975628.8
3000	180000	88.273	2.514	41.91	46.49	2032560
6960	417600	88.043	2.744	45.75	50.75	4715539
7200	432000	88.034	2.753	45.90	50.91	4878144
8640	518400	88.003	2.784	46.41	51.48	5853773
10080	604800	87.961	2.826	47.12	52.26	6829402
11520	691200	87.94	2.847	47.47	52.65	7805030
12960	777600	87.919	2.868	47.82	53.04	8780659
14400	864000	87.899	2.888	48.15	53.41	9756288
17040	1022400	87.869	2.918	48.65	53.96	11544941

ASMB Crude Oil Evaporation Indoors

0.2 mm

time (m)	time (s)	wt (g)	loss (g)	wt %	vol (g)	theta
5	300	89.164	0.272	21.00411	23.30	8487
10	600	89.104	0.332	25.63737	28.44	16974
15	900	89.076	0.36	27.79956	30.84	25461
30	1800	89.032	0.404	31.19728	34.61	50922
60	3600	89	0.436	33.66836	37.35	101844
120	7200	88.965	0.471	36.37109	40.35	203688
240	14400	88.931	0.505	38.99661	43.26	407376
300	18000	88.922	0.514	39.69159	44.03	509220
1380	82800	88.856	0.58	44.78818	49.68	2342412
1440	86400	88.852	0.584	45.09706	50.02	2444256
2700	162000	88.825	0.611	47.18203	52.34	4582980
4320	259200	88.795	0.641	49.49866	54.91	7332768
5880	352800	88.789	0.647	49.96199	55.42	9980712
7320	439200	88.78	0.656	50.65698	56.19	12424968

Amauligak Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt%
15	900	338.751	292.3	1.266	0.63
30	1800	677.502	291.067	2.499	1.24
75	4500	1693.755	289.158	4.408	2.18
120	7200	2710.008	287.095	6.471	3.20
180	10800	4065.012	284.567	8.999	4.45
420	25200	9485.028	278.052	15.514	7.67
1200	72000	27100.08	268.491	25.075	12.40
1440	86400	32520.1	266.48	27.086	13.40
2640	158400	59620.18	260.575	32.991	16.32
2880	172800	65040.19	259.821	33.745	16.69
4080	244800	92140.27	256.183	37.383	18.49
4320	259200	97560.29	255.727	37.839	18.72
5400	324000	121950.4	253.594	39.972	19.77
8520	511200	192410.6	249.153	44.413	21.97
10080	604800	227640.7	247.42	46.146	22.82
11520	691200	260160.8	246.024	47.542	23.51
13080	784800	295390.9	244.6	48.966	24.22

10mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt%
15	900	508.14	224.497	1.709	1.27
30	1800	1016.28	223.594	2.612	1.94
75	4500	2540.7	222.082	4.124	3.06
120	7200	4065.12	220.37	5.836	4.33
180	10800	6097.68	218.601	7.605	5.65
420	25200	14227.92	214.081	12.125	9.01
1200	72000	40651.2	207.767	18.439	13.69
1440	86400	48781.44	206.431	19.775	14.69
2640	158400	89432.64	202.522	23.684	17.59
2880	172800	97562.88	202.022	24.184	17.96
4080	244800	138214.1	199.604	26.602	19.76
4320	259200	146344.3	199.294	26.912	19.99
5400	324000	182930.4	197.781	28.425	21.11
8520	511200	288623.5	194.209	31.997	23.76
10080	604800	341470.1	192.912	33.294	24.73
11520	691200	390251.5	191.964	34.242	25.43
13080	784800	443098.1	191.016	35.19	26.14

Amauligak Crude Oil Evaporation Indoors

5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt%
15	900	1016.28	160.124	0.945	1.42
30	1800	2032.56	159.471	1.598	2.41
60	3600	4065.12	158.453	2.616	3.94
120	7200	8130.24	156.779	4.29	6.46
180	10800	12195.36	155.373	5.696	8.58
420	25200	28455.84	152.739	8.33	12.54
1200	72000	81302.4	149.799	11.27	16.97
1440	86400	97562.88	149.235	11.834	17.82
2640	158400	178865.3	147.235	13.834	20.83
2880	172800	195125.8	146.969	14.1	21.23
4080	244800	276428.2	145.69	15.379	23.15
4320	259200	292688.6	145.528	15.541	23.40
5400	324000	365860.8	144.549	16.52	24.87
8520	511200	577247	142.568	18.501	27.86
10080	604800	682940.2	141.867	19.202	28.91
11520	691200	780503	141.394	19.675	29.62
13080	784800	886196.2	140.886	20.183	30.39

2.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
15	900	2032.2	116.283	1.15	3.52
30	1800	4064.4	115.678	1.755	5.38
60	3600	8128.8	114.067	3.366	10.31
120	7200	16257.6	114.111	3.322	10.18
180	10800	24386.4	113.386	4.047	12.40
420	25200	56901.6	112.151	5.282	16.18
1200	72000	162576	110.721	6.712	20.56
1440	86400	195091.2	110.426	7.007	21.47
2640	158400	357667.2	109.439	7.994	24.49
2880	172800	390182.4	109.325	8.108	24.84
4080	244800	552758.4	108.72	8.713	26.70
4320	259200	585273.6	108.643	8.79	26.93
5400	324000	731592	108.246	9.187	28.15
8520	511200	1154290	107.469	9.964	30.53
10080	604800	1365638	107.155	10.278	31.49
11520	691200	1560730	106.899	10.534	32.28
13080	784800	1772078	106.65	10.783	33.04

Amauligak Crude Oil Evaporation Indoors

1.0mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt%
15	900	10162.8	96.009	0.499	7.78
30	1800	20325.6	95.82	0.688	10.72
60	3600	40651.2	95.639	0.869	13.54
120	7200	81302.4	95.452	1.056	16.46
180	10800	121953.6	95.308	1.2	18.70
420	25200	284558.4	95.049	1.459	22.74
1200	72000	813024	94.705	1.803	28.10
1440	86400	975628.8	94.639	1.869	29.12
2640	158400	1788653	94.405	2.103	32.77
2880	172800	1951258	94.374	2.134	33.25
4080	244800	2764282	94.227	2.281	35.54
4320	259200	2926886	94.207	2.301	35.86
5400	324000	3658608	94.109	2.399	37.38
8520	511200	5772470	93.933	2.575	40.13
10080	604800	6829402	93.86	2.648	41.26
11520	691200	7805030	93.809	2.699	42.06
13080	784800	8861962	93.753	2.755	42.93

0.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt%
15	900	37316.43	91.751	0.189	13.10
30	1800	74632.86	91.722	0.218	15.11
60	3600	149265.7	91.667	0.273	18.92
120	7200	298531.4	91.621	0.319	22.11
180	10800	447797.2	91.575	0.365	25.29
420	25200	1044860	91.494	0.446	30.91
1200	72000	2985314	91.398	0.542	37.56
1440	86400	3582377	91.379	0.561	38.88
2640	158400	6567692	91.328	0.612	42.41
2880	172800	7164755	91.321	0.619	42.90
4080	244800	10150069	91.293	0.647	44.84
4320	259200	10747132	91.291	0.649	44.98
5400	324000	13433915	91.27	0.67	46.43
8520	511200	21195732	91.23	0.71	49.20
10080	604800	25076641	91.218	0.722	50.03
11520	691200	28659018	91.21	0.73	50.59
13080	784800	32539927	91.201	0.739	51.21

Bent Horn Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0		0	0.00	0.00
15	900	267.241	5.599	3.05	338.75
30	1800	265.279	7.561	4.12	677.50
60	3600	262.2	10.64	5.79	1355.00
120	7200	257.174	15.666	8.53	2710.01
270	16200	249.472	23.368	12.73	6097.52
360	21600	246.669	26.171	14.25	8130.02
420	25200	244.943	27.897	15.19	9485.03
530	31800	242.815	30.025	16.35	11969.20
1440	86400	234.193	38.647	21.05	32520.10
1680	100800	232.32	40.52	22.07	37940.11
1920	115200	230.857	41.983	22.86	43360.13
2880	172800	227.191	45.649	24.86	65040.19
3300	198000	225.84	47	25.60	74525.22
4320	259200	223.345	49.495	26.96	97560.29
4800	288000	222.374	50.466	27.48	108400.32
5760	345600	220.933	51.907	28.27	130080.38
6120	367200	220.433	52.407	28.54	138210.41
8640	518400	217.952	54.888	29.89	195120.58
10080	604800	216.777	56.063	30.53	227640.67
11520	691200	215.588	57.252	31.18	260160.77
12960	777600	214.633	58.207	31.70	292680.86
14400	864000	213.81	59.03	32.15	325200.96
20160	1209600	211.034	61.806	33.66	455281.34
21600	1296000	210.331	62.509	34.04	487801.44
22980	1378800	209.718	63.122	34.38	518966.53

Bent Horn Crude Oil Evaporation Indoors

10mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	208.495	0	0.00	0.00
15	900	202.374	6.121	4.95	508.14
30	1800	199.733	8.762	7.08	1016.28
60	3600	196.661	11.834	9.57	2032.56
120	7200	193.36	15.135	12.24	4065.12
270	16200	189.654	18.841	15.23	9146.52
360	21600	188.24	20.255	16.37	12195.36
420	25200	187.347	21.148	17.10	14227.92
530	31800	186.212	22.283	18.01	17954.28
1440	86400	181.431	27.064	21.88	48781.44
1680	100800	180.45	28.045	22.67	56911.68
1920	115200	179.584	28.911	23.37	65041.92
2880	172800	177.153	31.342	25.34	97562.88
3300	198000	176.201	32.294	26.11	111790.80
4320	259200	174.413	-34.082	27.55	146344.32
4800	288000	173.673	34.822	28.15	162604.80
5760	345600	172.56	35.935	29.05	195125.76
6120	367200	172.161	36.334	29.37	207321.12
8640	518400	170.17	38.325	30.98	292688.64
10080	604800	169.254	39.241	31.72	341470.08
11520	691200	168.354	40.141	32.45	390251.52
12960	777600	167.733	40.762	32.95	439032.96
14400	864000	167.129	41.366	33.44	487814.40
20160	1209600	165.193	43.302	35.01	682940.16
21600	1296000	164.704	43.791	35.40	731721.60
22980	1378800	164.281	44.214	35.74	778470.48

A20

Bent Horn Crude Oil Evaporation Indoors

5mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	152.885	0	0.00	0.00E+00
15	900	148.289	4.561	7.31	1.02E+03
30	1800	146.444	6.406	10.27	2.03E+03
60	3600	144.458	8.392	13.45	4.07E+03
120	7200	142.401	10.449	16.75	8.13E+03
270	16200	140.224	12.626	20.24	1.83E+04
360	21600	139.448	13.402	21.48	2.44E+04
420	25200	139.02	13.83	22.17	2.85E+04
530	31800	138.534	14.316	22.95	3.59E+04
1440	86400	136.159	16.691	26.76	9.76E+04
1680	100800	135.684	17.166	27.52	1.14E+05
1920	115200	135.305	17.545	28.13	1.30E+05
2880	172800	134.206	18.644	29.89	1.95E+05
3300	198000	133.783	19.067	30.57	2.24E+05
4320	259200	133.006	19.844	31.81	2.93E+05
4800	288000	132.703	20.147	32.30	3.25E+05
5760	345600	132.229	20.621	33.06	3.90E+05
6120	367200	132.061	20.789	33.33	4.15E+05
8640	518400	131.236	21.614	34.65	5.85E+05
10080	604800	130.857	21.993	35.26	6.83E+05
11520	691200	130.498	22.352	35.83	7.81E+05
12960	777600	130.203	22.647	36.30	8.78E+05
14400	864000	129.98	22.87	36.66	9.76E+05
20160	1209600	129.292	23.558	37.77	1.37E+06
21600	1296000	129.09	23.76	38.09	1.46E+06
22980	1378800	128.917	23.933	38.37	1.56E+06

Bent Horn Crude Oil Evaporation Indoors

2.5mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	124.87	0	0.00	0.00E+00
15	900	121.832	3.038	10.05	2.03E+03
30	1800	120.806	4.064	13.44	4.06E+03
60	3600	119.774	5.096	16.85	8.13E+03
120	7200	118.755	6.115	20.22	1.63E+04
270	16200	117.643	7.227	23.90	3.66E+04
360	21600	117.287	7.583	25.08	4.88E+04
420	25200	117.063	7.807	25.82	5.69E+04
530	31800	116.815	8.055	26.64	7.18E+04
1440	86400	115.763	9.107	30.12	1.95E+05
1680	100800	115.577	9.293	30.73	2.28E+05
1920	115200	115.419	9.451	31.25	2.60E+05
2880	172800	114.977	9.893	32.71	3.90E+05
3300	198000	114.806	10.064	33.28	4.47E+05
4320	259200	114.484	10.386	34.35	5.85E+05
4800	288000	114.351	10.519	34.79	6.50E+05
5760	345600	114.146	10.724	35.46	7.80E+05
6120	367200	114.073	10.797	35.70	8.29E+05
8640	518400	113.709	11.161	36.91	1.17E+06
10080	604800	113.546	11.324	37.45	1.37E+06
11520	691200	113.377	11.493	38.01	1.56E+06
12960	777600	113.25	11.62	38.43	1.76E+06
14400	864000	113.14	11.73	38.79	1.95E+06
20160	1209600	112.809	12.061	39.88	2.73E+06
21600	1296000	112.715	12.155	40.20	2.93E+06
22980	1378800	112.639	12.231	40.45	3.11E+06

Bent Horn Crude Oil Evaporation Indoors

1.0mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	105.022	0	0.00	0.00E+00
15	900	103.667	1.355	11.05	5.08E+03
30	1800	103.179	1.843	15.03	1.02E+04
60	3600	102.639	2.383	19.44	2.03E+04
120	7200	102.123	2.899	23.65	4.07E+04
270	16200	101.648	3.374	27.52	9.15E+04
360	21600	101.505	3.517	28.69	1.22E+05
420	25200	101.412	3.61	29.45	1.42E+05
530	31800	101.312	3.71	30.26	1.80E+05
1440	86400	100.861	4.161	33.94	4.88E+05
1680	100800	100.782	4.24	34.58	5.69E+05
1920	115200	100.718	4.304	35.11	6.50E+05
2880	172800	100.546	4.476	36.51	9.76E+05
3300	198000	100.486	4.536	37.00	1.12E+06
4320	259200	100.376	4.646	37.90	1.46E+06
4800	288000	100.331	4.691	38.26	1.63E+06
5760	345600	100.262	4.76	38.83	1.95E+06
6120	367200	100.237	4.785	39.03	2.07E+06
8640	518400	100.106	4.916	40.10	2.93E+06
10080	604800	100.05	4.972	40.55	3.41E+06
11520	691200	99.988	5.034	41.06	3.90E+06
12960	777600	99.94	5.082	41.45	4.39E+06
14400	864000	99.898	5.124	41.79	4.88E+06
20160	1209600	99.776	5.246	42.79	6.83E+06
21600	1296000	99.737	5.285	43.11	7.32E+06
22980	1378800	99.711	5.311	43.32	7.78E+06

Bent Horn Crude Oil Evaporation Indoors

0.5mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	96.961	0	0.00	0.00E+00
15	900	96.038	0.923	15.18	1.02E+04
30	1800	95.79	1.171	19.26	2.03E+04
60	3600	95.563	1.398	22.99	4.07E+04
120	7200	95.361	1.6	26.32	8.13E+04
270	16200	95.157	1.804	29.67	1.83E+05
360	21600	95.098	1.863	30.64	2.44E+05
420	25200	95.044	1.917	31.53	2.85E+05
530	31800	94.999	1.962	32.27	3.59E+05
1440	86400	94.785	2.176	35.79	9.76E+05
1680	100800	94.748	2.213	36.40	1.14E+06
1920	115200	94.718	2.243	36.89	1.30E+06
2880	172800	94.638	2.323	38.21	1.95E+06
3300	198000	94.608	2.353	38.70	2.24E+06
4320	259200	94.557	2.404	39.54	2.93E+06
4800	288000	94.538	2.423	39.85	3.25E+06
5760	345600	94.503	2.458	40.43	3.90E+06
6120	367200	94.489	2.472	40.66	4.15E+06
8640	518400	94.418	2.543	41.83	5.85E+06
10080	604800	94.39	2.571	42.29	6.83E+06
11520	691200	94.362	2.599	42.75	7.81E+06
12960	777600	94.339	2.622	43.13	8.78E+06
14400	864000	94.317	2.644	43.49	9.76E+06
20160	1209600	94.263	2.698	44.37	1.37E+07
21600	1296000	94.241	2.72	44.74	1.46E+07
22980	1378800	94.23	2.731	44.92	1.56E+07

Bent Horn Crude Oil Evaporation Indoors

0.19mm

time (m)	time (s)	wt (g)	loss (g)	wt%	theta
0	0	88.638	0	0.00	0
10	600	88.377	0.261	21.24	17829
20	1200	88.335	0.303	24.65	35658
30	1800	88.312	0.326	26.53	53487
45	2700	88.292	0.346	28.15	80230.5
60	3600	88.275	0.363	29.54	106974
90	5400	88.257	0.381	31.00	160461
120	7200	88.242	0.396	32.22	213948
180	10800	88.223	0.415	33.77	320922
240	14400	88.211	0.427	34.74	427896
360	21600	88.194	0.444	36.13	641844
1440	86400	88.14	0.498	40.52	2567376
1620	97200	88.137	0.501	40.76	2888298
1980	118800	88.132	0.506	41.17	3530142
2880	172800	88.116	0.522	42.47	5134752
3240	194400	88.111	0.527	42.88	5776596
5940	356400	88.091	0.547	44.51	10590426
7200	432000	88.085	0.553	45.00	12836880
8640	518400	88.08	0.558	45.40	15404256

Diesel Evaporation Indoors

15mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	112.92	264.313	0.264	0.14	0.28
15	900	338.76	263.858	0.719	0.38	0.52
30	1800	677.52	263.127	1.45	0.77	0.92
60	3600	1355.04	261.877	2.7	1.43	1.59
120	7200	2710.08	259.648	4.929	2.60	2.79
360	21600	8130.24	251.876	12.701	6.71	6.97
1440	86400	32520.96	232.043	32.534	17.19	17.65
2880	172800	65041.92	217.922	46.655	24.65	25.25
4320	259200	97562.88	210.297	54.28	28.68	29.36
6000	360000	135504	204.309	60.268	31.84	32.58
7680	460800	173445.1	199.098	65.479	34.59	35.39
8820	529200	199190.9	194.509	70.068	37.02	37.86
10260	615600	231711.8	191.806	72.771	38.44	39.31
12960	777600	292688.6	189.187	75.39	39.83	40.72
14400	864000	325209.6	186.784	77.793	41.10	42.02
15780	946800	356375.5	185.054	79.523	42.01	42.95
18600	1116000	420062.4	181.046	83.531	44.13	45.10
20160	1209600	455293.4	179.521	85.056	44.94	45.93
21840	1310400	493234.6	177.839	86.738	45.82	46.83
23040	1382400	520335.4	176.543	88.034	46.51	47.53
24480	1468800	552856.3	175.208	89.369	47.21	48.25

10mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	169.38	191.4	0.265	0.21	0.35
15	900	508.14	190.911	0.754	0.61	0.75
30	1800	1016.28	190.314	1.351	1.09	1.25
60	3600	2032.56	189.038	2.627	2.12	2.30
120	7200	4065.12	186.684	4.981	4.02	4.23
180	10800	6097.68	184.576	7.089	5.72	5.96
240	14400	8130.24	183.21	8.455	6.82	7.09
330	19800	11179.08	181.361	10.304	8.32	8.61
1140	68400	38618.64	170.655	21.01	16.95	17.41
1440	86400	48781.44	167.772	23.893	19.28	19.78
2880	172800	97562.88	159.57	32.095	25.90	26.53
4380	262800	148376.9	153.711	37.954	30.63	31.35
6960	417600	235777	147.275	44.39	35.82	36.64
8400	504000	284558.4	144.586	47.079	37.99	38.85
8640	518400	292688.6	144.124	47.541	38.36	39.23
9840	590400	333339.8	142.277	49.388	39.85	40.75
10080	604800	341470.1	141.961	49.704	40.11	41.01
11280	676800	382121.3	140.242	51.423	41.50	42.42
11520	691200	390251.5	139.992	51.673	41.70	42.63
12660	759600	428870.2	138.728	52.937	42.72	43.67
15720	943200	532530.7	135.719	55.946	45.15	46.14
17280	1036800	585377.3	134.392	57.273	46.22	47.23
18720	1123200	634158.7	133.257	58.408	47.13	48.17
20280	1216800	687005.3	131.997	59.668	48.15	49.20
21720	1303200	735786.7	131.023	60.642	48.94	50.00

Diesel Evaporation Indoors

5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	338.76	152.367	0.255	0.41	0.55
15	900	1016.28	151.989	0.633	1.02	1.18
30	1800	2032.56	151.421	1.201	1.94	2.11
60	3600	4065.12	150.43	2.192	3.54	3.74
120	7200	8130.24	148.727	3.895	6.29	6.54
180	10800	12195.36	147.271	5.351	8.64	8.94
240	14400	16260.48	146.145	6.477	10.45	10.79
330	19800	22358.16	144.901	7.721	12.46	12.83
1140	68400	77237.28	138.428	14.194	22.91	23.48
1440	86400	97562.88	136.643	15.979	25.79	26.42
2880	172800	195125.8	131.88	20.742	33.48	34.25
4380	262800	296753.8	128.823	23.799	38.41	39.28
6960	417600	471553.9	125.352	27.27	44.01	44.99
8400	504000	569116.8	124.014	28.608	46.17	47.19
8640	518400	585377.3	123.76	28.862	46.58	47.61
9840	590400	666679.7	122.864	29.758	48.03	49.08
10080	604800	682940.2	122.722	29.9	48.26	49.31
11280	676800	764242.6	121.895	30.727	49.59	50.67
11520	691200	780503	121.78	30.842	49.78	50.86
12660	759600	857740.3	121.085	31.537	50.90	52.01
15720	943200	1065061	119.574	33.048	53.34	54.49
17280	1036800	1170755	118.955	33.667	54.34	55.51
18720	1123200	1268317	118.435	34.187	55.18	56.36
20280	1216800	1374011	117.843	34.779	56.13	57.34
21720	1303200	1471573	117.39	35.232	56.86	58.08

Diesel Evaporation Indoors

2.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	677.4	120.93	0.273	0.90	1.05
15	900	2032.2	120.599	0.604	1.99	2.16
30	1800	4064.4	120.131	1.072	3.53	3.74
60	3600	8128.8	119.327	1.876	6.19	6.44
120	7200	16257.6	118.11	3.093	10.20	10.53
180	10800	24386.4	117.086	4.117	13.57	13.97
300	18000	40644	115.896	5.307	17.50	17.97
1140	68400	154447.2	112.167	9.036	29.79	30.49
1440	86400	195091.2	111.255	9.948	32.80	33.56
2880	172800	390182.4	108.819	12.384	40.83	41.74
4380	262800	593402.4	107.291	13.912	45.87	46.88
6960	417600	942940.8	105.601	15.602	51.44	52.56
8400	504000	1138032	104.873	16.33	53.84	55.00
8640	518400	1170547	104.752	16.451	54.24	55.41
9840	590400	1333123	104.279	16.924	55.80	57.00
10080	604800	1365638	104.16	17.043	56.19	57.40
11280	676800	1528214	103.789	17.414	57.42	58.64
11520	691200	1560730	103.711	17.492	57.67	58.91
12660	759600	1715177	103.331	17.872	58.93	60.18
15720	943200	2129746	102.425	18.778	61.91	63.23
17280	1036800	2341094	102.061	19.142	63.11	64.45
18720	1123200	2536186	101.796	19.407	63.99	65.34
20280	1216800	2747534	101.488	19.715	65.00	66.38
21720	1303200	2942626	101.241	19.962	65.82	67.21

Diesel Evaporation Indoors

1.0mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	1693.8	105.042	0.198	1.59	1.75
15	900	5081.4	104.715	0.525	4.20	4.42
30	1800	10162.8	104.326	0.914	7.32	7.59
60	3600	20325.6	103.672	1.568	12.55	12.93
120	7200	40651.2	102.88	2.36	18.90	19.39
180	10800	60976.8	102.44	2.8	22.42	22.98
300	18000	101628	101.761	3.479	27.86	28.52
1140	68400	386186.4	99.857	5.383	43.10	44.06
1440	86400	487814.4	99.539	5.701	45.65	46.65
2880	172800	975628.8	98.603	6.637	53.14	54.29
4380	262800	1483769	97.03	8.21	65.74	67.12
6960	417600	2357770	97.372	7.868	63.00	64.33
8400	504000	2845584	97.107	8.133	65.12	66.50
8640	518400	2926886	97.054	8.186	65.55	66.93
9840	590400	3333398	96.852	8.388	67.16	68.58
10080	604800	3414701	96.824	8.416	67.39	68.81
11280	676800	3821213	96.667	8.573	68.64	70.09
11520	691200	3902515	96.64	8.6	68.86	70.31
12660	759600	4288702	96.494	8.746	70.03	71.50
15720	943200	5325307	96.19	9.05	72.46	73.98
17280	1036800	5853773	96.067	9.173	73.45	74.98
18720	1123200	6341587	95.975	9.265	74.18	75.73
20280	1216800	6870053	95.857	9.383	75.13	76.70
21720	1303200	7357867	95.772	9.468	75.81	77.39

Diesel Evaporation Indoors

0.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	3387.6	100.424	0.198	3.30	3.50
15	900	10162.8	100.198	0.424	7.07	7.34
30	1800	20325.6	99.895	0.727	12.12	12.49
60	3600	40651.2	99.554	1.068	17.81	18.28
120	7200	81302.4	99.124	1.498	24.98	25.59
180	10800	121953.6	98.865	1.757	29.30	29.99
270	16200	182930.4	98.6	2.022	33.72	34.49
1140	68400	772372.8	97.724	2.898	48.32	49.38
1440	86400	975628.8	97.553	3.069	51.18	52.29
2880	172800	1951258	97.117	3.505	58.45	59.69
4380	262800	2967538	96.814	3.808	63.50	64.84
6960	417600	4715539	96.471	4.151	69.22	70.67

0.1mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %	vol %
5	300	12438.9	92.517	0.12	9.55	9.86
15	900	37316.7	92.437	0.2	15.91	16.35
30	1800	74633.4	92.325	0.312	24.82	25.43
60	3600	149266.8	92.231	0.406	32.30	33.05
120	7200	298533.6	92.138	0.499	39.70	40.59
180	10800	447800.4	92.063	0.574	45.66	46.67
270	16200	671700.6	92.024	0.613	48.77	49.83
1140	68400	2836069	91.878	0.759	60.38	61.67
1440	86400	3582403	91.83	0.807	64.20	65.56
2580	154800	6418472	91.731	0.906	72.08	73.58
2880	172800	7164806	91.715	0.922	73.35	74.88
4380	262800	10896476	91.662	0.975	77.57	79.18
6960	417600	17314949	91.615	1.022	81.31	82.99

Endicott Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
17	1020	383.928	292.722	0.468	0.23
30	1800	677.52	292.461	0.729	0.36
60	3600	1355.04	291.912	1.278	0.63
120	7200	2710.08	290.976	2.214	1.09
240	14400	5420.16	289.441	3.749	1.85
360	21600	8130.24	288.014	5.176	2.56
480	28800	10840.32	286.735	6.455	3.19
1440	86400	32520.96	281.823	11.367	5.62
1920	115200	43361.28	279.541	13.649	6.75
2880	172800	65041.92	276.366	16.824	8.32
3360	201600	75882.24	275.759	17.431	8.62
4320	259200	97562.88	274.912	18.278	9.03
4800	288000	108403.2	274.523	18.667	9.23
7680	460800	173445.1	273.092	20.098	9.93
8760	525600	197835.8	272.673	20.517	10.14

10mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
14	840	474.264	221.176	0.373	0.28
30	1800	1016.28	220.864	0.685	0.51
60	3600	2032.56	220.338	1.211	0.90
120	7200	4065.12	219.444	2.105	1.57
240	14400	8130.24	218.04	3.509	2.62
360	21600	12195.36	216.834	4.715	3.52
480	28800	16260.48	215.822	5.727	4.27
1440	86400	48781.44	212.207	9.342	6.96
1920	115200	65041.92	211.52	10.029	7.48
2880	172800	97562.88	209.404	12.145	9.05
3360	201600	113823.4	208.937	12.612	9.40
4320	259200	146344.3	208.247	13.302	9.92
4800	288000	162604.8	207.92	13.629	10.16
7680	460800	260167.7	206.686	14.863	11.08
8760	525600	296753.8	206.31	15.239	11.36

Endicott Crude Oil Evaporation Indoors

5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
13	780	880.776	156.101	0.34	0.52
30	1800	2032.56	155.785	0.656	0.99
60	3600	4065.12	155.318	1.123	1.70
120	7200	8130.24	154.575	1.866	2.83
240	14400	16260.48	153.525	2.916	4.42
360	21600	24390.72	152.786	3.655	5.54
480	28800	32520.96	152.219	4.222	6.40
1440	86400	97562.88	150.352	6.089	9.23
1920	115200	130083.8	149.882	6.559	9.95
2880	172800	195125.8	149.068	7.373	11.18
3360	201600	227646.7	148.789	7.652	11.60
4320	259200	292688.6	148.344	8.097	12.28
4800	288000	325209.6	148.122	8.319	12.62
7680	460800	520335.4	147.325	9.116	13.82
8760	525600	593507.5	147.096	9.345	14.17

2.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
15	900	2032.2	109.076	0.397	1.16
30	1800	4064.4	108.804	0.669	1.96
60	3600	8128.8	108.378	1.095	3.20
90	5400	12193.2	108.056	1.417	4.15
120	7200	16257.6	107.804	1.669	4.88
240	14400	32515.2	107.11	2.363	6.91
360	21600	48772.8	106.688	2.785	8.15
480	28800	65030.4	106.396	3.077	9.00
1440	86400	195091.2	105.463	4.01	11.73
1920	115200	260121.6	105.166	4.307	12.60
2880	172800	390182.4	104.79	4.683	13.70
3360	201600	455212.8	104.643	4.83	14.13
4320	259200	585273.6	104.41	5.063	14.81
4800	288000	650304	104.298	5.175	15.14
7680	460800	1040486	103.913	5.56	16.27
8760	525600	1186805	103.805	5.668	16.58

Endicott Crude Oil Evaporation Indoors

1.0mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
15	900	5081.4	103.101	0.339	2.54
30	1800	10162.8	102.91	0.53	3.97
60	3600	20325.6	102.653	0.787	5.90
90	5400	30488.4	102.487	0.953	7.14
120	7200	40651.2	102.37	1.07	8.02
240	14400	81302.4	102.085	1.355	10.15
360	21600	121953.6	101.936	1.504	11.27
480	28800	162604.8	101.839	1.601	12.00
1440	86400	487814.4	101.512	1.928	14.45
1920	115200	650419.2	101.393	2.047	15.34
2880	172800	975628.8	101.262	2.178	16.32
3360	201600	1138234	101.21	2.23	16.71
4320	259200	1463443	101.127	2.313	17.33
4800	288000	1626048	101.088	2.352	17.62
7680	460800	2601677	100.934	2.506	18.78
8760	525600	2967538	100.888	2.552	19.12

0.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	wt %
15	900	10162.8	94.518	0.306	4.58
30	1800	20325.6	94.398	0.426	6.38
60	3600	40651.2	94.262	0.562	8.42
90	5400	60976.8	94.183	0.641	9.60
120	7200	81302.4	94.13	0.694	10.39
240	14400	162604.8	94.009	0.815	12.20
360	21600	243907.2	93.945	0.879	13.16
480	28800	325209.6	93.901	0.923	13.82
1440	86400	975628.8	93.741	1.083	16.22
1920	115200	1300838	93.68	1.144	17.13
2880	172800	1951258	93.623	1.201	17.98
3360	201600	2276467	93.599	1.225	18.34
4320	259200	2926886	93.557	1.267	18.97
4800	288000	3252096	93.538	1.286	19.26
7680	460800	5203354	93.447	1.377	20.62
8760	525600	5935075	93.424	1.4	20.96

Endicott Crude Oil Evaporation Indoors

0.185mm

time (m)	time (s)	wt (g)	loss (g)	wt %
5	300	91.489	0.034	2.54
19	1140	91.443	0.08	5.97
30	1800	91.417	0.106	7.92
45	2700	91.398	0.125	9.34
60	3600	91.389	0.134	10.01
90	5400	91.38	0.143	10.68
120	7200	91.361	0.162	12.10
240	14400	91.333	0.19	14.19
360	21600	91.317	0.206	15.38
480	28800	91.313	0.21	15.68
1440	86400	91.275	0.248	18.52
1920	115200	91.262	0.261	19.49
2880	172800	91.252	0.271	20.24
3360	201600	91.252	0.271	20.24
4320	259200	91.239	0.284	21.21
4800	288000	91.238	0.285	21.28
7680	460800	91.222	0.301	22.48
8760	525600	91.219	0.304	22.70

North Slope Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	theta	wt %	vol %
1	60	23	0.07	0.09
2	120	45	0.12	0.14
3	180	68	0.15	0.17
5	300	113	0.21	0.24
10	600	226	0.35	0.40
15	900	339	0.51	0.57
30	1800	678	0.91	1.02
60	3600	1355	1.67	1.87
120	7200	2710	3.05	3.43
180	10800	4065	4.19	4.70
240	14400	5420	5.25	5.89
300	18000	6775	6.07	6.80
360	21600	8130	6.88	7.72
1200	72000	27101	12.34	13.84
1440	86400	32521	13.25	14.85
1680	100800	37941	14.07	15.77
2640	158400	59622	15.81	17.72
2880	172800	65042	16.17	18.12
4080	244800	92143	17.41	19.52
4500	270000	101628	17.77	19.91
8460	507600	191061	19.45	21.80
10080	604800	227647	19.87	22.27
11760	705600	265588	20.29	22.74
12960	777600	292689	20.52	23.00
14400	864000	325210	20.80	23.31
18720	1123200	422772	20.93	23.45
20160	1209600	455293	21.57	24.18
24480	1468800	552856	22.14	24.81
25980	1558800	586732	22.30	24.99
28560	1713600	644999	22.55	25.28
30000	1800000	677520	22.69	25.43

10mm

time (s)	time (s)	theta	wt%	vol%
1	60	34	0.12	0.14
2	120	68	0.16	0.18
3	180	102	0.21	0.24
5	300	169	0.31	0.35
10	600	339	0.56	0.63
15	900	508	0.76	0.85
30	1800	1016	1.35	1.51
60	3600	2033	2.47	2.78
120	7200	4065	4.23	4.74
180	10800	6098	5.99	6.72
240	14400	8130	6.88	7.71
300	18000	10163	7.89	8.84
360	21600	12195	8.68	9.73
420	25200	14228	9.38	10.52
540	32400	18293	10.61	11.90
1380	82800	46749	14.74	16.52
1860	111600	63009	15.91	17.84
2880	172800	97563	17.46	19.57
4320	259200	146344	18.84	21.11
8620	517200	292011	20.77	23.27
10080	604800	341470	21.26	23.83
11520	691200	390252	21.68	24.29
12960	777600	439033	22.00	24.66
14400	864000	487814	22.30	24.99
18720	1123200	634159	23.10	25.89
20160	1209600	682940	23.40	26.23

North Slope Crude Oil Evaporation Indoors

5mm

time (m)	time(s)	theta	wt%	vol%
1	60	68	0.47	0.53
2	120	136	0.57	0.64
3	180	203	0.68	0.76
5	300	339	0.90	1.01
10	600	678	1.34	1.51
15	900	1016	1.83	2.06
30	1800	2033	2.93	3.29
60	3600	4065	4.71	5.28
120	7200	8130	7.54	8.45
180	10800	12195	9.23	10.35
240	14400	16260	10.43	11.69
300	18000	20326	11.53	12.93
360	21600	24391	12.62	14.14
1200	72000	81302	16.92	18.96
1440	86400	97563	17.55	19.67
1680	100800	113823	18.20	20.40
2640	158400	178865	19.70	22.08
2880	172800	195126	19.96	22.37
4080	244800	276428	21.01	23.55
4500	270000	304884	21.33	23.91
8460	507600	573182	23.15	25.94
10080	604800	682940	23.66	26.52
11760	705600	796764	24.11	27.02
12960	777600	878066	24.38	27.32
14400	864000	975629	24.87	27.88
18720	1123200	1268317	25.77	28.89
20160	1209600	1365880	25.87	29.00

2.5mm

time (m)	time(s)	theta	wt%	vol%
1	60	135	0.42	0.47
2	120	271	0.62	0.69
3	180	406	0.76	0.85
5	300	677	1.13	1.27
10	600	1355	2.00	2.24
15	900	2032	2.63	2.95
30	1800	4064	4.62	5.18
60	3600	8129	7.42	8.32
120	7200	16258	10.50	11.77
180	10800	24386	12.40	13.90
270	16200	36580	14.07	15.77
300	18000	40644	14.81	16.60
360	21600	48773	15.44	17.31
1200	72000	162576	19.29	21.62
1440	86400	195091	19.87	22.27
1680	100800	227606	20.42	22.88
2640	158400	357667	21.75	24.38
2880	172800	390182	21.96	24.61
4080	244800	552758	22.99	25.77
4500	270000	609660	23.31	26.12
8460	507600	1146161	25.17	28.21
10080	604800	1365638	25.74	28.85
11760	705600	1593245	26.20	29.37
12960	777600	1755821	26.57	29.78
14400	864000	1950912	26.90	30.15
18720	1123200	2536186	27.60	30.93
20160	1209600	2731277	27.80	31.16

North Slope Crude Oil Evaporation Indoors

1.0mm

time (m)	time (s)	theta	wt%	vol%
1	60	339	0.73	0.82
2	120	678	1.23	1.38
5	300	1694	2.24	2.52
10	600	3388	3.95	4.42
15	900	5081	5.18	5.81
30	1800	10163	7.46	8.36
60	3600	20326	10.83	12.14
120	7200	40651	13.85	15.52
180	10800	60977	15.62	17.50
240	14400	81302	16.46	18.45
300	18000	101628	17.26	19.34
360	21600	121954	17.94	20.11
420	25200	142279	18.52	20.76
540	32400	182930	19.36	21.70
1380	82800	467489	21.83	24.46
1860	111600	630094	22.66	25.40
2880	172800	975629	23.81	26.69
4320	259200	1463443	25.24	28.29
8620	517200	2920111	27.38	30.69
10080	604800	3414701	27.86	31.22
11520	691200	3902515	28.28	31.69
12960	777600	4390330	28.70	32.17
14400	864000	4878144	29.10	32.61
18720	1123200	6341587	29.90	33.51
20160	1209600	6829402	30.20	33.85

0.5mm

time (m)	time(s)	theta	wt%	vol %
1	60	678	1.45	1.63
2	120	1355	2.61	2.93
3	180	2033	3.44	3.86
5	300	3388	4.82	5.41
10	600	6775	7.03	7.89
15	900	10163	8.77	9.83
30	1800	20326	11.36	12.74
60	3600	40651	14.01	15.70
120	7200	81302	16.41	18.39
180	10800	121954	18.19	20.39
255	15300	172768	19.16	21.48
300	18000	203256	19.67	22.05
360	21600	243907	20.20	22.64
1200	72000	813024	23.41	26.24
1440	86400	975629	23.89	26.78
1680	100800	1138234	24.43	27.38
2640	158400	1788653	25.74	28.84
2880	172800	1951258	25.91	29.04
4080	244800	2764282	27.07	30.34
4500	270000	3048840	27.41	30.72
8460	507600	5731819	29.32	32.86
10080	604800	6829402	29.86	33.46
11760	705600	7967635	30.26	33.91
12960	777600	8780659	30.62	34.32
14400	864000	9756288	31.00	34.75
18720	1123200	12683174	31.80	35.64
20160	1209600	13658803	32.10	35.98

North Slope Crude Oil Evaporation Indoors

0.3mm

time (m)	time (s)	theta	wt %	vol%
1	60	1129	1.61	1.80
2	120	2258	3.60	4.04
3	180	3387	5.04	5.65
5	300	5646	7.03	7.88
10	600	11291	10.19	11.42
15	900	16937	11.90	13.34
30	1800	33874	14.89	16.69
60	3600	67748	16.89	18.93
120	7200	135497	19.44	21.78
180	10800	203245	20.65	23.15
240	14400	270994	21.10	23.65
300	18000	338742	21.71	24.33
360	21600	406490	23.03	25.82
420	25200	474239	23.09	25.88
540	32400	609736	23.81	26.69
1380	82800	1558213	26.19	29.35
1860	111600	2100200	27.08	30.35
2880	172800	3251923	28.29	31.71
4320	259200	4877885	29.57	33.14
8620	517200	9733187	31.62	35.44
10080	604800	11381731	31.95	35.81
11520	691200	13007693	32.45	36.37
12960	777600	14633654	33.00	36.99
14400	864000	16259616	33.28	37.30
18720	1123200	21137501	34.22	38.35
20160	1209600	22763462	34.27	38.41

Panuke Crude Oil Evaporation Indoors

15mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	269.2	0	0.00	0.00
15	900	338.751	254.175	15.025	8.43	9.29
30	1800	677.502	246.203	22.997	12.90	13.99
60	3600	1355.004	233.608	35.592	19.96	21.42
120	7200	2710.008	217.941	51.259	28.74	30.66
240	14400	5420.016	201.956	67.244	37.71	40.09
360	21600	8130.024	193.917	75.283	42.22	44.83
480	28800	10840.03	188.547	80.653	45.23	48.00
1440	86400	32520.1	174.461	94.739	53.13	56.31
1920	115200	43360.13	170.509	98.691	55.34	58.64
2880	172800	65040.19	165.849	103.351	57.96	61.39
3360	201600	75880.22	163.969	105.231	59.01	62.50
4320	259200	97560.29	161.21	107.99	60.56	64.12

10mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	205.185	0	0.00	0.00
15	900	508.14	193:46	11.725	9.95	10.90
30	1800	1016.28	186.904	18.281	15.52	16.75
60	3600	2032.56	177.286	27.899	23.69	25.34
120	7200	4065.12	166.43	38.755	32.90	35.04
240	14400	8130.24	156.526	48.659	41.31	43.88
360	21600	12195.36	151.677	53.508	45.43	48.21
480	28800	16260.48	148.406	56.779	48.21	51.13
1440	86400	48781.44	139.64	65.545	55.65	58.96
1920	115200	65041.92	137.26	67.925	57.67	61.09
2880	172800	97562.88	134.477	70.708	60.03	63.57
3360	201600	113823.4	133.308	71.877	61.02	64.61
4320	259200	146344.3	131.472	73.713	62.58	66.25

Panuke Crude Oil Evaporation Indoors

5mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	146.433	0	0.00	0.00
15	900	1016.28	137.47	8.963	15.38	16.60
30	1800	2032.56	132.946	13.487	23.14	24.76
60	3600	4065.12	127.65	18.783	32.23	34.32
120	7200	8130.24	122.695	23.738	40.73	43.26
240	14400	16260.48	118.731	27.702	47.53	50.42
360	21600	24390.72	116.725	29.708	50.97	54.04
480	28800	32520.96	115.31	31.123	53.40	56.59
1440	86400	97562.88	111.463	34.97	60.00	63.53
1920	115200	130083.8	110.384	36.049	61.85	65.48
2880	172800	195125.8	109.123	37.31	64.01	67.76
3360	201600	227646.7	108.58	37.853	64.94	68.74
4320	259200	292688.6	107.693	38.74	66.47	70.34

2.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	104.324	0	0.00	0.00
15	900	2032.2	98.736	5.588	19.25	20.67
30	1800	4064.4	95.991	8.333	28.70	30.62
49	2940	6638.52	93.973	10.351	35.66	37.93
60	3600	8128.8	93.214	11.11	38.27	40.68
78	4680	10567.44	92.293	12.031	41.44	44.02
120	7200	16257.6	90.986	13.338	45.95	48.75
240	14400	32515.2	89.207	15.117	52.07	55.20
360	21600	48772.8	88.285	16.039	55.25	58.54
480	28800	65030.4	87.648	16.676	57.44	60.85
1440	86400	195091.2	85.842	18.482	63.67	67.39
1920	115200	260121.6	85.289	19.035	65.57	69.40
2880	172800	390182.4	84.671	19.653	67.70	71.63
3360	201600	455212.8	84.4	19.924	68.63	72.62
4320	259200	585273.6	84.009	20.315	69.98	74.03

Panuke Crude Oil Evaporation Indoors

1.0mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	102.25	0	0.00	0.00
15	900	5081.4	98.583	3.667	31.19	33.24
30	1800	10162.8	97.545	4.705	40.02	42.52
49	2940	16599.24	96.924	5.326	45.30	48.08
60	3600	20325.6	96.705	5.545	47.17	50.04
78	4680	26423.28	96.433	5.817	49.48	52.47
120	7200	40651.2	96.037	6.213	52.85	56.02
240	14400	81302.4	95.433	6.817	57.99	61.42
360	21600	121953.6	95.108	7.142	60.75	64.33
480	28800	162604.8	94.892	7.358	62.59	66.26
1440	86400	487814.4	94.219	8.031	68.31	72.28
1920	115200	650419.2	93.991	8.259	70.25	74.32
2880	172800	975628.8	93.722	8.528	72.54	76.73
3360	201600	1138234	93.604	8.646	73.55	77.78
4320	259200	1463443	93.458	8.792	74.79	79.09

0.5mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	95.956	0	0.00	0.00
2	120	45.1668	95.17	0.786	13.38	14.50
15	900	10162.8	93.616	2.34	39.84	42.33
30	1800	20325.6	93.21	2.746	46.76	49.61
49	2940	33198.48	92.956	3	51.08	54.16
60	3600	40651.2	92.86	3.096	52.72	55.87
78	4680	52846.56	92.742	3.214	54.73	57.99
120	7200	81302.4	92.573	3.383	57.60	61.01
240	14400	162604.8	92.327	3.629	61.79	65.42
360	21600	243907.2	92.193	3.763	64.07	67.82
480	28800	325209.6	92.075	3.881	66.08	69.93
1440	86400	975628.8	91.75	4.206	71.62	75.75
1920	115200	1300838	91.646	4.31	73.39	77.62
2880	172800	1951258	91.527	4.429	75.41	79.75
3360	201600	2276467	91.468	4.488	76.42	80.81
4320	259200	2926886	91.4	4.556	77.58	82.02

Panuke Crude Oil Evaporation Indoors

0.1mm

time (m)	time (s)	theta	wt (g)	loss (g)	Wt%	Vol%
0	0	0	68.859	0	0.00	0.00
2	120	4975.524	68.472	0.387	34.71	36.93
15	900	37316.43	68.258	0.601	53.90	57.12
17	1020	42291.95	68.248	0.611	54.80	58.07
30	1800	74632.86	68.205	0.654	58.65	62.12
47	2820	116924.8	68.166	0.693	62.15	65.80
60	3600	149265.7	68.147	0.712	63.86	67.59
78	4680	194045.4	68.127	0.732	65.65	69.48
120	7200	298531.4	68.097	0.762	68.34	72.31
240	14400	597062.9	68.048	0.811	72.74	76.93
360	21600	895594.3	68.018	0.841	75.43	79.76
480	28800	1194126	67.996	0.863	77.40	81.84
1440	86400	3582377	67.959	0.9	80.72	85.33
1920	115200	4776503	67.935	0.924	82.87	87.59
2880	172800	7164755	67.928	0.931	83.50	88.25
3360	201600	8358880	67.913	0.946	84.84	89.67
4320	259200	10747132	67.91	0.949	85.11	89.95