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The Emission of Methane from UK Wetlands

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SUMMARY

Sets of peat monoliths have been installed in open-top chambers at ITE and investigations into the factors controlling emission fluxes of methane are being investigated. Emission fluxes in the range 0 to 400 ng m^{-2} s^{-1} have been observed. The magnitude of the emission flux is a function of peat temperature in the surface layer and height of the water table. Data from an automatic weather station will permit the modelling of potential changes in methane efflux due to changes in climate.

Preparations for field-based measurements of methane emission from peat bogs are well advanced. The first collaborative experiments will take place in July 1992 with colleagues from the Universities of Manchester and Edinburgh.

INTRODUCTION

Methane (CH_4) is a radiatively active gas present in trace quantities (currently 1.7 ppm(v)) in the atmosphere. Although the atmospheric concentration of methane is small when compared with other radiatively active gases such as carbon dioxide, there is great interest in studying the sources and sinks of methane because of the high radiative activity of the molecule. Current estimates suggest that around 15% of the "radiative forcing" which has occurred in the period 1980-1990 was due to methane. Direct measurements of atmospheric methane concentration made over the last few years together with samples taken from dated ice cores show that the concentration has doubled since the start of the industrial revolution (TRENDS 91, 1991) and is now increasing at a rate of approximately 1% per year (Figure 1) (Khalil *et al*, 1989). Such a rate of increase has clear implications for the contribution to global warming due to methane.

The main sources of methane may be divided into two types: natural and anthropogenic. Anthropogenic sources include rice paddies, landfill sites, cattle and other domesticated ruminants, mining and the extraction and distribution of natural gas. Estimates for the total anthropogenic emission lie between 200 and 600 Tg yr^{-1}. Natural sources include termites and wild ruminants but the main source is thought to be areas of tundra and wetland where anaerobic organisms convert fixed carbon to methane. Estimates for the emissions from these sites are subject to large uncertainties but values between 60 and 180 Tg yr^{-1} which have been suggested indicate that they, together with rice paddies, represent a significant portion of the global methane emission inventory.

It is clear that a better understanding of the mechanisms controlling methane emissions from wetlands is required to enable better estimates of global emissions to be made, and to allow predictions of the effect which changes in climate may have on emissions. ITE has therefore started a programme of research into the emission of methane from UK wetlands in association with groups from the Universities of London, Manchester, Edinburgh and Cardiff. The wetlands chosen for this study are the peat bogs of northern and western Scotland and northern England. These were chosen because they represent a

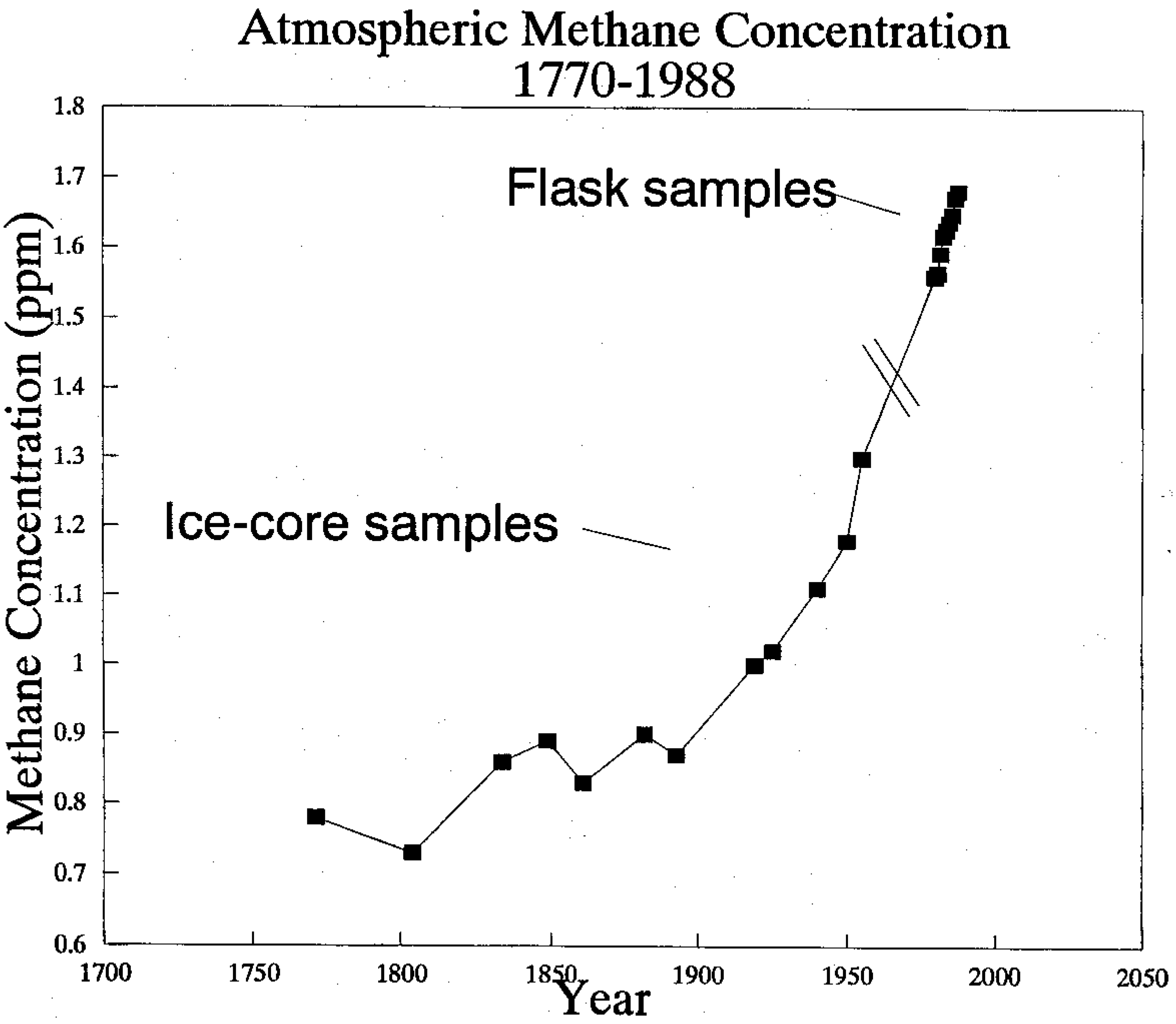


Figure 1: Trends in Atmospheric Methane Concentrations

significant portion of the UK land area and a small (3%) but significant proportion of the global land area. These sites are also similar in their carbon balance and ecology to the extensive wetlands of Scandinavia and eastern Russia, and form a vast reserve of fixed carbon which has the potential to be released as methane or carbon dioxide. This pool has been estimated at 600 Gt C globally compared with the present 455 Gt C present in the atmosphere (Clymo, 1992), and the factors governing release of this carbon pool are very sensitive to environmental variables such as temperature and water table height.

This report describes the methods and objectives of the study and presents some preliminary results.

EXPERIMENTAL DETAILS

This study is divided into two main approaches. The first comprises work based at ITE Edinburgh studying fluxes from individual peat monoliths installed in open-top chambers whilst the second will involve measurements in the field using a variety of micro-meteorological techniques. These will be described in turn.

Open-Top Chamber Studies

Objectives.

To develop a technique for measuring methane on a continuous basis which would allow fluxes from individual peat monoliths to be measured and related to variations in temperature and water status. Operation of an automatic weather station on a peat bog to allow the results obtained under controlled conditions to be related to the conditions on a typical bog.

Methods.

Instrumentation: Conventionally, methane is measured using a gas chromatograph (GC) fitted with a flame ionisation detector (FID) which responds to all hydrocarbons. Separation of each species of hydrocarbon is achieved using a chromatography column. This technique is not sensitive enough for the sort of studies employed here and is only capable of analysing a few samples per hour. An alternative scheme was devised to measure methane on a continuous basis using a GC with FID and employing a catalytic oxidiser to destroy higher molar weight hydrocarbons. The principle of the oxidiser is shown in Figure 2 for a platinum-based catalyst. If a stream of mixed hydrocarbons is passed through such a column the heavier hydrocarbons will be prefentially oxidised as temperature increases, the last species to be destroyed being methane. By operating at a temperature which destroys a small proportion (10%) of incoming methane the absence of higher hydrocarbons can be assured. The exact temperature used depends on catalyst area, flowrate and catalyst column geometry.

This technique was successfully employed using a conventional Carlo-Erba GC/FID (Figure 3). The catalyst column was placed in the GC oven and the gas supplies replumbed to allow sample air to be compressed, passed to the catalyst then burnt in the FID. Optimum sensitivity was obtained for this particular system with a flowrate of 400 ml min^{-1} and a column temperature of 180°C. At ambient methane concentrations of 1.7 ppm(v) this instrument can resolve concentration differences of 12 ppb.

Peat Monoliths: One hundred and twenty peat monoliths (0.3 m diameter, 0.4 m deep) were extracted from two sites near Kinlochbervie, north-west Scotland, and placed in identically-sized polythene buckets. Samples of all three types of peat were removed: i) Pool-type, usually having standing water at the surface; ii) Lawn-type with water table close to or just below the surface; iii) Hummock type with water table well below the surface. These types are characterised by different plant species compositions and hence different peat structures.

The peat monoliths were transported to Edinburgh and sunk into the ground within open-top chambers fitted with lids to exclude rain. Thermocouples were

Figure 2: Catalytic Oxidation of Hydrocarbons by Platinum

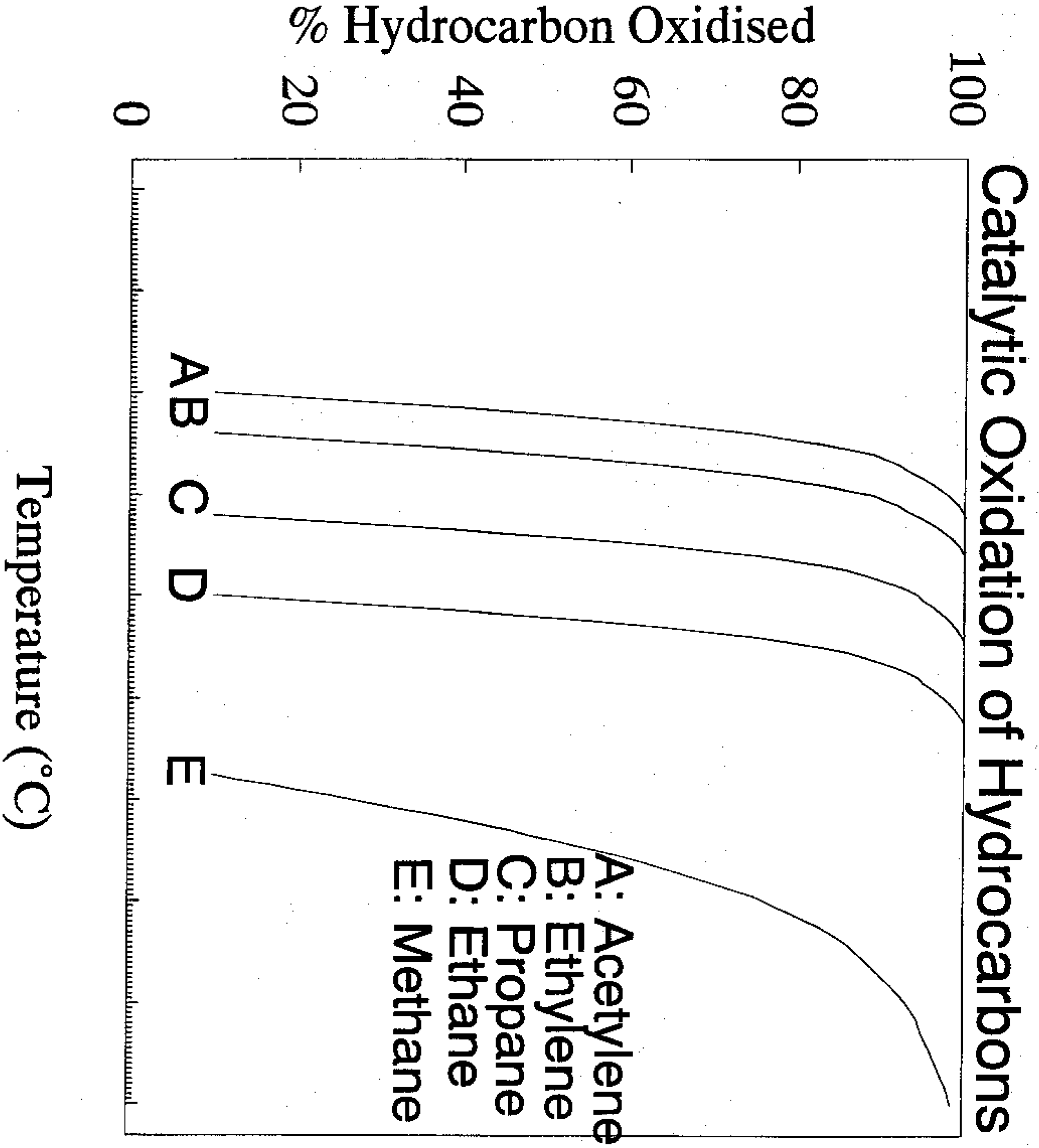
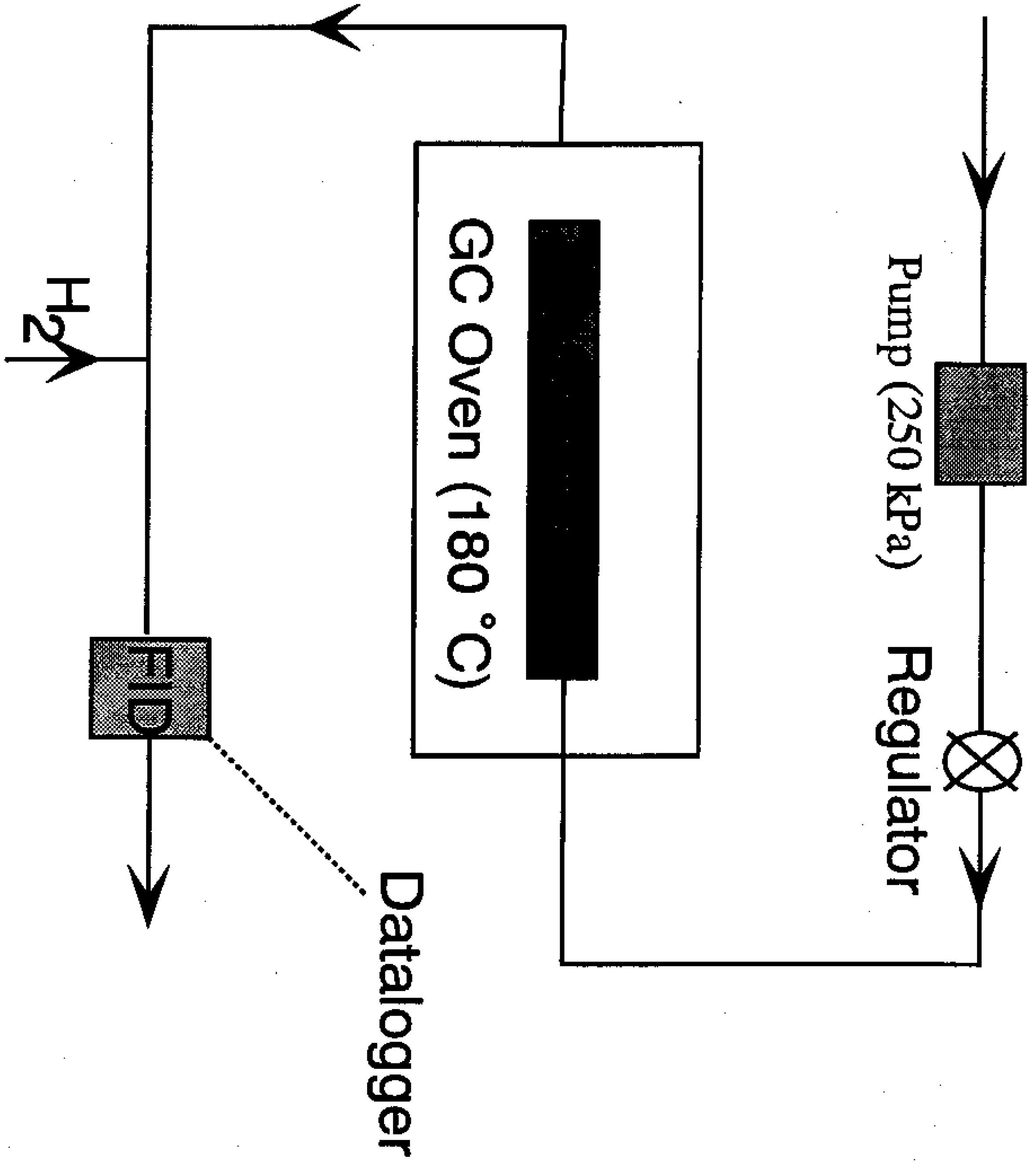


Figure 3: A Modified Gas Chromatograph for Determining Ambient Methane



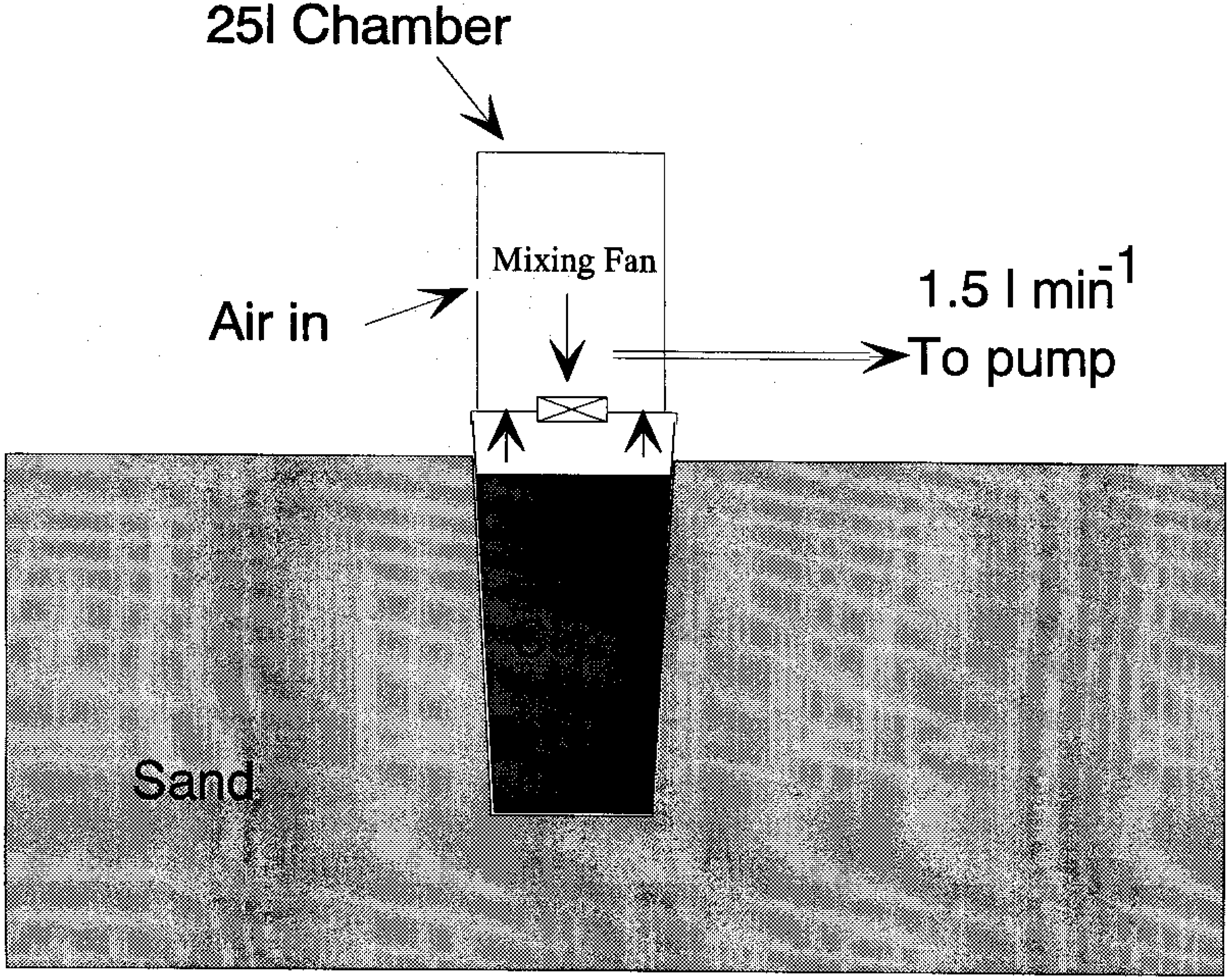


Figure 4: A Method of Measuring Methane Emission from Peat Monoliths

installed at several depths within several of the cores to monitor peat temperature and water table height was maintained using de-ionised water at levels similar to those found in natural conditions. A small flux-chamber was constructed, incorporating a mixing fan which could be placed over individual cores (Figure 4). Air was drawn from within this chamber at 1.5 l min^{-1} and passed to the GC/FID for analysis. The air within the chamber was replaced by inflow of ambient air. This system allows direct calculation of emission fluxes using the equation

$$F=\frac{V(\chi_o-\chi_i)}{A}$$

where F is the methane flux (μg m^{-2} s^{-1}), V is the flowrate (m^3 s^{-1}), χ_o and χ_i are methane concentrations within and outside the chamber respectively (μg m^{-3}) and A is the area of the core (m^2).

Automatic Weather Station: An automatic weather station (AWS) has been put in place on Ellergower Moss in south-west Scotland. This station is monitoring windspeed, temperature, solar radiation, rainfall, relative humidity, water table position and peat temperatures at different depths and in different types of peat. A second AWS will be installed in the far north of Scotland in Spring 1992 to provide a comparison with the milder southern site.

Results and Future Programme: Initial results are showing systematic differences between methane emission rates for different types of core. Table 1 shows the range of fluxes measured from six cores of each type when peat temperatures in the upper 10 cm were between 10 and 12°C. In all cases water table height was maintained at depths typical of field conditions for each type of core.

Table 1: Emission Fluxes by Core Type

Core Type	Pool	Lawn	Hummock
Flux ng m^{-2} s^{-1}	200-400	100-150	0-50

A clear trend is apparent: the wetter - and hence more anaerobic - cores produced larger methane fluxes. This may be simply related to the water table height or may reflect different quantities of available carbon acting as the substrate for methanogenesis. Tests were carried out on the pool type cores to determine the effect of lowering the water table but maintaining temperature in the range 10-12°C. Initially the water level was set 5cm above the surface of the peat then reduced in three steps until it was 10 cm below the peat surface (see Table 2).

Table 2: Methane Fluxes from Pool type Cores (ng m^{-2} s^{-1})

5cm Standing Water	Water at Surface	5cm Water Table	10 cm Water Table
200-400	200-400	100-200	50-100

This test established a clear link between water table height and methane emission flux but as yet is the only data available which illustrates this relationship. More extensive work will be carried out during 1992 studying the responses of all three core types.

The effect of peat temperature on methane efflux rate was also studied on one pool type core. This core had the water table maintained within very close limits (±5 mm) and had peat temperatures recorded at 5,10,20 and 40 cm depth. Figure 5 shows the relationship obtained and indicates a very strong response of methane flux to temperature. This relationship only held with the temperatures measured at 5 cm depth: no clear relationship with temperatures at lower levels was observed. An Arrhenius plot (Figure 6) of this data indicated an activation energy of 68 kj $mole^{-1}$, a value typical of microbiological

Figure 5: Effect of Temperature on Rate of Methane Production

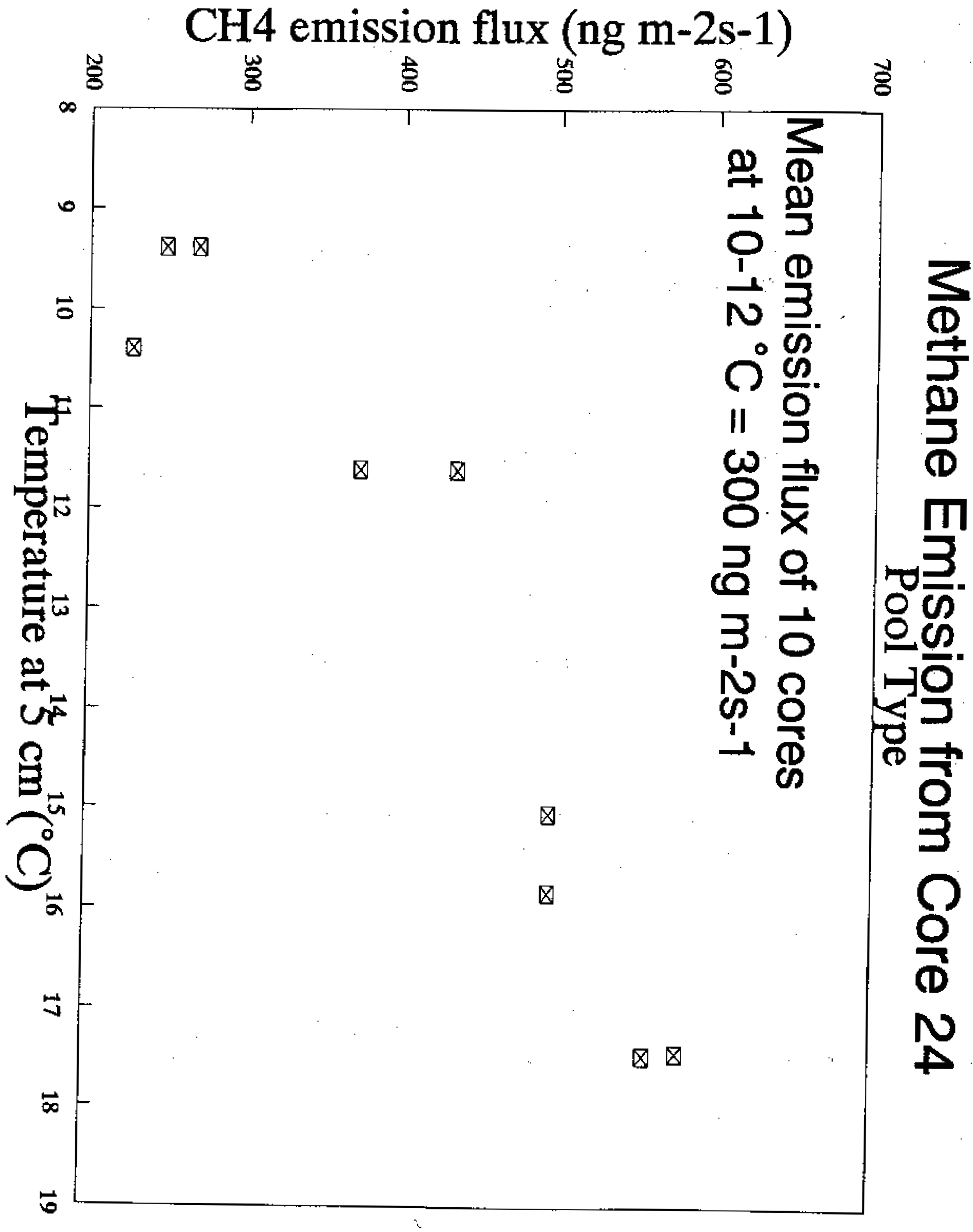
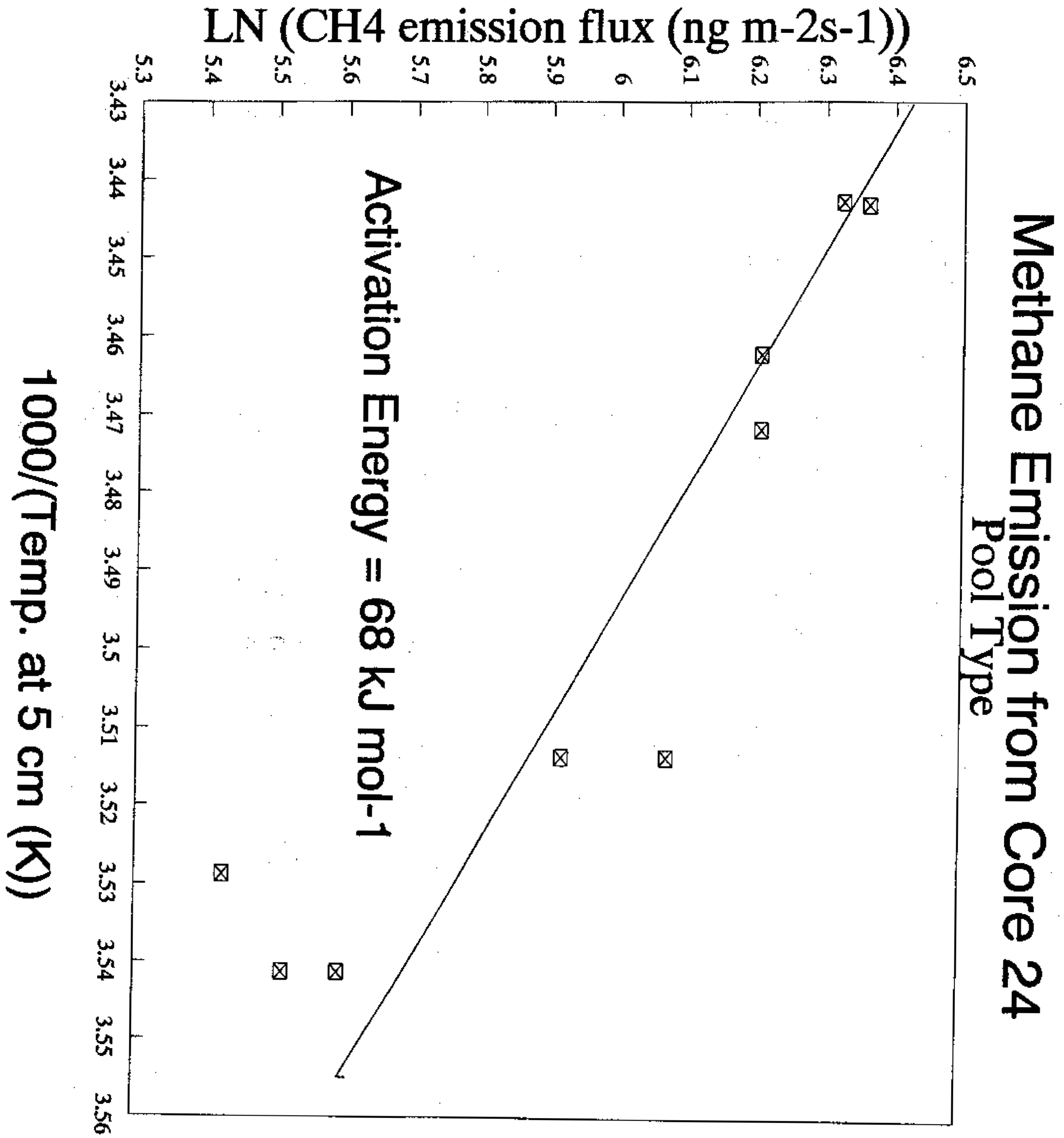


Figure 6: Determination of Activation Energy for Methane Production



processes.

The programme of work for 1992 involves continuing measurements of methane fluxes across replicated cores over a wide range of temperatures and water statuses. Using this information we hope to construct a simple model of methanogenesis which can use data from the AWS's to allow modelling of fluxes from intact bogs and predict the potential effects of climatic change on methane emissions from the northern wetlands.

Field Measurements

Objectives

To directly measure methane fluxes in the field using a variety of instruments and techniques, integrating over areas from less than one square metre to several square kilometres. These studies will assist in validating the models developed from the studies in open-top chambers. The first campaign lasting three weeks will take place in July 1992 in the flow country of Caithness, north-east Scotland where extensive areas of peat bog are to be found.

Methods

Cuvette: Small flux chambers similar to those described above will be used to measure methane fluxes from pool, lawn and hummock areas of the selected site. The instrument used will be a Hewlett-Packard 5890 GC/FID modified in the same way as the Carlo-Erba GC/FID described above.

Aircraft: On several occasions during the campaign it is intended to fly a light aircraft at low altitude collecting flask samples of air along a transect parallel to the wind direction. Because of the large expanse of bog it may prove possible to detect a concentration gradient of methane along the transect and use this gradient to deduce a bulk methane flux for a large segment of northern Scotland. Analysis of the samples will be performed on the Hewlett-Packard GC/FID described above. A Remtech Doppler Sodar will be on site measuring upper air windspeeds and inversion layer level. Information from this device will be required to translate methane gradients measured by the aircraft into mean fluxes.

Flux-Gradient: Measurements of methane concentrations at several heights close to the surface in order to detect gradients in concentration. Unless methane fluxes are very large this is unlikely to be successful because of the poor sensitivity of the GC/FID and the small concentration gradients expected. The technique may however work under calm conditions when turbulent exchange is small and will be attempted when conditions are suitable.

Long-Path Absorption: This is a further technique for measuring methane concentrations in air. This instrument (Siemens-Plessey Hawk) is an infra-red laser absorption device which selectively detects a portion of one of the absorption peaks of methane by making small alterations in the wavelength of the transmitted light. Laser source and detector are housed in one unit whilst a reflector is placed at any distance from 10 to 300 m away, the instrument being aligned initially by eye and then by tuning circuitry. This instrument will be used in two ways:

i) Measuring the rise in methane concentration under a nocturnal inversion. Inversion depth will be recorded by the doppler sodar.
In recent trials of the Hawk over an anaerobic agricultural soil no such rise in methane concentration was detected. However, colleagues from ITE Merlewood confirmed, using cuvette techniques, that there was no detectable methane release from that site. During the same period another Hawk tuned to measure nitrous oxide (N_2O) successfully measured the accumulation and subsequent dispersion of that species as the nocturnal inversion formed then broke up, so we are confident that this technique will provide valuable results.

ii) Observing the rise in methane concentration in a 25 m long horticultural tunnel placed on the bog. This is in effect a large cuvette technique which will integrate over an area of 50 m^2 and will be able to include pool, lawn and hummock regions within one cuvette. To avoid artefacts caused by the presence of the tunnel, it will be necessary to limit measurements to a few per day and leave the tunnel rolled back for the rest of the time. This technique has been successfully used by colleagues at the Scottish Agricultural College with a Hawk tuned for nitrous oxide (Scott, 1992).

Experience with the Hawk in the field has shown the need for a stable base in order to maintain optical alignment. It is anticipated that a large, fairly heavy "raft" will be required when working on a soft bog, and details of this are currently being considered. In subsequent campaigns it may prove possible to use the Hawk to make flux-gradient measurements, although this will require development of precise optical switching systems in order to maintain alignment.

Eddy-correlation: This technique probably offers the most sensitive and elegant way to measure methane emission from large areas. The ultrasonic anemometer required to measure micro-meteorological data has already been purchased and wide experience of using it in the field has been built up. Specifications and pricing for a tunable diode laser system to make fast measurements of methane are being discussed and delivery of the instrument is expected in October 1992. It is anticipated that winter 1992-1993 will be used for commissioning the instrument and the first field measurements will be carried out during the summer 1993 campaign.

CONCLUSIONS

The programme of work at ITE Edinburgh studying methane emissions is now well under way. Instrumentation and peat monoliths have been installed and investigations of the effects of temperature and water status on methane fluxes are in progress. The data obtained so far has established clear effects of temperature and water status on rates of methane efflux and further work in progress will quantify these effects and allow models to be developed. By August 1992 a full years data will be available from the AWS and modelling of an annual emission inventory for one site can begin.

Instruments for the field-based measurements are being prepared and a large collaborative campaign in northern Scotland is planned for summer 1992. A wide variety of instruments and techniques will be deployed at this site in collaboration with colleagues from the Universities of Manchester and Edinburgh.

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