A NOTE ON PRECALCINATION IN CEMENT MANUFACTURE

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ABSTRACT

This note presents the thermal analysis and other design aspects of the precalciners to be added to the existing kilns at the Puttalam Cement Works in order to increase their capacity from 740 to 1000 tonnes of clinker per day each.

1.0 The principal thermal processes in the manufacture of Portland cement by the dry process comprise (i) the preheating of the raw meal (a finely pulverized mixture of limestone and clay), (ii) the calcination (i.e., the conversion to calcium oxide) of the calcium carbonate in the limestone, (iii) sintering of the raw meal to form complex aluminosilicates (clinker), and (iv) the controlled cooling of clinker.

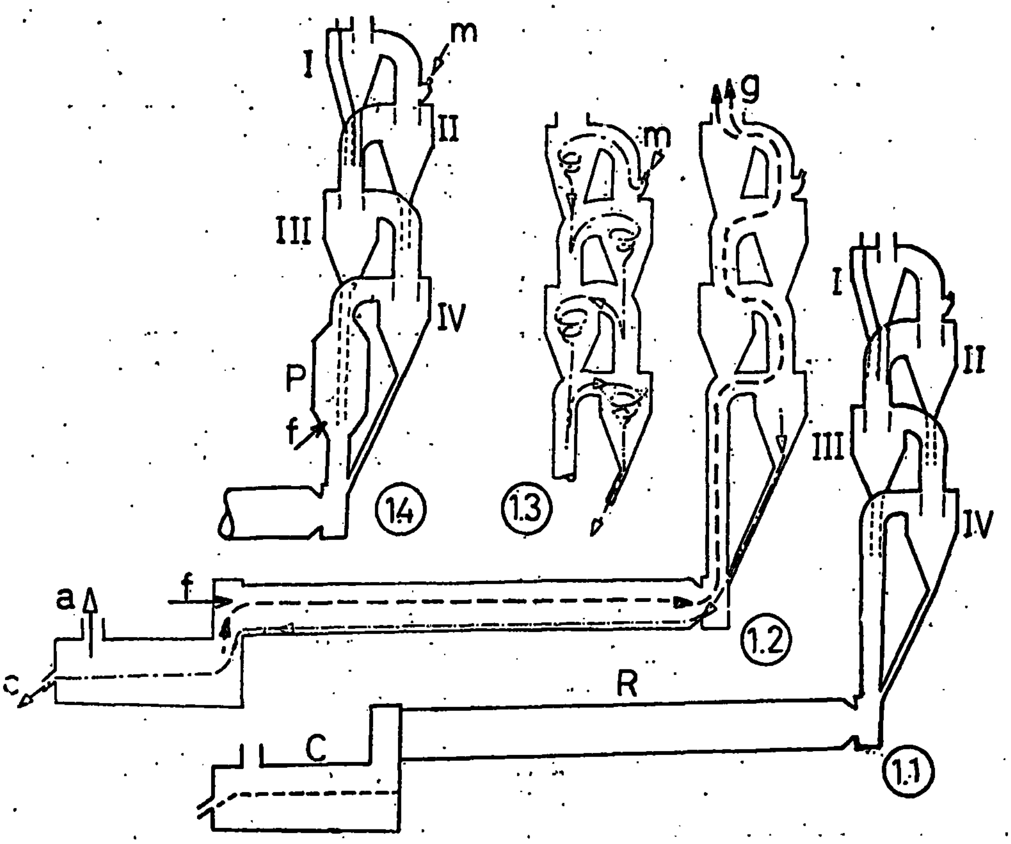
1.1 Existing dry-process kilns, generally, use cyclone preheaters where the raw meal is heated in suspension. Until the seventies, both the calcination and sintering processes were carried out in a rotary kiln. The cooling of the clinker is done in a clinker cooler which also serves as an air preheater for the rotary kiln. (See Fig.1).

1.2 In recent kiln designs most of the calcination is done outside the rotary kiln in a precalciner, within the suspension preheater system (Fig. 1). Several existing kilns have been modified within the past few years to include precalciners. The advantages of precalcination are two-fold: on the one hand, the bulk of the heat load for calcination is shifted out of the rotary kiln and, hence, it is possible to sinter more material within the rotary kiln; and, on the other, because the major part of the heat input to the kiln is used for calcination the thermal load on the rotary kiln is substantially reduced, even after an increase in the kiln output.

1.3 This note is about the thermal design of precalciners for the two cement kilns at the Puttalam Cement Works (PCW).

2.0 Several effective designs of precalciners are available. (See Fig. 3). But, since the proposed precalciner is essentially a modification to an existing kiln, not all the available designs will be suitable for adoption.

2.1 The principal differences between the different designs of precalciners concern the air supply system and the fuel burning system. There are also differences in constructional features.



1. Preheater, Rotary Kiln and Clinker Cooler Layout
1.1 System without precalcination
1.2 gas flow path and part of material flow path
1.3 Material flow path in suspension preheater
1.4 System with precalciner

C — Clinker Cooler, R — Rotary Kiln,
a — Cooler air to dust collector fan, c — clinker, f — Fue,
g — gas, m — material,
I, II, III and IV refer, respectively, to the first, second, third and fourth cyclones.

2.2 Although precalciners have been in successful operation for some years, there is still uncertainity about some important design parameters. There is some disagreement about the optimum values of the gas speed and particle residence time in the precalciner, two parameters which, in the main, determine the overall dimensions of the precalciner chamber.

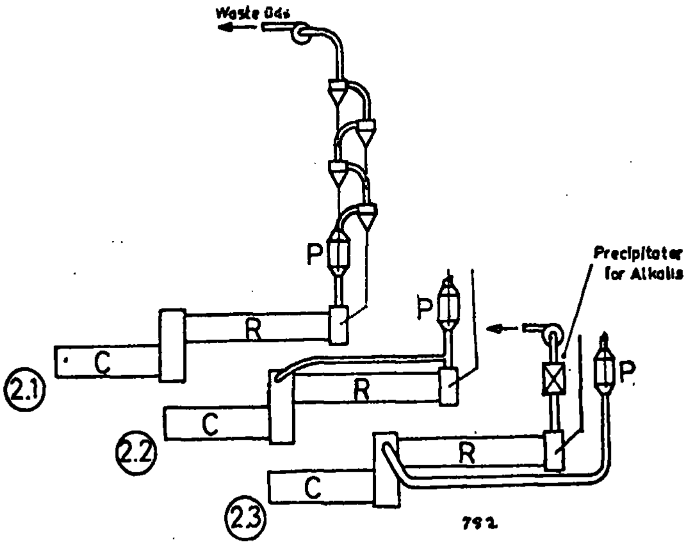
2.3 In designing the precalciners for PCW, accent was placed on economy and easy fabrication. But the design also ensured that the necessary safety limits for the temperature and velocity of gas in any section of the kiln were not exceeded, so that the smooth operation of the kiln will not be hampered by defects in the design of the precalciner.

2.4 It is not possible to discuss in this note the detailed design of the precalciners for PCW; nor is it possible to go into details about the operation of the kiln with precalcination. The discussion will be confined to the main design features of the precalciner, and reference to other components of the kiln will be only where necessary.

3.0 The air supply systems for precalciners may be divided into three broad groups: (i) systems where the entire air supply to the precalciner flows through the rotary kiln, (ii) systems where part of the air supply is through the rotary kiln and part directly from the clinker cooler, and (iii) systems where the entire air supply bypasses the rotary kiln. Total bypassing of the rotary kiln is done in large kilns where there are more than one string of cyclone preheaters and the kiln gases are used for preheating the raw meal in one of the strings and the rest of the preheating is done by the gases from the precalciner. The need to supply combustion air to the precalciner through a separate ducting may also arise if the kiln gases have to be bypassed in order to reduce the alkali content in the clinker or if the gas velocity in the kiln may exceed the stipulated maximum at any location. With the production target at 1000 t/d of clinker per kiln and with 90% of the calcination outside the rotary kiln, and given the low alkali content of he raw material available, the entire air supply to the precalciner could be taken through the rotary kiln.

4.0 The fuel burning system and precalciner geometry selected (Fig. 3.1) for the present purpose are simple in form, easy to fabricate and to erect, and more economical than those in more sophistciated precalciners which are more suitable for new kilns with much larger output.

4.1 The fuel burning system provides for the mixing of the fuel and the raw meal before they come in contact with the combustion air. This mixing ensures that the gas temperature within the precalciner does not exceed 950°C and cuts down the risk of the gases leaving the precalciner having an excessively high temperature. It also ensures that the process is easy to regulate.

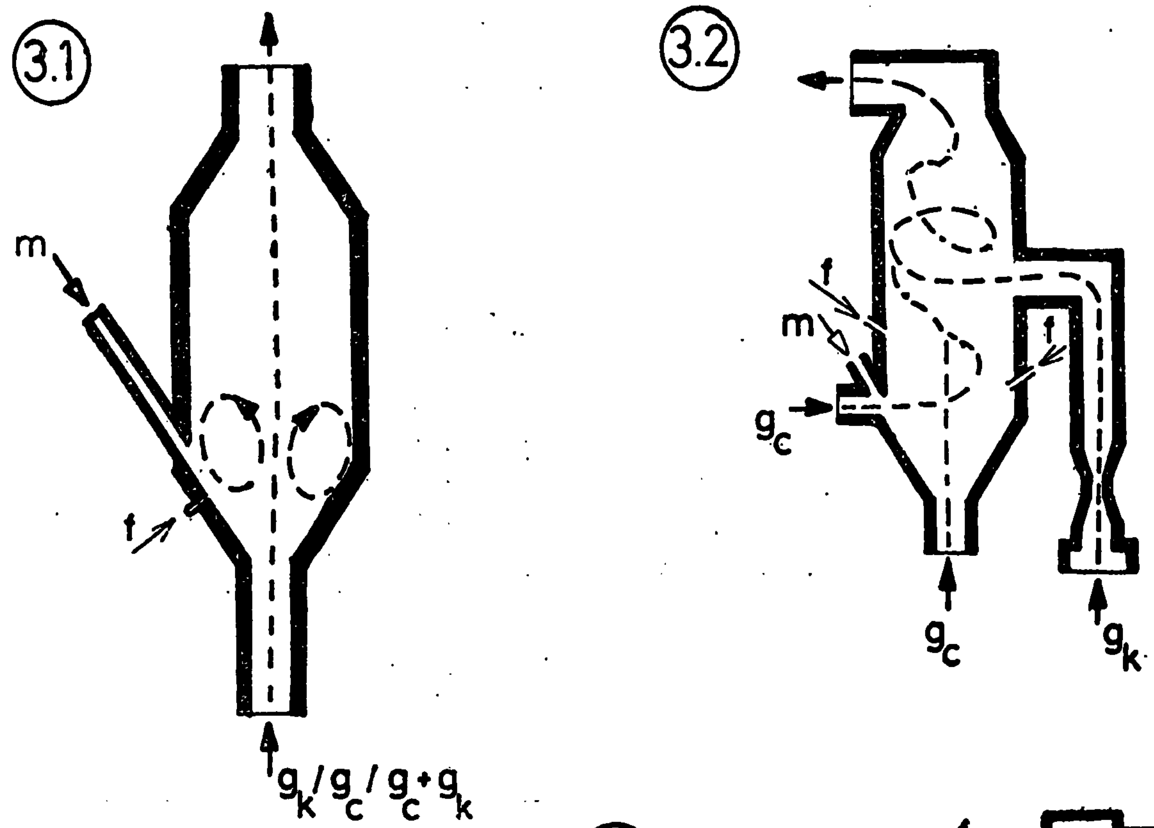


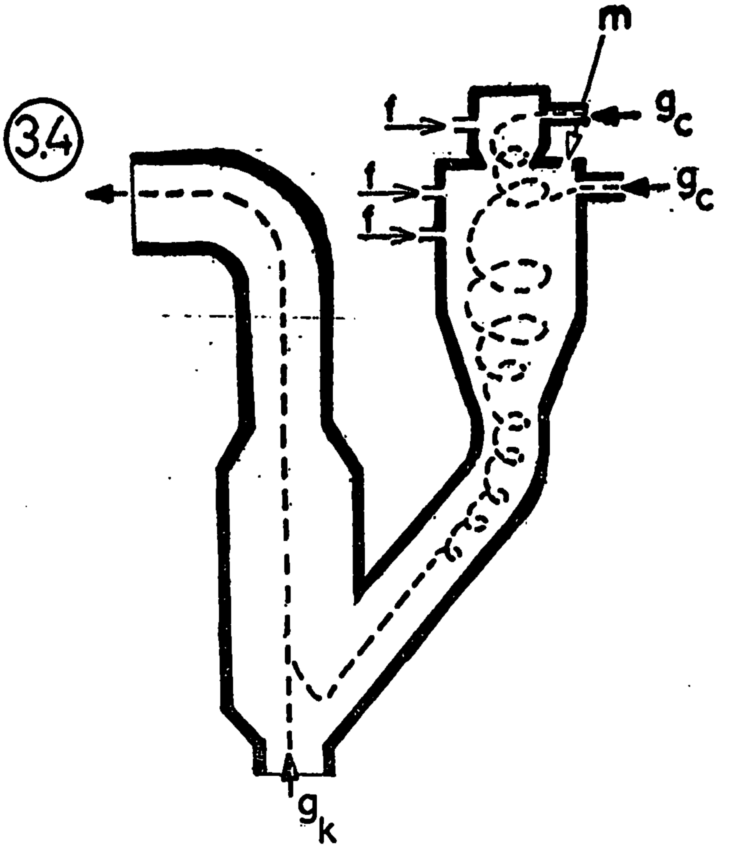
2. Air Supply to the Precalciner
2.1 All air through kiln
2.2 Part of the air through the kiln
2.3 All air bypassing the kiln

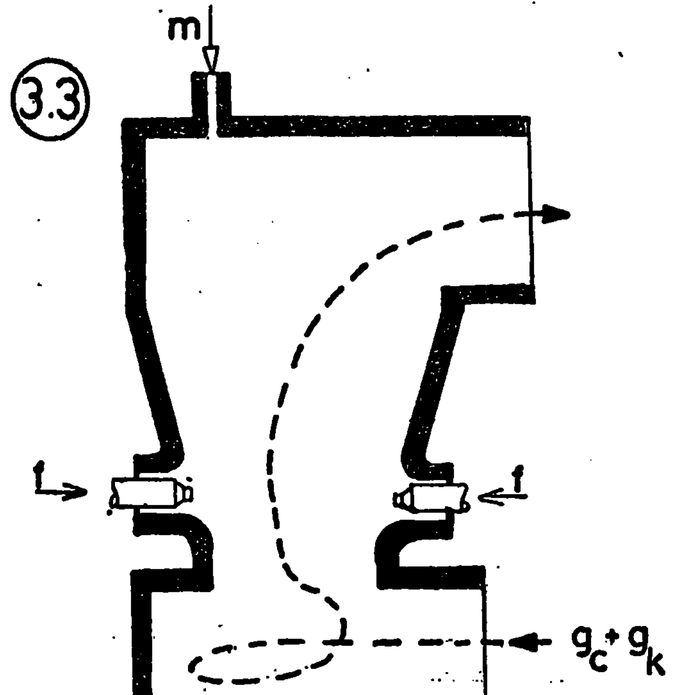
5.0 The mean gas velocity in the precalciner determines the diameter of the precalcimer chamber: the gas velocity ranges from 5 m/s (or less) to 15 m/s in the existing designs. The gas velocity should be large enough to ensure adequate turbulence: a gas velocity of 5 m/s was considered adequate for the given precalciner geometry. This velocity, in addition, made it possible to keep the length of the chamber relatively small and the ratio of the lateral dimension to the length close to the one which would give the minimum surface area or the precalciner. This in turn meant that the precalciner was light and compact and that the cost of the supporting structure was minimum.

6.0 There is some difference in opinion about the minimum necessary residence time for the particles. Although a residence time of 2 to 2.5 seconds will be in good agreement with accepted practice, it was considered useful to make an independent estimate of the order of magnitude of the necessary minimum residence time.

6.1 Reference 1 gives some information about the material and gas temperature distributoin in preheater systems without precalcination. The heat transfer characteristics for the four gas ducts are clearly dissimilar. Variations in the thermal properties and in the composition of the gas and the material, and heat transfer to the surroundings are factors contributing to the observed differences. The data for the duct leading to the fourth cyclone in the preheater system without precalcination are more relevant to our present analysis than are those for the other three ducts. The gas and material temperatures in the above duct are close to that in the proposed precalciner with low-temperature combustion.







3. Precalcining systems showing different methods of fuel burning and supply of material and gas.
- 3.1 F. L Smidth (FLS) Process
- 3.2 Kawasaki Spouted-Bed and Vortex-Chamber (KSV) Process
- 3.3 Suspension Preheater Flash-Chamber (SF) Process
- 3.4 Reinforced Suspension Preheater (RSP) Process

f — fuel, g_c — Gas from clinker cooler, g_k — Gas through kiln, m — material.

6.2 In the approximate analysis below, the thermal and transport properties of the material and the gas are taken to be the same as in the duct for which heat transfer data is available, although, in fact, both the gas and the material do undergo change in composition during calcination. The purpose of the present analysis is to make a rough estimate of the necessary heat transfer time and the above assumption will not lead to serious error.

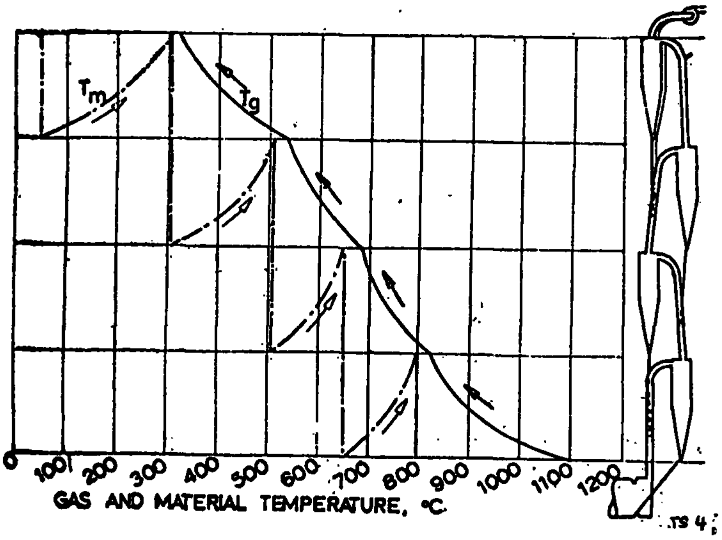
6.3 It is assumed that the material entering the fourth cyclone is 10% calcined and that the calcination starts after the material reaches its maximum temperature within the duct. This assumption simplifies the analysis and gives a marginally conservative estimate of the heat transfer time. The material in the precalcinator is assumed to undergo isothermal calcination and the combustion process within the precalciner chamber is taken as isothermal. This assumption is supported by the observations reported in Ref. 1 and 5.

6.4 The heat transfer analysis is given below and the corresponding temperature distributions are shown in Fig. 5. Assuming equal heat transfer coefficients in both instances, and taking the mass flow ratio of gas and material and thermal properties to be the same,

$$\frac{(dq/dt)_1}{(T_g - T_m)_1} = \frac{(dq/dt)_2}{(T_g - T_m)_2}$$

Hence,

$$t_{r,2} = t_{r,1}\,\frac{\left(\int_0^{Q_1} dq/\Delta T\right)_1 Q_2}{\left(\int_0^{Q_2} dq/\Delta T\right)_2 Q_1}$$



4. Gas and Material Temperature Distribution in Preheater System.
T_m — Material temperature, T_g — gas temperature

where, the symbols and subscripts used means the follwing,

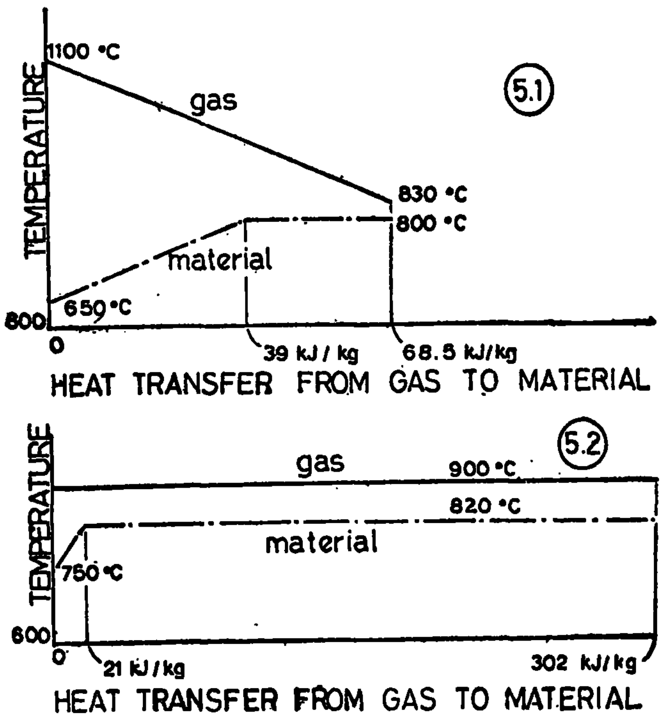
Symbols :

q	=	heat transfer from gas to material
Q	=	total heat gain by material
T	=	temperature
t	=	time
t_r	=	residence time
ΔT	=	$T_g - T_m$

Subscripts :

g	=	gas
m	=	material
1	=	gas duct from kiln to fourth cyclone in preheater system without precalcination
2	=	precalciner chamber

The temperature variations shown in Fig. 5 are based on data available in Ref. 1 and 5 and the assumption of isothermal combustion and isothermal precalcination permits simple computation of the necessary residence time, with reasonable accuracy. The mean gas velocity in the duct is taken as 30 m/s and effective duct length as 10 m, giving $t_{r,1}$ a value of 0.33 second.



5. Hypothetical Temperature Distribution of Gas and Material
5.1 for duct from kiln to 4th cyclone
5.1 fos precalciner chamber

6.5 The heat transfer time is estimated to be around 2.5 seconds. The time for chemical reactions is an order of magnitude smaller than that for heat transfer and is therefore neglected in the analysis. The slip velocity of the particle of nominal size and spherical shape is around 0.25 m/s and that of the actual particles will be somewhat larger because of agglomeration of the particles. This will result in a larger residence time for the particles than is based on the slip for the particles; the effect of gas recirculation in the lower portion of the precalciner will again be to increase the mean residence time of the particles. The latter effect alone will more than compensate the under estimate of the residence time by neglecting the time for chemical reactions.

6.6 The estimated residence time is in fair agreement with that in accepted practice. A chamber height of 10 m was selected to permit a nominal residence time of 2 seconds with mean gas velocity of 5 m/s with slip velocity for particles taken as 0. The particle slip and residence time in the ducting from the chamber to the fourth cyclone will serve as adequate safeguard against any possible underestimate.

7.0 The chamber diameter for a mean gas velocity of 5 m/s and a mean gas flow rate of 68 m^3/s at 900°C and 100 k Pa was estimated at 4.12 m. With brick lining of the same specifications as in the rest of the preheater system the overall diameter of the chamber is 4.5 m.

References/Bibliography

1. Duda, Walter H., *Cement Data*, 2nd ed., Weisbaden: Bauverlag GmBH, 1979.
2. Qwech, L., *Pyroprocessing, VDZ Kongress 77, Process of Cement Man ıfacturing*, organized by Verein Deutscher Zementwerke e.V., Dusseldorf, proceeaings published by Bauverlag GmBH, Weisbadne and Berlin, 1979.
3. Cement Research Institute of India, *Detailed Project Report on Productivity Enhancement for Sri Lanka, Cement Industry*, Nov. 1978.
4. FLS Newsfront, *Precalcining . . . Principles and Problems*, No. 12.74, Copenhagen: F. L. Smidth & Co. 1974.
5. FLS Newsfront, (*PrecalcinerIndustrial-Scale 'ests.* No. 12.74, Copenhagen: F. L. Smidth & Co., 1974.
6. FLS N:wsfront, *New Precalcining Kiln Started in Japan*, N›. 7.78, Copenhagen: F. L. Smidth & Co., 1978.

Acknowledgements

The work reported here was undertaken in connection with the project to increase the productivity of the Puttalam Cement Works. The project, undertaken at the request of the Chairman, Sri Lanka Cement Corporation, was carried out in collaboration with the engineering staff of the Puttalam Cement Works. Thanks are due to Mr. Asoka Somaratne, Chairman, Sri Lanka Cement Corporation, for his active encouragement and kind cooperation. Thanks are also due to Mr. M. D. J. F. Jayamanne, Works Manager, Puttalam Cement Works, who played a key role in getting the authors to participate in the project, and to Messrs. S. Jeyakumar and M. H. Wickremasinghe, Mechanical Engineers at the Puttalam Cement Works, who were closely associated with the work reported here and in the rest of the project. The kindness of Professor B. L. Panditharatne, Vice-Chancellor, University of Peradeniya, in granting the authors permission to participate in the project is acknowledged with thanks.

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