FEASIBILITY STUDIES OF AN ON-LINE IDENTIFICATION TECHNIQUE

A thesis submitted for the degree of Doctor of Philosophy

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Summary.

This thesis is concerned with the study of a non-sequential identification technique, so that it may be applied to the identification of process plant mathematical models from process measurements with the greatest degree of accuracy and reliability.

In order to study the accuracy of the technique under differing conditions, simple mathematical models were set up on a parallel hybrid computer and these models identified from input/output measurements by a small on-line digital computer.

Initially, the simulated models were identified on-line. However, this method of operation was found not suitable for a thorough study of the technique due to equipment limitations. Further analysis was carried out in a large off-line computer using data generated by the small on-line computer. Hence identification was not strictly on-line.

Results of the work have shown that the identification technique may be successfully applied in practice. An optimum sampling period is suggested, together with noise level limitations for maximum accuracy.

A description of a double-effect evaporator is included in this thesis. It is proposed that the next stage in the work will be the identification of a mathematical model of this evaporator using the technique described.

A paper, entitled "A study of an on-line identification technique", and based on part of the work presented in this thesis, has been accepted for presentation at an I.Ch.E./B.C.S. Symposium to be held in Nottingham in September, 1971. The title of the Symposium is "On-line Computer Methods relevant to Chemical Engineering."

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Contents

Chapter 1

1.1 Introduction.

Since the early part of the 20th Century increasing use has been made of measuring instruments and automatic controllers for the control of industrial processes (43). Industrial process automation has been concerned with the measurement and control of such variables as pressure, temperature, level and flow. These individual controllers were grouped into control centres where the human operator was provided with indicating equipment, high and low level alarms and recording equipment.

Control system design procedures have been generally based on the use of the complex function theory of mathematics. These procedures were 'borrowed' from electrical circuit theory and were essentially for the analysis of single input, single output linear systems. They include the use of the Laplace transform for problem solution and Bode diagrams, Nyquist diagrams and Root locus plots for stability analysis (44).

Due to the nature of the analogue controllers used almost exclusively up until comparatively recently, the form of the controllers has been limited to the well known PID controller. (Proportional-Integral-Derivative). These analogue controllers have generally been pneumatic in operation.

1.2 Application of computers and electronic equipment for control.

Early in the 1950's the first electronic control instruments were introduced, and at this time it was predicted that there would be a steady decline in the use of pneumatic controllers. Typically, 1965 was seen as the crossover point when the use of electronic controllers would exceed 50% of total (45). This crossover point has still not been reached, primarily due to the higher cost of electronic controllers and also to the fire hazards encountered in the use of electronic equipment in flammable atmospheres.

At this time interest began to arise in the use of digital computers for data-logging applications. In this case the computer was used merely as a recording instrument, logging signals from various measuring instruments. Controllers were still pneumatic, and electronic signals for the computers were obtained from pneumatic/electronic converters. Notice that the computer was now being used on-line; in other words it had to keep pace with the plant whose operation it was monitoring.

Interest in the use of data-logging systems was soon superseded by the desire to use computers for closed-loop control. The first recorded use of a closed loop installation went on stream at the Texaco, Port Arthur refinery in the U.S.A. in 1958 (45). This system used an RW 300 supervisory computer to operate the set points of pneumatic controllers. Since this time many applications of closed-loop computer control have been made.

1.3 Methods of computer control.

In modern computer control applications, a hierarchical system of control is generally used. Starting with the process, the first requirement is for control of the type normally achieved using analogue PID controllers, whilst the second is for control of set points, the set points being computed from a steady state plant model according to some production schedule.

These two requirements are usually carried out separately. Individual loop control is carried out by analogue controllers, or by a small, relatively unsophisticated control computer. The computer software would generally be at Assembler language level, i.e. high efficiency but high implementation cost. The set points are computed using a more sophisticated high level language program in a considerably larger computer, this computer being called the supervisory computer.

In cases where the supervisory computer is controlling analogue controller set points, this is termed supervisor-set-point-control, or S.S.P.C. Where a small computer is used to carry out the functions of analogue controllers, the term direct digital control, or D.D.C. is used.

1.4 Justification for using computer control.

The use of computer control cannot be justified as an economical alternative to the use of analogue controllers, and justification for control computers is rarely based on this proposition. The advantages of using computers on-line may be summarised as follows (46):

(1) The speed of the computer allows it to collect far more data about the process from measuring instruments than standard recording equipment.

(2) Its high degree of resolution allows it to read such data far more accurately. This accuracy is, of course, limited by the accuracy of the measuring instrument itself.

(3) Its large memory allows the computer to accumulate far more data for comparison and analysis.

(4) Its calculating power and speed allow it to use complex relationships instead of individual items of data as the bases for decisions.

(5) It can be provided with confidential cost and price data and management directives which cannot with impunity be made available to human operators.

(6) The computer can be provided with far more facts about the relationships between process variables.

The principal justification for a control computer may therefore be seen to be a far greater knowledge of the process being controlled and considerably superior control thus being achieved.

1.5 Impact of control computers on control theory.

Until the advent of computers, there was little need for the development of any control theory further than that already mentioned. However, once on-line computers had arrived, workers began to take a closer look at the problem of controlling complex processes.

The theory used until this time had been developed for simple linear processes. Chemical plants, on the other hand, are generally multivariable, non-linear and time-varying processes; multivariable due to the many inputs and outputs of the system; non-linear due to, for instance, the presence of non-linear flow characteristics and reaction rates; and time-varying due to the effect of fouling on the operation of heat exchangers and furnaces, ageing of catalysts in catalyst beds, day-to-day variation in ambient temperature and wind effects, etc.

Modern methods of analysis at present being developed to cope with the problems outlined above include the mathematical description of the process in state variable form (47); the use of the second method of Lyapunov to study stability (48); the development of methods to identify plant models, discussed later by the author in detail; methods of control system design for multivariable systems utilising a classical mechanics approach (49), and the Inverse Nyquist Array (50); and optimisation techniques developed by Bellman and Pontryagin (51).

Given the techniques outlined above, however, computer control is at present still principally based on the approaches mentioned earlier for simple systems. Reasons for this are manifold. Possibly the most important reason for the retention of PID controllers is the familiarity of present day plant operators with them. Use of more sophisticated control algorithms requires a considerable amount of retraining, which is expensive.

Modern Control theory is still very much in its infancy at present. Future years will probably show a marked swing towards the use of more sophisticated control methods as more processes come under computer control, and more experience is accumulated. These trends will be dependent to a certain extent on labour costs, but if the present increase in labour costs is continued, the trends will be accelerated.

1.6 Implementation of computer control on existing plant.

In general most computer control applications have been on existing plant. It is useful at this stage to consider how best a possible computer control application may be approached.

The first problem to be faced before any computer is purchased is that of establishing a relevant steady-state mathematical model for the plant. From this mathematical model studies can be made to establish the cost-sensitive areas of the process, where the most likely gains are to be made from computer control. Apart from the question of maximising profit through close control of the cost-sensitive process variables, other aspects can be considered at this stage. These are the identification of the areas of the process where control is difficult for practical reasons, areas of the process where labour costs can be reduced by the use of a control computer and areas where close control is required due to the hazardous nature of the process being controlled.

Having established the areas of the process where computer control will be introduced, the next stage is the establishment of dynamic models for these areas. From these dynamic models, simulation studies and the application of modern control techniques will reveal optimal control configurations.

The identification of a dynamic model can be separated into two parts. The first is the development of the structure of the model, or the mathematical form of the relationships between process variables. These structures can be developed from the application of the theory of the process under consideration, or may be more simple approximating forms. The complexity of the model will depend upon the use to which it is going to be put.

Having established the structure of the model, the next stage is to determine the values of the model parameters, such that the model response corresponds as closely as possible with the response of the process under consideration. Techniques for computing the values of these parameters are known as identification techniques. The model parameters are computed from a knowledge of the input and output characteristics, deduced from input/output data for the process under consideration. Thus from data taken from the process itself, accurate models can be established which are essential for sound control system design. Given this control system design, computer control can be implemented with excellent chances of success.

The identification of the dynamic model is of considerable importance, as can be seen, and a great deal of effort is currently being put into developing new identification techniques. Not many cases of their actual implementation have been reported, however.

1.7 Other uses of process models.

In the identification of the plant model in the case above there may well be time-varying process parameters, as have been discussed previously. Thus it may well be necessary to continually update controller settings to give optimal control as the system parameters vary. One way of doing this may be to continually update the process model using a rapid identification technique, and hence continually recompute the optimal controller settings. Implementation of such schemes have been reported (52, 53).

The identification of more sophisticated models is a necessity if more modern control techniques are to be implemented. From these models optimal control trajectories can be computed by the use of such techniques as dynamic programming or Pontryagin's principle.

1.8 Implementation of identification techniques.

The greatest problem in the application of identification techniques to real plant is the requirement that such a plant be disturbed as little as possible from its normal operating conditions. This is to ensure that no off-specification product is produced, and that production schedules can be adhered to.

Methods of identification attempt generally to use noisy signals inherent in large plant operation as forcing functions. Obviously a dynamic model cannot be identified if the process is completely stationary. Other methods use normal operating condition changes made by the supervisory computer or the operators. A third approach is to add pseudo-random noise with known characteristics to the system inputs.

All these approaches have their uses.

1.9 Analysis of identification technique behaviour.

Before an identification technique can be reliably used on real plant, it is necessary to know the effect on the accuracy of the technique of such considerations as noise, sampling period, sample size, etc. Little has been reported in the literature about the analysis of any identification technique with this thought in mind. A few authors have reported the study of the use of identification techniques for particular process plant models.

The author has approached this problem in what he considers as realistic a way as possible. Methods have been developed to study the behaviour of a particular identification technique using simulated process models. At the same time work is being carried out in the Department of Chemical Engineering to commission on-line instrumentation for a pilot scale double-effect evaporator and it is upon this plant that the identification technique will be tested in future work.

Originally these two projects were initiated as a single project by the author. However, the work involved was too extensive for one project and so it was split, the author continuing with the study of the identification technique. Some details of the evaporator system will be given to show the type of plant to be used as a testbed for the identification technique.

Chapter 2

The problem of identification can be defined mathematically as follows:

Given a set of equations governing the behaviour of a system,

$$\dot{\underline{x}}\ (t) = \underline{f}\{\underline{x}\ (t),\ \underline{\alpha}(t),\ t\} + \underline{b}\ \underline{w}\ (t)$$

$$\underline{y}\ (t) = \underline{g}\{\underline{x}\ (t),\ t\} + \underline{c}\ \underline{v}(t)$$

where $\underline{x}$ (t) are the system states; $\underline{\alpha}$(t) are the state parameters defining the model, which, it is assumed, may vary with time; $\underline{b}$,$\underline{c}$,$\underline{f}$ and $\underline{g}$ are linear or non-linear transition functions; $\underline{y}$ (t) are the system outputs; $\underline{w}$ (t) are the uncontrolled system inputs and $\underline{v}$(t) are measurement noises.

It is required to estimate $\underline{\alpha}$(t), given a knowledge of $\underline{y}$ (t) and $\underline{w}$ (t).

In certain cases estimation of $\underline{x}$ (t), the system states, is also possible.

2.1 Classification of identification techniques.

Identification techniques can be split into two distinct groups, sequential and non-sequential. In sequential estimation techniques, the computation is initiated by using trial initial values of the parameters, and every additional set of observations is used to update these values. As the number of observations increases, obviously the accuracy of prediction of the parameters increases.

Non-sequential estimation methods rely on taking a number of observations of y(t) at different times and then effectively fitting a best-fit curve to the dynamic response of the system.

Apart from the classification of estimation techniques into sequential and non-sequential types, different techniques are required for linear and non-linear systems. Hence identification techniques can be subgrouped into 4 different classes.

(a) Linear, non-sequential techniques.

(b) Non-linear, non-sequential techniques.

(c) Linear, sequential techniques.

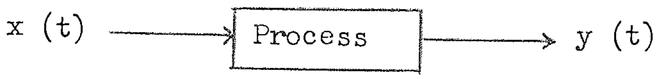
(d) Non-linear, sequential techniques.

2.2 Linear, non-sequential techniques.

Correlation Analysis:

The principal technique used in this group is that using correlation analysis. Briefly, the method is derived as follows (4):

Given a linear process with an input x (t) and an output y (t)



The relationship between input and output is

$$y\ (t) = \int_0^\infty h(\tau).\ x(t-\tau)\,d\tau \quad \text{(Superposition Integral)} \qquad 2.2.1$$

where $h(\tau)$ is the impulse respose of the process.

In terms of frequency the above may be written

$$Y\ (w) = H\ (w)\ X\ (w).$$

Here H(w) is the process frequency response or transfer function and Y(w) and X(w) are the Fourier transforms of y(t) and x(t).

It can be shown using the superposition integral that:

$$\phi_{xy}(t) = \int_{-\infty}^{\infty} h(\tau)\ \phi_{xx}(t-\tau)\,d\tau \qquad 2.2.2$$

and hence,

$$\Phi_{xy}(w) = H\ (w)\ .\ \Phi_{xx}(w)\ .$$

ϕ_{xx} and ϕ_{xy}, and Φ_{xx} and Φ_{xy} are correlation functions and spectral density functions respectively and are related to x(t) and y(t) as follows:

$$\phi_{xx}(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x(t)\ x\ (t+\tau)\ dt$$

$$\phi_{xy}(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x(t)\ y\ (t+\tau)\ dt$$

$$\Phi_{xx}(w) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \phi_{xx}(\tau)\ e^{-i\omega\tau}\,d\tau$$

$$\Phi_{xy}(w) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \phi_{xy}(\tau)\ e^{-i\omega\tau}\,d\tau$$

On inspection of equation 2.2.2 it can be seen that it has the form of the superposition integral, given in equation 2.2.1. If if were possible to find a forcing function whose autocorrelation function had the shape of a unit impulse, then the impulse response of the system would be given by $\phi_{xy}(t)$. As it happens, the autocorrelation function of white noise is an impulse, so driving the system with white noise allows the estimation of the impulse response directly from the cross-correlation function.

There are two principal drawbacks to this technique. First of all, the solution gives either the impulse response of the system as a function of time, or the frequency response as a function of frequency. Both are sets of numbers from which system parameters have to be estimated indirectly. Secondly, to obtain reasonable estimates of the impulse or frequency response, the system under consideration must be disturbed with white noise, or noise with characteristics similar to white noise. White noise has the characteristic that it excites all frequencies of the system with an equal amplitude. In practice it is virtually impossible to obtain, but near approximations are made with the Random Telegraph Signal and the Pseudo-random binary chain code. Hutchinson and Shelton (5) have studied the application of the above technique to a refinery distillation column and compared the use of the Random Telegraph Signal with the Pseudo-random binary chain code. The latter signal was found to be more advantageous.

Woodburn, King and Everson (6) have used the technique to study the estimation of process parameters in packed towers where mixing is taking place. The design of test signals is discussed.

Least Squares Techniques.

Least Squares methods have been suggested and used by Bray, et al (7) and Chien and Aris (8).

Bray, et al applied the technique to the model-making of a Water-gas shift converter, whilst Chien and Aris applied it to a batch reactor.

A linear predictor of the form

$$y\ (t) = \sum_i b_i\ x_i\ (t)$$

is used, where y(t) is the system output and x_i (t) are the system inputs. Values of b_i are required to minimise the sum of the squares,

$$S = \sum_{n=0}^{t-1} \left\{ y\ (t-n) - b_i\ x_i\ (t-n) \right\}^2$$

More recent observations were weighted more heavily than older observations by using a weighting function of exponential form.

The drawback of this technique is the limitation on the form of the mathematical model of the system, which is constrained to be a linear algebraic relationship between the system outputs and the various inputs.

Another approach to this problem is to use a least squares curve-fitting technique in the Laplace domain. The effect of transforming systems of linear differential equations is to convert them to sets of algebraic equations, to which least squares curve-fitting can easily be applied. A numerical technique must be used to transform the known values of input and output as functions of time to values of input and output as functions of the Laplace operator, s. Such techniques have been suggested by Bellman, et al (9) and Carr, et al (10,27). The difference between the techniques used by the two authors is only in the type of numerical transformation technique used. The author has utilised that suggested by Bellman in his work. A review of numerical Laplace Transform techniques is given in a later section.

2.3 Non-linear, non-sequential techniques.

Quasilinearisation.

The estimation of system parameters in more general systems, including non-linear systems, can be carried out using quasilinearisation.

This method has been used by Bellman, et al (11), Lee (12) and Gavalas & Seinfeld (13) to determine reaction rate constants from kinetic data.

Consider the system described by the equations,

$$\dot{\underline{x}} = \underline{f}\ (\underline{x}, \underline{\alpha}, t),$$

$$\underline{x}\ (o) = \underline{a} \qquad 2.2.3$$

where $\underline{\alpha}$ is a vector of unknown system parameters and $\underline{x}$

are the system states. Given a set of observed values of the output b_i, taken at times t_i, it is required to choose the $\underline{\alpha}$ to minimise the sum of the squares.

$$S = \sum_{i=1}^{N} \{ x_1(t_i) - b_i \}^2$$

Combining the $\underline{\alpha}$ with the $\underline{x}$ into a new vector, $\underline{z}$, equation 2.2.3 may be written

$$\dot{\underline{z}} = \underline{f}(\underline{z}, t), \quad \underline{z}(0) = \underline{z}_0 \qquad 2.2.4$$

and

$$S = \sum_{i=1}^{N} \{ z_1(t_i) - b_i \}^2 \qquad 2.2.5$$

Using some arbitrary starting values for the unknown system parameters, $\underline{z}$ (o), equation 2.2.4 is now integrated to give the solutions of the equation at t_i, the observation times.

Equation 2.2.4 is linearised about $\underline{z}^{(o)}$, the solutions of 2.2.4, to give

$$\dot{\underline{z}}^{(1)} = \underline{f}(\underline{z}^{(o)}, t) + \left[\frac{\partial \underline{f}}{\partial \underline{z}} \right]_{\underline{z}^{(o)}} \left\{ \underline{z}^{(1)}(t) - \underline{z}^{(o)}(t) \right\}$$

This gives a linear ordinary differential equation in $\underline{z}^{(1)}$, the new estimate of the unknown system parameters.

This can be solved analytically to give a general solution consisting of a particular solution plus n homogeneous solutions, where n is the number of states included in vector $\underline{z}$. At t = 0 these solutions will give the unknown system states.

These solutions can be substituted in equation 2.2.5 and hence the new estimates of the unknown system states can be determined by solving the equations

$$\frac{\partial S}{\partial \alpha_i} = 0 \; , \quad i = 1, 2 \ldots N.$$

This process can be repeated until all the unknown system states converge within set limits.

Problems arising with the use of this technique are suggested by Seinfeld (14) as:

(a) Non-convergence due to poor initial estimates of the unknown parameters.

(b) Difficulty in the solution of the algebraic equations because of ill-conditioning.

It is difficult to determine if either of these points will be important in a particular problem before actual computation is carried out.

Donnelly & Quon (15) have proposed a modification of the algorithm to improve the convergence characteristics. However, it appears to make the algorithm even more complex than it already is. The complexity of the algorithm is possibly its greatest drawback. However, it is still a useful technique for identifying non-linear equations.

A method termed the method of parameter influence coefficients has been found by Allison (16) to be identical to quasilinearisation, apart from procedural differences. For a set of system equations in state variable form, quasilinearisation is advantageous, whilst for other forms of the system equations the method of parameter influence coefficients should be used.

2.4 Linear, sequential estimation techniques.

Linear sequential estimation techniques are developments of a digital filtering technique suggested by Kalman (17). This is basically a technique for obtaining accurate estimates of system states from noisy measurements. The system parameter estimation problem is tackled by embedding them in the system state equations as system states. Kalman's estimator constrained the uncontrolled system inputs and the measurement noise to be Gaussian in form. The estimator is used to identify parameters when the system under consideration is disturbed by random noise only. Kalman deduced the estimator using Hilbert space theory and developed the estimator for the discrete form of the system equations. This form of the problem emphasises a statistical approach to the development of the estimator.

Kalman and Bucy (18) extended this work to the continuous form of the system equations and Cox (19) deduced the estimator using dynamic programming.

Another approach to the sequential estimation problem was made by Bellman, et al (20) and Detchmendy and Sridhar (21), who made no assumptions about the form of the disturbances and applied a more straightforward least squares approach. They developed this approach for continuous systems, while Sridhar and Pearson (22) developed it for discrete systems. Gavalas and Seinfeld (23) have applied the filter proposed by Detchmendy & Sridhar to the estimation of states and kinetic parameters in a tubular reactor with catalyst decay.

Sequential estimation techniques have distinct advantages for the estimation of parameters in noisy systems, however, the estimators are recursive in form and require a considerable number of matrix manipulations. This makes them considerably slower than non-sequential techniques, which is a distinct disadvantage in industrial systems where time is at a premium due to the large amount of house-keeping done by the on-line computers.

2.5 Non-linear, sequential techniques.

Coggan & Noton (24) have developed a rigorous treatment of the non-linear sequential estimation case utilising a local quasi-linearisation technique. The method of Detchmendy & Sridhar (21) utilises a global quasilinearisation technique and is more approximate than that of Coggan & Noton.

2.6 Estimation Techniques for distributed parameter systems.

Methods have been developed by Seinfeld (25) and Tzafestas and Nightingale (26) for the estimation of parameters in distributed parameter systems. However, they are very complex and not really practical for on-line work.

2.7 Numerical Laplace Transform Techniques.

As the author's work centres around the use of a numerical Laplace Transform technique, it is appropriate to give a review of the literature appertaining to this subject.

Numerical Laplace Transform techniques can be divided into two types, one of which is concerned with the calculation of f(t), given a knowledge of f(s), its Laplace Transform; and the other which is concerned with the calculation of f (s), given values of f(t) in the time domain.

The author's prime interest is with the latter type, knowledge of the values of f (s) being required from known values of f (t) such that identification can be carried out in the Laplace domain.

For completeness, the first type of numerical transform techniques will be briefly reviewed before a more detailed study of transform techniques of the second type is carried out.

Early work done on the numerical inversion of the Laplace Transform was based on a formula suggested by Widder (28) from a general inversion formula proposed by Post (29). This formula represents the general case of a set of inversion methods suggested by Alfrey (30), ter Haar(31) and Schapery (32). Cost (33) has reviewed these methods for use in some problems of visco-elastic stress analysis. The general formula is based on the shifting property of the Dirac delta function , and may be written,

$$f(t) = \lim_{n \to \infty} \left[\frac{(-1)^n s^{n+1}}{n!} \cdot \frac{d^n}{ds^n} f(s) \right]_{s = \frac{n}{t}} .$$

Erdélyi (34) has derived inversion formulae giving f(t) as a series of orthogonal functions, where the coefficients of the expansion are finite linear combinations of the values assumed by f(s) at a set of equidistant points.

Salzer (35, 36, 37) has studied the use of quadrature formulas for the solution of the inversion integral,

$$f(t) = \frac{1}{2\pi i} \int_{c-i\infty}^{c+i\infty} f(s) e^{st} ds .$$

Coming now to the estimation of f(s), given f(t), Bellman (38) has developed an approach utilising a Legendre-Gauss quadrature approximation for the solution of the integral,

$$f(s) = \int_0^\infty e^{-st} f(t)\,dt .$$

Apart from obtaining f (s) from a knowledge of f (t), the inverse problem is also solved, giving the method a marked advantage over other transform methods. Carr & Cook (39, 42) have developed similar methods utilising slightly different quadrature formulae. Luke (55) has reviewed the original work by Bellman, and includes some useful references on numerical Laplace Transform techniques.

A drawback of the inversion formulae developed by Bellman is that f (t) and f (s) are only obtained for a restricted number of non-equidistant points. However, Piessens (40) has developed a method for extending the number of values of f (t) obtained from inversion of f (s) and Felts & Cook (41) have derived a method for extending the range of the estimated values of f (s) from a knowledge of f (t).

Bellman's method may be summarised as follows:

The Laplace Transform is defined:

$$f(s) = \int_0^\infty e^{-st} f(t)\,dt \qquad 2.7.1$$

Introducing a new variable of integration for the independent variable, $r = e^{-t}$,

$$f(s) = \int_0^1 r^{s-1} f(-\ln r)\,dr \qquad 2.7.2$$

The above equation can be approximated by a Gaussian quadrature formula, giving,

$$f(s) = \sum_{i=1}^{N} w_i r_i^{s-1} f(-\ln r_i) \qquad 2.7.3$$

where the w_i are weighting functions.

Bellman computes the roots, r_i, and weights, w_i in the above equation using the Legendre polynomials. The roots and weights are tabulated (38) for N = 3 to N = 15, as are the values of $t_i = -\ln r_i$. The matrix $w_i r_i^{s-1}$ is tabulated (3) as a square matrix for values of N from 3 to 15. The Tables for $w_i r_i^{s-1}$ and t_i are shown in Appendix V.

The numerical inversion of the Laplace Transform by Bellman will not be considered here, except to say that the method generates an inversion matrix which is ill-conditioned.

A point worth noting, however, about the numerical transform technique, is the use of time scaling factors.

Consider a function $f(at)$, where a is a time scale factor, then

$$\mathcal{L}\{f(at)\} = \int_0^\infty e^{-st} f(at)\,dt$$
$$= \frac{1}{a}\int_0^\infty e^{-\frac{st}{a}} f(t)\,dt = \frac{F(\frac{s}{a})}{a}.$$

Introducing the numerical approximation for $F\left(\frac{s}{a}\right)$,

$$F\left(\frac{s}{a}\right) = a\sum_{i=1}^{N} w_i r_i^{s-1} f(-a\ln r_i)$$

$$= a\sum_{i=1}^{N} w_i r_i^{s-1} f(at_i).$$

Note that the transform has been time-scaled; however the matrix $w_i r_i^{s-1}$ is not affected.

2.8 Conclusion.

Considering the identification techniques discussed, obviously the techniques giving the largest amount of information are the sequential identification techniques. However, these require a great deal of computation time.

Opting for an identification technique which gave promise of being economical in both accuracy and computer time, the author chose to study the possibilities of identification in the Laplace domain using a numerical Laplace transform technique. This technique has the added advantage that many chemical engineers are familiar with the Laplace transform.

Choice of the particular Laplace Transform technique to be used was limited, Bellman's being chosen as the coefficients of the formula were well documented.

Non-linear processes to be identified would be approximated in their operating region by linearised models.

Chapter 3

In this chapter the apparatus used by the author in his work is discussed. The basic items of equipment used were a double-effect evaporator, an E.A.L. MDP-200 data-logging system, an E.A.L. HY-48 parallel hybrid computer and a PDS.1020 digital computer. The author also had access to an I.C.L. 1905 digital computer. These items of equipment will be discussed in turn and the connections between the various items of equipment will be discussed.

Photographs of the equipment are shown in figures 3.3 and 3.4.

3.1 The double-effect evaporator.

The evaporator system, consisting of a climbing film effect followed by a forced circulation effect, was purchased from Kestner-A.P.V. Ltd. and is capable of evaporating 300 lbs/hr. of water. A line drawing of the evaporator system is given in fig. 3.1.

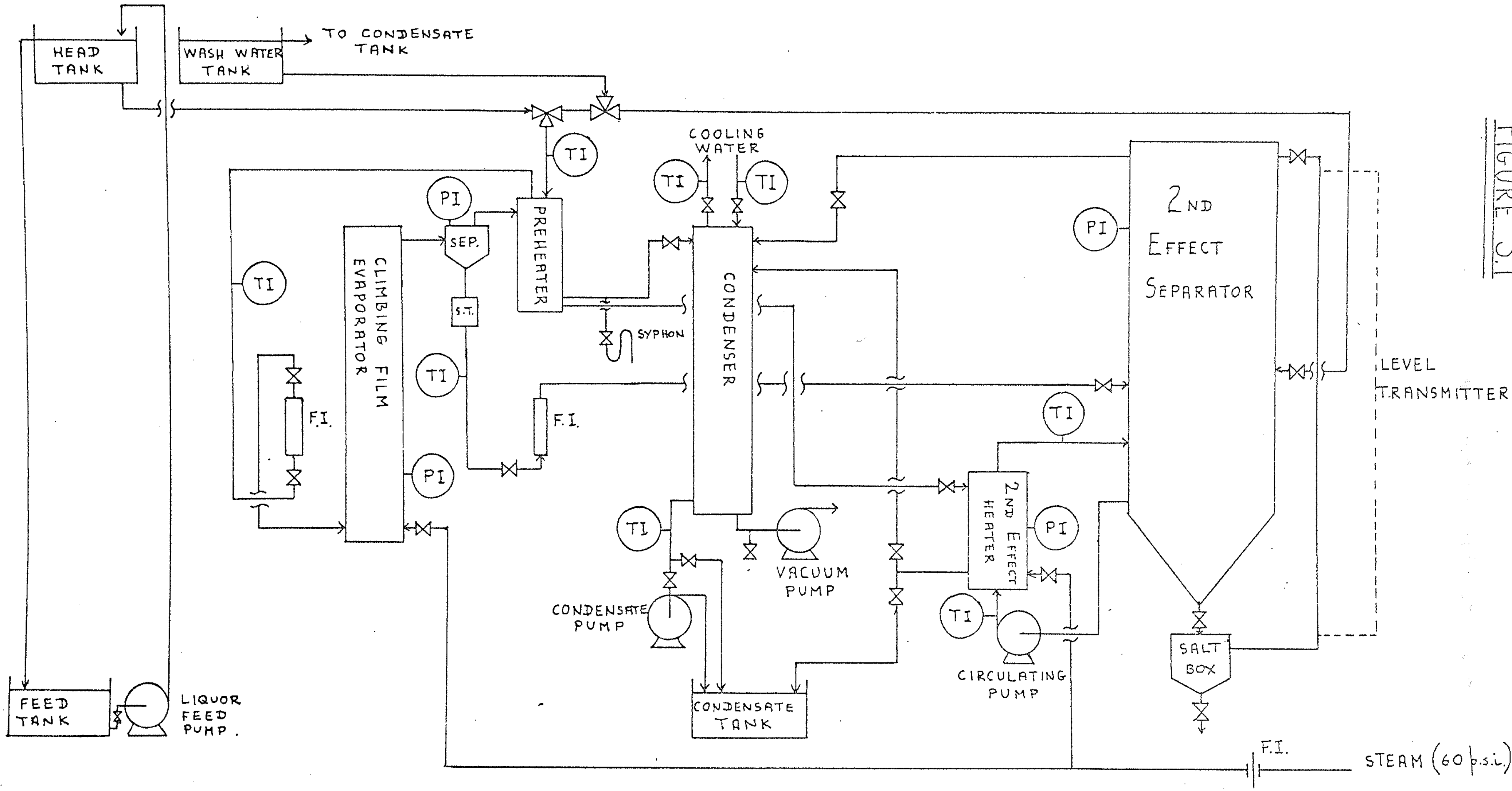
The weak liquor to be concentrated is prepared in the weak liquor feed tank. From here it is pumped up to the weak liquor head tank. From here it flows under gravity head to either the preheater of the 1st effect, or to the 2nd effect separator. The two effects can thus be operated separately or in series. Operating the two effects in series will be considered first.

Weak liquor passes through the preheater, where it is heated by vapour from the first effect separator. It then passes through a rotameter to the base of the climbing film evaporator.

The climbing film evaporator is heated on the shell side by steam supplied from an external source. Condensed steam is removed through a steam trap to the condensate tank. The weak liquor is partially evaporated in the climbing film tubes and the mixed phase passes to the first effect separator.

From here the vapour passes to the preheater; any vapour left un-condensed in this unit can be passed to the condenser or the shell side of the 2nd effect heater as desired. The liquor, now in a concentrated form, passes to the 2nd effect separator.

FIGURE 3.1



DOUBLE EFFECT EVAPORATOR (MODIFIED)

Liquor in the 2nd effect separator is circulated through a heat exchanger, where further heat is added. On return to the separator, vapour flashes off under the decreased pressure. This vapour then passes to the condenser. Any solids precipitating can be collected in the salt-box and then drained.

Heat to the 2nd effect heater can be supplied either by steam from the external steam supply or uncondensed vapour from the 1st effect preheater. Generally in the latter case additional steam is necessary to keep the 2nd effect separator liquor level steady.

The system can be run under vacuum or at atmospheric pressure, vacuum being drawn on the condenser.

When running the first effect alone, concentrated liquor is collected in the 2nd effect separator, or the line to the 2nd effect separator is broken and an S-bend syphon attached under the steam trap. Liquor can then be collected separately. When working under vacuum this latter alternative is not possible.

The 2nd effect can be run alone under vacuum or at atmospheric pressure utilising the weak liquor supplied directly from the feed tank.

3.1.1 Instrumentation.

Rotameters were supplied on the liquor feed lines to both effects, but not on the liquor line from the 1st effect to the 2nd effect. Thermocouples were supplied to monitor the following temperatures:

Preheater inlet.

Climbing film evaporator inlet.

1st Effect separator outlet.

2nd Effect heater inlet.

2nd Effect heater outlet.

Condenser cooling water inlet.

Condenser cooling water outlet.

Condensate from the condenser.

There were Bourdon pressure gauges to monitor the following pressures:

Climbing film evaporator shell-side pressure.

2nd Effect heater shell-side pressure.

2nd Effect separator pressure.

The thermocouple readings could be monitored by a self-compensating potentiometer on a remote control panel. The Pressure gauges and the pump controls were also positioned on this control panel.

3.1.2 Modifications.

The only modifications made of any importance were the addition to the plant of a number of on-line measuring instruments. The rotameter on the liquor feed line to the climbing film evaporator was removed and replaced by a Fischer-Porter variable area flowmeter with an output signal in the range 4-20mA , and a similar instrument was fitted on the line to the 2nd effect separator. The reason for the choice of variable area flowmeters was in both cases the low flows encountered, together with the low permissible pressure drop across the instruments. This was particularly so in the case of the flowmeter between the two effects, where the allowable head was measured in inches WG .

An orifice plate was inserted in the steam line to the evaporator and the steam flow monitored by a Fischer-Porter differential pressure transducer, again with a 4-20mA output signal.

The level of liquor in the 2nd effect separator was monitored by differential pressure transducer, the take-off points being as shown in fig. 3.1.

The 3 pressures monitored by the Bourdon gauges were also monitored by Bell & Howell pressure transducers, each giving a 0-40 mV output. An additional transducer was installed to monitor the pressure in the 1st effect separator.

3.2 The E.A.L. HY-48 parallel hybrid computer.

This is a standard 10 volt parallel hybrid machine, consisting of an analogue section with a complement of:

34 D.C. Amplifiers.
10 Track/Store Amplifiers.
14 Integrators.
30 Manual set Potentiometers.
30 Servoset Potentiometers.
4 Bipolar multipliers.
1 X^2 D.F.G.
5 V.D.F.G.'s.
5 Manual function switches.
6 Comparators.
12 D/A switches.
6 D.P.D.T. switches.

and a logic section with a complement of:

2 Clock Timers.
Integrator logic controls.
T/S Amplifier logic controls.
Comparator logic outputs.
D/A switch logic controls.
D.P.D.T. switch logic controls.
4 General purpose registers.
2 Down-counters.
4 Function switches.
2 Monostables.
2 Differentiators.
20 2-input AND gates.
Logical mode control.
Logic 'I' and logic '0' sources.

The logic section was driven from a digital clock with a variable frequency up to 1 Mc/s. The Analogue and logic sections could be controlled by separate Mode switches, or from the logic section of the computer. Trunk lines existed on both the logic and analogue sections for the transmission of signals to other items of equipment via plugs in the back of the machine. Trunk lines in the analogue section of the machine were used to transmit signals through wiring from the analogue section to the MDP-200 data logger, discussed in a later section.

3.3 The PDS 1020 digital computer.

This was a first generation digital computer with a 4.6 mS. cycle time delay-line memory system. It had a 4 K word memory, each word consisting of 16 bits and sign. There were seven hardware registers: the accumulator, next instruction register, present instruction register, word length register, index register, link address register and sign register. Arithmetic was decimal, and included hardware multiply and divide. Addressing and commands were coded in hexadecimal form.

For program control there existed 4 standard sense-switches and 10 macro switches. These latter switches could be used to force manually a jump to different sections of program. Input could be effected by on-line typewriter, keyboard or paper tape reader and output via typewriter or paper tape punch. There were also facilities for the parallel input and output of information to remote devices, in this particular case a data-logging system.

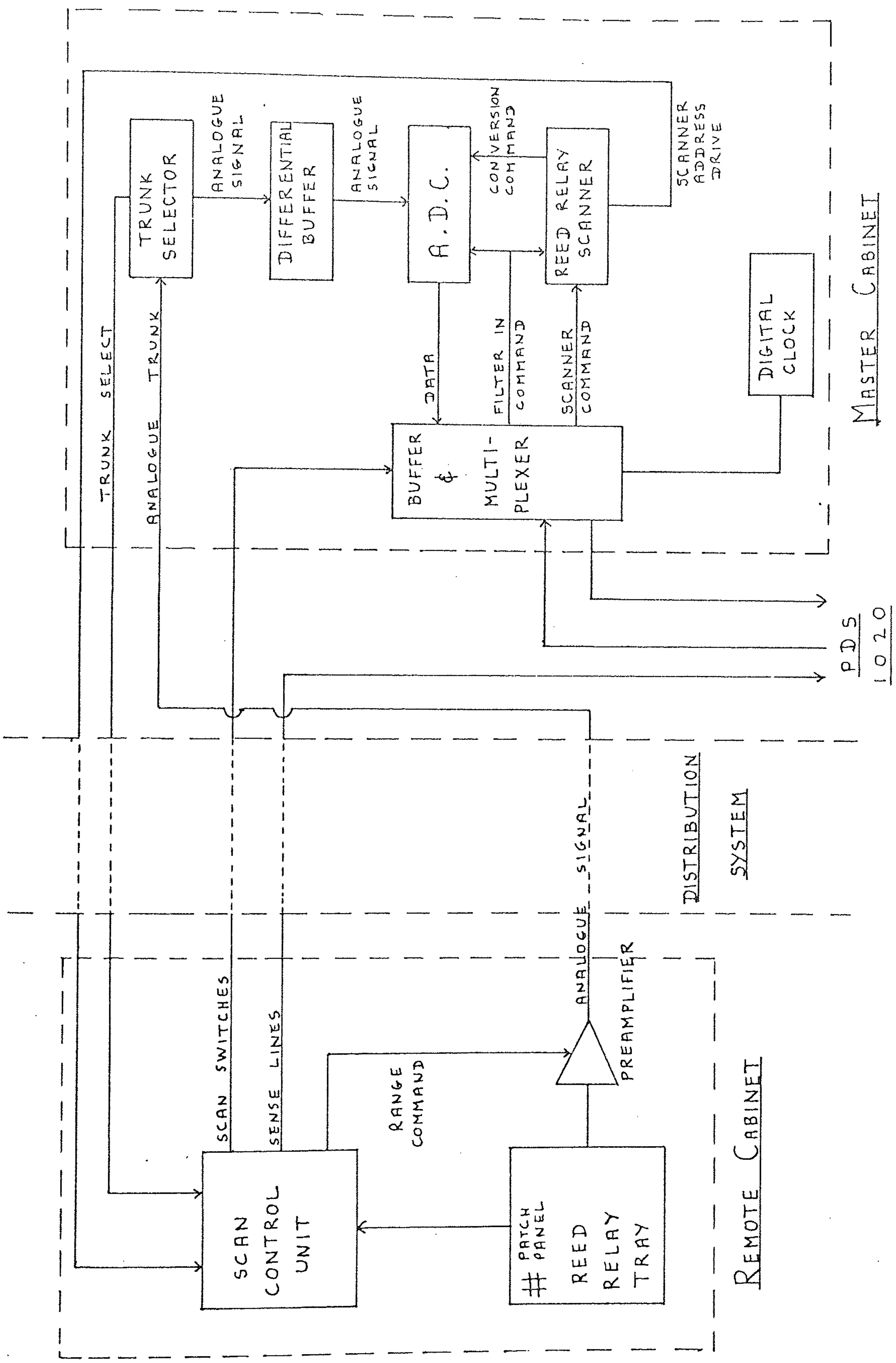
Programming was implemented through an Assembler language package.

3.4 The E.A.L. MDP 200 Data logging system.

This system was used under the control of the PDS. 1020 to digitise analogue signals and transfer the resulting numbers into the PDS. 1020 for processing. A diagrametic sketch of the system is shown in fig. 3.2.

The data-logging system was made up in two sections. The

FIGURE 3.2



M.D.P. 200 DATA LOGGING SYSTEM

first section, housed in the master cabinet which was situated near the computer, consisted of the Buffer and Multiplexer, Digital clock, Reed relay scanner, Analogue to Digital converter, Differential buffer and Trunk selector. The second section, housed in the remote cabinet which was situated near the apparatus from which signals were to be monitored, consisted of the Scan control unit, Reed Relay tray, Gain control patch panel and the Preamplifier. The remote cabinet also housed a de la Rue Zerac Ice-point Reference chamber for thermocouple inputs; scan switches, which will be discussed later; and 4 sense lines, which had an identical action to the sense switches on the PDS.1020.

Operation of the M.D.P. 200 was initiated by the output of a command from the PDS. 1020 down the parallel output lines to the Buffer & Multiplexer unit. This unit acted as a buffer and translator between the PDS. 1020 and the MDP. 200. This command could refer to the digital clock, a particular channel on the reed relay tray or the scan switches.

The readings from the digital clock were in hours and minutes, or in seconds and $\frac{1}{10}$ seconds, depending on the command used. The digital clock could be used in two modes, the synchronous mode or the asynchronous mode. The asynchronous mode was as above.

In the synchronous mode readings of the digital clock were controlled by a timer, which could be manually set to multiples of $\frac{1}{10}$ second. In this mode the digital clock could only be read at the end of each timing period set by the timer. At all other times the MDP. 200 was held up until the end of the timing period. In this way sampling times could be controlled from the PDS. 1020.

The Scan switches were a set of four manual digi-switches on the remote cabinet. Through these, decimal numbers could be set up from the remote cabinet and read into the PDS. 1020. In conjunction with the sense-lines they could be used for remote program control.

Readings from the digital clock and scan switches were made directly through the Buffer and Multiplexer. The reading of analogue input channels was more complex.

From the Buffer and Multiplexer the command to read a particular channel was directed to the Reed relay scanner. Filtering of the particular channel signal could be carried out remotely through a switch on the master cabinet, or through programming. From the Reed relay scanner a signal was sent to the scan control unit to activate the Reed relay on the channel under consideration.

The incoming signal was passed to the preamplifier, where any required magnification of the signal took place. Magnifications of 1, 10, 100 or 1000 were possible on the system, the required gain being set through programming or remotely on a patch-panel on the remote cabinet.

Between the remote cabinet and the master cabinet existed a distribution network of screened cabling and junction boxes, in order that the remote cabinet could be situated in any one of three laboratories. The remote cabinet could be plugged into a junction box in any one of the three laboratories and through the distribution system, communicate with the master cabinet.

The logic wiring was duplicated at each junction box but from each junction box, for the purposes of decreasing the effect of noise on the signal, a separate line existed to direct the analogue signal to the Trunk selector in the master cabinet. The Trunk selector was used to identify which junction box the analogue signal was to be routed from.

From the Trunk selector the analogue signal was routed through a Differential buffer to remove the effects of differences in electrical ground level between the remote cabinet and the master cabinet. The analogue signal was converted to a digital signal in the A.D.C. (Analogue/Digital converter) on the receipt of a conversion command from the Reed relay scanner.

The Scanning rate of the system was about 30 channels/sec.

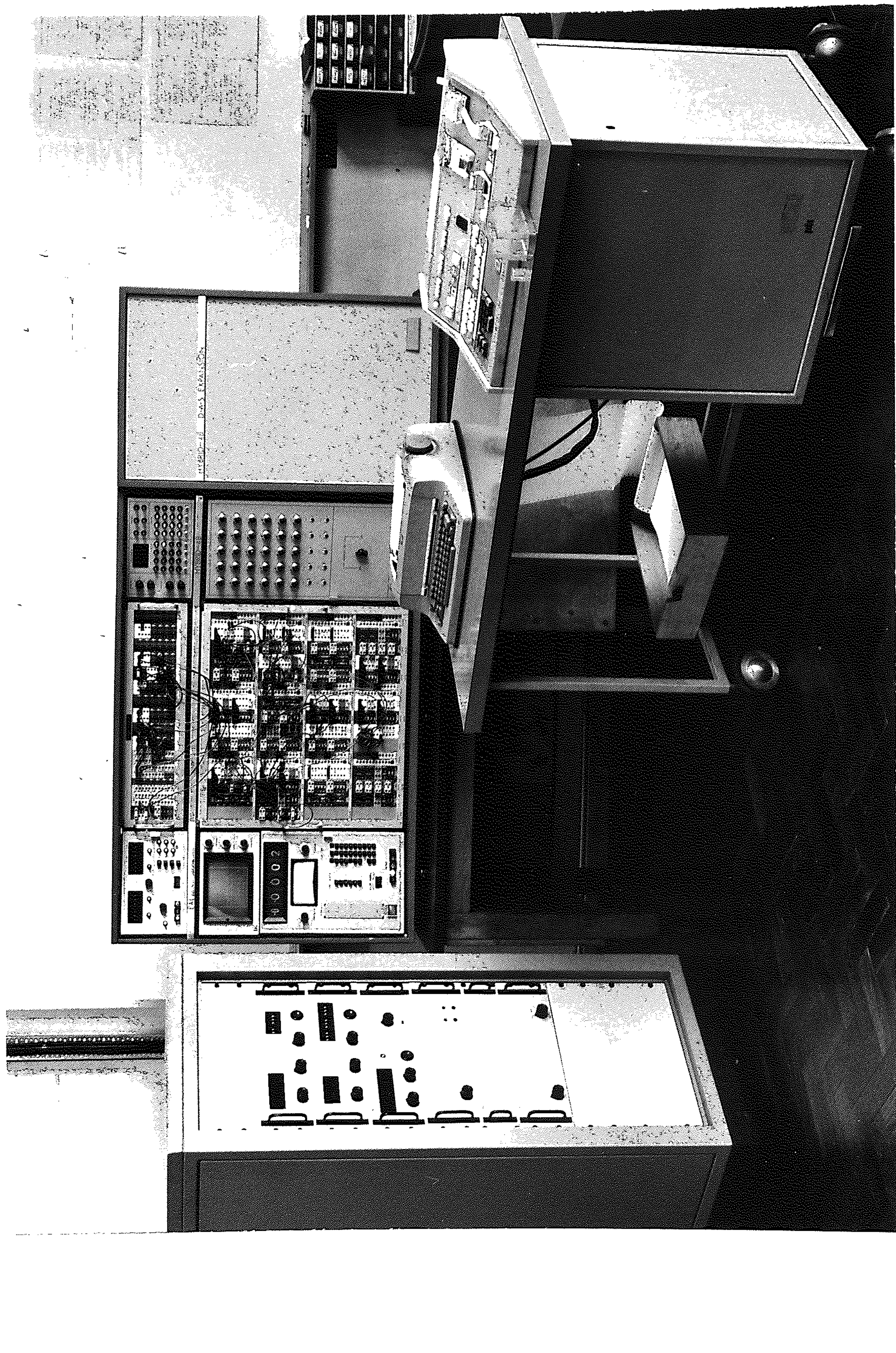
with the filter out and 8 channels/sec. with it in. The difference in scanning rates was due to the settling time of the filter.

3.5 Equipment link-ups used.

The Data-logging system was used to log signals from both the double-effect evaporator and the HY-48. A general program was written to log signals from either apparatus, this program being discussed in Chapter 5.

In addition to the equipment described above, a large I.C.L. 1905 digital computer was used for more sophisticated and complex programming problems. Algol programs analysing data collected and sorted by the PDS. 1020 were processed on this machine.

FIGURE 3.3



Photograph showing, from l. to r., the MDP. 200 Master cabinet, the HY-48 computer and the PDS. 1020 computer.

FIGURE 3.4

Photograph showing the double effect evaporator with the MDP. 200 Remote cabinet in the left background.

Chapter 4

The estimation technique used by the author will now be presented, together with a discussion of the problems involved in utilising the technique. The methods of analysing the technique will also be discussed.

4.1 The Identification Technique.

The problem may be defined as follows:

Given a multivariable system defined by the following state equations,

$$\underline{\dot{x}}\ (t) = \underline{f}\left\{\underline{x}\ (t),\ t,\ \underline{\alpha}\right\} \qquad 4.1.1$$

where the vector $\underline{x}$ (t) is a vector of the system states including inputs, $\underline{\alpha}$ is a vector of unknown parameters and initial conditions and t is time, it is required to evaluate $\underline{\alpha}$, knowing $\underline{x}$ (t).

Transforming 4.1.1,

$$s\ \underline{x}\ (s) = \underline{g}\left\{\underline{x}\ (s),\ s,\ \underline{\alpha}\right\}$$

This expression defines a set of algebraic equations and may be written,

$$\underline{x}\ (s) = \underline{G}\left\{s,\ \underline{\alpha}\right\} \qquad 4.1.2$$

Bellman's numerical Laplace transform technique (1) is now utilised to transform $\underline{x}$ (t), which is known. Utilising this technique will introduce errors, as the transforming technique is an approximate one. Further errors may, of course, be introduced by inaccuracies in the measurement of $\underline{x}$ (t) or inaccuracies in the model. Lumping these errors, the following expression can be deduced for the residuals,

$$\underline{e}_s = \underline{x}\ (s) - \underline{G}\left\{s,\ \underline{\alpha}\right\} \qquad 4.1.3$$

$\underline{e}_s$ are the residual errors for a particular value of s, and $\underline{x}$ (s) are now the numerically transformed system states.

It is required to find the values of the state parameters and initial conditions so that the predicted model fits the data in the best possible fashion. Mathematically, we require to maximise some objective function by a suitable choice of $\underline{\alpha}$.

For each value of s there is a residual, e_s, hence we can write the Moment Matrix of residuals,

$$\underline{M} = \sum_{s=1}^{N} \underline{e}_s \underline{e}_s^T$$

where N = the number of observations of $\underline{x}(t)$.

It can be seen that $\underline{M}$ is the sum of the squares of the residuals.

The general objective function to be maximised has the form

$$S(\underline{\alpha}) = \psi(\underline{M})$$

The following objective functions are available (2):

(a) Weighted Least Squares:

$$\psi = -\mathrm{Tr}\{\underline{Q}\,\underline{M}\} \qquad 4.1.4$$

where $\underline{Q}$ is some non-singular weighting matrix.

(b) Maximum likelihood (errors in x (s) are assumed to be normally distributed with zero mean and known covariance matrix $\underline{V}$):

$$\psi = -\tfrac{1}{2}\mathrm{Tr}\{\underline{V}^{-1}\underline{M}\} \qquad 4.1.5$$

(c) Maximum likelihood ($\underline{V}$ is unknown):

$$\psi = -\frac{N}{2}\ln\det\underline{M} \qquad 4.1.6$$

where N = No. of observations.

The state parameters may also be subject to inequality constraints,

$$\psi_i(\underline{\alpha}) \leq 0 \quad , \quad i = 1, 2 \ldots . m$$

These reflect constraints which the parameters may have to satisfy, i.e. chemical rate constants must be +ve, etc.

Obviously the simplest and most rapid evaluation of $\underline{\alpha}$ is through the least squares criterion. The covariance matrix, $\underline{V}$ is not likely to be known, and 4.1.6 would have to be maximised by some iterative optimisation procedure.

Equation 4.1.4 can be translated into the well-known minimisation of the sum of the squares by writing

$$\psi = \mathrm{Tr}\,\underline{M}$$

$\underline{Q}$ is assumed to be a unit matrix.

Hence $\underline{\alpha}$ can be found by solving the set of equations,

$$\frac{\partial \psi}{\partial \alpha_i} = 0 \quad ; \quad i = 1,2 .. m .$$

As the equations are linear, solution of the above is straightforward.

4.2 Implementation.

Time Scaling and sampling interval:

On a closer consideration of Bellman's transform technique, two problems of utilising the method stand out immediately.

Given the numerical Laplace transform of x (t),

$$x(s) = \sum_{i=1}^{N} w_i r_i^{s-1} x(t_i) \quad , \quad s = 1, 2 \ldots N ,$$

it can be seen that the times at which the function x is required to be observed are given by:

$$t_i = - \ln r_i \quad .$$

From tabulations of the values of t_i for various quadrature sizes, completed by Bellman (1) and repeated in Appendix V , it is seen that the values of t_i are unevenly spaced and that they fall within a very limited range numerically. (Maximum range: 5.115372 for a 15 point quadrature formula).

The problem of uneven spacing is a practical one, in that valuable time can be wasted in clocking the sampling interval during run-time on the computer. The problem is simplified by using the smallest computed value of t_i as the basic time unit, all other values of t_i being rounded to the nearest multiple of this smallest value of t_i. The adjustments to the t_i were found to produce a neglible error in the measured variable for the models considered. (see Appendix Id).

Overcoming the limited numerical range of the t_i was carried out using time-scaling techniques. Timescaling can be carried out either in the time domain or the Laplace domain. Consider first time-scaling in the Laplace domain. From Laplace transform theory it can be deduced that if

$$\mathcal{L}\{x(t)\} = \int_0^\infty e^{-st} x(t)\, dt = x(s) ,$$

then $$\mathcal{L}\{x(at)\} = \frac{x(\frac{s}{a})}{a}.$$

Hence: $$\frac{x(\frac{s}{a})}{a} = \sum_{i=1}^{N} w_i r_i^{s-1} x(-a \ln r_i)$$

or $$x\left(\frac{s}{a}\right) = a \sum_{i=1}^{N} w_i r_i^{s-1} x(at_i), \quad s = 1, 2 \ldots N.$$

Values of $(w_i r_i^{s-1})$ have been tabulated by the author (3), so the above equation may be written:

$$x(s) = a \sum_{i,j=1}^{N} M_{ij} x(at_i), \quad s = \frac{1}{a}, \frac{2}{a} \ldots \frac{N}{a},$$

where

$$M_{ij} = w_i r_i^{s-1}, \quad s = j; \; i, j = 1, 2 \ldots N.$$

Time-scaling in the time domain is done on the state equations themselves and is relatively straightforward. $x(s)$ is computed with no time scaling. The substitution made is $t = kt_r$, where t_r is real time and k is the scaling factor.

Other Factors to be considered.

Having noted the possibilities of varying the sampling interval sizes by time-scaling, a question that arises is what the effect is of time-scale on the accuracy of prediction of the system parameters. It would be imagined that this accuracy of prediction would be related to the spread of observations over the response time of the disturbed system. Part of the work done in this thesis is directed towards a consideration of this relationship.

Other points which have to be considered are:

(a) Effect of signal noise:

Signals coming from remote on-line instruments are often corrupted by noise. The effect of different noise levels on the accuracy of prediction needs to be studied.

(b) Number of observations required:

Obviously the fewer observations it is necessary to make, the faster the speed of estimation. As the calculation of x (s) requires matrix multiplication, the speed of prediction will be approximately proportional to the square of the number of observations. Signal noise and the order of the state model may well have an effect on the number of observations required for a particular estimation accuracy.

(c) Effect of disturbing signal amplitude:

The effect of the amplitude of the disturbing signals may well have an effect on the accuracy of the predicted parameters. The required amplitude of the disturbing signal may be affected by the noise levels on the state measurements.

Obviously at steady state the system will be unobservable and no parameters can be estimated.

(d) Identification Initiation:

It is necessary to know immediately the system has been disturbed such that the required observations can be made. Some method must be found of monitoring possible disturbing signals. Here it must be pointed out that there will always be a slight error due to the fact that the time of initiation of the disturbing signal will never be known exactly. The error is negligible, however, for systems with large time constants as are found in chemical plant.

(e) Distance-velocity lags:

Work done by the author (3) on the use of the shifting theorem to identify distance-velocity lags by numerical Laplace transform techniques was unsuccessful. Estimates of any distance-velocity lags would have to be made from process measurements before the identification technique could be applied.

4.3 Models Tested.

Three models were used in the author's work, the mathematical equations governing these models being described:

(1) $$\frac{dx}{dt} + ax = a$$

(2) $$\frac{dx}{dt} + ax = b$$

$$(3) \quad \frac{dx}{dt} + ax = f\ (t)$$

Where a, b are unknown model parameters, x is the state variable and f (t) is an input of unknown form. All initial conditions are zero.

Numerically transforming the above equations, the solutions for the unknown model parameters can be written from the identification technique:

$$(1) \quad a = \sum_{s=1}^{N} \frac{s^2 x(s) \{ s x(s) - 1 \}}{\{ s x(s) - 1 \}^2}$$

$$(2) \quad a = \frac{\sum_{s=1}^{N} s x(s) . \sum_{s=1}^{N} s^2 x(s)/N - \sum_{s=1}^{N} s^3 x^2(s)}{\sum_{s=1}^{N} s^2 x^2(s) - \{ \sum_{s=1}^{N} s x(s) \}^2/N}$$

$$b = \frac{\sum_{s=1}^{N} s^2 x(s) + a \sum_{s=1}^{N} s x(s)}{N}$$

$$(3) \quad a = \frac{\sum_{s=1}^{N} \{ g(s) - s g^2(s) \}}{\sum_{s=1}^{N} g^2(s)}$$

$$\text{where } g\ (s) = \frac{x\ (s)}{f\ (s)}$$

A specimen derivation for (1) is given in Appendix I (c).

4.4 Method of Study.

Before continuing with a detailed discussion of the various programs, a brief outline of the methods adopted will be given.

The first program written to evaluate the usefulness of this identification technique was a straightforward on-line program for the PDS. 1020, taking as its data readings monitored through the logging system from a simulation on the HY-48. The program and simulation circuit are discussed in section 5.4.

Model parameters were set by potentiometers on the HY-48 and these settings compared with the results from the identification technique. Different noise levels could be added to the simulation output from a pseudo-random noise generator on the HY-48. The statistical characteristics of the added noise were evaluated from a separate on-line program, shown in section 5.7.

Only the first model described above was studied using this program, as it very soon became clear that this was a very laborious method of studying the technique.

The next stage of study consisted of using the PDS. 1020 as a monitoring computer only and evaluating the model parameters in an off-line program for every possible time scale and sample size, given a particular number of readings from the PDS. 1020. This off-line processing was done by an Algol program in the ICL. 1905, data being fed in from tape generated from the PDS. 1020. Details are shown in section 5.5.

This was a distinct improvement over the initial identification program, as a number of identifications could be carried out from a single run of the PDS. 1020 monitor program. The model studied was again a single parameter model with an input of known form. The tape interface between the PDS. 1020 and the ICL. 1905 was tested by a small separate program. (section 5.7).

It was still not possible to carry out an analysis of the effect of noise on the accuracy of identification without carrying out a number of runs using this program and a considerable amount of tape was used in its execution. Means and standard deviations of the results were computed separately and this tended again to be very tedious.

The finally developed test programs carried out a fixed number of runs on the HY-48 - PDS. 1020 linkup, sorted the data in the PDS. 1020 monitor program and evaluated the statistical characteristics of the results off-line. Operator effort was at a minimum in this case. Details are given in section 5.6.

Two models were tested in detail by this method, the models being numbers (2) and (3) given in the previous section. Model (2) was chosen over model (1) so that the forcing function amplitude was also estimated. The forcing function used on the HY-48 simulation for the case where the form of the input was unknown to the identification programs was the output of a 1st Order lag.

The parameters varied in these analyses were:

(a) The model parameter.

(b) The forcing function final amplitude.

(c) The added noise levels.

For each set of the above parameters, the effect of sample size and time scale could also be studied.

Off-line programs were written to establish the accuracy of the identification technique, given true models. (section 5.3). The solutions of these true models were computed analytically.

Chapter 5

5.1 Introduction.

In this chapter the digital computer software and the parallel hybrid computer circuits will be discussed in detail. Only block diagrams of the Assembler language programs will be shown, while the Algol programs will be presented in full. Assembler language programs are listed in Appendix VI.

The programs can be split into 6 groups. These groups are summarised below:

(a) The general logging program:

This program was developed as a general program to log results from runs on the double effect evaporator and simulations on the HY-48.

(b) Off-line Identification tests:

These programs were developed to compute the estimated parameters from true models and were used as backup programs for the later on-line programs.

(c) On-line Identification Programs:

This program was a true on-line program for estimating parameters from data monitored from the HY-48 or the double-effect evaporator. The HY-48 simulation used by the author with this program is shown.

(d) Single-cycle monitor programs with off-line processing:

This group includes a PDS. 1020 monitoring program and an Algol off-line processing program. The HY-48 simulation used was similar to that in (c). A slightly different model was used.

(e) Repetitive-operation monitor programs with off-line processing:

This group contains the more highly sophisticated repetitive operation programs developed from those in the preceding group.

(f) Support software:

This includes a program for the on-line estimation of the statistical characteristics of the added noise from the pseudo-random noise generator on the HY-48. Another program was developed to test the tape interface between the PDS.1020 and the ICL. 1905.

Each of these groups will be described in detail in the following sections, program flow charts, listings or circuit diagrams being shown where relevant.

5.2 The general logging program.

This program is designed to be operated under either sense line control or sense switch control, depending on whether the program is to be operated from the remote data logging cabinet or the PDS. 1020 itself. As it is written for the PDS. 1020, it is an Assembler language program. A block diagram of the program is shown in figure 5.2.

The program is initiated from the computer, which first requires to known whether the filter is to be software controlled or out and whether control will be from the remote logging cabinet or the computer keyboard. Data can be input to the program from the remote cabinet using the scan switches under the control of sense line 3.

Having received this information, the computer goes into a cycle round sense switch/sense line 2. As the sense lines and sense switches are paralleled in this program, future reference will only be to sense switches.

At this point the operator must decide whether he wishes to carry out repetitive scans of data from the apparatus to which the data logger is connected, or whether single individual operations are to be carried out. This choice is controlled by the setting of sense switch 4 and transfer of control to either mode is initiated from sense switch 2.

Considering the repetitive mode first, information is read in concerning the range of channels to be scanned, i.e. the first and last channel numbers. Should a channel be requested outside the range possible on the data logger, an error message is output and the program halts.

The optimum gain settings for each channel are now automatically evaluated and the resultant gains for each channel are printed out. Should any channel reading go outside the range of the A.D.C. during operation of the repetitive mode, the error message OVERFLOW is printed out, channel gains are automatically recomputed and the cycle continues.

A further decision has to be made by the operator before the repetitive mode is initiated. This is whether or not the channel readings are to be automatically scaled to give true values of the parameters being monitored, i.e. temperature in ^{o}C, pressure in psia., etc. This is controlled from sense switch 1. Scaling factors are input in the single operation mode and are discussed in a later paragraph.

Having computed and printed the gains, the computer goes into the cycle shown in the block diagram, until such time that sense switch 4 is switched off. Channel readings can be taken under timer control from the digital clock, should the clock be in the synchronous mode. When sense switch 4 is switched off, the program control returns to sense switch 2.

In the single operation mode, 8 possible operations can be carried out by input of a selection number through the computer keyboard or scan switches. The operations and associated selection numbers are shown below:

Selection Number	Operation
0	Program returns to start.
1	Input channel range.
2	Compute and print channel gains.
3	Read and print channels - scaled values.
4	Select input mode and filter. This operation is only possible from the computer.
5	Input and print channel calibration factors. Parameter values, y, are related to voltage readings, x, by a straight line relationship, $y = mx + c$.

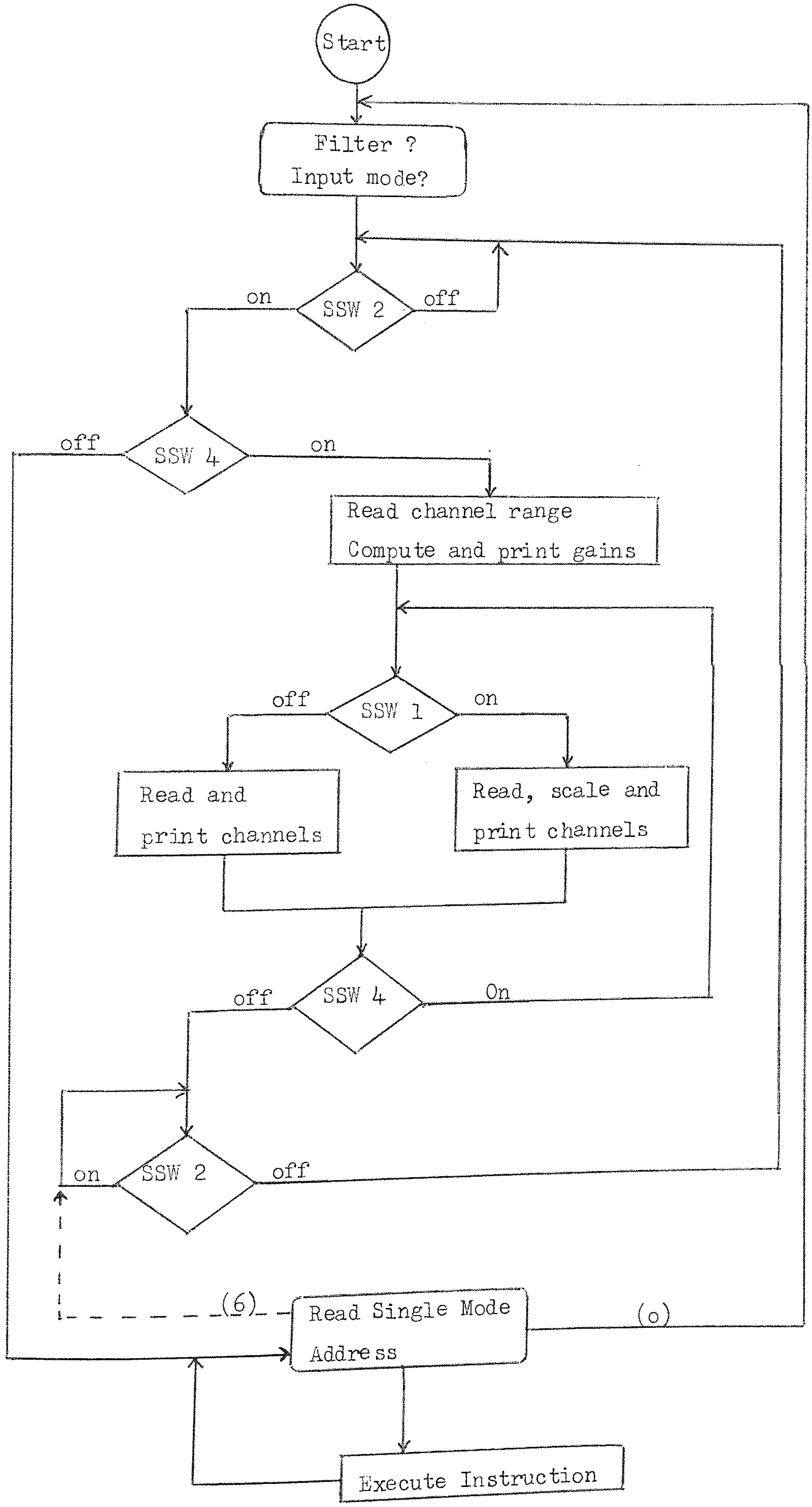
Selection Number	Operation
	m and c are the calibration factors to be input.
6	Return to main program loop.
7	Input channel range, input and print channel scaling factors.

Note that for this program typewriter tabs should be set in multiples of 14 to obtain the best output format.

A set of specimen results from this program is given in Appendix II a, and the program is listed in Appendix VI.

Figure 5.2.

General logging program block diagram.



5.3 Off-line indentification programs.

Two off-line identification programs were written. The first, written in PDS. 1020 Assembler language, estimated results for a model with an input of known form, in this case a step function. The second was an Algol program to estimate results for a model with an unknown input. Both programs utilised the technique of calculating the response of known models from analytical relationships, and then estimating the model parameters from this known response. Comparison of the known model parameters with those estimated from the known responses gave an indication of the effectiveness of the identification technique under ideal conditions.

5.3.1 Identification of a model with known input form.

This program was written to be operated under the control of the macro switches on the PDS. 1020. Using these, the program could be entered at various points, as shown in the block diagram in fig. 5.3.1.

The program starts with the input of the sample size to be used, the elements of the matrix, $M_{is} = w_i \, r_i^{s-1}$ and values of the times $t_i = -\ln r_i$. The proposed time scale to be used is input, followed by the true values of the model parameters.

The required values of x (t), the model outputs, are computed from analytical relationships. Hence x (s) is calculated, followed by the estimation of the model parameters. The true and estimated model parameters are printed out. The values of x (s) and x (t) computed can be obtained by depressing macro switches G and I respectively.

Data to the program can be fed in from tape or keyed in through the keyboard, choice being controlled from sense switch 1. Two standard subroutines were used with this program, a floating point interpreter for automatic floating point arithmetic operations, and a related floating point output subroutine for the printout of floating point numbers.

Specimen results for this program are given in Appendix II b.

The model form is described mathematically,

$$\frac{dx}{dt} + ax = b, \quad x(o) = 0$$

True values of a and b are fed in consecutively when requested. The solution of the above equation, giving the response, x (t), is

$$x = \frac{b}{a}\left(1 - e^{-at}\right)$$

A similar program was written for the model form,

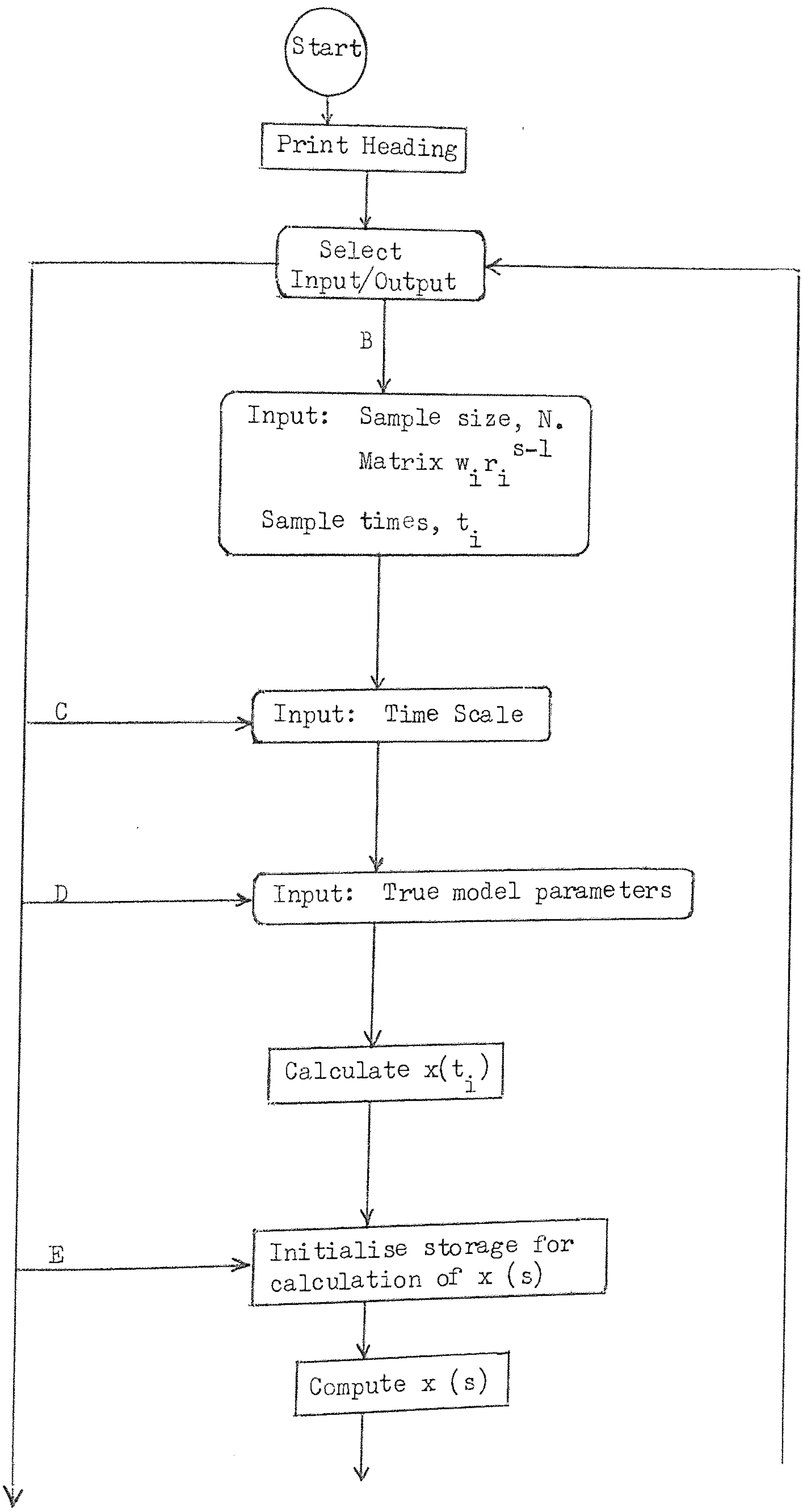
$$\frac{dx}{dt} + ax = a, \quad x(o) = 0$$

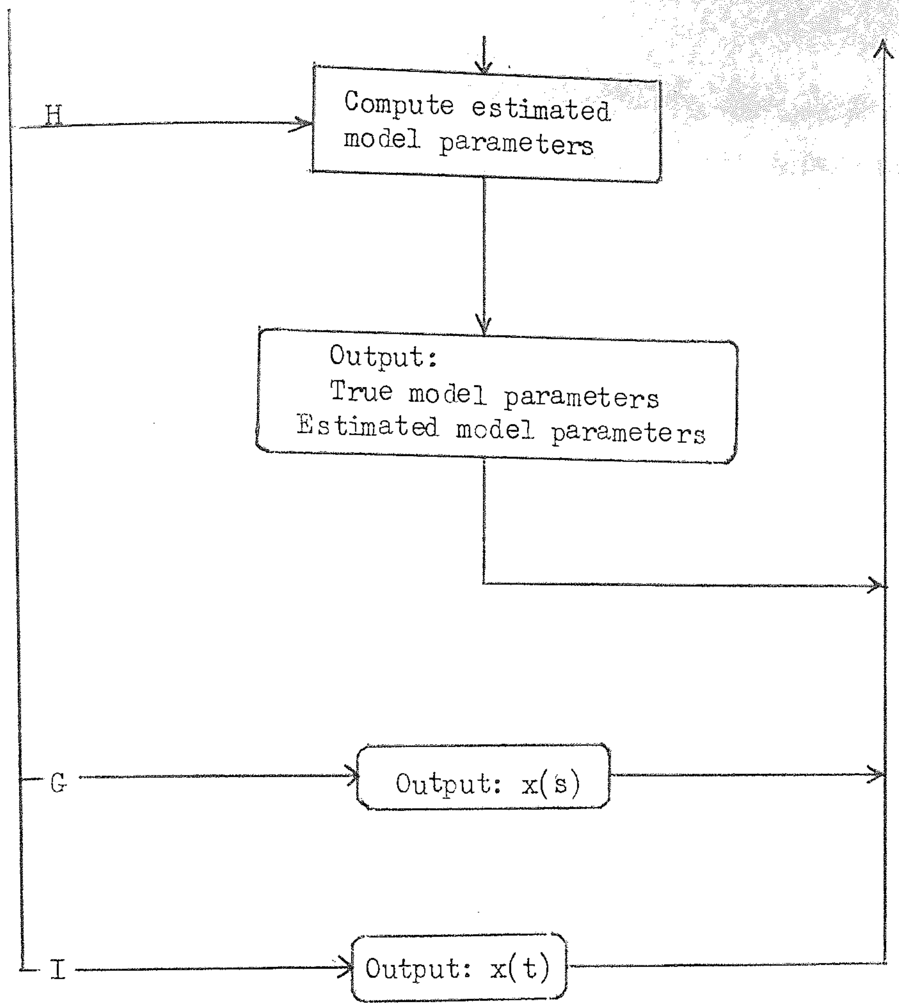
The solution is:

$$x = 1 - e^{-at}$$

Figure 5.3.1

Block diagram for the off-line identification of a model with known input form.





Standard Subroutines used:

Floating Point Interpreter.

Floating Point Output.

Note.

SSW 1 ON: Input from tape.

SSW 1 OFF: Input from K/B.

5.3.2. Identification of model with unknown input form.

This program, written in Algol, computed the response of one first order system and then used this response as an input to a second first order system. The response of this second first order system was calculated analytically. From a knowledge of the input and output curves for the second first order system, an estimation could be made of the model parameters of this system. The estimated values of these model parameters could then be compared with the true values. The program is listed in fig. 5.3.2, while a variable reference table and the input data format specification are shown in tables 5.3.2 (a) and 5.3.2 (b) respectively.

The program first requires the input of the sample size together with related values of $w_i r_i^{s-1}$ and t_i. The number of calculations required for this particular sample size is input.

The set of parameters necessary for the computation of the inputs and outputs to the system are read in. The inputs and outputs, and hence the estimated value of the model parameter, are computed for a range of time scale values and the results printed out. After every ten parameter estimations for different time scales, the values of the system inputs and outputs are printed to give some idea of the spread of samples over the total response curves.

The above process is repeated for different sets of parameters, the number of sets used being controlled by a counter, CALCS. At the end of this period a new value for the sample size is read in, and the process repeated. Should the sample size be set to zero, then the program terminates. Results from this program are shown in Appendix II b.

The forcing function is generated as the output of the following model,

$$\frac{dR}{dt} + WR = A \quad , \quad R(0) = 0 \quad ,$$

and the system model is given as

$$\frac{dX}{dt} + TRUE * X = R, \quad X(0) = 0,$$

where R, W, A, TRUE and X are defined in table 5.3.2 (a).

Table 5.3.2 (a)

Below is a reference table for the variable defined in the program:

Variable Name	Reference
I,J,K,L	General counters
DIM	Sample size
CALCS	No. of calculations per sample size
A STORE, B STORE	Buffer stores
TRUE	True system parameter
EST	Estimated system parameter
SCALE	Time scale
W, A	Model parameters - forcing function
MATRIX	$w_i r_i^{s-1}$
TIME	t_i
G	System impulse response in terms of Laplace operator, s.
X,R	System response and forcing function respectively
XS, RS	Laplace transforms of X and R

Table 5.3.2 (b)

Input data format

Data from cards

DIM

MATRIX: row by row

TIME

CALCS

A

W

TRUE

A

W

TRUE

etc.

} Number of parameter settings controlled by CALCS

DIM

Repeat above procedure. To stop, set DIM = 0

Figure 5.3.2

Off-line Identification Program for model with unknown input form.

```
'BEGIN' 'INTEGER' I,J,K,L,DIM,CALCS;
'REAL' ASTORE, BSTORE,EST,TRUE,SCALE,W,A;
'COMMENT' FIRST ORDER LAG. ;
SELECT OUTPUT (0);
START:  DIM: = READ;
'IF' DIM=0 'THEN' 'GOTO' FINISH;
'BEGIN''REAL''ARRAY' MATRIX [1:DIM, 1:DIM],G,X,R,XS,RS,TIME[1:DIM];
'FOR'  J:=1 'STEP' 1 'UNTIL' DIM 'DO'
'FOR' I:=1  'STEP' 1 'UNTIL' DIM 'DO'
MATRIX[I,J]:=READ;
'FOR' I:=1 'STEP' 1 'UNTIL' DIM 'DO'
TIME[I]:=READ;
CALCS:=READ:
'FOR' K:=1 'STEP' 1 'UNTIL' CALCS 'DO'
'BEGIN' A:=READ;
W:=READ;
TRUE:=READ;
NEWLINE (4);
WRITETEXT ('('INPUT%SIGNAL%FORCING%FUNCTION = %')');
PRINT (A,0,5);
NEWLINE (2);
WRITETEXT('('INPUT%SIGNAL%TIME%CONSTANT=%')');
PRINT(W,0,5);
NEWLINE (2);
WRITETEXT ('('SYSTEM%TIME%CONSTANT=%')');
PRINT (TRUE,0,5);
NEWLINE(2);
WRITETEXT('('TIME%SCALE'('7S')'ESTIMATE')');
NEWLINE(2);
L:=0;
'FOR' SCALE:=1/0.119574 'STEP' 1/0.119574
'UNTIL' (21/0. 119574+0.001) 'DO'
'BEGIN' ASTORE:=BSTORE:=0.0;
'FOR' I:=1 'STEP' 1 'UNTIL' DIM 'DO'
'BEGIN'
```

```
X[I]:=(A/W)*(1/TRUE-(W/(TRUE*(W-TRUE)))*
EXP(-TRUE*SCALE*TIME[I])+(1/(W-TRUE))*
EXP(-W*SCALE*TIME[I]));
R[I]:=(A/W)*(1-EXP(-W*SCALE*TIME[I]));
'END';
L:=L+1 ;
'IF' L=10 'THEN' 'BEGIN'
NEWLINE (1);
SPACE (3);
WRITETEXT ('INPUT'('10S')'OUTPUT')');
NEWLINE(2);
'FOR' L:=1 'STEP' 1 'UNTIL' DIM 'DO'
'BEGIN'
PRINT(R[L],3,5);
SPACE (2);
PRINT (X[L],3,5);
NEWLINE (1);
'END';
L:=0;
NEWLINE (2);
'END';
'FOR' I:=1 'STEP' 1 'UNTIL' DIM 'DO'
'BEGIN'
XS[I]:=RS[I]:=0.0:
'FOR' J:=1 'STEP' 1 'UNTIL' DIM 'DO'
'BEGIN' XS[I]:= XS[I]+SCALE*MATRIX[J,I]*X[J];
RS[I]:=RS[I]+SCALE*MATRIX[J,I]*R[J];
'END';
G[I]:=XS[I]/RS[I];
ASTORE:=ASTORE+G[I]-I*G[I]↑2/SCALE;
BSTORE:=BSTORE+G[I]↑2;
'END';
EST:=ASTORE/BSTORE;
PRINT(SCALE,0,5);
SPACE(2);
PRINT(EST,0,5);
NEWLINE(1);
'END';
'END';
'END';
'GOTO' START;
FINISH:'END';
```

5.4 The on-line identification programs.

A PDS. 1020 program computed values of the numerical Laplace transform of the input from a variable number of channels on the logging system, these channels being connected to the HY-48 simulation. The program was on-line in the sense that the values of the numerical Laplace transform were continually being calculated between sampling times, with the limitation that the clock could only be read once during each timer setting period, as the computer was immobilised at this stage until the end of this timing period. Only a limited amount of computation could be done during the timing period, otherwise there was a chance that the timer increment would be missed.

A small section of program was added to this program to compute estimated parameter values for a particular model, given numerical values of the Laplace transform. The model used in this case was described mathematically.

$$\frac{dx}{dt} + ax = a, \quad x(o) = 0$$

where a was the unknown parameter.

This model was chosen for its simplicity, together with the fact that the response of the model simulated on the HY-48 was limited to a final response amplitude of 1 machine unit at all times, as is shown by the analytical solution of the above equation,

$$x = 1 - e^{-at}$$

A block diagram of this program is shown in figure 5.4.1.

The HY-48 simulation circuit is shown in figure 5.4.2. This simulation includes a random noise generator. Two channels from the HY-48 were monitored by the above PDS. 1020 program, the first was a control channel, giving the simulation output uncorrupted by noise and the second gave the simulation output plus added noise from the noise generator. The statistical characteristics of the added noise were computed using a small on-line support program, described in section 5.6.

The Identification program required information concerning the sample size, conversion matrix and sampling times before the identification routine could be initiated. The sampling times were taken as multiples of the smallest sampling time given by the theory for the particular required sample size. These times were scaled to giving sampling times as multiples of the clock timer setting on the logging system, usually 1 second. The time-scale factor was chosen accordingly in either the s or t domain.

From these values of sampling times, sample time counters, CX, could be evaluated, giving the number of clock timer increments between samples.

First and last channel numbers, giving the range of channels to be scanned, were read in. These channels had to be consecutive.

The identification routine could be initiated in two ways. The first was under the control of sense switch 2. The preferable alternative method was to go into a loop continuously scanning the output of one of the channels to be scanned until the value of this output changed by more than a set small value. Hence the identification routine could be started. For this method, the channel acting as control channel for the identification program had to be read in, together with the limit on the signal amplitude change before the identification routine was to be initiated.

Initialisation of some storage locations was also necessary before computation could continue. This included the zeroing of three counters which played an important part in the routine: CO, the clock counter, SC, the sample counter and NN, a matrix computation counter. The use of these counters will be dealt with in detail in the following paragraphs.

On entering the identification routine the clock was read and the clock counter, CO, was incremented by one. CO was compared with CX to establish whether the sampling period was complete.

If it was complete, all the required channels were scanned, and the sample counter, SC, was incremented by one. If all required samples had been taken, CX was set to zero and the program continued to the matrix computation routine, which will be discussed below. If more samples were required, CX was reset and the program returned to the clock counter.

If the sampling period was not complete after the clock counter update, then the sample counter was compared with NN, the matrix computation counter. Initially NN and SC were both zero, so the program continued to cycle on the clock counter.

After SC had been updated and the channels scanned, however, SC was greater than NN, and the program entered the matrix computation routine.

This routine calculated the values of a single column of elements from the formula

$$x(s) = x(s) + w_1 r_1^{s-1} x(t_1) \ .$$

i.e. The above formula was evaluated for s = 1,2,..N. Only one channel was considered for each entry to this routine. On leaving the routine, a check was made on whether x(s) had been updated for all the channels read during the previous scan. If it had, NN was updated by one. Otherwise on return to the matrix computation routine x(s) was updated for another channel.

Should all the scan computations have been completed, i.e. x(s) evaulated for all the channels considered, then the program transferred to the parameter estimation routine. Alternatively, depending on the value of CX, which showed whether all samples had been taken or not, the program transferred to the clock counter or the matrix computation routine.

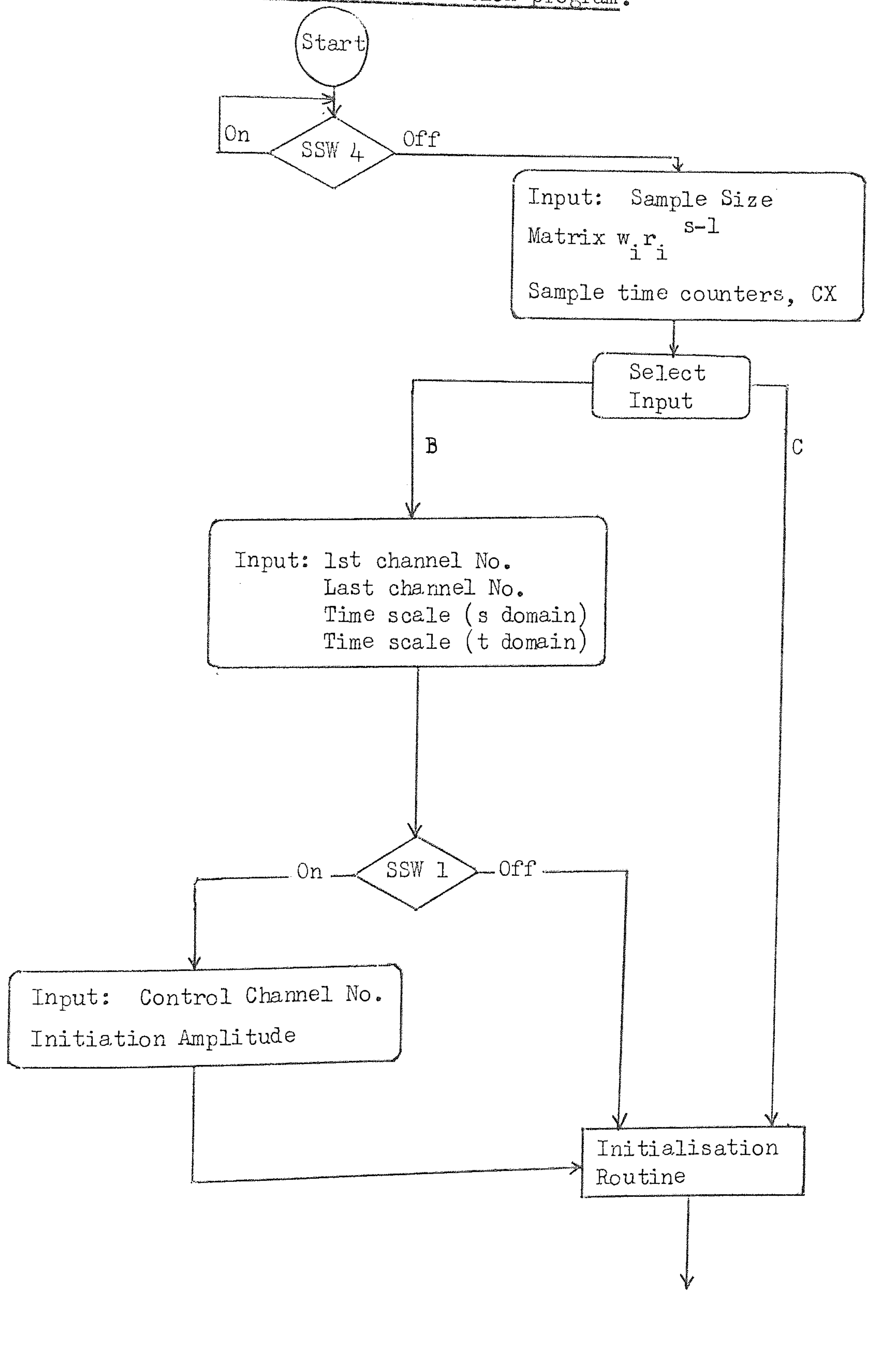
Input to this program could be from either keyboard or tape, depending on the setting of sense switch 3.

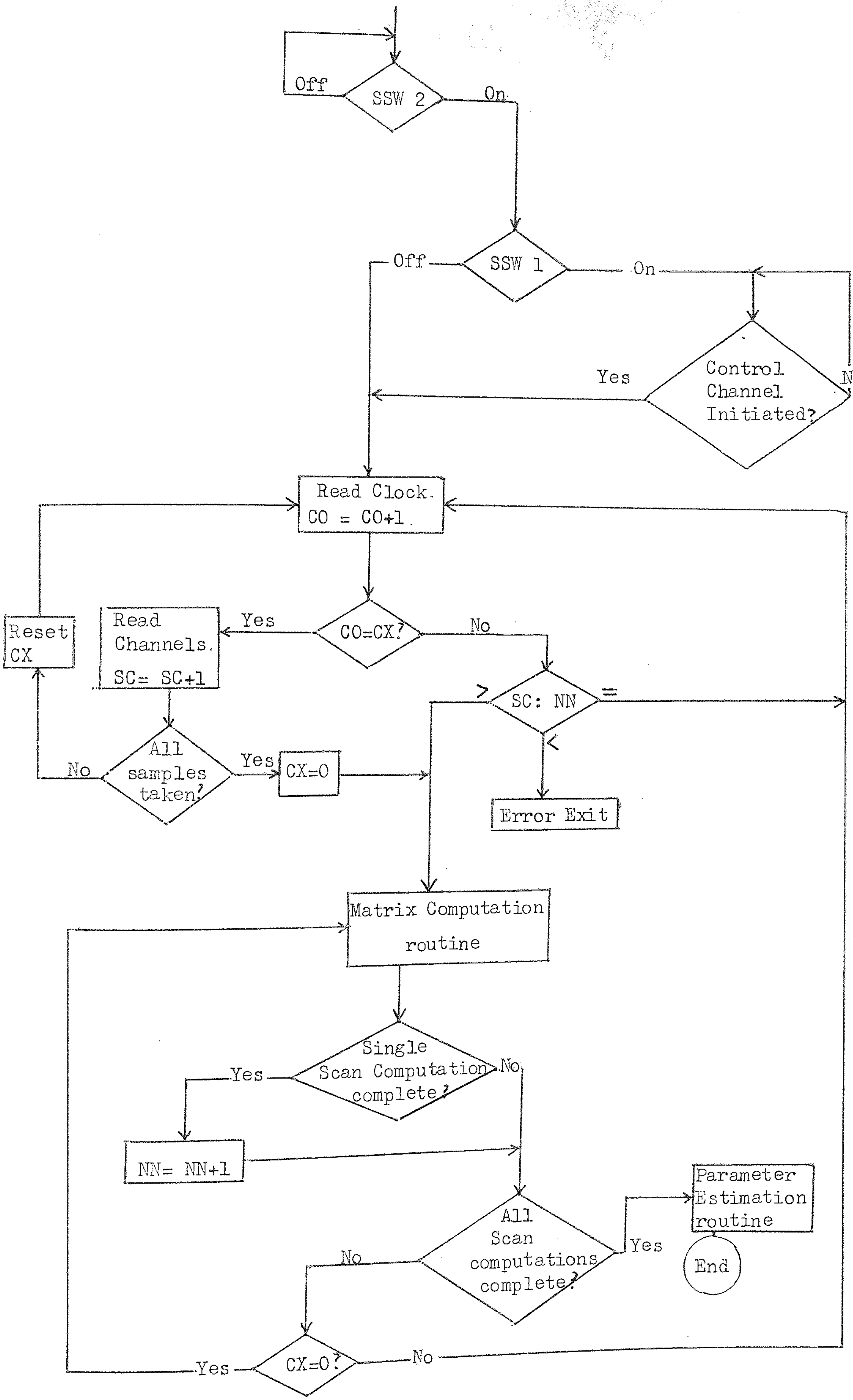
<u>Model parameter estimation routine.</u>

This program floated the values of x (s) computed by the above program using a standard subroutine. The parameter, a, was computed for the control channel and the channel corrupted by noise and the results were output to the typewriter. Standard subroutines used were a floating point interpreter and a floating point output routine.

Figure 5.4.1.

Block diagram of the on-line identification program.

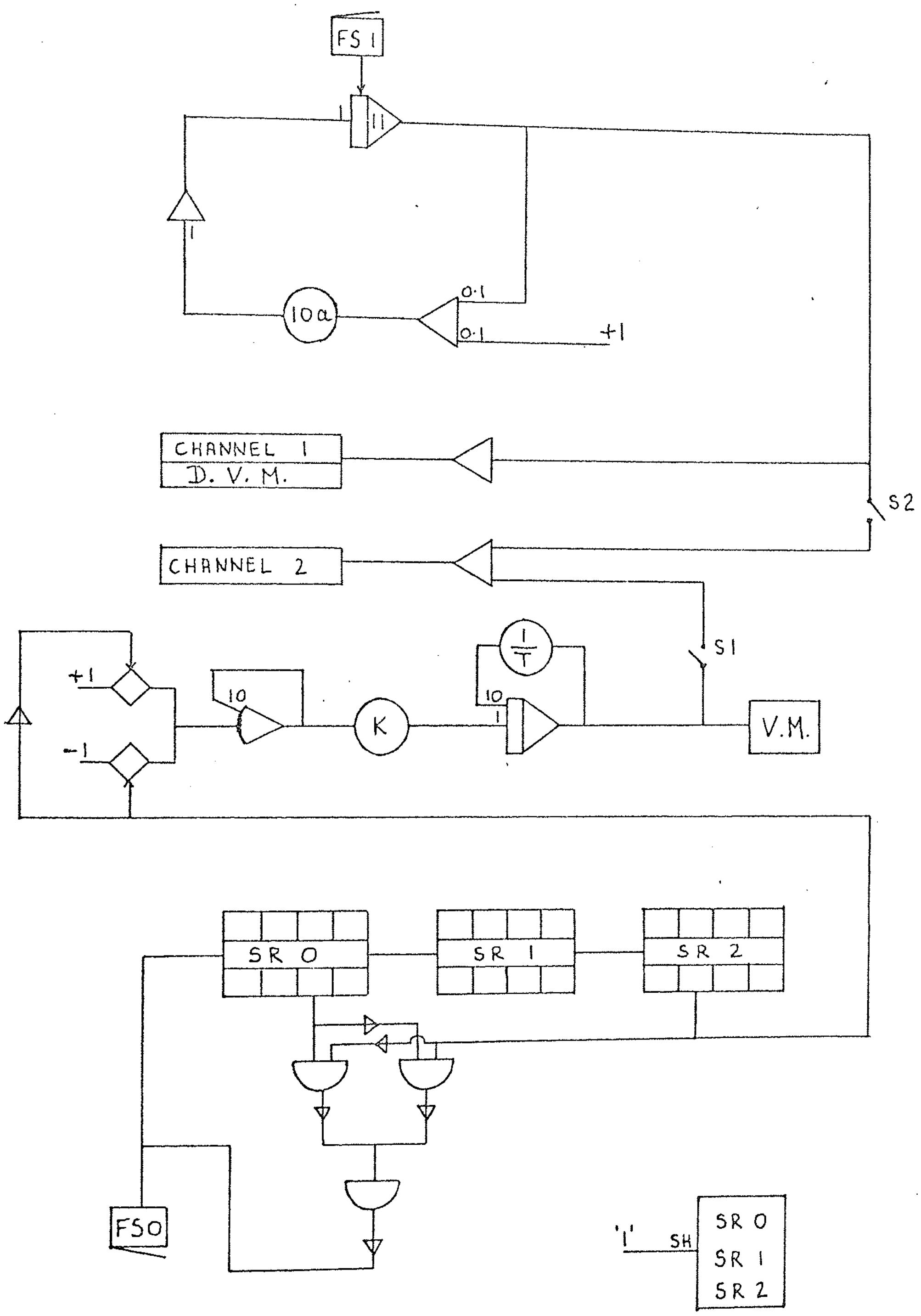




SSW 2
Off
On
SSW 1
Off
On
Control Channel Initiated?
Yes
No
Read Clock. CO = CO+1.
CO=CX?
Yes
No
Read Channels. SC= SC+1
Reset CX
All samples taken?
No
Yes
CX=0
SC: NN
>
=
<
Error Exit
Matrix Computation routine
Single Scan Computation complete?
Yes
No
NN= NN+1
All Scan computations complete?
No
Yes
Parameter Estimation routine
End
CX=0?
Yes
No

FIGURE 5.4.2

HYBRID CIRCUIT DIAGRAM (1)



CLOCK FREQUENCY SETTING : 10 c./s.

The HY-48 simulation.

This is shown in figure 5.4.2. The model simulation itself was comparatively small, as can be seen. It was generated round integrator 11, and initiated from a logic function switch FS1. The output of the model passed through an inverter to channel 20 on the logging system and also the HY-48 digital voltmeter.

It also passed through an analogue function switch, S2 to another inverter, where a pseudo-random noise signal was added through S1.

The pseudo-random noise generator consisted of a small filtering circuit of time constant T and input gain K. The input was driven by a plus or minus one reference voltage, depending on the state of the two complementary D/A switches.

These switches were controlled from a series of shift registers and AND gates connected as shown. The signal from this series was pseudo-random in form. The speed with which the signal was generated was controlled by the clock frequency setting on the HY-48 and was set at 10 c/s.

Results from these programs are shown in Appendix IIc.

5.5. Single-cycle identification programs with off-line processing.

These programs consisted of an on-line monitoring program for the PDS. 1020 and an off-line processing program for the ICL. 1905. The HY-48 simulation used was identical to that discussed in the previous section and shown in figure 5.4.2.

The PDS. 1020 on-line monitor program.

This program constituted 6 separate discrete operations, each operation initiated from a macro switch. The operations are summarised in the block diagram shown in figure 5.5.1.

Initially information is input concerning the number of scans to be taken on each channel, the number of channels to be scanned and the number of the first channel to be scanned.

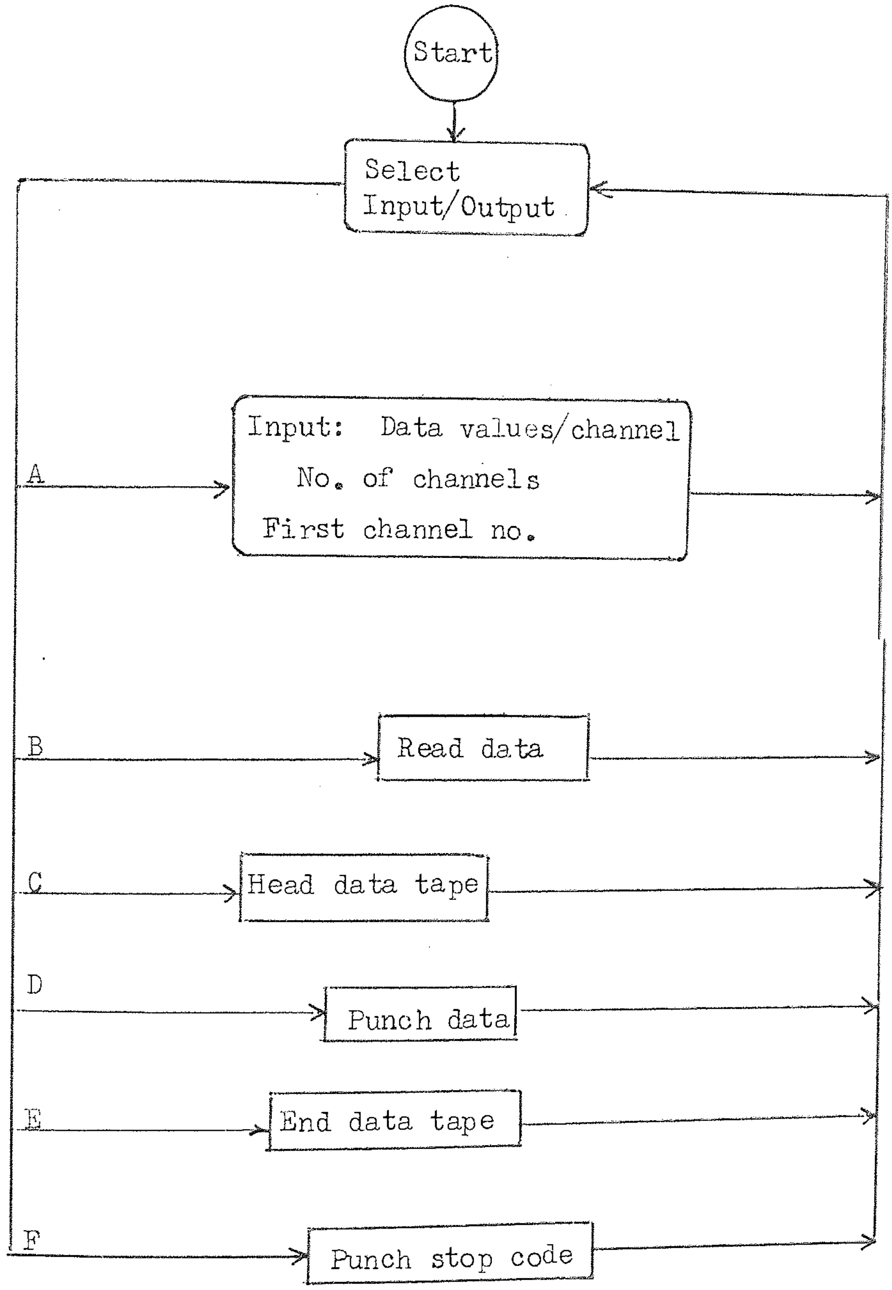
The data tape is headed with information for the ICL. 1905 operating system from macro switch C.

On depressing macro switch B the program cycles on the first channel to be scanned until its value changes by more than 10 mV. Channels are then scanned repetitively under control of the clock on the logging system until all the required samples have been taken. The samples are stored in the PDS. 1020 memory.

These samples are then punched onto tape by depressing macro switch D. The stop code is to inform the ICL. 1905 operating system that a particular data tape has been read in, and the End data tape code informs it that all data tapes have been read in.

Figure 5.5.1.

Block diagram of the PDS. 1020 on-line monitor program. (Single cycle).



Off-line parameter estimation program.

This was an Algol program, written to process the data tape produced by the PDS. 1020 monitor program. The program is listed in figure 5.5.2., while a variable reference table and the input data format are given in tables 5.5.2(a) and 5.5.2(b) respectively.

Values of $w_i r_i^{s-1}$ and t_i are read in for sample sizes of 3, 6, 9, 12 and 15. This is followed by input data consisting of the run number, logging system timer setting, number of channels scanned and the number of scans per channel.

The data tape is then read into the ICL. 1905 memory. The data is sorted so that all possible sampling intervals for all possible sample sizes (3,6,9,12 and 15) are covered.

Parameter estimations are made in a procedure EVALUATE after the numerical computation of the Laplace transforms required.

Results from runs with these programs are shown in Appendix II e.

Table 5.5.2(a)

Variable Reference Table.

Variable Name	Reference
I,J,K,L,S	General counters.
NN	Data values per channel.
NO	Number of channels scanned .
RN	Run number.
SI	Sampling interval.
TMP	Clock timer setting on the logging system.
CF	Time scale factor
BU	CF * TMP
FCOUNT	Real subscript estimate.
SUB	Integer subscripts.
SS	Time scaled Laplace operator.

Variable Name	Reference
A	Model parameters.
ABOVE, BELOW	Buffer stores.
M	$w_i r_i^{s-1}$
X	Values of x(t) from tape.
T	t_i
F	Laplace Transforms.

Table 5.5.2(b)

Input data format.

Data from cards.

For sample sizes of 3,6,9,12 and 15, read consecutively:

M, row by row

T

RN

TMP

NO

NN

Data from tape.

Data tape from PDS.1020 monitor program.

X

Data from cards.

RN

If RN = 0 computation stops, otherwise the above process is repeated.

NOTE

Input of M and T is in the order

$w_i r_i^{s-1}$ $\quad i = N, N-1, \ldots \ldots 1$

$S = 1,2, \ldots \ldots N$

t_i $\quad i = N, N-1, \ldots \ldots 1$

Figure 5.5.2

Off-line processing program. (Single cycle case)

```
'BEGIN''COMMENT' ZLOGANAL,PRICE,CESTF109;
'INTEGER' I,J,K,S,NN,NO,RN;
'REAL' SI,CF,BU,FCOUNT,TMP;
'REAL''ARRAY' A[1:5],T[1: 15, 1:15],F[1:15,1:5],M[1:15,1:15,1:15];
'PROCEDURE' EVALUATE;
'BEGIN''INTEGER' L;
'REAL' ABOVE,BELOW,SS;
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'BEGIN' ABOVE:BELOW:=SS:=0;
'FOR' L:=1 'STEP' 1 'UNTIL' K 'DO'
'BEGIN' SS:=SS+CF;
ABOVE:ABOVE-SS↑2*F[L,J]*(SS*F[L,J]-1);
BELOW:=BELOW+(SS*F[L,J]-1)↑2;
'END';
A[J]:=ABOVE/BELOW;
NEWLINE(4);
WRITETEXT ('('CHANNEL%NUMBER=%')');
PRINT(J,2,0);
NEWLINE(2);
WRITETEXT('('TIME%CONSTANT=%')');
OUTPUT(A[J]);
'END';
'END';
NEWLINE(1);
WRITETEXT('('DATA%ANALYSIS%PROGRAM.')');
WRITETEXT('(''('1C')'------------------------')');
NEWLINE(2);
SELECTINPUT(0);
SELECTOUTPUT(0);
'FOR' K:=3 'STEP' 3 'UNTIL' 15 'DO'
'BEGIN''FOR' I=1 'STEP' 1 'UNTIL' K 'DO'
'FOR' J=1 'STEP' 1 'UNTIL' K 'DO'
M[I,J,K]:=READ;
'FOR' I:=1 'STEP' 1 'UNTIL' K 'DO'
T[I,K]: = READ;
'END';
START:SELECTINPUT(0);
RN:=READ;
'IF' RN=0 'THEN' 'GOTO' FINISH;
TMP:READ;
NO:=READ;
NN:=READ;
NEWLINE(4);
WRITETEXT('('RUN%NUMBER=%')');
PRINT(RN,2,0);
WRITE TEXT ('(''('1C')--------------------')');
NEWLINE(1);
WRITETEXT('('TIME%MARKER%PULSE%SETTING=%')');
PRINT(TMP,2,1);
NEWLINE(1);
WRITETEXT ('('NUMBER%OF%CHANNELS=%')');
PRINT(NO,2,0);
NEWLINE(1);
WRITETEXT('('DATA%VALUES%PER%CHANNEL=%')');
PRINT(NN,3,0);
SELECTINPUT (3);
'BEGIN''REAL''ARRAY' X[1:NN,1:5];
'INTEGER''ARRAY' SUB[1:NN];
'FOR' I:=1 'STEP' 1 'UNTIL' NN 'DO'
```

```
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
X[I,J]:=READ;
'FOR' K:=3 'STEP' 3 'UNTIL' 15 'DO'
'BEGIN' SI:=0;
NEWLINE (5);
WRITETEXT('('QUADRATURE%SIZE=%')');
PRINT(K,2,0);
WRITETEXT('(''('1C')'----------------------')');
RETURN:SI:=SI+TMP;
CF:=T[1,K]/SI;
BU:=CF*TMP;
'IF' T[K,K]/BU > NN 'THEN''GOTO'CONTINUE;
NEWLINE(2);
WRITETEXT('('SAMPLING%INTERVAL=%')');
PRINT(SI,2,1);
SUB[1]:=ENTIER(SI/TMP+0.01);
'FOR' I:=2 'STEP' 1 'UNTIL' K 'DO'
'BEGIN'
FCOUNT:=T[I,K]/BU;
'IF' (FCOUNT-ENTIER(FCOUNT)) 'GE' 0.5 'THEN' SUB[I]:=ENTIER(FCOUNT)+1
'ELSE' SUB[I]:=ENTIER(FCOUNT);
'END';
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'FOR' S:=1 'STEP' 1 'UNTIL' K 'DO'
'BEGIN' F[S,J]:=0;
'FOR' I:=1 'STEP' 1 'UNTIL' K 'DO'
F[S,J]:=F[S,J]+M[S,I,K]*X[SUB[I],J]/CF;
'END';
EVALUATE;
'GOTO' RETURN;
CONTINUE:'END';
'END';
'GOTO' START;
FINISH:'END';
```

5.6 Repetitive-Operation identification programs with off-line processing.

These programs included a monitor program for the PDS. 1020 which was controlled from the digital clock on the HY-48. By slaving the PDS. 1020 to the HY-48 in this way, fixed numbers of runs could be monitored and punched without operator interference.

The PDS. 1020 sorted the data prior to punching it onto tape, which reduced the tape consumption considerably.

The off-line Algol program computed the means and standard deviations of the resulting model parameter estimations from all the runs.

The HY-48 Simulation.

The simulation was similar to that shown in figure 5.4.2 with the addition of a timing circuit to operate the model and an analogue logic signal to control operation of the PDS. 1020 monitor program. The circuit is shown in figure 5.6.1(a).

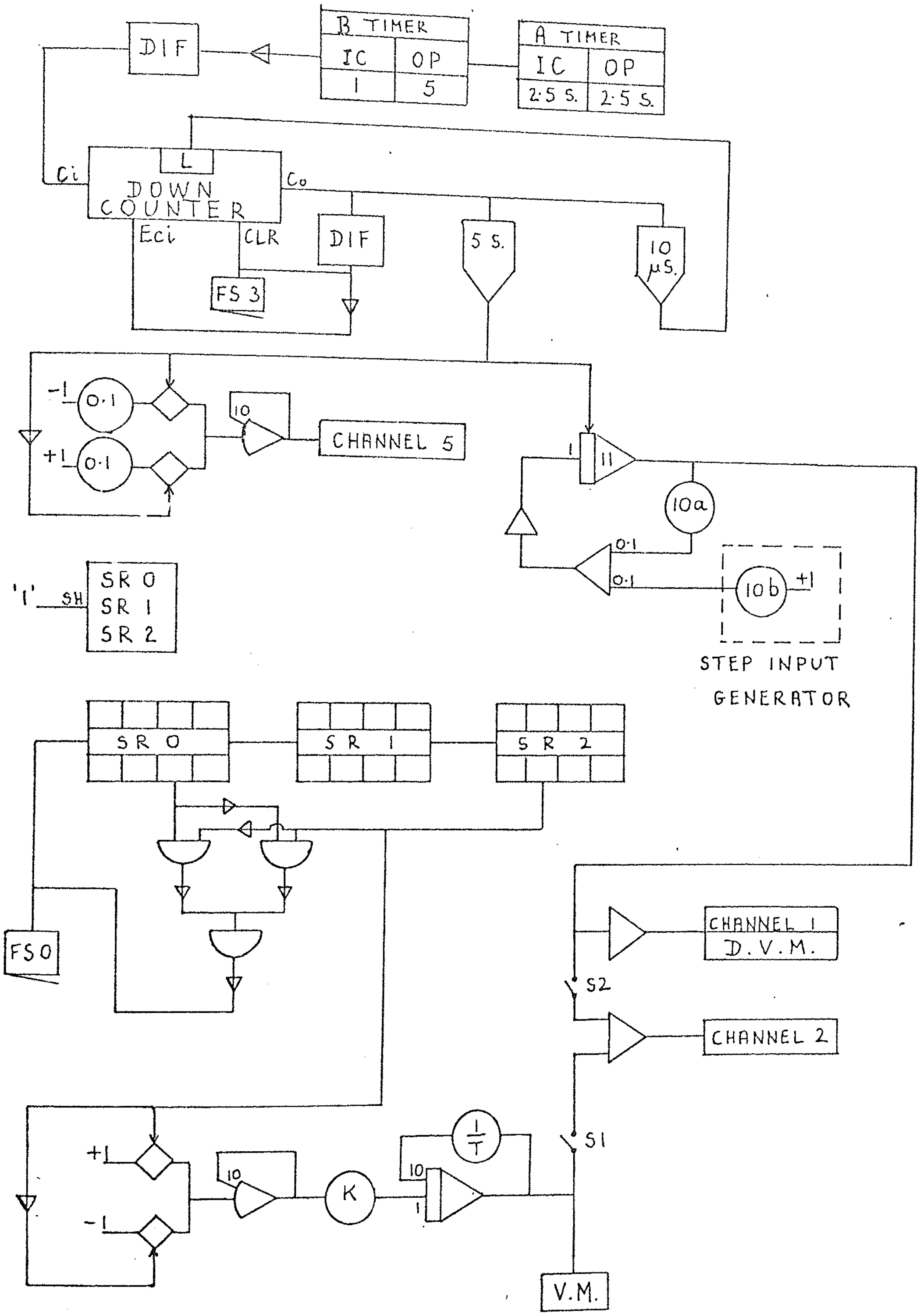
The timing signal was generated from two timers in series with the settings as shown. The output of the second timer gave a logic '1' signal to the differentiator every 30 secs. The pulse from the differentiator activated a down counter which was initially set by digi-switches on the logic control panel. At the end of the down counter sequence, i.e., when the down counter had decremented to zero, a pulse was produced on the Co line from the down counter. This signal temporarily disabled the down counter input by setting ECi to logic '0', reloaded the down counter to the value set up on the digi-switches through a monostable with a 10μS setting and reset the analogue simulation for a period of about 5 secs. through a monostable. This latter signal also set a logic signal to -IV for about 5 seconds. At all other times this signal was at + IV. The signal was monitored from the PDS. 1020 through channel 5.

The model simulated was a first order lag with a step input, given as:

$$\frac{dx}{dt} + ax = b, \quad x(o) = 0.$$

FIGURE 5.6.1(a).

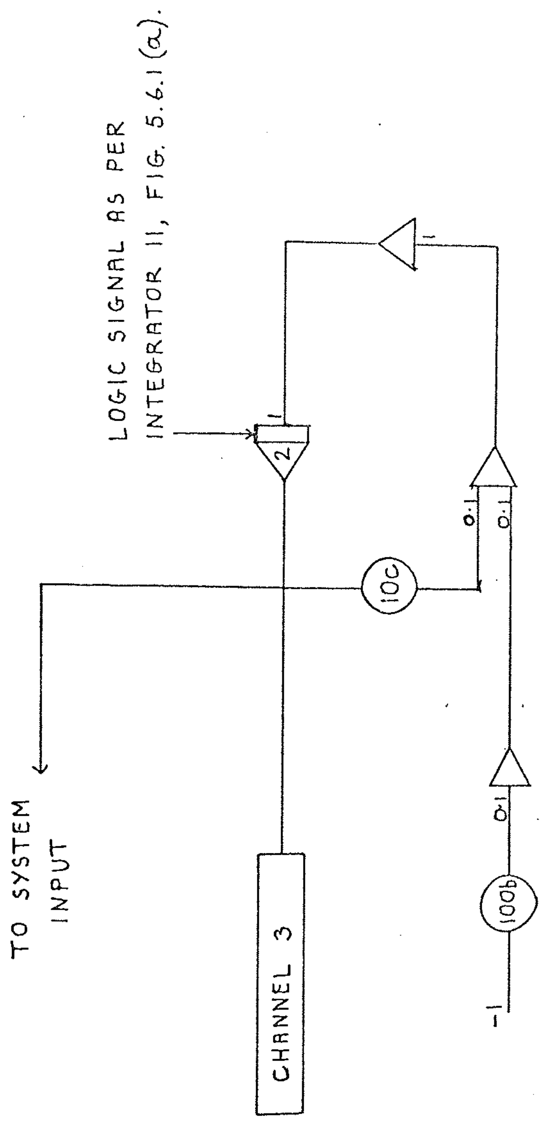
HYBRID CIRCUIT DIAGRAM (2)



CLOCK FREQUENCY SETTING : 10 c./s.

Figure 5.6.1 (b).

Hybrid Circuit Diagram (3)



FORCING FUNCTION GENERATOR

The solution of this equation is:

$$x = \frac{b}{a} \left(1 - e^{-at} \right)$$

Hence b was always set less than a to keep the final response below 1 machine unit.

Figure 5.6.1 (b) shows the circuit modification for the forcing function of unknown form.

<u>The P.D.S. 1020 monitoring program.</u>

This program was similar to the monitor program described previously, with the addition of two further operations. A block diagram of the program is shown in figure 5.6.2.

The first, under the control of macro F, generated counters giving the maximum number of samples possible with the given number of scans to be taken, for each possible sample size. This was obtained by rounding down to the nearest integer the value of $\frac{N}{T}$, where N is the number of scans to be taken per channel, and T is the largest value of t_i for a particular sample size.

Macro E controlled a small executive program, which, once initiated, placed the PDS. 1020 under control of the HY-48 until all runs had been completed.

The number of runs to be carried out was first input. The program then cycled on channel 5 until the logic signal went negative. This showed that the simulation had been reset, and the read data rountine proceeded to cycle on the first channel to be scanned until it changed by more than 10 mV, showing the simulation to be again operating. Data was then read in under control of the logging system clock.

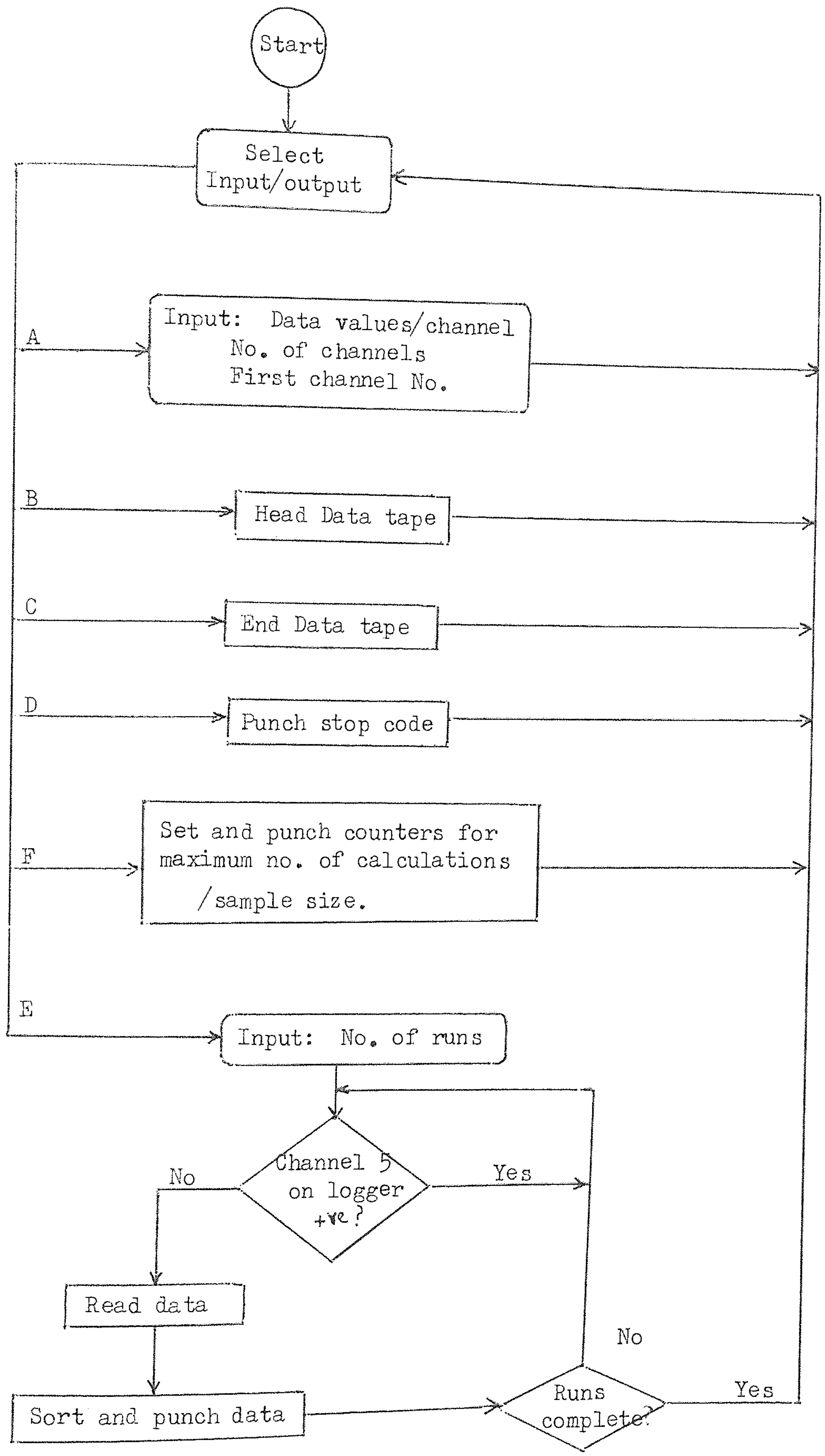
When the data had been read in, it was sorted by the program and then punched onto tape. The data was sorted into samples so that direct calculation of the numerical Laplace Transform could be made in the Algol program, and hence the model parameters predicted.

If all runs had been completed at this time, the program halted.

Otherwise it again cycled on channel 5 until it went negative and the process was repeated. It may be noted here that HY-48 was operating under the control of the timing circuit during the operation of the monitor program.

Figure 5.6.2

Block diagram of the PDS.1020 monitor program. (Repetitive operation).



Off-line processing program.

This program is very similar to the previous off-line processing program except in this case the model parameters are not printed out but are stored for the computation of the means and standard deviations at the termination of all the parameter estimations. These means and standard deviations are printed out, together with the related sampling intervals and overall sampling periods. The overall sampling periods were taken as the time between the initiation of a run and the time at which the last channel reading used by the identification technique was read.

The program is listed in figure 5.6.3, while a variable reference table and the input data format are shown in tables 5.6.3(a) and 5.6.3(b) respectively.

Results from this program are given in Appendix III. The procedure EVALUATE is shown for the known forcing function case and has to be slightly modified for the case of the unknown forcing function.

Table 5.6.3 (a).

Variable Reference table

Variable Name	Reference
I,J,K,KK,N,M,L,S	General counters.
NN	Data values per channel.
NO	Number of channels.
RN	Run number.
N1	Number of sets of readings.
FCOUNT	Real subscript counter.
SUB	Integer subscript.
RSI	Sampling interval counter.
SI	Sampling interval.
CF	Time scale factor.
TMP	Timer setting on logging system.

A1, A2, A3	Buffer stores.
SS	Time scaled Laplace operator.
A, B	Model parameters.
STAN	Standard deviation.
MEAN	Mean.
MM	$w_i r_i^{s-1}$
T	t_i
F	x(s)
X	x(t) from PDS. tape.
SP	Sampling period.
C	Number of samples per sample size.

Table 5.6.3(b).

Input data format.

Data from cards.

For sample sizes of 3,6,9,12 and 15, read consecutively:

MM, row by row

T

RN

TMP

NO

NN

N1

Data from tape

Data tape from PDS. 1020 repetitive-operation monitor program.

C }
X }

Sets of data from tape controlled by N1

NOTE.

Input of MM and T is in the order:

$w_i r_i^{s-1}$ $\quad i = N, N-1, \ldots\ldots 1$

$\quad s = 1, 2, \ldots\ldots\ldots N$

t_i $\quad i = N, N-1, \ldots\ldots 1$

where N = sample size.

Figure 5.6.3

Off-line processing program (Repetitive operation case)

```
'BEGIN''COMMENT' ZLOGANAL02,PRICE,CESTF109;
'INTEGER' I,J,K,KK,S,N,NN,NO,RN,M,N1;
'REAL' FCOUNT,TMP;
'REAL''ARRAY' STAN,MEAN[1:2:1:5,1:60,1:2],MM[1:15,1:15,1:5],
T,F[1:15,1:5], SI,CF[1:5,1:60], A,B[1:5];
'INTEGER''ARRAY' SP[1:5,1:60], C[1:5];
'PROCEDURE' EVALUATE;
'BEGIN''INTEGER' L;
'REAL' A1,A2,A3,A4,SS;
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'BEGIN' A1:=A2:=A3:=A4:=SS:=0;
'FOR' L:=1 'STEP' 1 'UNTIL' KK 'DO'
'BEGIN' SS:=SS+CF[K,M];
A1:=A1+SS*F[L,J];
A2:=A2+SS↑2*F[L,J];
A3:=A3+SS↑3 *F[L,J]↑2;
A4:=A4+SS↑2*F[L,J]↑2;
'END';
A[J]:=(A1*A2/KK-A3)/(A4-A1↑2/KK);
B[J]:=(A2+A[J]*A1)/KK;
'END';
'END';
SELECTINPUT (0);
SELECTOUTPUT(0);
NEWLINE(1);
WRITETEXT ('('DATA%ANALYSIS%PROGRAM')');
WRITETEXT('(''('1C')'----------------------')');
'FOR' K:=1 'STEP' 1 'UNTIL' 5 'DO'
'BEGIN' KK:=K*3;
'FOR' I:=1 'STEP' 1 'UNTIL' KK 'DO'
'FOR' J:=1 'STEP' 1 'UNTIL' KK 'DO'
MM[I,J,K]:=READ;
'FOR' I:=1 'STEP' 1 'UNTIL' KK 'DO'
T[I,K]: = READ;
'END';
RN:=READ;
TMP:=READ;
NO:=READ;
NN:=READ;
N1:=READ;
NEWLINE(4);
WRITETEXT ('('RUN%NUMBER=%')');
PRINT(RN,3,0);
```

```
WRITETEXT('(''('1C')'---------------------')');
NEWLINE (2);
WRITETEXT ('('TIME%MARKER%PULSE%SETTING=%')');
PRINT(TMP,2,1);
NEWLINE(1);
WRITETEXT('('NUMBER%OF%CHANNELS=%')');
PRINT(NO,2,0);
NEWLINE(1);
WRITETEXT('('DATA%VALUES%PER%CHANNEL=%')');
PRINT(NN,3,0);
NEWLINE(1);
WRITETEXT('('SETS%OF%READINGS=%')');
PRINT(N1,2,0);
SELECTINPUT(3);
'BEGIN''REAL''ARRAY' X[1:15,1:NO];
'REAL' RSI:
'FOR' K:=1 'STEP' 1 'UNTIL' 5 'DO'
'BEGIN'
C[K]:=READ;
'IF' C[K]=0 'THEN' 'GOTO' CONTINUE;
KK:=K*3;
RSI:=0;
'FOR' M:=1 'STEP' 1 'UNTIL' C[K]'DO'
'BEGIN'
RSI:=RSI+TMP;
SI[K,M]:=RSI;
CF[K,M]:=T[1,K]/SI[K,M];
SP[K,M]:=ENTIER((T[KK,K]/T[1,K])*SI[K,M]);
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'BEGIN'
STAN[1,K,M,J]:= STAN[2,K,M,J]:=0;
MEAN[1,K,M,J]:=MEAN[2,K,M,J]:=0;
'END';
'END';
CONTINUE:'END';
'FOR' N:=1 'STEP' 1 'UNTIL' N1 'DO'
'BEGIN'
'FOR' K:=1 'STEP' 1 'UNTIL' 5 'DO'
'BEGIN' KK:=K*3;
'FOR' M:=1 'STEP' 1 'UNTIL' C[K] 'DO'
'BEGIN' 'FOR' I:=1 'STEP' 1 'UNTIL' KK 'DO'
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
X[I,J]:= READ;
'FOR' J:=1 'STEP' 1 'UNTIL' NO'DO'
'FOR' S:=1 'STEP' 1 'UNTIL' KK 'DO'
'BEGIN' F[S,J]:=0;
'FOR' I:=1 'STEP' 1 'UNTIL' KK 'DO'
F[S,J]:=F[S,J]+MM[S,I,K]*X[I,J]/CF[K,M];
'END';
EVALUATE;
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'BEGIN'
MEAN[1,K,M,J]:=MEAN[1,K,M,J]+A[J];
MEAN[2,K,M,J]:=MEAN[2,K,M,J]+B[J];
STAN[1,K,M,J]:=STAN[1,K,M,J]+A[J]↑2;
STAN[2,K,M,J]:=STAN[2,K,M,J]+B[J]↑2;
'END';
'END';
'END';
'END';
'FOR' N:=1 'STEP' 1 'UNTIL' 2 'DO'
```

```
'BEGIN'
NEWLINE(4);
WRITETEXT ('('TIME%CONSTANT%')');
PRINT(N,1,0);
WRITETEXT ('(''('1C')'-------------------')');
NEWLINE(3);
'FOR' K:=1 'STEP' 1 'UNTIL' 5 'DO'
'BEGIN' KK:= K*3;
WRITETEXT ('('QUADRATURE%SIZE=%')');
PRINT(KK,2,0);
WRITETEXT ('(''('1C')'-------------------')');
NEWLINE(2);
SPACE (25);
WRITETEXT('('CHANNEL%1'('10S')'CHANNEL%2')');
NEWLINE (1);
SPACE(25);
WRITETEXT('('---------'('10S')'---------')');
NEWLINE(1);
WRITETEXT('('%%SP%%%%SI%%%%%%MEAN%%%%%%STD.DEV.
%%%%%%MEAN%%%%%%STD.DEV.')');
NEWLINE(2);
'FOR' M:=1 'STEP' 1 'UNTIL' C[K]'DO'
'BEGIN'
PRINT(SP[K,M],3,0);
PRINT(SI[K,M],2,1);
'FOR' J:=1 'STEP' 1 'UNTIL' NO 'DO'
'BEGIN'
STAN[N,K,M,J]:=SQRT (STAN[N,K,M,J]-MEAN[N,K,M,J]↑2/N1)/(N1-1));
MEAN[N,K,M,J]:=MEAN[N,K,M,J]/N1;
PRINT(MEAN[N,K,M,J],1,5);
PRINT(STAN[N,K,M,J],0,5);
SPACE(3);
'END';
NEWLINE(1);
'END';
NEWLINE(2);
'END';
'END';
NEWLINE(6);
WRITETEXT('(''('6S')'-----------')');
'END';
'END';
```

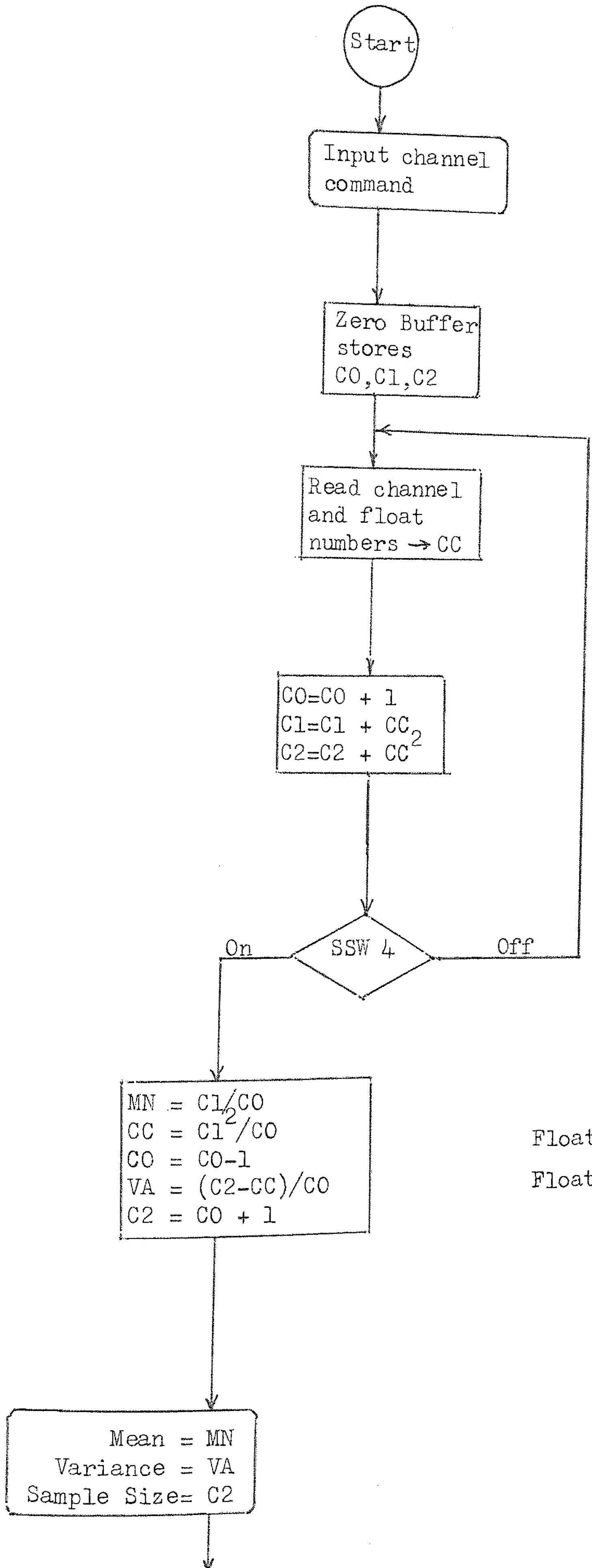
5.7 Support programs.

An on-line statistical program was written to evaluate the mean and standard deviation of the added noise from the pseudo-random noise generator. Its operation was very simple and can be understood by inspection of the block diagram shown in figure 5.7.1. Results are shown in Appendix IId.

A small Algol program was written to test the tape interface between the PDS. 1020 and the ICL. 1905. Known numbers were punched onto tape from the PDS. 1020; the tape was read and the numbers printed out by the ICL. 1905. The program is self-explanatory and is listed in figure 5.7.2. A variable reference table and the input data format are shown in tables 5.7.2 (a) and 5.7.2(b). Results are shown in Appendix II e.

Figure 5.7.1.

On-line statistical program.



Standard Subroutines

Floating Point Interpreter	S/R
Floating Point Output	S/R
Float	S/R

Table 5.7.2 (a).

Variable Reference table - READERTEST.

Variable Name	Reference
I,K	General counters
NUMBER	Numbers read from PDS. 1020 tape.

Table 5.7.2 (b).

Data input format - READERTEST

Data from tape.

PDS. 1020	output tape.
NUMBER	twenty times.

Figure 5.7.2.

Interface Test program.

```
'BEGIN''COMMENT' READERTEST,PRICE,CESTF109;
'REAL''ARRAY'NUMBER[1:100];
'INTEGER' I,K;
SELECTOUTPUT (0);
K:= 20;
NEWLINE (2);
SELECTINPUT(3);
'FOR' I=1 'STEP' 1 'UNTIL' K 'DO'
'BEGIN'
NUMBER[I]:= READ;
PRINT(NUMBER[I],1,4);
NEWLINE(1);
'END';
NEWLINE(2);
'END';
```

Chapter 6

In this chapter the results from the various programs are discussed, together with the methods of analysis, where relevant. An overall analysis of the work, in the light of its possible application to real problems, is made and the direction further work should take discussed.

6.1 The general logging program.

This program was written primarily to assist with the commissioning and calibration of on-line instruments on the evaporator. Its other uses were for monitoring the dynamic response of the evaporator, or logging steady state values.

A typical print out is shown in Appendix II a.

6.2 Support programs.

Before discussing the on-line identification program results, some support program results will be briefly mentioned.

6.2.1 Off-line identification programs:

These were primarily written to test, under ideal conditions, the identification technique for values of the parameters to be used in the on-line identification work. They were also particularly useful in aiding the debugging of on-line programs for the PDS. 1020, which were written in Assembler language. Some results are shown in Appendix II b.

6.2.2 On-line statistical analysis program:

This program was used to evaluate the statistical characteristics of the pseudo-random noise generated on the HY-48. The results are shown in Appendix II d and are tabulated against the required noise generator parameter settings.

6.2.3 Tape interface test routine:

This was used to verify that the tape code conversion routine in PDS. 1020 monitor program was working satisfactorily. Results agreed with the numbers stored in the PDS. 1020 memory.

6.3 The on-line identification program.

This was the first program used to study the identification technique. Six specimen sets of results are shown in Appendix IIc, together with their associated mean and standard deviations.

The NUMBER OF QUADRATURE POINTS refers to the sample size. TIME FACTOR converts Bellman's time units to seconds for the numerical estimation of the Laplace transform, while TIME CORRECTION FACTOR does the equivalent conversion for the system's mathematical model. The CONTROL SIGNAL INITIATE AMPLITUDE gives the required size of the disturbance on the control channel in mV which will initiate the identification routine.

Notice that the results are printed in pairs. The first number of each pair is the parameter estimate from the control channel readings and the second number is the parameter estimate from channel 21, readings which can be corrupted by noise. The parameter settings for which runs were carried out are tabulated together with the results in Appendix II c.

Considering run 1, when neither channel has any added noise, it can be seen that the second results are about 2.5% higher than the first, overall. This difference is due to the time lag between scanning the first channel and the second, and is a consequence of the low scanning speed of the logging system combined with the slowness of the PDS. 1020 cycle time.

Later results will show that considerably higher sampling periods are preferred for more accurate parameter estimation and so the effect of scanning speed will be minimised. It would certainly be an important factor, however, where several channels are going to be scanned simultaneously.

Runs 2-6 show the effect of increasing the added noise levels at a set sampling period and the effect of varying the sampling period, the added noise levels being kept constant.

The effect of increasing the noise levels is to increase the value of the standard deviation of the results, showing increased spread of the parameter estimation results. Increasing the sampling period decreases the standard deviation of the results, showing increased accuracy of estimation. The means of the parameter estimates are reasonably accurate in all cases.

A point to be considered concerns the setting of the logging system clock timer. In the author's work it was set invariably to 1 second. However, there is no reason why this setting should not be made smaller or larger. Obviously, the larger the setting the less accurate the approximation for t_i and vice versa. The choice made by the author was arbitrary but made under the limitations of computing speed of the PDS. 1020 and the scanning speed of the logging system.

If the clock timer setting is set too low, the program may miss the clock timer increment. About $\frac{1}{2}$ second is required for the program to scan two channels and carry out the associated computation for the numerical transformation of the results, hence 1 second is a reasonable choice.

Another point to consider and which is connected to what has already been said, is the initiation of the identification routine. The identification routine can be initiated at any time during a sampling interval and the clock timer count will commence from the clock timer pulse immediately following the initiation signal. This means that the timer pulse count routine can be delayed anything up to the value of the sampling interval. Thus further inaccuracies are introduced.

From the point of view of identifying chemical plant models, this is not too serious, as the time constants are generally large and, as mentioned already, identification is more accurate with large sampling periods, where the effect of this error is minimised. However, the larger the clock timer setting, the greater the errors that are introduced.

Despite the errors induced by limitations on the sampling time accuracy, the results of this program are excellent. They show that the identification technique can be used accurately in on-line work with computation time down to a minimum.

However, the amount of data that this particular computer can process on-line is limited, due to the lack of a proper interrupt facility and the slow cycle-time. Having proved that the technique can be applied under realistic conditions, this computer was hence used only as a sampling computer, the data being punched onto tape. Processing of this tape was carried out off-line.

The remainder of the work done by the author is concerned with the characteristics of the identification technique under differing conditions. However, the limitations on sampling time accuracy and scanning rate are adhered to, such that the aim of providing information about the applicability of the technique under real conditions is not lost sight of.

6.4 On-line monitoring, off-line processing programs.

The single-cycle program results are of academic interest only, the repetitive-operation programs giving more valuable results. However, the program and results (Appendix II e) are shown as an indication of how the final configuration developed from the initial on-line program.

Results from the repetitive-operation program are shown in Appendix III. These results will be discussed in the following pages.

6.4.1 Method of analysis:

Given the results in Appendix III, the problem then arises as to how best analyse the large amount of data available.

First consideration was given to the means of the parameter estimates under different conditions and graphs were drawn showing these means against the sampling period expressed in terms of the system time constant, $\tau = \frac{1}{a}$. The means were plotted as percentage deviations from the true parameter setting. Only a sample size of 3 was considered, as there were insufficient data from the other sample sizes for reasonable analysis due to equipment limitations.

These graphs are shown in Appendix IV, graphs 22-33. Graphs 22-30 show the results of the estimation of a for the model with a known forcing function, whilst graphs 31-33 show those for the model with an unknown forcing function.

To facilitate the interpretation of the results in terms of noise levels, sampling periods, system parameters, forcing function amplitude and sample sizes, graphs were drawn of the standard deviation of the estimated value of the parameter under consideration against the standard deviation of the added noise for various sampling period lengths and differing sample sizes. These graphs are shown in Appendix IV, graphs 1-21.

Two sets of confidence limits were drawn on the graphs. Specimen calculations for these confidence limits are shown in Appendix I b. The first set, designated $C.L.^{1}$, referred to the confidence with which it could be assumed that the mean of the sets of parameter estimations under the particular conditions operating was within 10% of the true population mean. These confidence limits were used as a check on the estimated means for each noise level.

The second set of confidence limits, designated $C.L.^{2}$, referred to the confidence with which it could be assumed that a single parameter estimation under the particular conditions operating was within 10% of the population mean.

The value of 10% was chosen since a sensitivity analysis showed that a 10% error in the estimation of a or b was equivalent to a 10% error in system response to a step input (Appendix I a). The figure of 10% limit on response accuracy was chosen arbitrarily after discussion with workers on related problems in industry.

Note that the amplitude of the forcing function and the model parameter are being estimated simultaneously.

Reproducibility of the results can be assessed by comparing runs 105 and 106, both run under identical conditions. The two sets of results showed similar trends.

6.4.2 Discussion of results:

By inspection of the graphs showing means plotted against sampling period in terms of system time constant, τ (graphs 22-33), the following points may be noted.

Known forcing function.

(1) The results for the noise-free channel show regularly shaped curves with common characteristics.

(2) These characteristics show a gradual increase in accuracy of estimation with increasing sampling period. The curves show a turning point or point of inflection at a sampling period of about 7τ, after which the rate of change of slope of the curve begins to increase again.

(3) The accuracy of the estimations at this point is not 100% but show deviations of between 1% and 8%.

(4) The results for the noisy channel show that the spread of the results increases with a decrease in forcing function amplitude and also with a decrease in model parameter size.

Unknown forcing function.

(1) These results showed a greater spread than those for the known forcing function. This increased spread was probably due to the fact that both the input and output functions were approximated in the Laplace domain, whereas with the forcing function of known form only the output function was approximated in the Laplace domain.

(2) Results were more accurate for lower forcing function amplitudes, however, for more accurate assessment, results for larger

sampling periods are required.

From the above observations for the known forcing function case it may reasonably be concluded that the errors in estimation at the points of inflection of the curves are due to equipment and sampling limitations and that these points in fact show the sampling periods at which estimation is at its most accurate. From the off-line support programs, (Appendix II b), it may be shown that the results of estimations in the ideal case are accurate to within 1%. It can be seen from the graphs that reasonably accurate results may be obtained with sampling periods in the range 3-12τ.

Notice that for the case of the unknown forcing function, actual monitoring of the input and output signals was delayed for about 5 seconds due to the time taken for the system under identification to respond to the forcing function. This may have affected the accuracy of the results obtained, however, further work needs to be done in this area before any final conclusion can be reached.

Further, the forcing function final amplitude was chosen to give three distinct final response amplitudes for each model, these amplitudes being 0.1, 0.4 and 0.7.

Attention will now be turned to the analysis of the graphs of standard deviation of the estimates against noise level standard deviation. (Graphs 1-21). Discussion of these graphs may be separated into three sections: estimation of the model parameter for the model with known forcing function; estimation of the step amplitude in this case; and estimation of the model parameter where the forcing function has unknown form.

(a) Estimation of the model parameter, a, where the form of the forcing function is known. (Graphs 1 - 9).

Consideration of the graphs showed that the optimum sampling period appeared to be in the order of 7-7.5τ , which compares well with that estimated from the graphs of the means. Around this sampling period the standard deviations were lower than at other sampling periods.

The effect of sampling period length appeared to vary in a cyclic fashion, other reasonable sampling periods being $3-3.5\tau$ and $11-11.5\tau$.

This effect of sampling period length was accentuated by an increase in sample size. This was particularly the case with a sample size of 9, the standard deviations of the estimated values being much greater at sampling period lengths other than $7-7.5\tau$.

Generally, forcing functions generating larger final response amplitudes gave more accurate results than those for smaller response amplitudes. The exception was the case for a sample size of 3, where the converse appeared to hold. This exception is probably due to numerical rounding error occurring in the calculation of the parameter caused by the large time scaling factors encountered for this sample size.

The $C.L.^1$ lines showed that an insufficient number of estimates per point had been taken for the computed means to have any real significance, except for the low noise level or noise-free cases. Similarly, the $C.L.^2$ lines showed that too wide a range of noise levels had been used for a parameter estimate from a single sample to be within 10% of the true parameter value. The upper bound on the noise level should have been that with a standard deviation of about 0.025.

However, some general information could be deduced from the results. Table 6.1 gives the approximate maximum noise levels that can be tolerated for small sample sizes with particular values of the final response, $\frac{b}{a}$. These values were obtained by inspection of the graphs.

(b) Estimation of the step forcing function amplitude for the case where the form of the forcing function is known. (Graphs 10-18).

The characteristics of the estimation of the step forcing function amplitude were similar to those of the estimation of the model parameter, a, however the standard deviations of the results were much more dependent on the size of the final response, $\frac{b}{a}$.

For small values of $\frac{b}{a}$ the standard deviations varied widely with sampling period, while at large values the standard deviation was smaller and practically constant. From these results it appeared that the optimum sampling period for small values of $\frac{b}{a}$ was nearer 6τ.

Table 6.1 gives approximate allowable standard deviation limits for the added noise levels for the estimation of b, deduced by inspection of the graphs.

(c) Estimation of the model parameter, a, in the case of an unknown forcing function. (Graph 19-27).

Results were only obtained in this case for a = 0.01, i.e. sampling periods of up to 4τ. The effects of sampling period length within this range, however, appeared to be similar to those in the case of the known forcing function.

Again, the graphs showed that the range of noise levels considered was too wide. However, it appeared from the results that the noise levels that could be tolerated for a value of $\frac{b}{a} = 0.1$ were higher than those for higher values of $\frac{b}{a}$. The standard deviation of the noise levels that could be tolerated for values of $\frac{b}{a} = 0.7$ and 0.4 was approximately 0.002, whilst that for $\frac{b}{a} = 0.1$ was approximately 0.006.

Table 6.1

Known forcing function, estimation of a.

$\frac{b}{a}$	Maximum allowable noise level standard deviation
0.7	0.1
0.4	0.007
0.1	0.002

Known forcing function, estimation of b.

$\frac{b}{a}$	Maximum allowable noise level standard deviation
0.7	0.01
0.4	0.008
0.1	0.006

6.5 Further work

The work done by the author has been concerned with the identification of two very simple models, however a considerable amount of information has been gained about the operation of the identification technique. The main advance of the work has been the development of an approach to the study of non-sequential identification techniques in general.

The programs developed can be very easily modified to study the identification technique for a variety of models under widely varying conditions and the identification of particular models can be studied in considerable depth under very realistic conditions.

It is apparent that the technique's only drawback is the limitation on the noise levels. This, it is considered, would not be a serious limitation in many cases. The unequal interval sampling period would not be a problem on chemical plant models where the system time constants are large.

One possible way of dealing with a system containing severe noise would be the combination of this technique with correlation analysis techniques, system parameters being identified from a knowledge of the impulse response curve using the convolution integral and the numerical Laplace Transform technique. This method would probably be very accurate.

The next stage in the study of the

usefulness of the identification technique would be its application to a real process problem. The plant used will obviously be the double-effect evaporator. As it is a pilot-scale plant, it is ideal for the purposes of this study.

A simulated model would be set up on the HY-48 with time constants set in the region of the true time constants, and the identification of this model tested using the already prepared software. Having assessed the optimum conditions for the operation of the identification technique under conditions similar to those on the evaporator, the technique could be used for system modelling with considerable confidence.

The technique is, of course, applicable only to linearised models, these being set up around the operating region. The use of approximate models for non-linear systems introduces another problem, that of the choice of the form of the approximating model. This could be done by choosing the model whose sum of squares of the residuals is least.

In the author's work all models were run at their real-time speeds, no time-scaling of the models or monitor scanrate being attempted. This was due to the slow cycle time of the PDS. 1020 and also, more important, to the limited scanning speed of the MDP. 200 logging system. Neither could a true on-line program be written due to the lack of interrupt system on the PDS. 1020. A more modern computer with full interupt capability and a more rapid cycle time would alleviate the first problem and eliminate the second. Time-scaling capability would still be limited by the logging system scanning rate.

Given a high speed logging system and also some interfacing between the HY-48 and the digital computer, the results so laboriously obtained by the author could be carried in a matter of seconds. Results from the monitor program could be stored on a disc until a large number of runs had been carried out, and then processed by a separate program.

Despite all the drawbacks, however, meaningful results have been obtained which should prove useful to anyone intent on using this particular non-sequential identification technique.

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Appendices

Appendix I

(a) Specimen derivation of the sensitivity of the response of a first order system to system parameter variations

Given a first order system,

$$\frac{dx}{dt} + ax = b, \quad x(0) = 0,$$

where x is the state variable and a and b are system parameters, the solution is given as

$$x = \frac{b}{a}\left(1 - e^{-at}\right)$$

Now,

$$\frac{\partial x}{\partial a} = \frac{b}{a}\left[t\, e^{-at} - \frac{1}{a}(1 - e^{-at})\right]$$

and $\Delta x = \frac{\partial x}{\partial a} \Delta a$

$$\text{or} \quad \frac{\Delta x}{x} = \frac{\partial x}{\partial a} \frac{\Delta a}{x}$$

$$= \frac{\frac{b}{a}\left[t\, e^{-at} - \frac{1}{a}(1 - e^{-at})\right]\Delta a}{\frac{b}{a}\left(1 - e^{-at}\right)}$$

$$= \left[\frac{(1+at)e^{-at} - 1}{1 - e^{-at}}\right] \frac{\Delta a}{a} \quad \ldots\ldots\ldots\ldots(1)$$

$$\text{Now} \quad \frac{\partial}{\partial t}\left(\frac{\Delta x}{x}\right) = \Delta a \left[\frac{at(at - 1)\, e^{-3at}}{1 - e^{-at}}\right]$$

At the turning points,

$$\frac{\partial}{\partial t}\left(\frac{\Delta x}{x}\right) = 0$$

Solving the above, the turning points are found to be at

$$t = 0$$

$$t = \infty$$

$$t = \frac{1}{a}$$

Equation (1) will now be solved for these values of t.

At $t = \frac{1}{a}$, $\frac{\Delta x}{x} = -0.4179 \frac{\Delta a}{a}$

At $t = 0$, $\frac{\Delta x}{x} = 0$

At $t = \infty$, $\frac{\Delta x}{x} = -\frac{\Delta a}{a}$

By inspection it can be seen that the maximum fractional variation in x for a given variation in a will be given by:

$$\frac{\Delta x}{x} = -\frac{\Delta a}{a}$$

Similarly, it may be shown for variation in parameter b,

$$\frac{\Delta x}{x} = \frac{\Delta b}{b}$$

(b) Specimen calculation of the standard deviation limit for confidence limits of 95%, given a permissable error of 10% in the result

From Brownlee (54),

$$u_{0.975} = 1.96$$

$$u_{0.025} = -1.96$$

Given a 10% allowable error on a parameter value of 0.01, then

$$0.001 = 1.96 \frac{\sigma}{\sqrt{N}}$$

where σ = standard deviation

N = No. of results

For $N = 15$,

$$0.001 = 1.96 \frac{\sigma}{\sqrt{15}}$$

and $\sigma = 2 \times 10^{-3}$

(c) Specimen derivation of the unknown model parameter for a simple model

Given a model,

$$\frac{dx}{dt} + ax = a, \quad x(o) = 0$$

where a is unknown.

Transforming this equation,

$$s\,x(s) + ax(s) = \frac{a}{s}$$

If $\bar{x}$ is obtained from numerical transformation of values of x (t), the sum of the squares of the residuals may be written:

$$S = \sum_{s=1}^{N} \{ s^2 x(s) + a s x(s) - a \}^2$$

Hence,

$$\frac{\partial S}{\partial a} = \sum_{s=1}^{N} 2.\{ s^2 x(s) + a s x(s) - a \}.(s x(s) - 1)$$

$$= 0$$

Simplifying,
$$a = \sum_{s=1}^{N} \frac{s^2 x(s) \{ s x(s) - 1 \}}{(s x(s) - 1)^2}$$

(d) Specimen calculation to show the effect of rounding of the sampling time on the accuracy of the measured value of x

Consider the model,

$$\frac{dx}{dt} + ax = b, \qquad x(o) = 0.$$

The rate of change of x with time is a maximum at $t = 0$, and falls off thereafter. It can be expected that the worst error in the measured value of x will be at the second sampling point, where rounding of the sampling time first takes place, and where b is large.

The value of x will be computed for the true and rounded values of t_2 for the model above, given a sample size of 3, $\frac{b}{a} = 0.7$, and a = 0.1 and 0.3. The percentage error in x can then be calculated.

(I) $\frac{dx}{dt} + 0.01\,x = 0.007$

From Bellman (1), for a sample size of 3,

$$t_1 = 0.119574$$

$$t_2 = 0.693147$$

Hence, if t_1 is scaled to 1 second, t_2 will be scaled to 0.693147 / 0.119574 = 5.7968 seconds. The rounded value of t_2 will then be 6 seconds.

The solution of the model, given a = 0.01, is:

$$x = 0.7\,(1 - e^{-0.01t})$$

Substituting for t with both the true and rounded values of t_2,

$x = 0.039424$ (t_2 true)

$x = 0.040765$ (t_2 rounded)

The percentage error in x is 3.4%. This is with the minimum time-scaling factor possible.

For a = 0.3,

$x = 0.111736$ (t_2 true)

$x = 0.115311$ (t_2 rounded)

The percentage error in x is 3.2%

This can be considered negligible in both cases, as considerably larger time-scaling factors are used in practice, giving sampling intervals of 10 - 20 seconds.

Appendix II

(a) Specimen printout for general logging program

This printout shows the operation of the general logging program, initially taking scaled voltage readings for 8 thermocouples on the double-effect evaporator, and then inputting calibration factors and logging the true temperatures (^{o}F)

General Logging Program

Filter (In or No)?: No

Input from Scan or K/bd?: K/bd

First Channel No.: 20

Last Channel No.: 27

GAINS

20	21	22	23	24	25
26	27				
1000	1000	1000	1000	1000	1000
1000	1000				

CHANNEL READINGS

20	21	22	23	24	25
26	27				
0.600	1.139	0.647	1.824	1.480	1.489
1.787	1.144				
0.600	1.133	0.638	1.800	1.430	1.459
1.764	1.157				
0.594	1.147	0.644	1.826	1.450	1.457
1.780	1.199				
0.599	1.150	0.670	1.846	1.467	1.500
1.818	1.160				
0.599	1.150	0.671	1.841	1.428	1.470
1.848	1.230				
0.600	1.148	0.603	1.841	1.452	1.590
1.853	1.216				

0.600	1.152	0.663	1.838	1.409	1.408
1.750	1.145				
0.600	1.157	5.959	1.830	1.417	1.413
1.720	1.067				

CALIBRATION FACTORS (INPUT BASES, THEN GRADIENTS).

20	21	22	23	24	25
26	27				
32.	32.	32.	32.	32.	32.
32.	32.				
45.	45.	45.	45.	45.	45.
45.	45.				

First Channel No.: 20

Last Channel No.: 27

GAINS

20	21	22	23	24	25
26	27				
1000	1000	1000	1000	1000	1000
1000	1000				

CHANNEL READINGS

20	21	22	23	24	25
26	27				
58.955	83.165	61.655	112.37	96.17	99.905
115.205	85.685				
59.	83.615	61.43	114.305	97.88	98.6
111.74	83.3				
58.91	83.3	61.97	113.36	97.205	101.435
116.6	86.855				
58.955	83.3	61.745	113.9	98.33	98.285
112.685	85.955				
58.505	83.525	60.665	112.865	97.835	100.22
116.015	88.43				
58.505	83.165	61.835	113.72	96.485	96.8
110.66	83.75				
58.91	83.39	62.06	113.495	96.08	96.8
111.2	83.66				
58.955	83.57	61.7	113.855	98.465	98.555
113.	86.855				

58.46 110.3	83.435 83.3	62.195	113.81	96.305	96.305
59. 112.145	82.58 85.1	61.07	113.045	95.72	96.8
58.685 113.	83.705 85.415	60.8	113.45	98.51	99.365

(b) Off-line parameter estimation results

(I) Model with known forcing function

NOTE: The values of time scale used refer to initial sampling interval values as shown in the following table.

Time Scale	Sampling Interval
41.8151	5
83.6302	10
167.2604	20

Modelling Technique Test Program

No. of Quadrature Points: 03

Time Scale: .83630200+ 2+

Input Time Constants!

True Time Constants:

.10000000+ 1-
.70000000+ 2-

Estimated Time Constants:

.10041194+ 1-
.70073393+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.40000000+ 2-

Estimated Time Constants:

.10040775+ 1-
.40041370+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.10000000+ 2-

Estimated Time Constants:

.10048921+ 1-
.10012953+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.14000000+ 1-

Estimated Time Constants:

.19992566+ 1-
.13998410+ 1-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.80000000+ 2-

Estimated Time Constants:

.19993697+ 1-
.79993086+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.20000000+ 2-

Estimated Time Constants:

.19993650+ 1-
.19998249+ 2-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.21000000+ 1-

Estimated Time Constants:

.29991335+ 1-
.20995507+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.12000000+ 1-

Estimated Time Constants:

.29992992+ 1-
.11997814+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.30000000+ 2-

Estimated Time Constants:

.30004058+ 1-
.30000905+ 2-

Time Scale: .16726040+ 3+

Input Time Constants!

True Time Constants:

.10000000+ 1-
.70000000+ 2-

Estimated Time Constants:

.99966216+ 2-
.69993203+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.40000000+ 2-

Estimated Time Constants:

.99968740+ 2-
.39996593+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.10000000+ 2-

Estimated Time Constants:

.10009785+ 1-
.10005325+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.14000000+ 1-

Estimated Time Constants:

.20027238+ 1-
.14013866+ 1-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.80000000+ 2-

Estimated Time Constants:

.20028408+ 1-
.80082236+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.20000000+ 2-

Estimated Time Constants:

.20048178+ 1-
.20033208+ 2-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.21000000+ 1-

Estimated Time Constants:

.30857521+ 1-
.21485905+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.12000000+ 1-

Estimated Time Constants:

.30856376+ 1-
.12277325+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.30000000+ 2-

Estimated Time Constants:

.30895676+ 1-
.30721859+ 2-

Time Scale: .41815100+ 2+

Input Time Constants!

True Time Constants:

.10000000+ 1-
.70000000+ 2-

Estimated Time Constants:

.10676026+ 1-
.70706946+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.40000000+ 2-

Estimated Time Constants:

.10678489+ 1-
.40405910+ 2-

Input Time Constants!

True Time Constants:

.10000000+ 1-
.10000000+ 2-

Estimated Time Constants:

.10694771+ 1-
.10104647+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.14000000+ 1-

Estimated Time Constants:

.20081711+ 1-
.14014526+ 1-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.80000000+ 2-

Estimated Time Constants:

.20082154+ 1-
.80083590+ 2-

Input Time Constants!

True Time Constants:

.20000000+ 1-
.20000000+ 2-

Estimated Time Constants:

.20098957+ 1-
.20026302+ 2-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.21000000+ 1-

Estimated Time Constants:

.29961091+ 1-
.20991337+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.12000000+ 1-

Estimated Time Constants:

.29961288+ 1-
.11995081+ 1-

Input Time Constants!

True Time Constants:

.30000000+ 1-
.30000000+ 2-

Estimated Time Constants:

.29975366+ 1-
.29993499+ 2-

(II) Model with unknown forcing function

Input Signal Final Amplitude = 3.50000& -4

Input Signal Time Constant = 5.00000& -2

System Time Constant = 1.00000& -2

Time Scale	Estimate
8.36302& 0	2.05623& -2
1.67260& 1	1.34435& -2
2.50891& 1	1.15021& -2
3.34521& 1	1.07446& -2
4.18151& 1	1.03965& -2
5.01781& 1	1.02198& -2
5.85412& 1	1.01255& -2
6.69042& 1	1.00763& -2
7.52672& 1	1.00548& -2

INPUT	OUTPUT
0.00275	0.01441
0.00661	0.21958
0.00700	0.55905

8.36302& 1	1.00523& -2
9.19932& 1	1.00634& -2
1.00356& 2	1.00847& -2
1.08719& 2	1.01137& -2
1.17082& 2	1.01484& -2
1.25445& 2	1.01870& -2
1.33808& 2	1.02284& -2
1.42171& 2	1.02713& -2
1.50534& 2	1.03150& -2
1.58897& 2	1.03588& -2

INPUT	OUTPUT
0.00442	0.04799
0.00698	0.42606
0.00700	0.67729

1.67260& 2	1.04019& -2
1.75623& 2	1.04441& -2

Input Signal Final Amplitude = 2.00000& -4

Input Signal Time Constant= 5.00000& -2

System Time Constant = 1.00000& -2

Time Scale	Estimate
8.36302& 0	2.05623& -2
1.67260& 1	1.34435& -2
2.50891& 1	1.15021& -2
3.34521& 1	1.07446& -2
4.18151& 1	1.03965& -2
5.01781& 1	1.02198& -2
5.85412& 1	1.01255& -2
6.69042& 1	1.00763& -2
7.52672& 1	1.00548& -2

INPUT	OUTPUT
0.00157	0.00823
0.00378	0.12547
0.00400	0.31945

8.36302& 1	1.00523& -2
9.19932& 1	1.00634& -2
1.00356& 2	1.00847& -2
1.08719& 2	1.01137& -2
1.17082& 2	1.01484& -2
1.25445& 2	1.01870& -2
1.33808& 2	1.02284& -2
1.42171& 2	1.02713& -2
1.50534& 2	1.03150& -2
1.58897& 2	1.03588& -2

INPUT	OUTPUT
0.00253	0.02742
0.00399	0.24346
0.00400	0.38702

1.67260& 2	1.04019& -2
1.75623& 2	1.04441& -2

Input Signal Final Amplitude = 5.00000& -5

Input Signal Time Constant = 5.00000& -2

System Time Constant = 1.00000& -2

Time Scale	Estimate
8.36302& 0	2.05623& -2
1.67260& 1	1.34435& -2
2.50891& 1	1.15021& -2
3.34521& 1	1.07446& -2
4.18151& 1	1.03965& -2
5.01781& 1	1.02198& -2
6.69042& 1	1.00763& -2
7.52672& 1	1.00548& -2

INPUT	OUTPUT
0.00039	0.00206
0.00094	0.03137
0.00100	0.07986
8.36302& 1	1.00523& -2
9.19932& 1	1.00634& -2
1.00356& 2	1.00847& -2
1.08719& 2	1.01137& -2
1.17082& 2	1.01484& -2
1.25445& 2	1.01870& -2
1.33808& 2	1.02284& -2
1.42171& 2	1.02713& -2
1.50534& 2	1.03150& -2
1.58897& 2	1.03588& -2

INPUT	OUTPUT
0.00063	0.00686
0.00100	0.06087
0.00100	0.09676
1.67260& 2	1.04019& -2
1.75623& 2	1.04441& -2

(c) On-line parameter estimation results

The following table gives the parameter settings used for the runs shown for the on-line identification program.

Parameter/Run Number	1	2	3	4	5	6
a	0.01	0.01	0.01	0.01	0.01	0.01
Logging System timer setting	1 sec.	1 sec.	1 sec.	1 sec.	1 sec.	1 sec.
Sampling interval	1 sec.	1 sec.	1 sec.	1 sec.	2 sec.	3 sec.
Sampling period in terms of τ, the system time constant	0.98	0.98	0.98	0.98	1.97	2.95
Time Scale(s domain)	29.114	29.114	29.114	29.114	58.228	87.342
Sample size	6	6	6	6	6	6
Standard deviation of noise level added to output signal	-	0.022	0.061	0.102	0.022	0.022
Control signal initiate amplitude	10mV	10mV	10mV	10mV	10mV	10mV

Below are tabulated the means and standard deviations of the results for each run.

Run No.	Control Channel		Channel with added noise	
	Mean	Std. Dev.	Mean	Std. Dev.
1	0.009230	0.3762×10^{-3}	0.009467	0.3518×10^{-3}
2	0.009498	0.3340×10^{-3}	0.009819	0.1768×10^{-2}
3	0.009515	0.4305×10^{-3}	0.009629	0.3863×10^{-2}
4	0.009788	0.4434×10^{-3}	0.012055	0.9520×10^{-2}
5	0.010202	0.2358×10^{-3}	0.010221	0.1382×10^{-2}
6	0.009975	0.2168×10^{-3}	0.009940	0.6429×10^{-3}

RUN 1

Model Prediction Program

No. of Quadrature Points: 6

First Channel No.: 20

Last Channel No.: 21

Time Factor: 29.114000

Time Correction Factor: 1.000000

Control Channel No.: 20

Control Signal Initiate Amplitude: 10

.93145471+ 2-
.96116927+ 2-

.97284775+ 2-
.98799628+ 2-

.88418877+ 2-
.90448345+ 2-

.96685988+ 2-
.98484331+ 2-

.93376397+ 2-
.96031080+ 2-

.91293358+ 2-
.94943949+ 2-

.88013756+ 2-
.90039026+ 2-

.95914662+ 2-
.97453907+ 2-

.92390656+ 2-
.95096152+ 2-

.86475051+ 2-
.89282127+ 2-

RUN 2

.96118984+ 2-
.12137147+ 1-

.96946659+ 2-
.10435789+ 1-

.96497135+ 2-
.97871255+ 2-

.94598714+ 2-
.10298429+ 1-

.99560235+ 2-
.10542517+ 1-

.95896004+ 2-
.98640466+ 2-

.88785248+ 2-
.11974697+ 1-

.95314616+ 2-
.93659491+ 2-

.96692325+ 2-
.99564119+ 2-

.99151255+ 2-
.11914341+ 1-

.93962476+ 2-
.72296875+ 2-

.98354502+ 2-
.11555172+ 1-

.89994342+ 2-
.79654233+ 2-

.89643365+ 2-
.66833690+ 2-

.93246358+ 2-
.75770344+ 2-

RUN 3

.96212466+ 2-
.99696851+ 2-

.99423444+ 2-
.29333094+ 2-

.90452589+ 2-
.58543011+ 2-

.10032761+ 1-
.11233868+ 1-

.10065765+ 1-
.12654260+ 1-

.99321944+ 2-
.49173272+ 2-

.99280172+ 2-
.91185641+ 2-

.88827597+ 2-
.38082822+ 2-

.93293658+ 2-
.14841365+ 1-

.98345239+ 2-
.86629673+ 2-

.96463328+ 2-
.14281872+ 1-

.90148447+ 2-
.10578705+ 1-

.92913917+ 2-
.93621794+ 2-

.92214306+ 2-
.14945129+ 1-

.89383681+ 2-
.11274339+ 1-

RUN 4

.10123912+ 1-
.15028621+ 1-

.10125536+ 1-
.13300159+ 2-

.98101632+ 2-
.24621217+ 1-

.10061809+ 1-
.24718807+ 2-

.10268810+ 1-
.32696825+ 2-

.10503459+ 1-
.27194538+ 1-

.94338120+ 2-
.10251580+ 2-

.93419606+ 2-
.22112171+ 1-

.96665357+ 2-
.95116136+ 2-

.10074493+ 1-
.26559669- 2-

.91541857+ 2-
.15316400+ 1-

.99385890+ 2-
.13507531+ 1-

.89107664+ 2-
.98507384+ 2-

.98984413+ 2-
.15525824+ 1-

.95001057+ 2-
.22712085+ 1-

RUN 5

.99413214+ 2-
.11240015+ 1-

.10121732+ 1-
.93597143+ 2-

.10253683+ 1-
.91092300+ 2-

.10313011+ 1-
.11565080+ 1-

.10346159+ 1-
.11309642+ 1-

.10345173+ 1-
.11778555+ 1-

.10494682+ 1-
.10885906+ 1-

.10528091+ 1-
.94101922+ 2-

.97391199+ 2-
.76579530+ 2-

.99603497+ 2-
.11904252+ 1-

.10076720+ 1-
.94218161+ 2-

.10303443+ 1-
.90151194+ 2-

RUN 6

.97569615+ 2-
.94133644+ 2-

.98012787+ 2-
.10638204+ 1-

.96068039+ 2-
.99104217+ 2-

.98770757+ 2-
.98876236+ 2-

.97612296+ 2-
.96214486+ 2-

.98441511+ 2-
.10878114+ 1-

.10004658+ 1-
.97824053+ 2-

.98091048+ 2-
.92933810+ 2-

.10047882+ 1-
.94174036+ 2-

.10283155+ 1-
.97118834+ 2-

.10138201+ 1-
.94805277+ 2-

.10036719+ 1-
.97291849+ 2-

.10380806+ 1-
.10047422+ 1-

.10128422+ 1-
.96411920+ 2-

.10155764+ 1-
.11646678+ 1-

(d) Noise level calibrations

This table shows HY-48 pseudo-random noise generator settings against standard deviation of resultant noise, calculated by the on-line statistical analysis program. The mean of the noise was assumed zero. Specimen results are shown overleaf. The HY-48 digital clock speed was set at 10 cps.

K	$\frac{1}{T}$	Resultant Standard Deviation
0.1	0.1	0.022
0.3	0.1	0.061
0.5	0.1	0.106

Statistical Check.

Channel Command?

Mean: .35420560- 3-

Standard Deviation: .23203302+ 1-

Sample Size: .21300000+ 3+

Statistical Check.

Channel Command?

Mean: .30954166+ 2-

Standard Deviation: .62849814+ 1-

Sample Size: .23900000+ 3+

Statistical Check.

Channel Command?

Mean: .93748898+ 2-

Standard Deviation: .10695780+ 0-

Sample Size: .22600000+ 3+

Statistical Check.

Channel Command?

Mean: .13113861+ 2-

Standard Deviation: .21403573+ 1-

Sample Size: .20100000+ 3+

Statistical Check.

Channel Command?

Mean: .10136986- 2-

Standard Deviation: .61305706+ 1-

Sample Size: .21800000+ 3+

Statistical Check.

Channel Command?

Mean: .15348837+ 3-

Standard Deviation: .10552279+ 0-

Sample Size: .21400000+ 3+

Statistical Check.

Channel Command?

Mean: .12301369+ 3-

Standard Deviation: .22903727+ 1-

Sample Size: .36400000+ 3+

Statistical Check.

Channel Command?

Mean: .24996655+ 2-

Standard Deviation: .58575494+ 1-

Sample Size: .29800000+ 3+

Statistical Check.

Channel Command?

Mean: .36171641+ 2-

Standard Deviation: .10695318+ 0-

Sample Size: .26700000+ 3+

(e) Results from single-cycle monitoring, off-line processing runs

Data Analysis Program

Run Number = 19

Time marker pulse setting = 1.0
Number of channels = 2
Data values per channel = 400

Quadrature Size = 3

Sampling interval = 1.0

Channel number = 1

Time constant = 1.0244404266& -2:

Channel number = 2

Time constant = 6.7807126652& -3:

Sampling interval = 2.0

Channel number = 1

Time constant = 9.9813990807& -3:

Channel number = 2

Time constant = 1.3407521522& -2:

Sampling interval = 3.0

Channel number = 1

Time constant = 9.6999498829& -3:

Channel number = 2

Time constant = 1.1111033625& -2:

Sampling interval = 4.0

Channel number = 1

Time constant = 9.6719828306& -3:

Channel number = 2

Time constant = 8.6923691390& -3:

Sampling interval = 5.0

Channel number = 1

Time constant = 9.5969425987& -3:

Channel number = 2

Time constant = 7.9248990106& -3:

Sampling interval = 6.0

Channel number = 1

Time constant = 9.7445181079& -3:

Channel number = 2

Time constant = 9.1065439723& -3:

Sampling interval = 7.0

Channel number = 1

Time constant = 9.7563931284& -3:

Channel number = 2

Time constant = 1.0405835235& -2:

Sampling interval = 8.0

Channel number = 1

Time constant = 9.6503165722& -3:

Channel number = 2

Time constant = 1.0296432091& -2:

Sampling interval = 9.0

Channel number = 1

Time constant = 9.6666874492& -3:

Channel number = 2

Time constant = 9.8737959902& -3:

Sampling interval = 10.0

Channel number = 1

Time constant = 9.6636317177& -3:

Channel number = 2

Time constant = 9.3590941637& -3:

Sampling interval = 11.0

Channel number = 1

Time constant = 9.7017090654& -3:

Channel number = 2

Time constant = 9.2360758072& -3:

Sampling interval = 12.0

Channel number = 1

Time constant = 9.6826441280& -3:

Channel number = 2

Time constant = 8.9994727904& -3:

Sampling interval = 13.0

Channel number = 1

Time constant = 9.6260279660& -3:

Channel number = 2

Time constant = 8.7810457861& -3:

Sampling interval = 14.0

Channel number = 1

Time constant = 9.6165651812& -3:

Channel number = 2

Time constant = 9.1427579415& -3:

Sampling interval = 15.0

Channel number = 1

Time constant = 9.6407721994& -3:

Channel number = 2

Time constant = 9.1969696751& -3:

Sampling interval = 16.0

Channel number = 1

Time constant = 9.7081546145& -3:

Channel number = 2

Time constant = 1.016601215& -2:

Sampling interval = 17.0

Channel number = 1

Time constant = 9.7609766552& -3:

Channel number = 2

Time constant = 1.0287377151& -2:

Sampling interval = 18.0

Channel number = 1

Time constant = 9.6818327109& -3:

Channel number = 2

Time constant = 1.0641089805& -2:

Sampling interval = 19.0

Channel number = 1

Time constant = 9.7431351973& -3:

Channel number = 2

Time constant = 1.0238710134& -2:

Sampling interval = 20.0

Channel number = 1

Time constant = 9.7222698715& -3:

Channel number = 2

Time constant = 9.9596100194& -3:

Sampling interval = 21.0

Channel number = 1

Time constant = 9.7338619226& -3:

Channel number = 2

Time constant = 1.0233836267& -2:

Quadrature Size = 6

Sampling interval = 1.0

Channel number = 1

Time constant = 9.6601770848& -3:

Channel number = 2

Time constant = 6.8803824741& -3:

Sampling interval = 2.0

Channel number = 1

Time constant = 9.8083157230& -3:

Channel number = 2

Time constant = 1.0174617175& -2:

Sampling interval = 3.0

Channel number = 1

Time constant = 9.6610864479& -3:

Channel number = 2

Time constant = 1.0250291324& -2:

Sampling interval = 4.0

Channel number = 1

Time constant = 9.8299226174& -3:

Channel number = 2

Time constant = 9.4752872126& -3:

Quadrature Size = 9

Sampling interval = 1.0

Channel number = 1

Time constant = 9.6390480131& -3:

Channel number = 2

Time constant = 7.6905514897& -3:

(f) Tape interface test results

0.0000

0.0000

0.1111

-0.1111

0.2222

-0.2222

0.3333

-0.3333

0.4444

-0.4444

0.5555

-0.5555

0.6666

-0.6666

0.7777

-0.7777

0.8888

-0.8888

0.9999

-0.9999

Appendix III

This table gives the parameter settings for individual sets of runs using the repetitive operation program system. Runs 102 - 130 apply to the model with an unknown step forcing function, while runs 200 - 208 apply to the model with unknown forcing function. The logging system clock timer was set at 1 sec. for all these runs. Actual parameter settings used on the HY-48 are given in the table following this one. For runs 102-130 'Time Constant 1' is the parameter 'a', and 'Time Constant 2' parameter 'b'.

Run No.	Model Parameter a	Forcing function final amplitude	Noise Level standard deviation
102	0.01	0.007	0.022
103	0.01	0.007	0.061
104	0.01	0.007	0.106
105, 106	0.01	0.004	0.022
107	0.01	0.004	0.061
108	0.01	0.004	0.106
109	0.01	0.001	0.022
110	0.01	0.001	0.061
111	0.01	0.001	0.106
113	0.02	0.007	0.022
114	0.02	0.007	0.061
115	0.02	0.007	0.106
116	0.02	0.004	0.022
117	0.02	0.004	0.061
118	0.02	0.004	0.106
119	0.02	0.001	0.022
120	0.02	0.001	0.061
121	0.02	0.001	0.106
122	0.03	0.007	0.022
123	0.03	0.007	0.061
124	0.03	0.007	0.106
125	0.03	0.004	0.022
126	0.03	0.004	0.061
127	0.03	0.004	0.106
128	0.03	0.001	0.022
129	0.03	0.001	0.061
130	0.03	0.001	0.106
200	0.01	0.007	0.022
201	0.01	0.007	0.061
202	0.01	0.007	0.106
203	0.01	0.004	0.022
204	0.01	0.004	0.061
205	0.01	0.004	0.106
206	0.01	0.001	0.022
207	0.01	0.001	0.061
208	0.01	0.001	0.106

Run No.	Potentiometer settings				
	Model parameters			Noise level parameters	
	a	b	c	k	$\frac{1}{T}$
102	0.01	0.007	-	0.1	0.1
103	0.01	0.007	-	0.3	0.1
104	0.01	0.007	-	0.5	0.1
105	0.01	0.004	-	0.1	0.1
106	0.01	0.004	-	0.1	0.1
107	0.01	0.004	-	0.3	0.1
108	0.01	0.004	-	0.5	0.1
109	0.01	0.001	-	0.1	0.1
110	0.01	0.001	-	0.3	0.1
111	0.01	0.001	-	0.5	0.1
113	0.02	0.014	-	0.1	0.1
114	0.02	0.014	-	0.3	0.1
115	0.02	0.014	-	0.5	0.1
116	0.02	0.008	-	0.1	0.1
117	0.02	0.008	-	0.3	0.1
118	0.02	0.008	-	0.5	0.1
119	0.02	0.002	-	0.1	0.1
120	0.02	0.002	-	0.3	0.1
121	0.02	0.002	-	0.5	0.1
122	0.03	0.021	-	0.1	0.1
123	0.03	0.021	-	0.3	0.1
124	0.03	0.021	-	0.5	0.1
125	0.03	0.012	-	0.1	0.1
126	0.03	0.012	-	0.3	0.1
127	0.03	0.012	-	0.5	0.1
128	0.03	0.003	-	0.1	0.1
129	0.03	0.003	-	0.3	0.1
130	0.03	0.003	-	0.5	0.1
200	0.01	0.0035	0.05	0.1	0.1
201	0.01	0.0035	0.05	0.3	0.1
202	0.01	0.0035	0.05	0.5	0.1
203	0.01	0.002	0.05	0.1	0.1
204	0.01	0.002	0.05	0.3	0.1
205	0.01	0.002	0.05	0.5	0.1
206	0.01	0.0005	0.05	0.1	0.1
207	0.01	0.0005	0.05	0.3	0.1
208	0.01	0.0005	0.05	0.5	0.1

Data Analysis Program

Run Number = 102

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.05487	1.42358& -2	0.07547	2.03769& -1
36	2.0	0.02250	3.92147& -3	0.02071	3.56213& -2
54	3.0	0.01525	1.84745& -3	0.01292	2.15967& -2
73	4.0	0.01342	1.15155& -3	0.01296	1.53718& -2
91	5.0	0.01245	7.84935& -4	0.01555	6.81886& -3
109	6.0	0.01174	6.21509& -4	0.01172	6.21795& -3
127	7.0	0.01143	4.65119& -4	0.01410	5.73832& -3
146	8.0	0.01091	3.89018& -4	0.01076	3.66374& -3
164	9.0	0.01083	3.01282& -4	0.01225	2.92448& -3
182	10.0	0.01067	3.20532& -4	0.01106	3.18554& -3
200	11.0	0.01059	2.68689& -4	0.01023	1.97195& -3
219	12.0	0.01053	2.28434& -4	0.01085	3.00276& -3
237	13.0	0.01042	2.03248& -4	0.01039	2.33944& -3
255	14.0	0.01038	1.87355& -4	0.00931	2.08095& -3
273	15.0	0.01035	1.67200& -4	0.01174	6.31212& -3
292	16.0	0.01034	1.55655& -4	0.00985	1.81278& -3
310	17.0	0.01033	1.44879& -4	0.01067	1.81896& -3
328	18.0	0.01028	1.43209& -4	0.00974	1.83792& -3
346	19.0	0.01027	1.35032& -4	0.00985	2.33768& -3
365	20.0	0.01027	1.42069& -4	0.00936	1.68587& -3
383	21.0	0.01027	1.34167& -4	0.01013	2.19964& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01406	2.53438& -3	0.01314	1.93854& -2
197	2.0	0.01219	8.73060& -4	0.01175	4.58898& -3
295	3.0	0.01090	4.56448& -4	0.00975	4.07619& -3
394	4.0	0.01090	3.13536& -4	0.01059	2.80087& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01158	1.07909& -3	0.01196	6.94431& -3

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00992	1.12493& -3	0.01170	1.16383& -2
36	2.0	0.00857	5.42397& -4	0.00856	4.27758& -3
54	3.0	0.00781	3.43672& -4	0.00752	3.24458& -3
73	4.0	0.00769	2.65349& -4	0.00747	2.67540& -3
91	5.0	0.00761	2.11291& -4	0.00835	1.48526& -3
109	6.0	0.00755	1.86351& -4	0.00764	1.77458& -3
127	7.0	0.00752	1.56592& -4	0.00849	1.74500& -3
146	8.0	0.00735	1.38513& -4	0.00741	1.21004& -3
164	9.0	0.00736	1.15038& -4	0.00798	1.05209& -3
182	10.0	0.00734	1.27138& -4	0.00763	1.12243& -3
200	11.0	0.00733	1.12757& -4	0.00718	7.76792& -4
219	12.0	0.00732	1.00642& -4	0.00734	1.20825& -3
237	13.0	0.00726	9.18342& -5	0.00715	1.09153& -3
255	14.0	0.00725	8.83985& -5	0.00689	9.48417& -4
273	15.0	0.00725	8.08099& -5	0.00743	9.43666& -4
292	16.0	0.00725	7.68403& -5	0.00703	8.36197& -4
310	17.0	0.00725	7.35638& -5	0.00740	7.88695& -4
328	18.0	0.00721	7.35629& -5	0.00701	8.72772& -4
346	19.0	0.00722	7.08424& -5	0.00711	1.14745& -3
365	20.0	0.00722	7.53048& -5	0.00673	7.95997& -4
383	21.0	0.00722	7.20475& -5	0.00714	1.18524& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00779	4.42634& -4	0.00778	2.94522& -3
197	2.0	0.00766	2.43974& -4	0.00768	1.19901& -3
295	3.0	0.00739	1.60796& -4	0.00713	1.26702& -3
394	4.0	0.00743	1.27637& -4	0.00740	1.03349& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00751	2.81428& -4	0.00767	1.57477& -3

Data Analysis Program

Run Number = 103

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values Per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV
18	1.0	0.05918	1.54260& -2	-0.04070	1.16467& 0
36	2.0	0.02344	3.64968& -3	-0.01567	7.00791& -2
54	3.0	0.02083	2.01363& -2	0.06995	1.35510& -1
73	4.0	0.01377	1.06304& -3	0.03580	4.95599& -2
91	5.0	0.01264	8.18400& -4	0.01388	2.18293& -2
109	6.0	0.01326	5.79628& -3	0.01563	1.04959& -2
127	7.0	0.01145	4.53524& -4	0.02094	1.51875& -2
146	8.0	0.01033	2.45448& -3	0.01759	1.00489& -2
164	9.0	0.01081	3.17130& -4	0.01268	1.31493& -2
182	10.0	0.01071	2.57170& -4	0.01321	1.18305& -2
200	11.0	0.01060	2.33773& -4	0.01088	7.64671& -3
219	12.0	0.01055	2.22892& -4	0.00820	6.63748& -3
237	13.0	0.01042	1.90878& -4	0.00874	7.54863& -3
255	14.0	0.01038	1.83057& -4	0.01235	9.66654& -3
273	15.0	0.01036	1.68297& -4	0.01101	5.18082& -3
292	16.0	0.01034	1.60833& -4	0.01124	5.27422& -3
310	17.0	0.01033	1.61835& -4	0.00792	5.92433& -3
328	18.0	0.01028	1.46576& -4	0.01001	3.51862& -3
346	19.0	0.00964	2.37163& -3	0.01039	4.26881& -3
365	20.0	0.01026	1.23202& -4	0.00937	5.96049& -3
383	21.0	0.01025	1.19702& -4	0.01277	5.26358& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01476	2.63232& -3	0.04055	5.59313& -2
197	2.0	0.01233	7.93706& -4	0.00832	1.69143& -2
295	3.0	0.01096	4.52278& -4	0.01668	1.48986& -2
394	4.0	0.01094	2.91773& -4	0.01618	1.17781& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01183	1.09857& -3	0.01428	2.09945& -2

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.01022	1.20903& -3	0.00850	9.99003& -2
36	2.0	0.00866	5.11150& -4	0.00708	7.00613& -3
54	3.0	0.00801	6.84664& -4	0.01642	1.92458& -2
73	4.0	0.00774	2.51416& -4	0.01273	1.05757& -2
91	5.0	0.00764	2.16584& -4	0.00791	4.93962& -3
109	6.0	0.00758	2.27268& -4	0.00948	3.07227& -3
127	7.0	0.00750	1.50978& -4	0.01035	4.85839& -3
146	8.0	0.00716	7.47616& -4	0.00929	3.21584& -3
164	9.0	0.00734	1.19495& -4	0.00835	4.74252& -3
182	10.0	0.00734	1.03912& -4	0.00830	3.22613& -3
200	11.0	0.00732	9.85918& -5	0.00763	3.05104& -3
219	12.0	0.00731	9.67488& -5	0.00644	2.56855& -3
237	13.0	0.00724	8.67606& -5	0.00650	2.94517& -3
255	14.0	0.00724	8.46968& -5	0.00842	4.49904& -3
273	15.0	0.00724	8.03889& -5	0.00744	2.40808& -3
292	16.0	0.00724	7.86252& -5	0.00746	2.08134& -3
310	17.0	0.00724	7.99185& -5	0.00637	2.93446& -3
328	18.0	0.00720	7.35509& -5	0.00673	1.46034& -3
346	19.0	0.00683	1.43519& -3	0.00780	2.48569& -3
365	20.0	0.00720	6.47789& -5	0.00677	3.01326& -3
383	21.0	0.00720	6.37240& -5	0.00825	2.56903& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00788	4.52841& -4	0.01228	9.73088& -3
197	2.0	0.00768	2.23837& -4	0.00718	4.55252& -3
295	3.0	0.00739	1.58827& -4	0.00935	4.77750& -3
394	4.0	0.00743	1.18188& -4	0.00910	3.90363& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00755	2.84719& -4	0.00833	5.27547& -3

Data Analysis Program

Run Number = 104

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01678	1.08802& -1	-0.19254	7.47352& -1
36	2.0	0.01973	1.06623& -2	0.10411	2.98615& -1
54	3.0	0.01354	6.41205& -3	0.03000	1.41179& -1
73	4.0	0.01220	4.67282& -3	0.00030	4.74179& -2
91	5.0	0.01164	3.03660& -3	0.01321	4.65548& -2
109	6.0	0.00980	5.25808& -3	0.01686	4.52864& -2
127	7.0	0.01089	1.79600& -3	0.01430	1.88047& -2
146	8.0	0.01050	1.48586& -3	0.02694	3.27081& -2
164	9.0	0.01043	1.26813& -3	0.01121	1.77754& -2
182	10.0	0.01153	4.77144& -3	0.01748	1.76994& -2
200	11.0	0.01030	9.68589& -4	0.01268	1.28108& -2
219	12.0	0.01028	8.70868& -4	0.02046	1.60655& -2
237	13.0	0.01018	7.92679& -4	0.01055	1.35379& -2
255	14.0	0.01016	7.23608& -4	0.01028	1.06773& -2
273	15.0	0.01016	6.70835& -4	0.01143	9.66625& -3
292	16.0	0.01017	6.23646& -4	0.01308	1.07931& -2
310	17.0	0.01015	5.81932& -4	0.01450	9.70304& -3
328	18.0	0.00960	1.98127& -3	0.01111	1.03183& -2
346	19.0	0.01011	5.22114& -4	0.01302	1.16633& -2
365	20.0	0.01012	4.95944& -4	0.01424	9.06500& -3
383	21.0	0.01011	4.74518& -4	0.01114	5.90144& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01212	7.29837& -3	-0.00640	7.58248& -2
197	2.0	0.01146	2.66456& -3	0.01273	3.43205& -2
295	3.0	0.01044	1.66610& -3	0.01143	2.27648& -2
394	4.0	0.01054	1.28207& -3	0.01135	1.63220& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01064	3.43151& -3	0.00837	4.07604& -2

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.00827	3.84267& -3	0.01138	7.98593& -2
36	2.0	0.00817	1.37447& -3	0.02737	4.38892& -2
54	3.0	0.00748	1.09026& -3	0.01681	2.37415& -2
73	4.0	0.00740	9.76501& -4	0.00771	1.01671& -2
91	5.0	0.00738	7.69264& -4	0.00861	1.07753& -2
109	6.0	0.00694	1.56555& -3	0.01105	1.53156& -2
127	7.0	0.00732	5.77084& -4	0.00895	5.04496& -3
146	8.0	0.00718	5.15470& -4	0.01280	9.11397& -3
164	9.0	0.00719	4.71458& -4	0.00813	6.71750& -3
182	10.0	0.00726	5.24987& -4	0.01032	6.86770& -3
200	11.0	0.00718	4.01777& -4	0.00841	5.69286& -3
219	12.0	0.00718	3.76986& -4	0.01121	6.51955& -3
237	13.0	0.00713	3.54921& -4	0.00823	6.66461& -3
255	14.0	0.00713	3.35018& -4	0.00738	4.21693& -3
273	15.0	0.00713	3.19565& -4	0.00760	4.27154& -3
292	16.0	0.00714	3.05234& -4	0.00898	5.07604& -3
310	17.0	0.00714	2.91523& -4	0.00923	4.51676& -3
328	18.0	0.00687	9.09553& -4	0.00773	4.91261& -3
346	19.0	0.00711	2.71773& -4	0.00901	5.69919& -3
365	20.0	0.00712	2.62407& -4	0.00856	4.01747& -3
383	21.0	0.00712	2.54827& -4	0.00818	3.29407& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00743	1.21292& -3	0.00674	1.21531& -2
197	2.0	0.00743	7.34434& -4	0.00899	8.53873& -3
295	3.0	0.00720	5.73098& -4	0.00855	8.03886& -3
394	4.0	0.00727	5.05610& -4	0.00803	5.63376& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00724	8.75393& -4	0.00781	1.04251& -2

Data Analysis Program

Run Number = 105

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.05714	1.39629& -2	0.10983	2.08343& -1
36	2.0	0.02096	8.16174& -3	0.06555	1.80334& -1
54	3.0	0.01564	2.31902& -3	0.01351	2.20109& -2
73	4.0	0.01726	1.42208& -2	0.01143	1.85266& -2
91	5.0	0.01255	8.17655& -4	0.01178	8.91335& -3
109	6.0	0.01187	5.65255& -4	0.01341	8.76163& -3
127	7.0	0.01141	4.52376& -4	0.01214	7.18533& -3
146	8.0	0.01091	4.20179& -4	0.01043	7.85652& -3
164	9.0	0.01079	3.68561& -4	0.01193	5.47792& -3
182	10.0	0.01063	2.96072& -4	0.01259	6.75371& -3
200	11.0	0.01058	2.73346& -4	0.01016	4.45720& -3
219	12.0	0.01051	2.47030& -4	0.01024	5.20374& -3
237	13.0	0.01041	2.29332& -4	0.01116	4.32368& -3
255	14.0	0.01037	2.03805& -4	0.01060	4.37518& -3
273	15.0	0.01036	2.10996& -4	0.01102	6.66208& -3
292	16.0	0.01034	1.63155& -4	0.00981	2.66958& -3
310	17.0	0.01032	1.69718& -4	0.01101	3.72706& -3
328	18.0	0.01026	1.56014& -4	0.01135	2.88199& -3
346	19.0	0.01026	1.42391& -4	0.00912	2.73356& -3
365	20.0	0.01025	1.31959& -4	0.00968	3.04801& -3
383	21.0	0.01026	1.37841& -4	0.00969	3.40122& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01437	2.59234& -3	0.01360	2.57561& -2
197	2.0	0.01197	1.32820& -3	0.01321	1.33564& -2
295	3.0	0.01215	4.90083& -3	0.01033	6.35640& -3
394	4.0	0.01093	3.75864& -4	0.00965	5.15895& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01167	1.13590& -3	0.01190	1.28568& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00577	6.27594& -4	0.00813	6.91110& -3
36	2.0	0.00481	5.58225& -4	0.00746	9.48501& -3
54	3.0	0.00450	2.43297& -4	0.00435	1.85056& -3
73	4.0	0.00450	3.70065& -4	0.00408	2.08149& -3
91	5.0	0.00437	1.28433& -4	0.00435	1.20327& -3
109	6.0	0.00434	9.92481& -5	0.00462	1.50639& -3
127	7.0	0.00430	8.87852& -5	0.00451	1.22485& -3
146	8.0	0.00421	8.64699& -5	0.00411	1.50578& -3
164	9.0	0.00420	8.02502& -5	0.00445	1.11607& -3
182	10.0	0.00419	7.12712& -5	0.00469	1.40941& -3
200	11.0	0.00419	6.86669& -5	0.00413	1.02342& -3
219	12.0	0.00418	6.34405& -5	0.00411	1.08732& -3
237	13.0	0.00415	6.11840& -5	0.00444	1.05226& -3
255	14.0	0.00415	5.57350& -5	0.00424	1.07462& -3
273	15.0	0.00415	5.82781& -5	0.00416	1.12991& -3
292	16.0	0.00415	4.69415& -5	0.00408	7.73231& -4
310	17.0	0.00415	4.95774& -5	0.00433	9.06825& -4
328	18.0	0.00412	4.62421& -5	0.00432	7.31092& -4
346	19.0	0.00413	4.30079& -5	0.00384	8.19646& -4
365	20.0	0.00413	4.09772& -5	0.00401	8.83921& -4
383	21.0	0.00413	4.26238& -5	0.00400	1.03113& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00448	2.61829& -4	0.00456	2.20719& -3
197	2.0	0.00435	1.99313& -4	0.00470	2.16320& -3
295	3.0	0.00431	3.66934& -4	0.00416	1.17003& -3
394	4.0	0.00426	8.75545& -5	0.00398	1.05852& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00430	1.71863& -4	0.00445	1.72983& -3

Data Analysis Program

Run Number = 106

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.05576	1.50160& -2	-0.02027	2.74393& -1
36	2.0	0.01939	1.38998& -2	0.03516	7.17209& -2
54	3.0	0.01541	2.02840& -3	-0.01422	8.14872& -2
73	4.0	0.01346	1.17873& -3	-0.00131	7.15499& -2
91	5.0	0.01101	5.78255& -3	0.02010	1.00785& -2
109	6.0	0.01178	5.71669& -4	0.01426	8.85353& -3
127	7.0	0.01145	4.45306& -4	0.01577	9.23902& -3
146	8.0	0.00989	4.01368& -3	0.01444	6.39833& -3
164	9.0	0.01019	2.30674& -3	0.01144	5.73468& -3
182	10.0	0.01066	2.75737& -4	0.01074	7.26032& -3
200	11.0	0.01061	2.83249& -4	0.01382	7.44943& -3
219	12.0	0.01000	2.11064& -3	0.01303	3.64612& -3
237	13.0	0.01045	2.20484& -4	0.01110	2.84380& -3
255	14.0	0.01021	5.85695& -4	0.01056	4.48301& -3
273	15.0	0.01039	1.79925& -4	0.01213	2.35441& -3
292	16.0	0.01038	1.76305& -4	0.01066	2.37384& -3
310	17.0	0.01034	1.53888& -4	0.01085	3.20453& -3
328	18.0	0.01029	1.36487& -4	0.01159	3.13098& -3
346	19.0	0.01028	1.35628& -4	0.00966	5.11463& -3
365	20.0	0.00953	2.93543& -3	0.01149	2.64341& -3
383	21.0	0.01027	1.28288& -4	0.01176	2.19889& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01425	2.59778& -3	0.02500	2.89438& -2
197	2.0	0.01225	8.92397& -4	0.01411	1.31331& -2
295	3.0	0.01096	4.97164& -4	0.01019	5.07929& -3
394	4.0	0.01263	4.67118& -3	0.01025	5.21356& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01218	2.49273& -3	0.01688	1.03873& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00572	6.64419& -4	0.00520	8.17501& -3
36	2.0	0.00468	1.01859& -3	0.00663	5.03906& -3
54	3.0	0.00448	2.15984& -4	0.00279	4.23509& -3
73	4.0	0.00441	1.56124& -4	0.00394	4.59410& -3
91	5.0	0.00414	8.65211& -4	0.00528	1.65592& -3
109	6.0	0.00433	1.01350& -4	0.00486	1.52331& -3
127	7.0	0.00431	8.72501& -5	0.00506	1.74396& -3
146	8.0	0.00400	8.35263& -4	0.00490	1.11072& -3
164	9.0	0.00409	4.32124& -4	0.00430	1.05531& -3
182	10.0	0.00420	6.45080& -5	0.00427	1.62825& -3
200	11.0	0.00420	6.82217& -5	0.00485	1.51885& -3
219	12.0	0.00407	4.63924& -4	0.00478	9.39524& -4
237	13.0	0.00416	5.70125& -5	0.00425	7.20420& -4
255	14.0	0.00407	2.97826& -4	0.00430	1.13165& -3
273	15.0	0.00416	5.00249& -5	0.00465	5.86686& -4
292	16.0	0.00416	4.96792& -5	0.00438	7.60613& -4
310	17.0	0.00415	4.49897& -5	0.00416	7.70910& -4
328	18.0	0.00413	4.02961& -5	0.00445	8.65665& -4
346	19.0	0.00413	4.13416& -5	0.00413	1.10400& -3
365	20.0	0.00397	6.52431& -4	0.00449	7.84662& -4
383	21.0	0.00413	4.02771& -5	0.00465	6.94877& -4

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00447	2.59368& -4	0.00542	2.16736& -3
197	2.0	0.00439	1.43442& -4	0.00476	2.02185& -3
295	3.0	0.00424	1.01171& -4	0.00420	9.19111& -4
394	4.0	0.00435	3.55685& -4	0.00411	1.07100& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00433	2.08814& -4	0.00484	1.24247& -3

Data Analysis Program

Run Number = 107

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel - 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06293	1.39679& -2	-1.20919	2.87477& 0
36	2.0	0.02417	3.50243& -3	-0.16976	5.18205& -1
54	3.0	0.01611	1.76402& -3	0.06510	1.19296& -1
73	4.0	0.01414	1.06980& -3	0.02334	5.10245& -2
91	5.0	0.01291	7.23577& -4	0.06009	1.27806& -1
109	6.0	0.01206	6.27201& -4	0.01253	3.16097& -2
127	7.0	0.01162	4.43460& -4	0.03275	3.41309& -2
146	8.0	0.01113	3.57192& -4	0.03196	4.58274& -2
164	9.0	0.01097	3.04519& -4	0.01910	4.71987& -2
182	10.0	0.01081	2.73082& -4	0.01266	1.11109& -2
200	11.0	0.01071	2.20180& -4	0.01581	2.62785& -2
219	12.0	0.01067	2.17058& -4	0.01587	1.63040& -2
237	13.0	0.01053	1.90701& -4	0.02158	1.96971& -2
255	14.0	0.01048	1.81440& -4	0.02052	2.56912& -2
273	15.0	0.01046	1.59733& -4	0.01951	2.37292& -2
292	16.0	0.01044	1.48564& -4	0.01337	1.07512& -2
310	17.0	0.01042	1.39459& -4	0.01049	7.99305& -3
328	18.0	0.01037	1.31085& -4	0.01407	1.14500& -2
346	19.0	0.01035	1.29065& -4	0.01327	6.06974& -3
365	20.0	0.01036	1.13774& -4	0.01312	1.08119& -2
383	21.0	0.01035	1.16651& -4	0.01318	1.31990& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01547	2.36148& -3	0.04279	1.77142& -1
197	2.0	0.01401	3.66742& -3	0.01950	4.17842& -2
295	3.0	0.01113	4.36929& -4	0.02040	2.00079& -2
394	4.0	0.01028	2.30378& -3	0.01310	1.19393& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01218	1.01072& -3	0.03153	5.50792& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00609	6.52598& -4	-0.03635	1.40981& -1
36	2.0	0.00509	2.85754& -4	-0.00465	3.95190& -2
54	3.0	0.00460	1.90011& -4	0.01139	1.22462& -2
73	4.0	0.00453	1.41746& -4	0.00680	7.08415& -3
91	5.0	0.00447	1.13424& -4	0.01199	2.10529& -2
109	6.0	0.00442	1.07780& -4	0.00780	6.64652& -3
127	7.0	0.00438	8.48709& -5	0.00921	6.98489& -3
146	8.0	0.00429	7.43537& -5	0.00862	8.71360& -3
164	9.0	0.00428	6.70146& -5	0.00674	8.30141& -3
182	10.0	0.00427	6.47210& -5	0.00496	2.57561& -3
200	11.0	0.00426	5.35606& -5	0.00524	4.93033& -3
219	12.0	0.00426	5.49311& -5	0.00539	3.43160& -3
237	13.0	0.00422	4.99413& -5	0.00717	5.16250& -3
255	14.0	0.00422	4.90954& -5	0.00663	5.04221& -3
273	15.0	0.00422	4.40502& -5	0.00591	4.57806& -3
292	16.0	0.00421	4.20633& -5	0.00504	2.77394& -3
310	17.0	0.00421	4.04630& -5	0.00449	2.48796& -3
328	18.0	0.00419	3.91524& -5	0.00514	3.18842& -3
346	19.0	0.00419	3.89658& -5	0.00541	1.78350& -3
365	20.0	0.00419	3.50244& -5	0.00503	2.92170& -3
383	21.0	0.00419	3.69770& -5	0.00504	3.31203& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00464	2.40614& -4	0.01145	2.18376& -2
197	2.0	0.00446	1.68099& -4	0.00659	7.80448& -3
295	3.0	0.00431	8.85911& -5	0.00628	3.76837& -3
394	4.0	0.00407	7.23078& -4	0.00526	2.67954& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00443	1.52684& -4	0.00774	8.84003& -3

Data Analysis Program

Run Number = 108

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.04655	3.13577& -2	-0.61278	8.04127& -1
36	2.0	0.03247	3.96959& -2	-0.07952	5.57620& -1
54	3.0	0.01501	1.41206& -3	-0.02551	1.57080& -1
73	4.0	0.01335	9.62640& -4	0.01259	5.81792& -2
91	5.0	0.01097	5.91364& -3	0.03018	9.30670& -2
109	6.0	0.01782	1.60258& -2	0.01760	3.09710& -2
127	7.0	0.01134	3.55343& -4	0.03460	5.28317& -2
146	8.0	0.00986	4.17271& -3	0.04829	1.24002& -1
164	9.0	0.01076	2.63014& -4	0.01752	5.63977& -2
182	10.0	0.01068	2.25665& -4	0.00987	5.54026& -2
200	11.0	0.00972	3.29032& -3	0.02741	3.74720& -2
219	12.0	0.01054	1.72355& -4	0.01788	3.35968& -2
237	13.0	0.01042	1.48923& -4	0.01681	2.63461& -2
255	14.0	0.01038	1.47787& -4	0.01111	2.52484& -2
273	15.0	0.01036	1.31122& -4	0.01119	3.22739& -2
292	16.0	0.01037	1.08737& -4	0.01296	3.62698& -2
310	17.0	0.01033	1.18683& -4	0.00811	1.55014& -2
328	18.0	0.01030	1.24308& -4	0.01964	2.90999& -2
346	19.0	0.00904	3.30123& -3	0.01376	1.71558& -2
365	20.0	0.00967	2.32474& -3	0.02877	4.63704& -2
383	21.0	0.01029	9.52256& -5	0.01293	1.98201& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01390	1.91280& -3	-0.10309	1.83430& -1
197	2.0	0.01210	6.37540& -4	0.04043	8.27910& -2
295	3.0	0.01089	3.33026& -4	0.01510	4.27482& -2
394	4.0	0.01161	2.67339& -3	0.03187	5.27226& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01151	8.07780& -4	0.03116	1.01802& -1

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.00541	1.24495& -3	-0.03239	1.09416& -1
36	2.0	0.00508	6.22512& -4	0.00637	8.36952& -2
54	3.0	0.00448	1.51056& -4	0.00639	1.85920& -2
73	4.0	0.00443	1.27120& -4	0.00620	8.93097& -3
91	5.0	0.00417	8.81436& -4	0.01042	1.44776& -2
109	6.0	0.00449	4.08584& -4	0.00691	5.64720& -3
127	7.0	0.00432	6.90016& -5	0.01042	1.12397& -2
146	8.0	0.00403	8.59159& -4	0.01513	2.59494& -2
164	9.0	0.00423	5.75826& -5	0.00613	9.22350& -3
182	10.0	0.00424	5.11597& -5	0.00555	1.32863& -2
200	11.0	0.00400	8.44809& -4	0.00914	1.00088& -2
219	12.0	0.00422	4.33082& -5	0.00635	7.50028& -3
237	13.0	0.00419	3.92371& -5	0.00607	5.53687& -3
255	14.0	0.00418	3.93569& -5	0.00422	5.71362& -3
273	15.0	0.00419	3.62341& -5	0.00532	7.37240& -3
292	16.0	0.00419	3.08571& -5	0.00521	8.84256& -3
310	17.0	0.00418	3.52720& -5	0.00426	4.37944& -3
328	18.0	0.00417	3.66623& -5	0.00786	8.83802& -3
340	19.0	0.00374	1.14201& -3	0.00598	5.74799& -3
365	20.0	0.00395	8.32536& -4	0.00780	1.01415& -2
383	21.0	0.00417	2.94705& -5	0.00572	6.86252& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00448	1.92609& -4	0.00086	1.46118& -2
197	2.0	0.00441	1.03397& -4	0.01363	1.47227& -2
295	3.0	0.00426	6.68672& -5	0.00545	7.50794& -3
394	4.0	0.00430	5.72974& -5	0.00865	8.69722& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00432	1.22581& -4	0.00889	1.29773& -2

Data Analysis Program

Run Number = 109

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.04742	4.65498& -2	-0.01930	9.19048& -1
36	2.0	0.01799	1.49764& -2	0.48175	1.27792& 0
54	3.0	0.01246	8.80040& -3	-0.08030	2.47474& -1
73	4.0	0.01199	5.49845& -3	0.06454	1.23347& -1
91	5.0	0.01136	3.42132& -3	-0.01685	1.25829& -1
109	6.0	0.01105	2.56680& -3	0.02917	5.05238& -2
127	7.0	0.01070	2.00262& -3	0.03735	5.40378& -2
146	8.0	0.01046	1.62376& -3	0.01512	3.76040& -2
164	9.0	0.01033	1.42247& -3	0.01670	1.92935& -2
182	10.0	0.01023	1.23040& -3	0.04302	5.17115& -2
200	11.0	0.01024	1.12217& -3	0.02739	3.22823& -2
219	12.0	0.01024	9.67185& -4	0.02027	2.29261& -2
237	13.0	0.01011	8.48591& -4	0.01386	1.61176& -2
255	14.0	0.01010	8.27433& -4	0.01300	1.97448& -2
273	15.0	0.01011	7.38471& -4	0.00876	1.28201& -2
292	16.0	0.00943	2.70485& -3	0.02408	3.23921& -2
310	17.0	0.01009	5.99658& -4	0.01619	1.74292& -2
328	18.0	0.01004	6.13410& -4	0.00966	1.18638& -2
346	19.0	0.01009	5.86609& -4	0.01164	1.22064& -2
365	20.0	0.00956	1.96258& -3	0.01284	1.12299& -2
383	21.0	0.01008	5.38730& -4	0.01345	1.04490& -2

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.01172	9.26332& -3	-0.04376	1.52845& -1
197	2.0	0.01117	3.41701& -3	0.02896	5.46827& -2
295	3.0	0.01022	2.12916& -3	0.01685	2.48530& -2
394	4.0	0.01049	1.50445& -3	0.01464	1.40538& -2

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.01043	4.12629& -3	0.05271	1.36475& -1

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00138	4.50246& -4	0.00220	1.72514& -2
36	2.0	0.00117	2.68779& -4	0.02022	4.30133& -2
54	3.0	0.00107	2.10665& -4	-0.00038	5.60618& -3
73	4.0	0.00107	1.68288& -4	0.00360	6.04732& -3
91	5.0	0.00107	1.27042& -4	0.00084	2.77996& -3
109	6.0	0.00107	1.08325& -4	0.00199	2.12009& -3
127	7.0	0.00106	9.45940& -5	0.00272	2.83005& -3
146	8.0	0.00105	8.26644& -5	0.00173	2.47206& -3
164	9.0	0.00104	7.79559& -5	0.00145	1.00394& -3
182	10.0	0.00104	7.04476& -5	0.00275	2.21307& -3
200	11.0	0.00104	6.80638& -5	0.00196	1.58641& -3
219	12.0	0.00105	6.18135& -5	0.00169	1.38140& -3
237	13.0	0.00104	5.60551& -5	0.00135	1.02659& -3
255	14.0	0.00104	5.62285& -5	0.00131	1.26042& -3
273	15.0	0.00104	5.14165& -5	0.00102	8.95944& -4
292	16.0	0.00098	2.14037& -4	0.00208	2.12731& -3
310	17.0	0.00104	4.44282& -5	0.00140	9.14498& -4
328	18.0	0.00103	4.59418& -5	0.00108	9.07898& -4
346	19.0	0.00104	4.50471& -5	0.00117	8.60313& -4
365	20.0	0.00100	1.37056& -4	0.00129	8.65709& -4
383	21.0	0.00104	4.22551& -5	0.00134	7.79739& -4

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00108	2.20664& -4	0.00026	2.85321& -3
197	2.0	0.00107	1.34356& -4	0.00224	2.45868& -3
295	3.0	0.00104	1.04909& -4	0.00142	1.21405& -3
394	4.0	0.00106	8.62360& -5	0.00151	8.96770& -4

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00105	1.52290& -4	0.00276	5.29584& -3

Data Analysis Program

Run Number 110

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.04997	3.50044& -2	-0.23682	8.80551& -1
36	2.0	0.02115	1.22492& -2	0.56651	1.87343& 0
54	3.0	0.01349	6.87684& -3	0.01255	2.43694& -1
73	4.0	0.01249	5.02682& -3	-0.05283	5.22252& -1
91	5.0	0.01177	3.07704& -3	-0.10886	2.03788& -1
109	6.0	0.01124	2.30102& -3	-0.01413	5.84947& -2
127	7.0	0.01087	1.83991& -3	0.00163	1.06141& -1
146	8.0	0.01065	1.59442& -3	0.00406	1.52228& -1
164	9.0	0.01145	6.60408& -3	-0.04163	1.49371& -1
182	10.0	0.01034	1.13471& -3	-0.03923	7.24787& -2
200	11.0	0.01036	1.02856& -3	0.23029	9.96498& -1
219	12.0	0.01040	9.05717& -4	0.02724	6.50005& -2
237	13.0	0.01024	8.19604& -4	-0.00223	3.10086& -2
255	14.0	0.00974	2.12330& -3	0.01744	1.84877& -1
273	15.0	0.00995	1.19365& -3	0.00096	2.74674& -2
292	16.0	0.01019	6.43713& -4	0.02372	1.93447& -1
310	17.0	0.01016	5.92684& -4	0.00615	3.62205& -2
328	18.0	0.01012	5.69892& -4	0.00361	6.23459& -2
346	19.0	0.01020	5.59086& -4	0.00113	3.49980& -2
365	20.0	0.01016	4.91934& -4	-0.03403	1.00639& -1
383	21.0	0.01017	5.10192& -4	-0.00860	4.51645& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01152	8.63994& -3	-0.03772	4.47182& -1
197	2.0	0.01168	2.97315& -3	-0.00891	9.78434& -2
295	3.0	0.01164	5.17491& -3	0.00299	8.13486& -2
394	4.0	0.01062	1.37242& -3	-0.01042	1.13889& -1

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01086	3.55487& -3	-0.08151	1.87165& -1

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00139	3.43721& -4	-0.01604	4.20999& -2
36	2.0	0.00122	2.20741& -4	0.04873	1.29263& -1
54	3.0	0.00109	1.66589& -4	0.00748	1.69335& -2
73	4.0	0.00109	1.50480& -4	-0.00683	4.50854& -2
91	5.0	0.00108	1.12465& -4	-0.00437	1.44341& -2
109	6.0	0.00107	9.68587& -5	0.00187	4.63218& -3
127	7.0	0.00106	8.47424& -5	0.00161	7.55329& -3
146	8.0	0.00105	7.99227& -5	0.00193	1.12348& -2
164	9.0	0.00104	1.42910& -4	-0.00164	1.27430& -2
182	10.0	0.00104	6.46168& -5	-0.00141	7.85895& -3
200	11.0	0.0105	6.21269& -5	0.02713	1.08372& -1
219	12.0	0.00105	5.65913& -5	0.00452	6.63694& -3
237	13.0	0.00104	5.29785& -5	0.00101	2.04475& -3
255	14.0	0.00101	1.28457& -4	0.00227	1.66039& -2
273	15.0	0.00102	9.91486& -5	0.00112	2.01508& -3
292	16.0	0.00104	4.52830& -5	0.00144	1.02883& -2
310	17.0	0.00104	4.29118& -5	0.00172	3.51541& -3
328	18.0	0.00103	4.21409& -5	0.00101	5.91627& -3
346	19.0	0.00104	4.19876& -5	0.00140	3.30353& -3
365	20.0	0.00104	3.80325& -5	-0.00044	7.46964& -3
383	21.0	0.00104	3.93772& -5	0.00004	3.57758& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00106	2.20366& -4	0.00491	2.71568& -2
197	2.0	0.00109	1.16853& -4	0.00221	5.85339& -3
295	3.0	0.00107	1.26232& -4	0.00162	3.98104& -3
394	4.0	0.00106	7.72182& -5	0.00100	6.05735& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00106	1.30936& -4	-0.00098	1.04952& -2

Data Analysis Program

Run Number = 111

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06696	1.66389& -2	-0.15572	4.94959& -1
36	2.0	0.02615	3.79102& -3	-0.16092	3.01648& -1
54	3.0	0.01704	2.28126& -3	-0.07005	1.02448& -1
73	4.0	0.01445	1.28004& -3	-0.03456	2.00111& -1
91	5.0	0.01303	8.69966& -4	-0.06707	1.50380& -1
109	6.0	0.01522	1.17255& -2	-0.08455	1.09754& -1
127	7.0	0.01185	6.69359& -4	0.02639	1.21888& -1
146	8.0	0.01131	3.72038& -4	0.00173	1.10981& -1
164	9.0	0.01105	3.88069& -4	-0.04395	7.93050& -2
182	10.0	0.01089	4.45950& -4	-0.01831	6.98481& -2
200	11.0	0.01079	3.52660& -4	-0.02671	4.14065& -2
219	12.0	0.01074	2.64618& -4	-0.02947	8.88119& -2
237	13.0	0.01059	2.46424& -4	-0.01105	3.96063& -2
255	14.0	0.01056	2.35398& -4	-0.00919	4.80255& -2
273	15.0	0.01047	2.19054& -4	-0.01766	2.38107& -2
292	16.0	0.01045	1.93630& -4	0.00016	4.70552& -2
310	17.0	0.01047	1.93997& -4	-0.02093	2.56028& -2
328	18.0	0.01043	1.93795& -4	-0.01776	1.20555& -1
346	19.0	0.00979	2.46763& -3	-0.00308	4.87592& -2
365	20.0	0.00936	4.08042& -3	0.01164	5.91716& -2
383	21.0	0.01039	1.64778& -4	-0.00492	2.96210& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01617	2.89784& -3	-0.16707	1.88712& -1
197	2.0	0.01295	9.91548& -4	0.10895	5.40580& -1
295	3.0	0.01125	5.40801& -4	0.06339	3.42072& -1
394	4.0	0.01119	3.54094& -4	-0.01475	7.84917& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01246	1.23302& -3	-0.07541	1.34744& -1

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.00159	1.96578& -4	-0.00274	4.71495& -2
36	2.0	0.00132	8.00610& -5	0.01287	2.67332& -2
54	3.0	0.00118	6.24005& -5	-0.00085	9.00236& -3
73	4.0	0.00115	4.36150& -5	0.00637	3.39283& -2
91	5.0	0.00113	3.49480& -5	-0.00429	1.77182& -2
109	6.0	0.00115	1.06813& -4	-0.00204	7.50961& -3
127	7.0	0.00111	3.19992& -5	0.00618	1.64501& -2
146	8.0	0.00109	2.02595& -5	0.00073	1.09620& -2
164	9.0	0.00108	2.20087& -5	0.00105	8.47395& -3
182	10.0	0.00108	2.57139& -5	0.00172	5.56225& -3
200	11.0	0.00108	2.28539& -5	-0.00053	4.53065& -3
219	12.0	0.00108	1.85947& -5	-0.00173	1.19375& -2
237	13.0	0.00107	1.72488& -5	0.00134	4.20035& -3
255	14.0	0.00107	1.64839& -5	0.00054	3.75874& -3
273	15.0	0.00106	1.56712& -5	-0.00046	2.31789& -3
292	16.0	0.00106	1.44782& -5	0.00232	7.09344& -3
310	17.0	0.00106	1.49319& -5	-0.00031	3.53332& -3
328	18.0	0.00106	1.50656& -5	-0.00198	1.98412& -2
346	19.0	0.00101	2.14550& -4	0.00037	6.34806& -3
365	20.0	0.00101	2.09508& -4	0.00328	8.03369& -3
383	21.0	0.00106	1.31399& -5	0.00044	2.75115& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00119	7.54686& -5	-0.00228	1.18969& -2
197	2.0	0.00115	4.14126& -5	0.01409	4.56217& -2
295	3.0	0.00109	2.85243& -5	0.01087	3.88386& -2
394	4.0	0.00110	2.21195& -5	0.00162	6.15451& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00112	4.81137& -5	-0.00031	7.19562& -3

Data Analysis Program

Run Number = 113

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.05982	1.20815& -2	0.13707	4.63719& -2
36	2.0	0.03107	3.49645& -3	0.03954	2.03834& -2
54	3.0	0.02437	1.85453& -3	0.02966	9.96292& -3
73	4.0	0.02294	1.19848& -3	0.02336	8.30666& -3
91	5.0	0.02216	8.90787& -4	0.02049	4.39067& -3
109	6.0	0.02166	7.03059& -4	0.02325	4.72324& -3
127	7.0	0.02141	5.83657& -4	0.02350	3.94618& -3
146	8.0	0.02104	5.03748& -4	0.02211	3.51911& -3
164	9.0	0.02098	4.42481& -4	0.02154	3.43154& -3
182	10.0	0.02088	4.01287& -4	0.02249	4.22801& -3
200	11.0	0.02083	3.57523& -4	0.02103	3.45180& -3
219	12.0	0.02078	3.28049& -4	0.02023	2.94403& -3
237	13.0	0.02067	3.08614& -4	0.02067	3.74351& -3
255	14.0	0.01964	3.83499& -3	0.02059	3.65296& -3
273	15.0	0.02061	2.74026& -4	0.01881	3.05214& -3
292	16.0	0.02058	2.61659& -4	0.02010	2.59165& -3
310	17.0	0.02055	2.46541& -4	0.02065	3.07881& -3
328	18.0	0.02051	2.36724& -4	0.02018	2.51278& -3
346	19.0	0.02051	2.25182& -4	0.01998	2.63458& -3
365	20.0	0.02051	2.21664& -4	0.02080	2.50910& -3
383	21.0	0.02052	2.08147& -4	0.02030	1.95630& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02389	2.56669& -3	0.02958	7.35032& -3
197	2.0	0.02273	9.85701& -4	0.02464	5.62922& -3
295	3.0	0.02119	6.11949& -4	0.02134	3.25467& -3
394	4.0	0.02136	4.49425& -4	0.02109	2.07199& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02172	1.28590& -3	0.02283	5.02807& -3

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01878	1.73468& -3	0.02832	7.35218& -3
36	2.0	0.01654	8.38353& -4	0.01808	4.56455& -3
54	3.0	0.01520	5.65756& -4	0.01639	2.45857& -3
73	4.0	0.01504	4.34262& -4	0.01550	3.03951& -3
91	5.0	0.01492	3.62938& -4	0.01431	1.44186& -3
109	6.0	0.01484	3.11861& -4	0.01552	1.59811& -3
127	7.0	0.01478	2.75015& -4	0.01551	1.90895& -3
146	8.0	0.01457	2.49258& -4	0.01500	1.40414& -3
164	9.0	0.01457	2.28928& -4	0.01469	1.73296& -3
182	10.0	0.01455	2.15182& -4	0.01532	1.78082& -3
200	11.0	0.01455	1.95247& -4	0.01474	1.81605& -3
219	12.0	0.01453	1.85805& -4	0.01422	1.51036& -3
237	13.0	0.01445	1.78609& -4	0.01448	1.95480& -3
255	14.0	0.01371	2.83689& -3	0.01410	1.98553& -3
273	15.0	0.01444	1.63453& -4	0.01346	1.72498& -3
292	16.0	0.01443	1.57381& -4	0.01423	1.49187& -3
310	17.0	0.01443	1.50843& -4	0.01442	1.76040& -3
328	18.0	0.01439	1.46161& -4	0.01440	1.51742& -3
346	19.0	0.01439	1.40656& -4	0.01411	1.39338& -3
365	20.0	0.01440	1.39999& -4	0.01451	1.50131& -3
383	21.0	0.01441	1.31710& -4	0.01432	1.26703& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01520	7.25583& -4	0.01651	2.07147& -3
197	2.0	0.01517	4.04336& -4	0.01596	2.15335& -3
295	3.0	0.01464	2.93920& -4	0.01459	1.28187& -3
394	4.0	0.01479	2.37899& -4	0.01470	1.19338& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01476	4.88784& -4	0.01510	2.23547& -3

Data Analysis Program

Run Number = 114

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06944	1.75092& -2	0.28622	3.03889& -1
36	2.0	0.03394	5.17765& -3	0.06473	7.50687& -2
54	3.0	0.02591	2.71494& -3	0.05030	4.13079& -2
73	4.0	0.02397	1.75628& -3	0.03544	2.87447& -2
91	5.0	0.02297	1.31801& -3	0.02571	1.60885& -2
109	6.0	0.02228	1.03035& -3	0.02498	1.46850& -2
127	7.0	0.01973	5.88734& -3	0.03174	1.99064& -2
146	8.0	0.02152	7.41202& -4	0.02405	1.07445& -2
164	9.0	0.02030	4.14035& -3	0.02241	1.20307& -2
182	10.0	0.02127	5.77332& -4	0.02012	1.09289& -2
200	11.0	0.02118	5.35701& -4	0.03022	8.66099& -3
219	12.0	0.02111	4.91702& -4	0.02554	6.88790& -3
237	13.0	0.02099	4.57626& -4	0.02310	8.98019& -3
255	14.0	0.02094	4.37803& -4	0.02453	7.42810& -3
273	15.0	0.02090	4.01791& -4	0.02223	5.49315& -3
292	16.0	0.02086	3.81496& -4	0.02459	7.69086& -3
310	17.0	0.02083	3.62362& -4	0.02176	7.07190& -3
328	18.0	0.02079	3.54621& -4	0.02192	7.39317& -3
346	19.0	0.02077	3.38539& -4	0.02396	5.38914& -3
365	20.0	0.02077	3.21161& -4	0.02556	7.02591& -3
383	21.0	0.02077	3.19159& -4	0.02279	8.97656& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02763	7.42474& -3	0.05678	3.79178& -2
197	2.0	0.02273	3.49386& -3	0.03248	1.24958& -2
295	3.0	0.02176	8.96878& -4	0.02831	1.06153& -2
394	4.0	0.02180	6.61436& -4	0.02683	9.63209& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02284	1.88328& -3	0.03206	1.53226& -2

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.02027	2.56581& -3	0.05471	5.36166& -2
36	2.0	0.01729	1.25235& -3	0.02824	2.12645& -2
54	3.0	0.01572	8.33893& -4	0.02362	1.21391& -2
73	4.0	0.01545	6.40610& -4	0.02032	1.01254& -2
91	5.0	0.01528	5.38654& -4	0.01526	5.37893& -3
109	6.0	0.01514	4.58782& -4	0.01668	6.43661& -3
127	7.0	0.01415	2.44590& -3	0.01937	8.66370& -3
146	8.0	0.01483	3.67345& -4	0.01658	4.98167& -3
164	9.0	0.01431	1.90144& -3	0.01514	5.72416& -3
182	10.0	0.01478	3.09470& -4	0.01417	5.71928& -3
200	11.0	0.01476	2.94440& -4	0.01905	3.96106& -3
219	12.0	0.01474	2.75796& -4	0.01743	3.73277& -3
237	13.0	0.01465	2.61963& -4	0.01570	4.43431& -3
255	14.0	0.01464	2.54460& -4	0.01695	4.12425& -3
273	15.0	0.01463	2.38132& -4	0.01573	3.41663& -3
292	16.0	0.01462	2.30536& -4	0.01675	5.05694& -3
310	17.0	0.01461	2.20975& -4	0.01494	3.29507& -3
328	18.0	0.01457	2.18080& -4	0.01534	4.20563& -3
346	19.0	0.01457	2.10304& -4	0.01690	3.32557& -3
365	20.0	0.01457	2.00895& -4	0.01754	3.83887& -3
383	21.0	0.01458	2.01579& -4	0.01618	5.70344& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.01582	1.07794& -3	0.02300	9.77618& -3
197	2.0	0.01508	1.90386& -3	0.01888	4.91500& -3
295	3.0	0.01494	4.31848& -4	0.01799	5.28033& -3
394	4.0	0.01505	3.50922& -4	0.01783	4.92530& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.01522	7.20963& -4	0.01815	5.28436& -3

Data Analysis Program

Run Number = 115

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06137	1.34088& -2	0.08711	7.14987& -1
36	2.0	0.03149	3.90620& -3	0.13070	3.19825& -1
54	3.0	0.02465	2.06144& -3	0.03223	8.51937& -2
73	4.0	0.02175	5.27233& -3	0.03377	5.42657& -2
91	5.0	0.02229	9.86699& -4	0.04113	4.07435& -2
109	6.0	0.02176	7.69684& -4	0.03364	2.61164& -2
127	7.0	0.02150	6.48634& -4	0.02743	1.90420& -2
146	8.0	0.02112	5.49812& -4	0.03601	2.73865& -2
164	9.0	0.01976	5.10766& -3	0.03324	2.45771& -2
182	10.0	0.02095	4.38017& -4	0.02046	1.14939& -2
200	11.0	0.02089	3.95933& -4	0.03177	3.73264& -2
219	12.0	0.02084	3.66248& -4	0.02236	1.61826& -2
237	13.0	0.01973	4.02568& -3	0.01877	9.89340& -3
255	14.0	0.02069	3.19590& -4	0.02373	1.56663& -2
273	15.0	0.01971	3.70559& -3	0.03982	3.36805& -2
292	16.0	0.02063	2.83822& -4	0.02810	1.63408& -2
310	17.0	0.02061	2.72001& -4	0.02237	1.20707& -2
328	18.0	0.02057	2.63308& -4	0.03197	3.18325& -2
346	19.0	0.01631	1.63411& -2	0.02631	1.61911& -2
365	20.0	0.02056	2.42735& -4	0.01737	1.03311& -2
383	21.0	0.02056	2.31639& -4	0.02663	1.93319& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02708	1.05671& -2	0.05331	6.55068& -2
197	2.0	0.02285	1.09573& -3	0.02835	2.79509& -2
295	3.0	0.02129	6.75153& -4	0.02729	1.94974& -2
394	4.0	0.02107	1.46945& -3	0.02166	1.71352& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02082	4.94074& -3	0.03399	3.19047& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01899	1.92262& -3	0.04386	9.01997& -2
36	2.0	0.01663	9.31671& -4	0.03825	7.11029& -2
54	3.0	0.01527	6.26567& -4	0.02050	2.13148& -2
73	4.0	0.01467	1.62287& -3	0.02013	2.00599& -2
91	5.0	0.01495	3.97509& -4	0.02283	1.44499& -2
109	6.0	0.01486	3.39916& -4	0.02098	1.15640& -2
127	7.0	0.01481	3.05247& -4	0.01835	8.74131& -3
146	8.0	0.01459	2.71174& -4	0.02211	1.27988& -2
164	9.0	0.01384	2.95399& -3	0.02160	1.18145& -2
182	10.0	0.01457	2.32810& -4	0.01425	5.17009& -3
200	11.0	0.01456	2.16136& -4	0.02067	1.88820& -2
219	12.0	0.01455	2.05060& -4	0.01569	8.05745& -3
237	13.0	0.01394	2.08678& -3	0.01312	5.38132& -3
255	14.0	0.01445	1.85330& -4	0.01720	8.93361& -3
273	15.0	0.01372	2.83096& -3	0.02290	1.37072& -2
292	16.0	0.01444	1.69755& -4	0.01840	9.13150& -3
310	17.0	0.01444	1.64679& -4	0.01558	7.07145& -3
328	18.0	0.01440	1.60786& -4	0.02016	1.45292& -2
346	19.0	0.01269	6.55283& -3	0.01791	8.57376& -3
365	20.0	0.01440	1.50874& -4	0.01222	5.29684& -3
383	21.0	0.01441	1.45490& -4	0.01745	1.02902& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01550	9.86370& -4	0.02560	2.03950& -2
197	2.0	0.01520	4.46859& -4	0.01865	1.32508& -2
295	3.0	0.01468	3.21860& -4	0.01782	8.91796& -3
394	4.0	0.01464	7.05736& -4	0.01531	9.16794& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01440	1.86817& -3	0.02022	1.18063& -2

Data Analysis Program

Run Number = 116

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.07607	1.17926& -2	0.09676	1.14433& -1
36	2.0	0.03598	3.37857& -3	0.00875	8.77036& -2
54	3.0	0.02695	1.76847& -3	0.02611	2.07435& -2
73	4.0	0.02455	1.21219& -3	0.01791	1.20340& -2
91	5.0	0.02340	8.51118& -4	0.02686	1.32471& -2
109	6.0	0.02262	6.84461& -4	0.02423	7.25061& -3
127	7.0	0.02222	5.70842& -4	0.02139	7.56137& -3
146	8.0	0.02173	4.82435& -4	0.02311	1.00057& -2
164	9.0	0.02157	4.28898& -4	0.02378	6.59959& -3
182	10.0	0.02144	4.00118& -4	0.02226	4.99732& -3
200	11.0	0.02134	3.50388& -4	0.02266	4.59369& -3
219	12.0	0.02124	3.23574& -4	0.02160	5.25113& -3
237	13.0	0.02111	3.09586& -4	0.02027	5.29908& -3
255	14.0	0.02104	2.75853& -4	0.02076	6.46949& -3
273	15.0	0.02098	2.60249& -4	0.02192	5.59113& -3
292	16.0	0.02093	2.44739& -4	0.02230	4.75929& -3
310	17.0	0.02090	2.51251& -4	0.02119	4.18380& -3
328	18.0	0.02085	2.20131& -4	0.02117	6.45277& -3
346	19.0	0.02082	2.13796& -4	0.02180	4.73125& -3
365	20.0	0.02082	2.19364& -4	0.02342	3.69165& -3
383	21.0	0.02082	2.03478& -4	0.02082	3.93702& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02740	2.46684& -3	0.03059	2.27972& -2
197	2.0	0.02412	9.57087& -4	0.02310	7.84555& -3
295	3.0	0.02203	5.78623& -4	0.02235	4.94897& -3
394	4.0	0.02197	4.49009& -4	0.02155	5.17090& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02308	2.22772& -3	0.02401	1.13665& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01212	9.97737& -4	0.01403	8.10367& -3
36	2.0	0.01016	4.69189& -4	0.00855	7.02560& -3
54	3.0	0.00916	3.11816& -4	0.00924	3.45032& -3
73	4.0	0.00895	2.48911& -4	0.00785	2.30258& -3
91	5.0	0.00884	1.97960& -4	0.00962	3.02669& -3
109	6.0	0.00875	1.71662& -4	0.00907	1.60142& -3
127	7.0	0.00869	1.53266& -4	0.00870	1.77014& -3
146	8.0	0.00854	1.35134& -4	0.00892	2.39788& -3
164	9.0	0.00853	1.25733& -4	0.00919	2.04593& -3
182	10.0	0.00851	1.21037& -4	0.00878	1.55223& -3
200	11.0	0.00849	1.09168& -4	0.00888	1.37013& -3
219	12.0	0.00848	1.02926& -4	0.00850	1.67106& -3
237	13.0	0.00842	9.91915& -5	0.00826	1.58217& -3
255	14.0	0.00841	9.16462& -5	0.00833	2.00614& -3
273	15.0	0.00840	8.78903& -5	0.00858	1.84965& -3
292	16.0	0.00839	8.34113& -5	0.00876	1.48902& -3
310	17.0	0.00839	8.64773& -5	0.00850	1.41575& -3
328	18.0	0.00836	7.65688& -5	0.00839	2.07231& -3
346	19.0	0.00836	7.49291& -5	0.00872	1.74059& -3
365	20.0	0.00836	7.77563& -5	0.00906	1.18194& -3
383	21.0	0.00836	7.27643& -5	0.00846	1.45752& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00928	4.02916& -4	0.00983	3.66317& -3
197	2.0	0.00902	2.23482& -4	0.00895	1.72687& -3
295	3.0	0.00862	1.57748& -4	0.00868	1.20114& -3
394	4.0	0.00866	1.34444& -4	0.00856	1.30554& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00868	7.59685& -4	0.00906	2.42471& -3

Data Analysis Program

Run Number = 117

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06523	1.76823& -2	1.66457	5.71588& 0
36	2.0	0.03282	5.18280& -3	0.30583	3.99836& -1
54	3.0	0.02527	2.71056& -3	0.06526	1.07177& -1
73	4.0	0.02352	1.77953& -3	0.03312	3.74001& -2
91	5.0	0.02262	1.31933& -3	0.04887	5.05105& -2
109	6.0	0.02201	1.03140& -3	0.02763	2.70147& -2
127	7.0	0.02172	8.47437& -4	0.02124	1.92803& -2
146	8.0	0.02130	7.29795& -4	0.02575	3.11777& -2
164	9.0	0.02120	6.41319& -4	0.02749	1.96542& -2
182	10.0	0.02110	5.78120& -4	0.01944	1.91111& -2
200	11.0	0.02105	5.17944& -4	0.02561	2.27841& -2
219	12.0	0.02098	4.84074& -4	0.03972	3.82741& -2
237	13.0	0.02086	4.51084& -4	0.02231	1.10434& -2
255	14.0	0.01982	3.96806& -3	0.03000	2.45762& -2
273	15.0	0.02076	3.96499& -4	0.02391	1.43882& -2
292	16.0	0.01980	3.50045& -3	0.02493	1.72442& -2
310	17.0	0.02070	3.60069& -4	0.01715	9.73651& -3
328	18.0	0.02067	3.46930& -4	0.02466	1.97168& -2
346	19.0	0.02065	3.31003& -4	0.02529	1.96055& -2
365	20.0	0.02064	3.17205& -4	0.02533	2.52724& -2
383	21.0	0.02065	3.10743& -4	0.02343	1.41789& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02511	3.77376& -3	0.07749	1.02622& -1
197	2.0	0.02325	1.44482& -3	0.05177	5.64232& -2
295	3.0	0.02150	8.91991& -4	0.03004	1.95130& -2
394	4.0	0.02297	5.50144& -3	0.02265	1.45003& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02235	1.88593& -3	0.04141	3.64459& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01123	1.47984& -3	0.07726	1.62036& -1
36	2.0	0.00972	7.14446& -4	0.05140	6.63960& -2
54	3.0	0.00887	4.75527& -4	0.01372	1.22934& -2
73	4.0	0.00873	3.67857& -4	0.01103	7.74414& -3
91	5.0	0.00865	3.07285& -4	0.01521	1.19951& -2
109	6.0	0.00859	2.60764& -4	0.01025	6.26843& -3
127	7.0	0.00855	2.29737& -4	0.00846	4.20140& -3
146	8.0	0.00841	2.06090& -4	0.00969	8.38421& -3
164	9.0	0.00841	1.89573& -4	0.01023	4.76891& -3
182	10.0	0.00840	1.76798& -4	0.00866	5.71962& -3
200	11.0	0.00840	1.62471& -4	0.01005	6.52406& -3
219	12.0	0.00838	1.55318& -4	0.01378	1.00523& -2
237	13.0	0.00833	1.46852& -4	0.00881	3.50985& -3
255	14.0	0.00791	1.65589& -3	0.01109	6.96830& -3
273	15.0	0.00832	1.33680& -4	0.00890	3.65026& -3
292	16.0	0.00789	1.60599& -3	0.00924	4.88393& -3
310	17.0	0.00831	1.25554& -4	0.00736	3.22306& -3
328	18.0	0.00829	1.21273& -4	0.00988	5.84041& -3
346	19.0	0.00829	1.16908& -4	0.00997	6.55420& -3
365	20.0	0.00829	1.13516& -4	0.00972	6.93898& -3
383	21.0	0.00829	1.11131& -4	0.00900	4.59813& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00891	6.14219& -4	0.01838	1.64907& -2
197	2.0	0.00881	3.38780& -4	0.01495	1.15441& -2
295	3.0	0.00847	2.44699& -4	0.01129	5.63673& -3
394	4.0	0.00873	7.88210& -4	0.00886	4.11069& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00859	4.11415& -4	0.01344	7.61712& -3

Data Analysis Program

Run Number = 118

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06498	2.75500& -2	-0.06938	1.11172& 0
36	2.0	0.03329	6.80791& -3	0.02612	2.06163& -1
54	3.0	0.02548	3.55365& -3	-0.06957	2.15782& -1
73	4.0	0.02364	2.37256& -3	0.08254	2.22389& -1
91	5.0	0.02270	1.71814& -3	0.09128	1.19296& -1
109	6.0	0.02207	1.35690& -3	0.03364	4.32595& -2
127	7.0	0.02177	1.13348& -3	0.06470	1.09827& -1
146	8.0	0.02134	9.68865& -4	0.05163	1.71847& -1
164	9.0	0.01999	5.50554& -3	0.01563	1.63020& -2
182	10.0	0.01990	4.60671& -3	0.04632	9.16697& -2
200	11.0	0.02107	7.00097& -4	0.05950	9.57828& -2
219	12.0	0.02098	6.39690& -4	0.01923	1.95785& -2
237	13.0	0.02086	6.08617& -4	0.17751	6.02990& -1
255	14.0	0.02082	5.60049& -4	0.04265	5.01856& -2
273	15.0	0.02078	5.30903& -4	0.03025	2.80132& -2
292	16.0	0.02704	1.42890& -2	0.03168	2.98667& -2
310	17.0	0.02071	4.98031& -4	0.01065	3.64809& -2
328	18.0	0.02068	4.65982& -4	0.02547	2.84605& -2
346	19.0	0.02065	4.35867& -4	0.01915	2.16129& -2
365	20.0	0.02064	4.35652& -4	0.02938	2.73645& -2
383	21.0	0.01986	3.10008& -3	0.01774	8.13151& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02725	5.07121& -3	0.08209	1.28045& -1
197	2.0	0.02336	1.92333& -3	0.03592	3.59891& -2
295	3.0	0.02154	1.16966& -3	0.02448	3.17066& -2
394	4.0	0.02162	8.86366& -4	0.04100	3.87988& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02293	3.17991& -3	0.04876	7.33354& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01129	2.11362& -3	0.02158	9.15731& -2
36	2.0	0.00980	9.28827& -4	0.01654	3.05686& -2
54	3.0	0.00892	6.224648& -4	-0.00182	3.04334& -2
73	4.0	0.00877	4.905348& -4	0.02992	5.26090& -2
91	5.0	0.00868	4.01113& -4	0.02278	2.23781& -2
109	6.0	0.00862	3.44830& -4	0.01047	7.98291& -3
127	7.0	0.00858	3.07749& -4	0.02232	3.05873& -2
146	8.0	0.00844	2.74896& -4	0.01492	3.88874& -2
164	9.0	0.00803	1.76800& -3	0.00711	4.20848& -3
182	10.0	0.00798	1.66837& -3	0.01631	2.31707& -2
200	11.0	0.00842	2.20230& -4	0.01881	2.43509& -2
219	12.0	0.00840	2.06502& -4	0.00903	6.62569& -3
237	13.0	0.00835	1.99938& -4	0.05605	1.81150& -1
255	14.0	0.00835	1.87330& -4	0.01729	1.82458& -2
273	15.0	0.00834	1.80968& -4	0.01207	1.00536& -2
292	16.0	0.00753	3.12985& -3	0.01194	9.92708& -3
310	17.0	0.00833	1.74096& -4	0.00665	1.02807& -2
328	18.0	0.00831	1.64450& -4	0.01045	1.08127& -2
346	19.0	0.00831	1.55533& -4	0.00853	9.90199& -3
365	20.0	0.00830	1.56609& -4	0.01222	1.04628& -2
383	21.0	0.00790	1.58663& -3	0.00874	2.11382& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00902	6.88008& -4	0.02148	2.17536& -2
197	2.0	0.00885	4.50620& -4	0.01217	8.36068& -3
295	3.0	0.00850	3.21741& -4	0.01026	8.62630& -3
394	4.0	0.00856	2.68270& -4	0.01509	1.21978& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00866	5.79488& -4	0.01511	1.42093& -2

Data Analysis Program

Run Number = 119

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06514	1.72787& -2	0.76951	4.04327& 0
36	2.0	0.03352	3.58569& -3	0.26975	5.23030& -1
54	3.0	0.02553	2.04232& -3	0.04648	1.79918& -1
73	4.0	0.02163	8.43594& -3	0.07628	1.78180& -1
91	5.0	0.02165	7.72019& -3	0.07074	1.21103& -1
109	6.0	0.02208	7.61985& -4	0.03324	3.76245& -2
127	7.0	0.02178	6.52638& -4	0.05201	1.16583& -1
146	8.0	0.02136	5.50740& -4	0.03309	5.03578& -2
164	9.0	0.02127	5.37598& -4	0.03166	3.20132& -2
182	10.0	0.02116	4.37355& -4	0.03647	3.35700& -2
200	11.0	0.01995	4.31985& -3	0.02822	2.54712& -2
219	12.0	0.02106	3.97776& -4	0.04297	4.73887& -2
237	13.0	0.02090	3.39682& -4	0.02285	1.31329& -2
255	14.0	0.02085	3.46554& -4	0.03671	4.48722& -2
273	15.0	0.02079	3.10665& -4	0.05099	8.19624& -2
292	16.0	0.02081	2.80986& -4	0.01887	1.16651& -2
310	17.0	0.02074	2.69746& -4	0.01691	1.20254& -2
328	18.0	0.01965	4.17158& -3	0.02396	1.67635& -2
346	19.0	0.02068	2.65577& -4	0.02597	2.14978& -2
365	20.0	0.02067	2.45257& -4	0.01746	9.26284& -3
383	21.0	0.02067	2.29886& -4	0.02861	3.03043& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02558	2.76698& -3	0.11321	2.16188& -1
197	2.0	0.02341	1.06802& -3	0.04366	4.87859& -2
295	3.0	0.02163	6.70821& -4	0.02944	2.10205& -2
394	4.C	0.02161	5.06023& -4	0.03775	4.33360& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02257	1.37022& -3	0.04162	4.59276& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00280	4.01899& -4	0.04189	1.73464& -1
36	2.0	0.00247	1.28837& -4	0.01213	1.69663& -2
54	3.0	0.00224	9.00211& -5	0.00233	4.94885& -3
73	4.0	0.00210	4.44317& -4	0.00508	9.04292& -3
91	5.0	0.00205	4.25465& -4	0.00451	5.30533& -3
109	6.0	0.00216	4.88039& -5	0.00321	2.55984& -3
127	7.0	0.00215	4.46631& -5	0.00410	6.90358& -3
146	8.0	0.00212	3.96767& -5	0.00297	3.51629& -3
164	9.0	0.00212	3.97246& -5	0.00283	1.86487& -3
182	10.0	0.00212	3.35317& -5	0.00336	2.40325& -3
200	11.0	0.00201	4.15259& -4	0.00286	2.20586& -3
219	12.0	0.00211	3.21172& -5	0.00381	2.80595& -3
237	13.0	0.00210	2.82486& -5	0.00231	1.02314& -3
255	14.0	0.00210	2.93700& -5	0.00302	2.09370& -3
273	15.0	0.00210	2.59581& -5	0.00450	6.14189& -3
292	16.0	0.00210	2.37775& -5	0.00194	8.08579& -4
310	17.0	0.00209	2.36625& -5	0.00185	1.06426& -3
328	18.0	0.00200	3.40007& -4	0.00273	1.62054& -3
346	19.0	0.00209	2.37753& -5	0.00269	1.84059& -3
365	20.0	0.00209	2.22152& -5	0.00199	9.40775& -4
383	21.0	0.00209	2.09091& -5	0.00271	2.29303& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00226	1.14236& -4	0.00654	9.65434& -3
197	2.0	0.00223	6.36052& -5	0.00358	3.06521& -3
295	3.0	0.00214	4.62048& -5	0.00277	1.51693& -3
394	4.0	0.00215	3.85949& -5	0.00333	2.62922& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00217	7.54203& -5	0.00336	2.46164& -3

Data Analysis Program

Run Number = 120

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.07430	1.48851& -2	-0.13690	5.34630& -1
36	2.0	0.03544	4.15096& -3	-0.05166	2.46629& -1
54	3.0	0.02645	2.48946& -3	-0.05418	1.85784& -1
73	4.0	0.02443	1.48220& -3	0.00832	1.61146& -1
91	5.0	0.02319	1.12697& -3	0.01540	2.89104& -1
109	6.0	0.02236	8.41546& -4	-0.01269	1.44049& -1
127	7.0	0.01104	8.02611& -4	0.00579	1.47951& -1
146	8.0	0.02158	6.47878& -4	0.00794	6.42010& -2
164	9.0	0.02145	5.68738& -4	-0.00818	8.10489& -2
182	10.0	0.02137	5.62474& -4	-0.00910	4.28522& -2
200	11.0	0.02132	4.88030& -4	-0.00384	5.45906& -2
219	12.0	0.02117	4.20344& -4	0.02634	6.46971& -2
237	13.0	0.02106	3.87451& -4	-0.01261	9.36050& -2
255	14.0	0.02099	3.72303& -4	-0.05416	1.56364& -1
273	15.0	0.02092	3.73268& -4	0.02804	6.25207& -2
292	16.0	0.02092	3.30587& -4	0.01264	1.83909& -2
310	17.0	0.02082	3.24892& -4	-0.00220	4.78068& -2
328	18.0	0.02079	3.30734& -4	-0.05015	1.85849& -1
346	19.0	0.01966	4.20789& -3	-0.00710	6.45327& -2
365	20.0	0.02073	2.65056& -4	-0.01300	5.46115& -2
383	21.0	0.02071	2.88885& -4	-0.00556	7.57670& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02703	3.23906& -3	-0.07035	2.54133& -1
197	2.0	0.02399	1.22627& -3	-0.00247	1.21663& -1
295	3.0	0.02193	8.03139& -4	0.00441	7.24253& -2
394	4.0	0.02186	5.57096& -4	0.02074	7.74813& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02328	1.59088& -3	-0.03470	1.75658& -1

Time Constant 2

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	0.00302	3.16425& -4	0.00860	3.41718& -2
36	2.0	0.00254	1.46589& -4	0.00323	1.64269& -2
54	3.0	0.00229	1.08502& -4	0.00306	1.27135& -2
73	4.0	0.00225	7.88775& -5	0.00598	1.62127& -2
91	5.0	0.00222	6.55920& -5	0.00851	3.46579& -2
109	6.0	0.00219	5.42658& -5	0.00389	1.24387& -2
127	7.0	0.00218	5.35187& -5	0.00389	1.72392& -2
146	8.0	0.00214	4.66739& -5	0.00248	5.77754& -3
164	9.0	0.00214	4.21279& -5	0.00165	8.29746& -3
182	10.0	0.00214	4.28345& -5	0.00027	3.81709& -3
200	11.0	0.00214	3.87076& -5	0.00155	4.33174& -3
219	12.0	0.00213	3.43022& -5	0.00439	7.56800& -3
237	13.0	0.00212	3.13001& -5	0.00039	8.17454& -3
255	14.0	0.00212	3.12168& -5	-0.00424	1.69113& -2
273	15.0	0.00211	3.11024& -5	0.00402	5.20225& -3
292	16.0	0.00212	2.79604& -5	0.00192	2.04618& -3
310	17.0	0.00211	2.83002& -5	0.00060	5.43725& -3
328	18.0	0.00210	2.91164& -5	-0.00628	2.41740& -2
346	19.0	0.00201	3.48517& -4	0.00035	5.03486& -3
365	20.0	0.00210	2.40185& -5	-0.00047	6.28710& -3
383	21.0	0.00210	2.64353& -5	0.00094	8.43753& -3

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00233	1.33400& -4	0.00103	1.61548& -2
197	2.0	0.00227	7.31500& -5	0.00253	7.15947& -3
295	3.0	0.00217	5.50961& -5	0.00203	4.11283& -3
394	4.0	0.00218	4.21815& -5	0.00318	5.53090& -3

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00222	8.79478& -5	0.00096	1.09901& -2

Data Analysis Program

Run Number = 121

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.07622	1.42570& -2	-0.18564	5.38074& -1
36	2.0	0.03600	4.00225& -3	-0.29318	2.51095& -1
54	3.0	0.02545	7.08789& -3	-0.09520	1.61800& -1
73	4.0	0.02465	1.43153& -3	-0.00672	1.18602& -1
91	5.0	0.02143	6.90216& -3	-0.09067	1.21466& -1
109	6.0	0.02260	9.04071& -4	0.01228	2.58392& -1
127	7.0	0.02220	6.81064& -4	-0.07271	1.08752& -1
146	8.0	0.02174	6.29552& -4	-0.01124	5.82520& -2
164	9.0	0.02161	5.54015& -4	-0.02542	7.20062& -2
182	10.0	0.02145	4.81755& -4	-0.00727	4.42504& -2
200	11.0	0.02139	4.43412& -4	-0.00212	6.03242& -2
219	12.0	0.02129	3.82092& -4	-0.00123	1.29158& -1
237	13.0	0.02112	3.89167& -4	-0.02248	1.26906& -1
255	14.0	0.02107	3.91766& -4	0.03318	9.61549& -2
273	15.0	0.01994	4.13987& -3	-0.02743	6.84413& -2
292	16.0	0.02101	2.97800& -4	-0.02082	4.31126& -2
310	17.0	0.01707	1.49643& -2	0.04033	1.86254& -1
328	18.0	0.02087	3.02689& -4	-0.00531	3.53414& -2
346	19.0	0.02084	2.56002& -4	0.03616	9.89935& -2
365	20.0	0.02080	2.59821& -4	-0.02054	6.32441& -2
383	21.0	0.02078	2.66008& -4	0.01176	6.36366& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02735	3.19480& -3	-0.04760	2.27334& -1
197	2.0	0.02418	1.17090& -3	-0.12829	1.55214& -1
295	3.0	0.02177	1.76492& -3	-0.01811	1.02345& -1
394	4.0	0.02197	5.07540& -4	-0.00533	6.74581& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02346	1.59037& -3	-0.05039	1.21890& -1

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00306	3.09698& -4	0.01780	3.90945& -2
36	2.0	0.00256	1.40622& -4	-0.00484	3.56468& -2
54	3.0	0.00225	2.69811& -4	-0.00328	1.52450& -2
73	4.0	0.00226	7.53429& -5	0.00307	1.17935& -2
91	5.0	0.00210	4.33121& -4	-0.00156	1.34936& -2
109	6.0	0.00220	5.80674& -5	0.00710	2.95795& -2
127	7.0	0.00219	4.71202& -5	-0.00021	1.18642& -2
146	8.0	0.00215	4.49596& -5	0.00175	7.34019& -3
164	9.0	0.00215	4.11467& -5	0.00173	9.38630& -3
182	10.0	0.00214	3.67691& -5	0.00326	5.37578& -3
200	11.0	0.00214	3.50798& -5	0.00030	4.13956& -3
219	12.0	0.00214	3.06612& -5	0.00269	1.54524& -2
237	13.0	0.00212	3.25182& -5	-0.00123	2.17614& -2
255	14.0	0.00212	3.32184& -5	0.00619	1.86573& -2
273	15.0	0.00203	3.23696& -4	-0.00254	1.27114& -2
292	16.0	0.00212	2.55297& -5	-0.00073	5.32016& -3
310	17.0	0.00190	8.40722& -4	0.00606	2.63322& -2
328	18.0	0.00211	2.71275& -5	0.00074	3.59081& -3
346	19.0	0.00211	2.31836& -5	0.00576	1.30460& -2
365	20.0	0.00210	2.33577& -5	-0.00109	6.93968& -3
383	21.0	0.00210	2.40330& -5	0.00411	8.00892& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00234	1.32037& -4	0.00926	1.57435& -2
197	2.0	0.00227	6.94917& -5	-0.00542	1.67424& -2
295	3.0	0.00216	1.12528& -4	0.00168	1.10238& -2
394	4.0	0.00218	3.89421& -5	0.00213	8.86906& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00223	8.81364& -5	0.00208	6.36849& -3

Data Analysis Program

Run Number = 122

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01960	2.56801& -2	-0.03229	2.34511& -1
36	2.0	0.02401	1.41641& -2	0.02000	2.01847& -2
54	3.0	0.02432	1.05959& -2	0.02585	1.30010& -2
73	4.0	0.02594	8.62781& -3	0.02979	1.04313& -2
91	5.0	0.02667	7.88182& -3	0.03121	1.07565& -2
109	6.0	0.02705	7.32919& -3	0.02764	1.01096& -2
127	7.0	0.02738	6.90016& -3	0.02823	9.73088& -3
146	8.0	0.02740	6.74844& -3	0.02731	8.78247& -3
164	9.0	0.02752	6.70869& -3	0.02796	8.70367& -3
182	10.0	0.02757	6.81688& -3	0.02699	8.35348& -3
200	11.0	0.02762	6.87918& -3	0.02734	7.45856& -3
219	12.0	0.02760	7.13045& -3	0.02667	8.91687& -3
237	13.0	0.02761	7.24922& -3	0.02892	8.59538& -3
255	14.0	0.02767	7.32345& -3	0.02954	7.71864& -3
273	15.0	0.02776	7.33113& -3	0.02811	7.25028& -3
292	16.0	0.02788	7.31441& -3	0.02785	7.75758& -3
310	17.0	0.02801	7.31997& -3	0.02735	8.17571& -3
328	18.0	0.02817	7.32523& -3	0.02771	7.93006& -3
346	19.0	0.02836	7.28804& -3	0.02808	7.61269& -3
365	20.0	0.02856	7.26990& -3	0.02863	8.00419& -3
383	21.0	0.02879	7.28719& -3	0.02912	8.07803& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02116	1.10645& -2	0.02486	1.14816& -2
197	2.0	0.02696	8.25067& -3	0.02595	8.00437& -3
295	3.0	0.02686	7.27092& -3	0.02743	8.07086& -3
394	4.0	0.02787	7.01549& -3	0.03055	1.08695& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02430	8.38680& -3	0.02555	4.29720& -3

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01840	5.33076& -3	0.01821	1.13068& -2
36	2.0	0.01918	5.03569& -3	0.01783	6.25687& -3
54	3.0	0.01865	4.74498& -3	0.01889	5.73257& -3
73	4.0	0.01905	4.71323& -3	0.02062	5.76873& -3
91	5.0	0.01927	4.72293& -3	0.01956	4.29435& -3
109	6.0	0.01941	4.67465& -3	0.01988	5.59656& -3
127	7.0	0.01952	4.62577& -3	0.02022	5.66725& -3
146	8.0	0.01941	4.59003& -3	0.01963	5.31157& -3
164	9.0	0.01948	4.59592& -3	0.01989	5.35303& -3
182	10.0	0.01953	4.61577& -3	0.01935	5.14010& -3
200	11.0	0.01956	4.63987& -3	0.01935	4.83210& -3
219	12.0	0.01958	4.66763& -3	0.01935	5.35078& -3
237	13.0	0.01957	4.67879& -3	0.02033	5.45378& -3
255	14.0	0.01961	4.70294& -3	0.02069	5.01856& -3
273	15.0	0.01965	4.72425& -3	0.01997	4.86502& -3
292	16.0	0.01972	4.74097& -3	0.01968	5.06223& -3
310	17.0	0.01979	4.76140& -3	0.01949	5.27397& -3
328	18.0	0.01986	4.77790& -3	0.01948	5.08183& -3
346	19.0	0.01997	4.78622& -3	0.01990	5.13556& -3
365	20.0	0.02008	4.80151& -3	0.02020	5.32246& -3
383	21.0	0.02022	4.83293& -3	0.02050	5.41146& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01790	4.66384& -3	0.01814	4.12796& -3
197	2.0	0.01943	4.79524& -3	0.01872	4.87877& -3
295	3.0	0.01923	4.63056& -3	0.01948	5.14818& -3
394	4.0	0.01973	4.67720& -3	0.02087	5.62823& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01839	4.60932& -3	0.01864	4.12875& -3

Data Analysis Program

Run Number = 123

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01383	3.18091& -2	0.05985	1.75517& -1
36	2.0	0.02326	1.17672& -2	0.00941	3.34246& -2
54	3.0	0.02416	8.17693& -3	0.03065	2.51103& -2
73	4.0	0.02585	6.77620& -3	0.02754	2.30954& -2
91	5.0	0.02669	6.07744& -3	0.02322	2.13558& -2
109	6.0	0.02732	4.98669& -3	0.02464	1.48166& -2
127	7.0	0.02775	4.26319& -3	0.03015	2.46801& -2
146	8.0	0.02789	3.76530& -3	0.03047	1.23108& -2
164	9.0	0.02813	3.38844& -3	0.03657	1.55937& -2
182	10.0	0.02830	3.10852& -3	0.03616	2.01751& -2
200	11.0	0.02844	2.88322& -3	0.03375	9.42246& -3
219	12.0	0.02729	5.53460& -3	0.02651	8.25497& -3
237	13.0	0.02864	2.55009& -3	0.03376	1.37752& -2
255	14.0	0.02876	2.42306& -3	0.03163	1.08890& -2
273	15.0	0.02889	2.31972& -3	0.02947	1.18411& -2
292	16.0	0.02903	2.22597& -3	0.03049	1.24785& -2
310	17.0	0.02920	2.15701& -3	0.03304	8.36722& -3
328	18.0	0.02342	2.29166& -2	0.03219	3.94220& -3
346	19.0	0.02957	2.03333& -3	0.03033	1.24429& -2
365	20.0	0.02979	1.98117& -3	0.03376	1.19503& -2
383	21.0	0.03003	1.94301& -3	0.03560	1.28414& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02018	1.06163& -2	0.01946	3.38885& -2
197	2.0	0.02735	4.88800& -3	0.02733	1.24480& -2
295	3.0	0.03017	1.16240& -2	0.02832	8.48523& -3
394	4.0	0.02698	6.98781& -3	0.03051	1.20603& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02419	6.49825& -3	0.02358	1.79115& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01780	5.18277& -3	0.03012	3.09807& -2
36	2.0	0.01921	3.43631& -3	0.01682	9.34954& -3
54	3.0	0.01884	2.91328& -3	0.02188	9.12235& -3
73	4.0	0.01933	2.75893& -3	0.02180	1.02055& -2
91	5.0	0.01959	2.70370& -3	0.01825	8.07127& -3
109	6.0	0.01982	2.41091& -3	0.01859	6.82286& -3
127	7.0	0.01998	2.19103& -3	0.02105	1.17817& -2
146	8.0	0.01992	2.01845& -3	0.02096	6.54343& -3
164	9.0	0.02004	1.88433& -3	0.02352	9.02765& -3
182	10.0	0.02013	1.78098& -3	0.02415	1.04632& -2
200	11.0	0.02020	1.69099& -3	0.02317	5.25739& -3
219	12.0	0.01923	4.26316& -3	0.01891	5.73566& -3
237	13.0	0.02026	1.54972& -3	0.02334	7.43290& -3
255	14.0	0.02033	1.49410& -3	0.02178	6.44331& -3
273	15.0	0.02040	1.44779& -3	0.02116	7.06569& -3
292	16.0	0.02048	1.40441& -3	0.02186	7.55209& -3
310	17.0	0.02057	1.37238& -3	0.02307	5.95777& -3
328	18.0	0.01799	1.02706& -2	0.02272	3.58776& -3
346	19.0	0.02077	1.31422& -3	0.02141	7.65919& -3
365	20.0	0.02090	1.28954& -3	0.02346	7.39397& -3
383	21.0	0.02104	1.27123& -3	0.02473	7.27038& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01785	3.48850& -3	0.01771	1.01779& -2
197	2.0	0.01986	2.30447& -3	0.02045	5.73806& -3
295	3.0	0.02024	2.89319& -3	0.02040	4.53170& -3
394	4.0	0.01942	3.89357& -3	0.02072	5.36873& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01860	2.79963& -3	0.01846	7.58319& -3

Data Analysis Program

Run Number = 124

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.28293	9.94628& -1	-0.05976	2.86114& -1
36	2.0	0.16961	4.91711& -1	0.12710	1.98701& -1
54	3.0	0.04536	7.13055& -2	0.08929	1.27848& -1
73	4.0	0.04132	5.13899& -2	0.03963	6.57914& -2
91	5.0	0.04117	4.87949& -2	0.03997	4.73181& -2
109	6.0	0.03358	1.83972& -2	0.02423	3.47044& -2
127	7.0	0.03294	1.50716& -2	0.02758	2.46425& -2
146	8.0	0.03135	9.13068& -3	0.04486	9.31373& -2
164	9.0	0.02969	2.37697& -3	0.03474	2.96334& -2
182	10.0	0.02481	1.49506& -2	0.03230	2.03150& -2
200	11.0	0.02603	8.71876& -3	0.02663	2.96089& -2
219	12.0	0.02735	7.62845& -3	0.05855	5.63216& -2
237	13.0	0.02716	8.48216& -3	0.03383	2.27922& -2
255	14.0	0.02723	8.52857& -3	0.03507	2.77238& -2
273	15.0	0.02728	8.69736& -3	0.02616	2.52207& -2
292	16.0	0.02737	8.76025& -3	0.03559	2.62574& -2
310	17.0	0.02749	8.80847& -3	0.02883	2.42757& -2
328	18.0	0.02763	8.85392& -3	0.03448	2.49323& -2
346	19.0	0.02781	8.84395& -3	0.04435	1.91213& -2
365	20.0	0.02634	1.06688& -2	0.03739	3.15743& -2
383	21.0	0.02821	8.93123& -3	0.03043	1.74107& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.06272	1.50252& -1	0.02314	8.23402& -2
197	2.0	0.03061	1.54634& -2	0.02498	3.26235& -2
295	3.0	0.02688	6.81167& -3	0.04541	2.11727& -2
394	4.0	0.02730	8.76113& -3	0.02919	2.37512& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02834	7.90871& -3	0.01957	5.66167& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01856	5.31788& -3	0.01462	3.19484& -2
36	2.0	0.02027	6.82932& -3	0.04491	5.06181& -2
54	3.0	0.01850	5.15844& -3	0.04207	3.43993& -2
73	4.0	0.01886	5.23922& -3	0.02402	1.47783& -2
91	5.0	0.01906	5.26930& -3	0.02772	1.88023& -2
109	6.0	0.01918	5.31739& -3	0.02133	1.41211& -2
127	7.0	0.01927	5.35696& -3	0.02093	1.08628& -2
146	8.0	0.01914	5.30245& -3	0.02770	3.16367& -2
164	9.0	0.01921	5.32147& -3	0.02371	1.30830& -2
182	10.0	0.01781	7.53971& -3	0.02198	1.14229& -2
200	11.0	0.01851	6.01951& -3	0.02002	1.36804& -2
219	12.0	0.01932	5.35487& -3	0.03128	2.11819& -2
237	13.0	0.01930	5.35035& -3	0.02423	1.30330& -2
255	14.0	0.01935	5.36169& -3	0.02405	1.26563& -2
273	15.0	0.01940	5.37586& -3	0.02082	1.01210& -2
292	16.0	0.01946	5.39125& -3	0.02401	1.64784& -2
310	17.0	0.01953	5.41078& -3	0.02101	1.28215& -2
328	18.0	0.01960	5.42918& -3	0.02350	1.58088& -2
346	19.0	0.01969	5.45504& -3	0.02673	1.53271& -2
365	20.0	0.01879	6.59564& -3	0.02569	1.72759& -2
383	21.0	0.01993	5.52159& -3	0.02231	1.09019& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01780	4.98059& -3	0.02178	1.78947& -2
197	2.0	0.01846	6.00030& -3	0.01897	1.40658& -2
295	3.0	0.01899	5.27934& -3	0.02626	1.34189& -2
394	4.0	0.01946	5.40302& -3	0.02228	1.13545& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01822	5.10421& -3	0.02083	1.35189& -2

Data Analysis Program

Run Number = 125

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01828	2.03082& -2	0.00902	9.59923& -2
36	2.0	0.02526	6.42394& -3	0.03225	4.06311& -2
54	3.0	0.02575	3.56674& -3	0.03040	1.30832& -2
73	4.0	0.02726	2.43009& -3	0.02975	1.49474& -2
91	5.0	0.02807	1.88725& -3	0.02868	1.17495& -2
109	6.0	0.02844	1.52355& -3	0.02850	1.06610& -2
127	7.0	0.02872	1.32318& -3	0.02734	6.44570& -3
146	8.0	0.02877	1.17816& -3	0.03201	7.32479& -3
164	9.0	0.02893	1.04592& -3	0.03283	7.12292& -3
182	10.0	0.02901	9.59442& -4	0.03073	4.68416& -3
200	11.0	0.02910	8.90806& -4	0.03138	8.40955& -3
219	12.0	0.02916	8.40454& -4	0.03020	7.63629& -3
237	13.0	0.02923	7.83731& -4	0.03077	6.89075& -3
255	14.0	0.02932	7.48746& -4	0.03127	6.20583& -3
273	15.0	0.02943	7.15263& -4	0.03000	5.61907& -3
292	16.0	0.02957	6.93852& -4	0.02991	6.74693& -3
310	17.0	0.02373	2.31182& -2	0.02823	7.23790& -3
328	18.0	0.02988	6.41526& -4	0.03150	7.39295& -3
346	19.0	0.03005	6.23728& -4	0.03268	6.19826& -3
365	20.0	0.03026	6.18338& -4	0.03012	4.01279& -3
383	21.0	0.03050	6.11149& -4	0.03181	7.48448& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02218	4.99103& -3	0.02123	2.48324& -2
197	2.0	0.02831	2.15155& -3	0.02901	9.53677& -3
295	3.0	0.02826	1.41103& -3	0.02934	6.08649& -3
394	4.0	0.03083	5.74321& -3	0.03069	6.08559& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02549	2.72897& -3	0.02493	1.22402& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01055	2.01577& -3	0.01006	7.81438& -3
36	2.0	0.01129	1.08534& -3	0.01265	5.93168& -3
54	3.0	0.01107	7.55409& -4	0.01199	2.85176& -3
73	4.0	0.01135	5.98040& -4	0.01182	5.15217& -3
91	5.0	0.01152	5.11347& -4	0.01197	2.96180& -3
109	6.0	0.01162	4.42973& -4	0.01168	2.97073& -3
127	7.0	0.01168	4.05441& -4	0.01132	1.81384& -3
146	8.0	0.01163	3.72325& -4	0.01250	2.26521& -3
164	9.0	0.01168	3.43330& -4	0.01287	2.15269& -3
182	10.0	0.01171	3.20994& -4	0.01248	1.43316& -3
200	11.0	0.01174	3.05715& -4	0.01233	2.78611& -3
219	12.0	0.01176	2.93060& -4	0.01194	2.49729& -3
237	13.0	0.01176	2.75948& -4	0.01238	2.42147& -3
255	14.0	0.01179	2.67586& -4	0.01236	2.12266& -3
273	15.0	0.01183	2.58480& -4	0.01196	1.86243& -3
292	16.0	0.01187	2.53179& -4	0.01183	2.28317& -3
310	17.0	0.01042	5.79386& -3	0.01129	2.60920& -3
328	18.0	0.01196	2.37082& -4	0.01250	2.57896& -3
346	19.0	0.01202	2.32563& -4	0.01299	2.11079& -3
365	20.0	0.01209	2.31892& -4	0.01218	1.45374& -3
383	21.0	0.01217	2.29854& -4	0.01271	2.65864& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01056	9.69015& -4	0.01053	4.45095& -3
197	2.0	0.01159	5.80177& -4	0.01191	2.62879& -3
295	3.0	0.01151	4.32335& -4	0.01173	1.95967& -3
394	4.0	0.01207	9.47553& -4	0.01238	1.93145& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01093	6.83900& -4	0.01090	3.03045& -3

Data Analysis Program

Run Number = 126

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.08240	1.61734& -2	0.80246	2.28409& 0
36	2.0	0.04122	1.72448& -2	-0.03822	2.68155& -1
54	3.0	0.03744	3.13780& -3	0.04509	5.59786& -2
73	4.0	0.03500	1.95714& -3	0.07554	6.03714& -2
91	5.0	0.03395	1.50823& -3	0.03615	2.58131& -2
109	6.0	0.03326	1.22407& -3	0.03166	6.66274& -2
127	7.0	0.03287	1.06713& -3	0.05410	3.55511& -2
146	8.0	0.03241	9.30046& -4	0.04255	2.93538& -2
164	9.0	0.03220	8.41750& -4	0.04467	3.33816& -2
182	10.0	0.03203	7.73070& -4	0.02756	1.65740& -2
200	11.0	0.03025	6.40093& -3	0.03443	2.85251& -2
219	12.0	0.03015	6.45040& -3	0.02998	1.82039& -2
237	13.0	0.03167	6.55921& -4	0.04606	4.44702& -2
255	14.0	0.03166	6.04860& -4	0.04604	2.52180& -2
273	15.0	0.03168	5.68333& -4	0.03346	1.69958& -2
292	16.0	0.03170	5.61046& -4	0.03745	3.30216& -2
310	17.0	0.03176	5.44638& -4	0.03863	2.18939& -2
328	18.0	0.03186	5.19142& -4	0.03698	2.30161& -2
346	19.0	0.03201	5.14023& -4	0.03780	3.08939& -2
365	20.0	0.03217	5.05381& -4	0.05541	3.54062& -2
383	21.0	0.03237	4.82388& -4	0.04278	2.39172& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.03783	3.97962& -3	0.05223	6.56088& -2
197	2.0	0.03301	8.16620& -3	0.03202	2.86025& -2
295	3.0	0.03266	1.12089& -3	0.03635	2.84603& -2
394	4.0	0.03093	7.00784& -3	0.03658	1.63156& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.03403	2.18767& -3	0.03895	2.95689& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01745	1.89857& -3	0.11066	2.38184& -1
36	2.0	0.01412	3.09390& -3	0.00520	3.04801& -2
54	3.0	0.01336	1.00004& -3	0.01576	1.28806& -2
73	4.0	0.01332	5.04032& -4	0.02297	1.49441& -2
91	5.0	0.01318	4.24537& -4	0.01362	7.15046& -3
109	6.0	0.01307	3.66834& -4	0.01423	1.38149& -2
127	7.0	0.01300	3.35274& -4	0.02009	1.17877& -2
146	8.0	0.01283	3.02479& -4	0.01683	9.53302& -3
164	9.0	0.01280	2.81003& -4	0.01622	8.51158& -3
182	10.0	0.01277	2.63233& -4	0.01128	5.58015& -3
200	11.0	0.01222	2.03767& -3	0.01365	8.95885& -3
219	12.0	0.01219	2.09636& -3	0.01268	6.55818& -3
237	13.0	0.01266	2.34433& -4	0.01794	1.31643& -2
255	14.0	0.01267	2.18793& -4	0.01803	8.45827& -3
273	15.0	0.01268	2.08315& -4	0.01297	5.11784& -3
292	16.0	0.01269	2.06652& -4	0.01463	1.05033& -2
310	17.0	0.01271	2.02632& -4	0.01528	7.18310& -3
328	18.0	0.01274	1.93991& -4	0.01356	7.00867& -3
346	19.0	0.01280	1.93563& -4	0.01471	9.92630& -3
365	20.0	0.01285	1.91566& -4	0.02173	1.16064& -2
383	21.0	0.01292	1.83618& -4	0.01633	7.56354& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.01371	8.23602& -4	0.01774	1.34613& -2
197	2.0	0.01295	2.10186& -3	0.01252	6.92581& -3
295	3.0	0.01291	3.51529& -4	0.01355	7.25524& -3
394	4.0	0.01242	2.25673& -3	0.01426	5.71112& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01315	5.70826& -4	0.01498	7.25327& -3

Data Analysis Program

Run Number = 127

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.01029	2.25892& -1	-0.18891	8.57150& -1
36	2.0	0.01821	8.33854& -2	0.10385	3.90718& -1
54	3.0	0.01773	4.60632& -2	-0.07920	5.86811& -1
73	4.0	0.01412	5.83866& -2	-0.01064	4.16143& -2
91	5.0	0.01224	5.51283& -2	-0.03810	1.78194& -1
109	6.0	0.02483	9.94733& -3	0.01798	6.29177& -2
127	7.0	0.02423	6.54385& -3	0.04652	4.53784& -2
146	8.0	0.02334	1.30744& -2	0.02749	6.32822& -2
164	9.0	0.02305	1.38435& -2	0.04084	3.56475& -2
182	10.0	0.02465	8.17065& -3	0.04223	6.50626& -2
200	11.0	0.02343	1.21853& -2	0.01989	5.14257& -2
219	12.0	0.02371	1.13755& -2	0.05620	7.87946& -2
237	13.0	0.02344	1.24060& -2	0.05659	1.36342& -1
255	14.0	0.02389	1.10306& -2	0.00969	3.35986& -2
273	15.0	0.02380	1.16669& -2	0.01245	7.90428& -2
292	16.0	0.02285	1.11898& -2	0.02979	3.27168& -2
310	17.0	0.02308	1.19655& -2	0.02341	2.30455& -2
328	18.0	0.02481	9.81489& -3	0.03634	8.34039& -2
346	19.0	0.02458	1.09257& -2	-0.00801	1.09741& -1
365	20.0	0.02504	1.00624& -2	0.03186	6.32248& -2
383	21.0	0.02503	1.07940& -2	0.02691	8.20466& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00844	7.24116& -2	0.15682	5.15112& -1
197	2.0	0.02271	1.92433& -2	0.00791	9.05064& -2
295	3.0	0.02062	1.57080& -2	0.04111	6.65688& -2
394	4.0	0.02589	5.35390& -3	0.00629	4.99450& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01164	5.08864& -2	0.02463	1.00445& -1

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00824	4.00460& -3	0.01894	1.42983& -1
36	2.0	0.00906	3.98861& -3	0.04684	8.12682& -2
54	3.0	0.00847	4.29548& -3	0.00428	9.58025& -2
73	4.0	0.00916	3.97231& -3	0.00550	4.34672& -3
91	5.0	0.00935	3.99737& -3	0.00388	3.56561& -2
109	6.0	0.00947	3.99730& -3	0.01216	1.72124& -2
127	7.0	0.00921	4.05003& -3	0.01454	1.33048& -2
146	8.0	0.00954	3.98450& -3	0.01387	1.99411& -2
164	9.0	0.00960	3.99831& -3	0.01592	1.12201& -2
182	10.0	0.00965	4.00787& -3	0.01781	1.87671& -2
200	11.0	0.00968	4.01382& -3	0.00944	1.54239& -2
219	12.0	0.00971	4.02180& -3	0.02158	2.68037& -2
237	13.0	0.00971	4.01795& -3	0.02134	3.34062& -2
255	14.0	0.00973	4.02376& -3	0.00764	7.55512& -3
273	15.0	0.00977	4.03602& -3	0.01136	1.41543& -2
292	16.0	0.00929	4.30326& -3	0.01164	1.26900& -2
310	17.0	0.00944	4.38990& -3	0.01076	6.60848& -3
328	18.0	0.00989	4.07729& -3	0.01713	3.11148& -2
346	19.0	0.00994	4.09904& -3	0.00102	3.97905& -2
365	20.0	0.00999	4.11943& -3	0.01589	1.86522& -2
383	21.0	0.01006	4.15025& -3	0.01332	3.02409& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00844	3.75146& -3	0.04267	1.05051& -1
197	2.0	0.00945	3.98464& -3	0.01271	1.59475& -2
295	3.0	0.00898	4.12785& -3	0.01629	1.87144& -2
394	4.0	0.00971	4.04757& -3	0.00868	9.31784& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00886	3.80607& -3	0.01547	1.94985& -2

Data Analysis Program

Run Number = 128

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.04610	1.49614& -2	0.11725	4.46261& -1
36	2.0	0.03390	4.68946& -3	0.06358	1.46093& -1
54	3.0	0.03064	2.79853& -3	0.09259	1.02470& -1
73	4.0	0.03064	1.84746& -3	0.06274	8.32648& -2
91	5.0	0.03060	1.42991& -3	0.05018	6.26398& -2
109	6.0	0.03045	1.20662& -3	0.07885	1.36222& -1
127	7.0	0.03055	9.93810& -4	0.05422	4.80069& -2
146	8.0	0.03043	8.28939& -4	0.01252	8.33236& -2
164	9.0	0.03037	7.57675& -4	0.06687	7.28663& -2
182	10.0	0.03037	7.00239& -4	0.07652	1.31501& -1
200	11.0	0.03036	6.82732& -4	0.02540	1.43575& -2
219	12.0	0.02308	2.31680& -2	0.04201	2.81955& -2
237	13.0	0.03032	5.98673& -4	0.03572	3.33961& -2
255	14.0	0.03038	5.74333& -4	0.02921	1.90081& -2
273	15.0	0.03040	5.82316& -4	0.05724	6.05453& -2
292	16.0	0.02947	4.34257& -3	-0.04570	4.12948& -1
310	17.0	0.03062	5.07258& -4	0.05787	7.20727& -2
328	18.0	0.03075	5.41943& -4	0.04298	2.75844& -2
346	19.0	0.03092	5.07910& -4	0.04389	2.50498& -2
365	20.0	0.03107	4.59983& -4	0.03904	3.28276& -2
383	21.0	0.03129	4.47672& -4	0.02906	2.10663& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02899	3.68939& -3	0.01683	6.35245& -2
197	2.0	0.03122	1.60405& -3	0.03002	4.75446& -2
295	3.0	0.03022	1.12058& -3	0.04971	2.96617& -2
394	4.0	0.03087	8.30126& -4	0.03744	2.44815& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02920	2.02467& -3	0.02676	4.33360& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00334	3.97925& -4	0.00828	1.01865& -2
36	2.0	0.00319	2.02423& -4	0.00513	6.49982& -3
54	3.0	0.00303	1.50085& -4	0.00693	6.10366& -3
73	4.0	0.00305	1.15481& -4	0.00547	5.56496& -3
91	5.0	0.00306	9.74906& -5	0.00410	3.28378& -3
109	6.0	0.00305	8.90271& -5	0.00597	8.37212& -3
127	7.0	0.00306	7.69364& -5	0.00500	3.76236& -3
146	8.0	0.00304	6.63328& -5	0.00236	4.64199& -3
164	9.0	0.00304	6.27937& -5	0.00590	4.96225& -3
182	10.0	0.00305	5.91058& -5	0.00621	8.59685& -3
200	11.0	0.00305	5.93098& -5	0.00272	1.15862& -3
219	12.0	0.00256	1.38419& -3	0.00372	1.80985& -3
237	13.0	0.00304	5.34232& -5	0.00365	2.54633& -3
255	14.0	0.00340	5.21605& -5	0.00304	1.77400& -3
273	15.0	0.00305	5.24661& -5	0.00490	4.77328& -3
292	16.0	0.00291	5.78288& -4	-0.00232	3.09321& -2
310	17.0	0.00306	4.71553& -5	0.00520	4.33959& -3
328	18.0	0.00307	4.99553& -5	0.00407	2.25833& -3
346	19.0	0.00309	4.69280& -5	0.00414	2.28350& -3
365	20.0	0.00310	4.38254& -5	0.00390	3.03402& -3
383	21.0	0.00312	4.27282& -5	0.00291	1.84993& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00297	1.83332& -4	0.00284	3.11208& -3
197	2.0	0.00310	1.09764& -4	0.00329	3.25485& -3
295	3.0	0.00303	8.66847& -5	0.00474	2.48376& -3
394	4.0	0.00309	6.94008& -5	0.00394	2.35100& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00297	1.29354& -4	0.00314	2.46430& -3

Run Number 129

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.03812	1.89106& -2	-0.27699	5.92916& -1
36	2.0	0.03088	5.82795& -3	0.14247	3.49134& -1
54	3.0	0.02868	3.43452& -3	-0.03810	2.20632& -1
73	4.0	0.02899	2.30774& -3	0.02747	9.50742& -2
91	5.0	0.02928	1.83458& -3	-0.00932	4.39632& -2
109	6.0	0.02941	1.56770& -3	-0.03530	1.47282& -1
127	7.0	0.02827	5.76716& -3	-0.03492	1.53746& -1
146	8.0	0.02952	1.40189& -3	0.02784	3.00883& -2
164	9.0	0.02960	1.42070& -3	-0.05538	9.84550& -2
182	10.0	0.02964	1.33780& -3	-0.01239	1.05661& -1
200	11.0	0.02961	1.42039& -3	-0.01439	7.02932& -2
219	12.0	0.02960	1.42792& -3	0.01350	7.85364& -2
237	13.0	0.02954	1.53087& -3	-0.02018	8.16529& -2
255	14.0	0.02957	1.48713& -3	0.00268	1.11994& -1
273	15.0	0.02961	1.62073& -3	-0.00094	2.42300& -2
292	16.0	0.02973	1.77426& -3	-0.04080	7.40469& -2
310	17.0	0.02985	1.82018& -3	0.03195	8.97369& -2
328	18.0	0.02987	1.88347& -3	-0.00799	5.08707& -2
346	19.0	0.03015	1.95364& -3	-0.02921	9.65986& -2
365	20.0	0.03031	1.94873& -3	0.00305	4.86807& -2
383	21.0	0.03047	1.97301& -3	0.00617	2.48582& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02647	4.43262& -3	-0.11950	1.92335& -1
197	2.0	0.02982	2.20709& -3	0.03497	9.79914& -2
295	3.0	0.02907	1.86073& -3	0.10967	3.33483& -1
394	4.0	0.02989	1.63608& -3	0.01588	5.74637& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.02718	3.34777& -3	0.00946	6.29264& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00306	4.77454& -4	0.00528	3.48753& -2
36	2.0	0.00301	2.61090& -4	0.01521	2.77598& -2
54	3.0	0.00288	2.04687& -4	0.00233	1.47705& -2
73	4.0	0.00291	1.64633& -4	0.00564	8.76079& -3
91	5.0	0.00293	1.41981& -4	0.00165	2.80257& -3
109	6.0	0.00294	1.23873& -4	-0.00102	1.57760& -2
127	7.0	0.00287	3.96167& -4	-0.00025	1.15210& -2
146	8.0	0.00294	1.11657& -4	0.00478	4.07549& -3
164	9.0	0.00295	1.13100& -4	-0.00231	9.43294& -3
182	10.0	0.00295	1.05719& -4	0.00049	1.27576& -2
200	11.0	0.00295	1.15432& -4	0.00024	5.62931& -3
219	12.0	0.00295	1.16275& -4	0.00333	5.96562& -3
237	13.0	0.00294	1.24085& -4	-0.00085	8.54787& -3
255	14.0	0.00295	1.21633& -4	0.00166	1.00138& -2
273	15.0	0.00295	1.35160& -4	0.00072	1.88494& -3
292	16.0	0.00296	1.49083& -4	-0.00362	7.69559& -3
310	17.0	0.00297	1.51870& -4	0.00469	9.91077& -3
328	18.0	0.00296	1.58281& -4	0.00022	5.29032& -3
346	19.0	0.00299	1.63381& -4	-0.00238	1.11756& -2
365	20.0	0.00300	1.61253& -4	0.00131	4.96058& -3
383	21.0	0.00301	1.62024& -4	0.00163	2.36851& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00280	2.26239& -4	-0.00011	8.59413& -3
197	2.0	0.00296	1.65229& -4	0.00531	7.68999& -3
295	3.0	0.00291	1.53497& -4	0.01184	3.27922& -2
394	4.0	0.00297	1.37053& -4	0.00243	3.82281& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00277	3.03913& -4	0.00217	3.22335& -3

Data Analysis Program

Run Number = 130

Time Marker Pulse Setting = 1.0
Number of Channels = 2
Data Values per Channel = 400
Sets of Readings = 15

Time Constant 1

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.06804	4.77695& -2	-0.16125	4.10084& -1
36	2.0	0.04079	1.63795& -2	-0.22854	3.99349& -1
54	3.0	0.03371	1.07402& -2	-0.09917	3.36356& -1
73	4.0	0.03239	8.56366& -3	-0.05779	9.48175& -2
91	5.0	0.03194	6.12296& -3	-0.00965	2.04417& -1
109	6.0	0.03177	5.09934& -3	0.02245	1.32701& -1
127	7.0	0.03153	4.35045& -3	-0.02589	9.60811& -2
146	8.0	0.02960	7.45913& -3	-0.03692	6.06816& -2
164	9.0	0.02980	6.97149& -3	-0.03598	7.32083& -2
182	10.0	0.03107	3.23489& -3	-0.03393	1.70458& -1
200	11.0	0.03096	2.94725& -3	0.00651	8.00294& -2
219	12.0	0.03097	2.74491& -3	0.00135	1.64288& -1
237	13.0	0.03084	2.63372& -3	-0.06773	1.60257& -1
255	14.0	0.03085	2.47692& -3	-0.01159	3.51536& -2
273	15.0	0.03099	2.42338& -3	-0.01735	3.53887& -2
292	16.0	0.03100	2.26210& -3	-0.01195	1.59179& -1
310	17.0	0.03108	2.21490& -3	0.00549	8.12312& -2
328	18.0	0.03118	2.15389& -3	-0.00364	5.46745& -2
346	19.0	0.02532	2.32879& -2	-0.03741	9.68501& -2
365	20.0	0.03041	4.32421& -3	-0.01194	3.23584& -2
383	21.0	0.03176	1.98607& -3	-0.00070	5.53455& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.03360	1.31361& -2	-0.01847	1.74029& -1
197	2.0	0.03324	5.98768& -3	-0.16656	7.31384& -1
295	3.0	0.03196	5.32352& -3	0.00475	1.56487& -1
394	4.0	0.03212	4.39578& -3	0.01008	4.36378& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.03159	7.58451& -3	-0.00228	9.92039& -2

Time Constant 2

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00404	1.24190& -3	0.01434	2.39361& -2
36	2.0	0.00354	7.08320& -4	-0.01302	4.75503& -2
54	3.0	0.00324	5.60698& -4	-0.00634	4.46554& -2
73	4.0	0.00320	5.09341& -4	0.00230	7.29276& -3
91	5.0	0.00318	4.10390& -4	0.00606	2.53545& -2
109	6.0	0.00318	3.67552& -4	0.00579	1.85106& -2
127	7.0	0.00317	3.32316& -4	-0.00092	1.20766& -2
146	8.0	0.00298	6.93640& -4	-0.00086	6.31732& -3
164	9.0	0.00303	5.39474& -4	-0.00063	1.07353& -2
182	10.0	0.00313	2.71279& -4	-0.00182	1.89727& -2
200	11.0	0.00313	2.52516& -4	0.00359	1.02363& -2
219	12.0	0.00313	2.40718& -4	0.00239	2.04138& -2
237	13.0	0.00311	2.33237& -4	-0.00021	1.50169& -2
255	14.0	0.00311	2.23039& -4	0.00146	2.97596& -3
273	15.0	0.00313	2.20648& -4	-0.00013	3.31501& -3
292	16.0	0.00313	2.07711& -4	0.00157	2.25843& -2
310	17.0	0.00314	2.04805& -4	0.00268	1.09625& -2
328	18.0	0.00314	2.00440& -4	0.00120	9.56211& -3
346	19.0	0.00276	1.54726& -3	-0.00538	1.85381& -2
365	20.0	0.00302	5.99226& -4	-0.00017	5.04086& -3
383	21.0	0.00319	1.88655& -4	0.00215	8.35318& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00324	6.48595& -4	0.00424	1.34387& -2
197	2.0	0.00326	4.10606& -4	-0.01335	8.40958& -2
295	3.0	0.00317	3.62146& -4	0.00554	2.12673& -2
394	4.0	0.00320	3.28668& -4	0.00281	4.03096& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00315	4.82382& -4	0.00326	7.16948& -3

Data Analysis Program

Run Number = 200

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	-0.02883	9.44889& -2	-0.17052	1.21462& -1
36	2.0	-0.00718	4.30435& -2	-0.02474	4.17360& -2
54	3.0	-0.00053	2.98881& -2	-0.00072	3.42762& -2
73	4.0	0.00167	2.27974& -2	0.00636	2.76745& -2
91	5.0	0.00046	1.87017& -2	-0.00116	1.97232& -2
109	6.0	0.00353	1.45650& -2	0.00143	1.41640& -2
127	7.0	0.00392	1.20050& -2	0.00466	1.28853& -2
146	8.0	0.00537	1.02361& -2	0.00461	1.05676& -2
164	9.0	0.00642	9.16550& -3	0.00768	1.17181& -2
182	10.0	0.00593	8.07457& -3	0.00636	8.56762& -3
200	11.0	0.00585	7.52257& -3	0.00443	7.04977& -3
219	12.0	0.00632	6.51499& -3	0.00595	6.61982& -3
237	13.0	0.00771	5.47654& -3	0.00767	5.62723& -3
255	14.0	0.00612	5.96156& -3	0.00582	6.20642& -3
273	15.0	0.00620	5.64182& -3	0.00638	6.15077& -3
292	16.0	0.00765	4.89703& -3	0.00857	5.52056& -3
310	17.0	0.00794	4.88608& -3	0.00890	5.97660& -3
328	18.0	0.00816	3.87053& -3	0.00780	3.85171& -3
346	19.0	0.00813	4.23841& -3	0.00775	4.02302& -3
365	20.0	0.00789	4.23282& -3	0.00781	4.19749& -3
383	21.0	0.00779	4.61288& -3	0.00801	4.73432& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	-0.00900	4.62626& -2	-0.03192	4.30648& -2
197	2.0	-0.00085	2.31972& -2	-0.00368	2.30364& -2
295	3.0	0.00335	1.49301& -2	0.00513	1.61603& -2
394	4.0	0.00523	1.03930& -2	0.00546	1.03889& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	-0.00312	3.29578& -2	-0.00847	3.19673& -2

Data Analysis Program

Run Number = 201

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00712	5.83411& -3	-0.32491	5.25713& -2
36	2.0	0.01039	4.55998& -3	-0.13781	7.16059& -2
54	3.0	0.01148	1.19004& -3	-0.03580	3.44384& -2
73	4.0	0.01041	2.66246& -4	-0.01615	3.20251& -2
91	5.0	0.01004	6.24398& -4	0.00728	1.59473& -2
109	6.0	0.00962	8.98988& -4	0.01384	9.24645& -3
127	7.0	0.00959	6.82666& -4	0.01195	1.31944& -2
146	8.0	0.01000	4.97427& -4	0.01022	6.54975& -3
164	9.0	0.00990	3.54915& -4	0.00695	9.39182& -3
182	10.0	0.00983	3.11480& -4	0.00774	5.19591& -3
200	11.0	0.00888	3.69808& -3	0.01462	7.97127& -3
219	12.0	0.00986	1.67231& -4	0.00900	4.25206& -3
237	13.0	0.01004	1.42244& -4	0.01025	4.58196& -3
255	14.0	0.01005	9.92854& -5	0.00778	2.27901& -3
273	15.0	0.00930	3.02059& -3	0.00879	5.11907& -3
292	16.0	0.01012	8.26370& -5	0.00854	4.00528& -3
310	17.0	0.01012	5.09170& -5	0.00947	2.28984& -3
328	18.0	0.01023	6.65951& -5	0.01049	3.38705& -3
346	19.0	0.01027	6.02466& -5	0.01106	2.44926& -3
365	20.0	0.01030	4.41536& -5	0.01024	2.46546& -3
383	21.0	0.01033	3.18625& -5	0.01214	2.57548& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00903	6.47593& -4	-0.07845	4.56304& -2
197	2.0	0.00984	3.38908& -4	-0.00239	2.32805& -2
295	3.0	0.00986	2.51994& -4	-0.00016	7.53601& -3
394	4.0	0.00984	5.80950& -5	0.00422	5.52018& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00954	2.20480& -4	-0.01126	3.00097& -2

Data Analysis Program

Run Number = 202

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00937	5.43571& -3	-0.26338	4.94405& -2
36	2.0	0.00935	1.05903& -3	-0.16184	7.39642& -2
54	3.0	0.01103	4.97250& -4	-0.05650	6.20447& -2
73	4.0	0.01047	2.91494& -4	-0.00503	2.55937& -2
91	5.0	0.00931	3.02955& -3	-0.01464	2.69801& -2
109	6.0	0.00915	2.45545& -3	-0.00289	1.12541& -2
127	7.0	0.00917	2.11666& -3	0.00253	1.49964& -2
146	8.0	0.01005	1.27004& -4	0.00452	4.27532& -2
164	9.0	0.00996	8.57926& -5	-0.00441	2.63837& -2
182	10.0	0.00985	7.20961& -5	0.00001	2.13034& -2
200	11.0	0.00795	5.09410& -3	-0.00007	1.07565& -2
219	12.0	0.00985	6.90078& -5	0.01513	8.02305& -3
237	13.0	0.01004	5.54935& -5	0.01039	5.16080& -3
255	14.0	0.01008	4.42663& -5	0.01339	8.97251& -3
273	15.0	0.01009	4.41221& -5	0.01190	4.49164& -3
292	16.0	0.01008	5.76593& -5	0.00943	4.76097& -3
310	17.0	0.01001	5.44105& -5	0.01037	4.40457& -3
328	18.0	0.01024	4.35410& -5	0.00969	4.34476& -3
346	19.0	0.00959	2.58912& -3	0.00932	4.59262& -3
365	20.0	0.01029	3.28556& -5	0.01137	5.33948& -3
383	21.0	0.01006	9.73253& -4	0.00764	2.60129& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00908	6.94808& -4	-0.09348	5.26602& -2
197	2.0	0.00969	1.65607& -4	-0.02965	4.14573& -2
295	3.0	0.00982	1.65607& -4	0.00223	1.73225& -2
394	4.0	0.00974	2.48393& -4	0.00394	6.10860& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00917	1.25639& -3	-0.03008	3.76380& -2

Data Analysis Program

Run Number = 203

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.03696	6.15663& -2	-0.22009	1.48346& -1
36	2.0	0.09486	2.79416& -1	-0.04699	9.04093& -2
54	3.0	0.02572	2.72947& -2	-0.00407	5.23898& -2
73	4.0	0.02075	1.95104& -2	0.00876	2.57064& -2
91	5.0	0.01802	1.53448& -2	0.00979	1.97390& -2
109	6.0	0.01598	1.21797& -2	0.00855	1.42881& -2
127	7.0	0.01439	1.10429& -2	0.01306	1.20658& -2
146	8.0	0.01486	9.56902& -3	0.01579	1.05949& -2
164	9.0	0.01358	8.93182& -3	0.01446	9.48128& -3
182	10.0	0.01153	7.02294& -3	0.01251	9.70911& -3
200	11.0	0.01153	7.02294& -3	0.01251	9.70911& -3
219	12.0	0.01145	7.97461& -3	0.01093	8.23089& -3
237	13.0	0.01228	5.21105& -3	0.01138	7.06039& -3
255	14.0	0.01048	8.02677& -3	0.01010	9.22644& -3
273	15.0	0.01268	5.14845& -3	0.01283	4.61837& -3
292	16.0	0.01005	5.72413& -3	0.01097	7.10224& -3
310	17.0	0.01170	5.63106& -3	0.01270	6.39005& -3
328	18.0	0.01191	3.43612& -3	0.01289	3.80082& -3
346	19.0	0.01182	3.30002& -3	0.01311	3.92245& -3
365	20.0	0.01225	3.92272& -3	0.01284	4.73054& -3
383	21.0	0.01220	3.71432& -3	0.01420	6.21316& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.02100	2.81974& -2	-0.05577	8.55147& -2
197	2.0	0.01676	1.44198& -2	0.01006	1.31356& -2
295	3.0	0.01445	9.85573& -3	0.01396	1.40044& -2
394	4.0	0.01365	7.25347& -3	0.01313	8.26655& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.01377	1.23459& -2	-0.00648	2.95663& -2

Data Analysis Program

Run Number = 204

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	0.00002	8.20376& -3	-0.25310	5.85474& -2
36	2.0	0.00738	1.85112& -3	-0.11722	6.05277& -2
54	3.0	0.01031	7.44135& -4	-0.03497	6.76941& -2
73	4.0	0.01011	3.85710& -4	-0.01198	2.54082& -2
91	5.0	0.00989	2.88154& -4	-0.00807	2.67865& -2
109	6.0	0.00967	2.05832& -4	-0.00342	1.12356& -2
127	7.0	0.00854	2.85187& -3	-0.00640	2.76649& -2
146	8.0	0.00994	1.11391& -4	0.00125	2.66599& -2
164	9.0	0.00984	1.42190& -4	0.00764	9.54150& -3
182	10.0	0.00942	1.57825& -3	0.00299	6.35004& -3
200	11.0	0.00847	3.91929& -3	0.00114	1.49583& -2
219	12.0	0.00984	1.25007& -4	0.00865	8.17895& -3
237	13.0	0.01003	1.04046& -4	0.00805	1.21054& -2
255	14.0	0.01000	5.36198& -5	0.00966	1.03590& -2
273	15.0	0.01007	9.23956& -5	0.00814	1.52748& -2
292	16.0	0.01003	6.73281& -5	0.01214	4.96467& -3
310	17.0	0.01006	7.60351& -5	0.01145	4.03489& -3
328	18.0	0.01021	6.14901& -5	0.00862	3.63536& -3
346	19.0	0.01021	7.54666& -5	0.00960	3.62627& -3
365	20.0	0.01024	6.91460& -5	0.01317	6.26333& -3
383	21.0	0.01029	6.43349& -5	0.01038	3.63835& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	0.00786	9.22190& -4	-0.08156	8.35672& -2
197	2.0	0.00890	1.34529& -3	-0.01431	2.25897& -2
295	3.0	0.00967	1.47900& -4	0.01233	1.01504& -2
394	4.0	0.00919	1.38638& -3	0.00398	6.27380& -3

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00900	9.58710& -4	-0.03547	4.64812& -2

Data Analysis Program

Run Number = 205

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
18	1.0	-0.00017	7.44558& -3	-0.27415	5.82639& -2
36	2.0	0.00676	1.36850& -3	-0.10478	3.64960& -2
54	3.0	0.00963	9.24718& -4	-0.06355	3.43679& -2
73	4.0	0.00860	3.72129& -3	-0.03609	3.29617& -2
91	5.0	0.00944	3.80697& -4	-0.03659	3.78935& -2
109	6.0	0.00860	2.34858& -3	-0.01533	3.46001& -2
127	7.0	0.00932	5.82031& -4	-0.00876	2.10359& -2
146	8.0	0.00954	9.47592& -5	-0.01771	2.50307& -2
164	9.0	0.00840	4.25704& -3	-0.01362	2.99954& -2
182	10.0	0.00915	1.52169& -3	-0.00535	2.36635& -2
200	11.0	0.00853	2.83925& -3	-0.00184	1.40779& -2
219	12.0	0.00963	1.41910& -4	0.00398	1.75375& -2
237	13.0	0.00908	3.31436& -3	0.00695	1.33253& -2
255	14.0	0.00917	1.64470& -3	0.00286	2.94945& -2
273	15.0	0.00992	5.70935& -4	0.00912	1.40725& -2
292	16.0	0.00883	2.93103& -3	0.00813	9.21729& -3
310	17.0	0.00889	2.89875& -3	0.01071	1.07798& -2
328	18.0	0.00973	1.08248& -3	0.00601	6.41949& -3
346	19.0	0.00936	2.56214& -3	0.01080	5.96818& -3
365	20.0	0.00946	2.46253& -3	0.01095	1.28261& -2
383	21.0	0.01009	1.08465& -4	0.00750	1.61519& -2

Quadrature Size = 6

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
98	1.0	0.00649	2.74513& -3	-0.12275	4.97681& -2
197	2.0	0.00692	4.90599& -3	-0.04212	3.07196& -2
295	3.0	0.00917	9.36355& -4	-0.00645	2.57725& -2
394	4.0	0.00829	2.51183& -3	-0.00392	1.81198& -2

Quadrature Size = 9

SP	SI	CHANNEL 1 MEAN	CHANNEL 1 STD. DEV.	CHANNEL 2 MEAN	CHANNEL 2 STD. DEV.
257	1.0	0.00915	1.70235& -3	-0.05073	3.12406& -2

Data Analysis Program

Run Number = 206

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	-0.04485	1.21849& -2	-0.24569	6.16763& -2
36	2.0	-0.00510	3.46061& -3	-0.12848	5.39237& -2
54	3.0	0.00328	1.83439& -3	-0.07023	5.12496& -2
73	4.0	0.00555	1.08821& -3	-0.04133	5.62495& -2
91	5.0	0.00519	4.31904& -3	-0.00557	6.59157& -2
109	6.0	0.00716	4.68591& -4	0.00537	1.72071& -2
127	7.0	0.00621	5.26932& -3	-0.00397	2.40459& -2
146	8.0	0.00712	3.74902& -3	0.00545	6.38851& -2
164	9.0	0.00882	3.96374& -4	-0.00462	2.70451& -2
182	10.0	0.00863	4.02428& -4	-0.00586	3.07801& -2
200	11.0	0.00655	4.66747& -3	-0.00354	1.54807& -2
219	12.0	0.00843	1.23768& -3	0.00655	1.14150& -2
237	13.0	0.00908	3.01279& -4	0.00382	1.12564& -2
255	14.0	0.00803	2.84028& -3	0.01057	8.46290& -3
273	15.0	0.00820	2.75199& -3	0.00503	1.39041& -2
292	16.0	0.00925	3.22066& -4	0.00805	6.35746& -3
310	17.0	0.00861	2.67234& -3	0.00995	7.53388& -3
328	18.0	0.00940	2.62181& -4	0.00992	1.23089& -2
346	19.0	0.00877	2.63087& -3	0.00903	8.40962& -3
365	20.0	0.00869	2.57334& -3	0.00946	7.49693& -3
383	21.0	0.00958	2.57973& -4	0.00596	4.52788& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	-0.00386	6.30177& -3	-0.12246	5.71765& -2
197	2.0	0.00480	3.59818& -3	-0.02728	4.19009& -2
295	3.0	0.00740	1.39061& -3	-0.00236	1.48662& -2
394	4.0	0.00835	4.12048& -4	0.00123	1.22440& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00455	2.00250& -3	-0.04367	3.91418& -2

Data Analysis Program

Run Number = 207

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	-0.04186	1.61825& -2	-0.23117	7.31180& -2
36	2.0	-0.00302	8.67285& -3	-0.13058	4.23662& -2
54	3.0	0.00235	7.79970& -3	-0.08539	5.37965& -2
73	4.0	0.00474	5.46105& -3	-0.06050	2.01861& -2
91	5.0	0.00634	4.43385& -3	-0.05673	2.35655& -2
109	6.0	0.00703	9.84261& -4	-0.03910	3.15307& -2
127	7.0	0.00789	1.07653& -3	-0.03606	1.89159& -2
146	8.0	0.00831	9.38401& -4	-0.01643	1.33781& -2
164	9.0	0.00827	5.62599& -4	-0.02267	2.60256& -2
182	10.0	0.00690	3.34569& -3	-0.02352	2.54485& -2
200	11.0	0.00852	4.75658& -4	-0.01750	1.48045& -2
219	12.0	0.00871	3.91356& -4	0.00266	2.32019& -2
237	13.0	0.00894	3.14261& -4	-0.00202	1.37383& -2
255	14.0	0.00912	1.88710& -4	-0.02340	7.14833& -2
273	15.0	0.00827	2.85452& -3	-0.01616	3.82659& -2
292	16.0	0.00917	2.70471& -4	-0.01092	2.19361& -2
310	17.0	0.00891	1.13062& -3	0.00147	1.22053& -2
328	18.0	0.00869	2.47064& -3	-0.00724	1.56046& -2
346	19.0	0.00961	2.43716& -4	0.00067	1.76661& -2
365	20.0	0.00953	2.20101& -4	0.00065	2.23131& -2
383	21.0	0.00893	2.37500& -3	-0.00333	1.35821& -2

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	-0.00036	8.73649& -3	-0.14019	3.49813& -2
197	2.0	0.00632	1.21413& -3	-0.06421	3.08205& -2
295	3.0	0.00737	1.50951& -3	-0.03454	2.34073& -2
394	4.0	0.00802	1.33071& -3	-0.02825	1.90315& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00471	3.62891& -3	-0.08224	3.94941& -2

Data Analysis Program

Run Number = 208[illegible]

Time Marker Pulse Setting = 1.0
Number of Channels = 3
Data Values per Channel = 400
Sets of Readings = 15

Quadrature Size = 3

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
18	1.0	-0.05347	4.77984& -2	-0.29039	3.40677& -2
36	2.0	-0.01107	2.83374& -2	-0.14470	3.16220& -2
54	3.0	0.00030	1.68310& -2	-0.09622	2.30451& -2
73	4.0	0.00195	1.30639& -2	-0.06480	2.04049& -2
91	5.0	0.00396	9.86765& -3	-0.04985	2.55363& -2
109	6.0	0.00573	7.66803& -3	-0.03558	1.62184& -2
127	7.0	0.00489	7.55793& -3	-0.02189	2.04587& -2
146	8.0	0.00588	9.55330& -3	-0.02582	2.54863& -2
164	9.0	0.00722	4.84371& -3	-0.02008	1.01132& -2
182	10.0	0.00721	4.39427& -3	-0.02005	1.85187& -2
200	11.0	0.00806	3.98413& -3	-0.02081	2.03846& -2
219	12.0	0.00723	6.64458& -3	-0.02300	2.18909& -2
237	13.0	0.00839	3.06714& -3	-0.01690	1.43328& -2
255	14.0	0.00803	2.97850& -3	-0.01203	1.10578& -2
273	15.0	0.00775	3.68835& -3	-0.00519	1.02404& -2
292	16.0	0.00877	2.50880& -3	-0.00790	1.25284& -2
310	17.0	0.00884	2.28549& -3	-0.00431	1.59643& -2
328	18.0	0.00781	3.94460& -3	-0.01600	1.76070& -2
346	19.0	0.00879	2.32009& -3	-0.00692	1.91003& -2
365	20.0	0.00924	1.98212& -3	-0.00872	1.78282& -2
383	21.0	0.00875	2.16754& -3	-0.00322	2.40149& -3

Quadrature Size = 6

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
98	1.0	-0.00786	2.55866& -2	-0.14650	4.48173& -2
197	2.0	0.00344	1.23076& -2	-0.06875	2.17948& -2
295	3.0	0.00567	7.81808& -3	-0.03599	2.42548& -2
394	4.0	0.00540	8.14642& -3	-0.02272	1.65932& -2

Quadrature Size = 9

		CHANNEL 1		CHANNEL 2	
SP	SI	MEAN	STD. DEV.	MEAN	STD. DEV.
257	1.0	0.00107	1.49313& -2	-0.08665	3.87649& -2

Appendix IV

Graphs 1 - 21 are the standard deviation graphs, whilst graphs 22 - 33 show the behaviour of the means of the parameter estimates.

For graphs 1 - 21 the following list is for curve identification:

————————	Sample Size = 3
———— ————	Sample Size = 6
———— – ————	Sample Size = 9

For graphs 22 - 33:

⊙	Noise free results
⊡	Results with added noise level of standard deviation 0.022

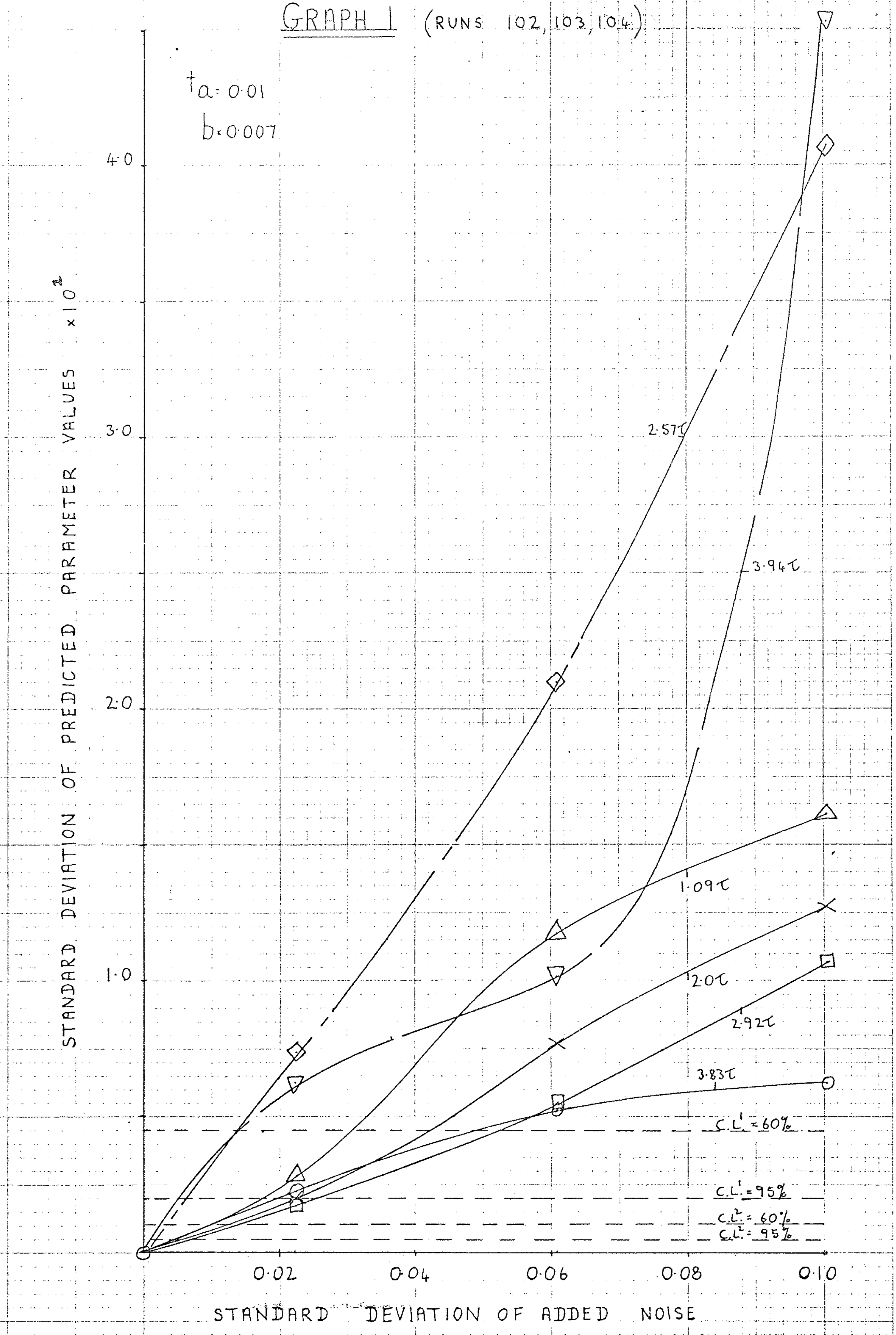
Notes

† This shows the parameter displayed in the graph.
(Note: Both parameters were estimated simultaneously.)

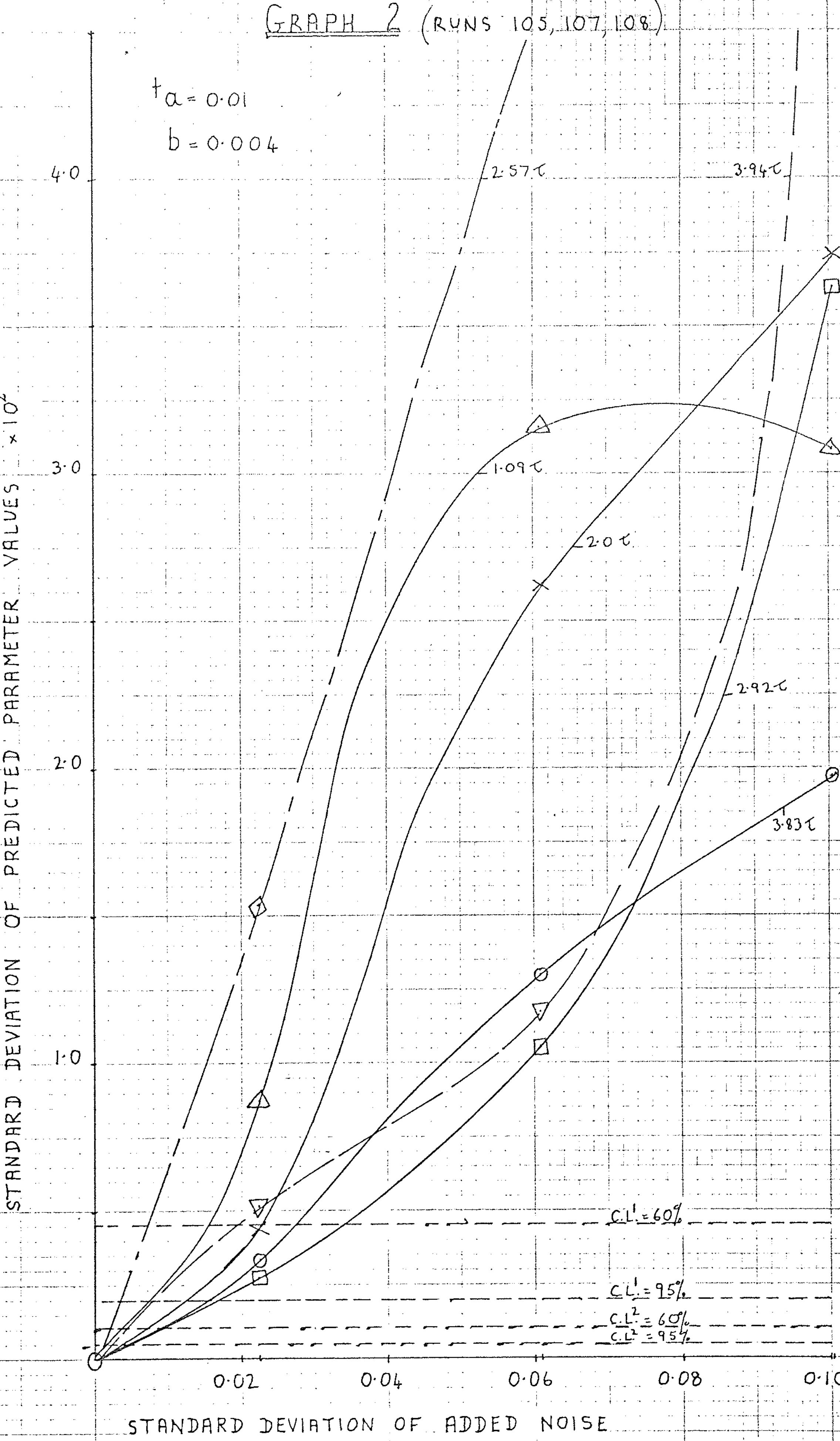
a : Model parameter

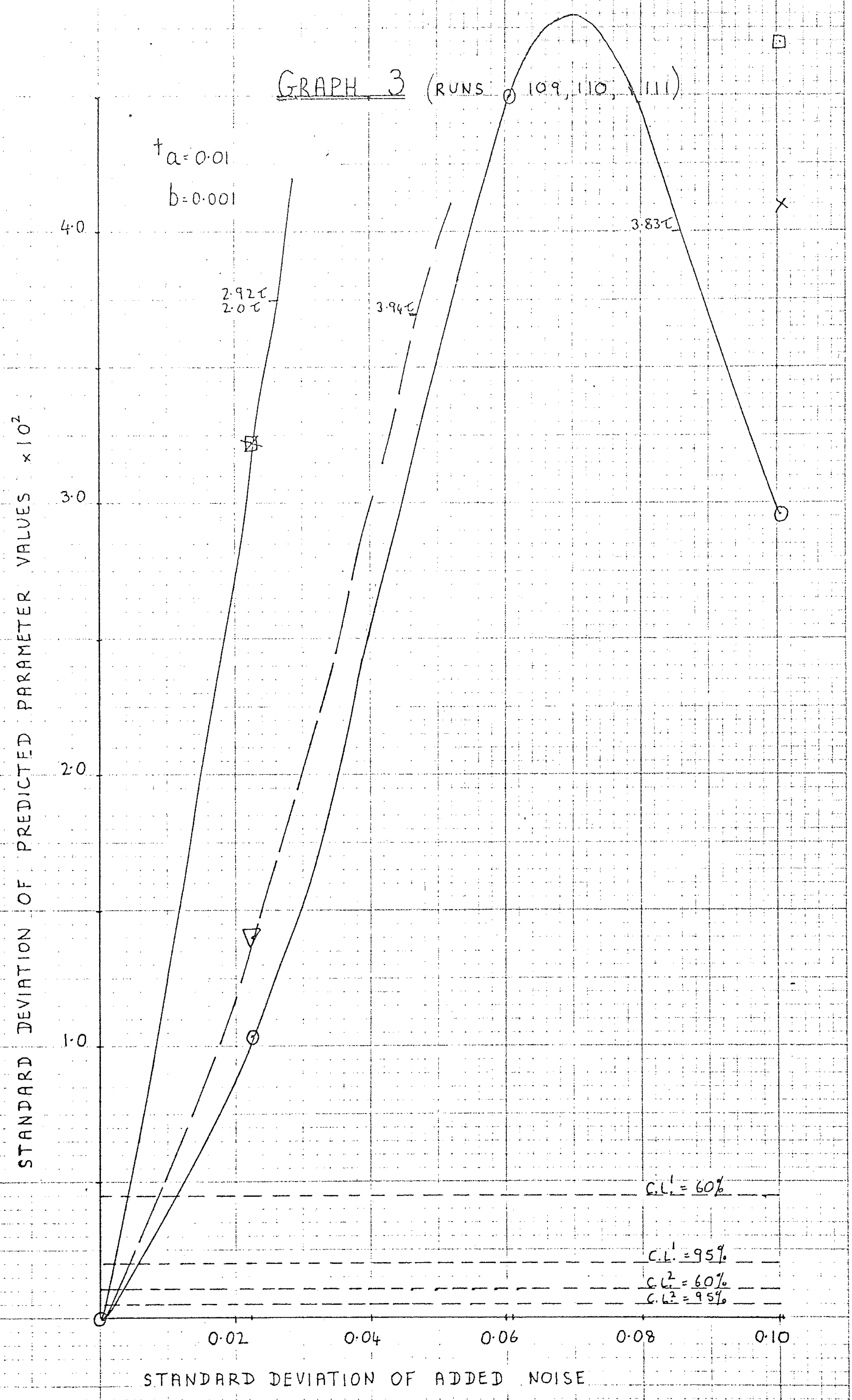
b : Step input amplitude

c : Forcing function final amplitude where the form of the forcing function is unknown

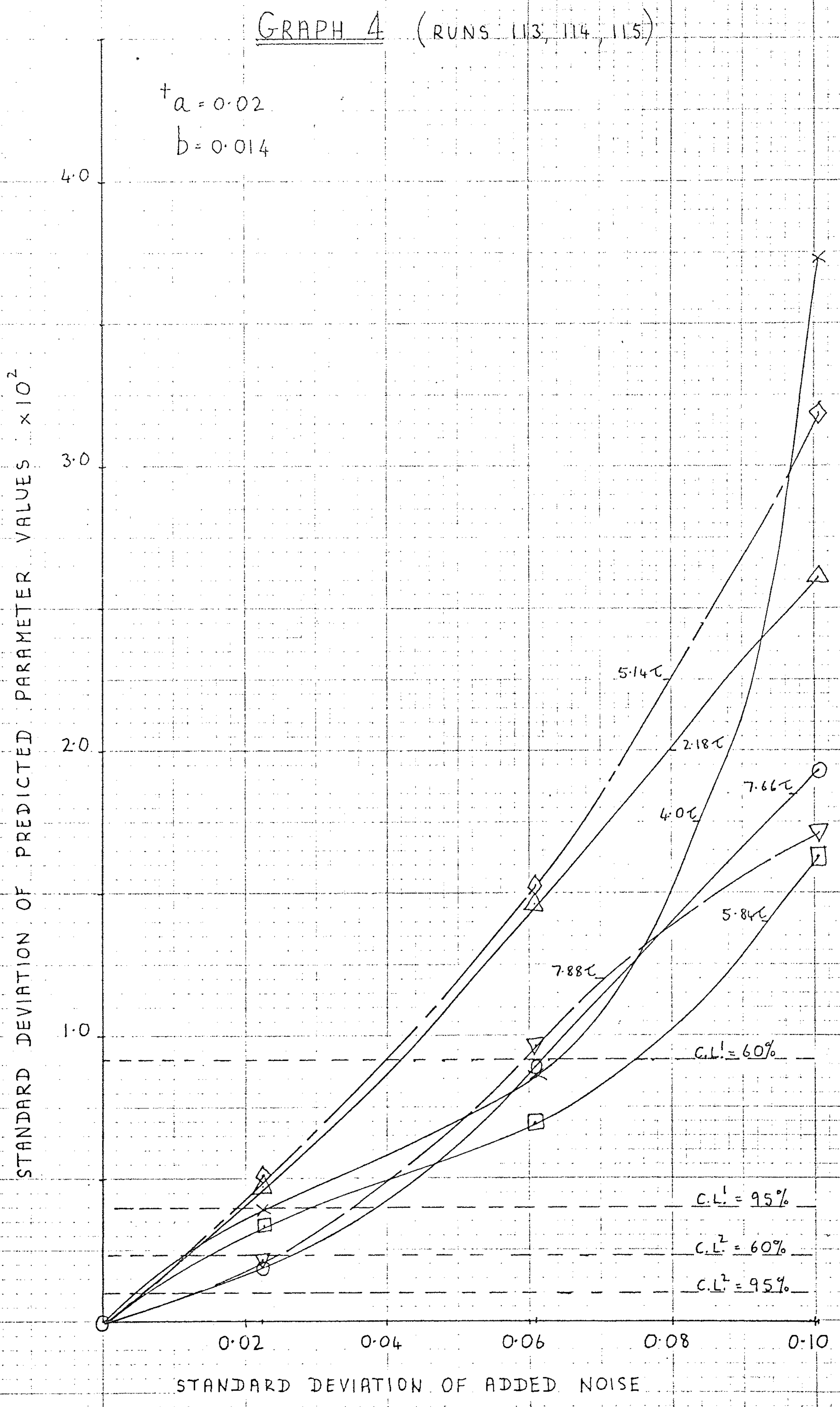


GRAPH I (RUNS 102, 103, 104)
ta=0·01
b=0·007
4·0
3·0
2·0
1·0
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10²
2·57τ
3·94τ
1·09τ
2·0τ
2·92τ
3·83τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE

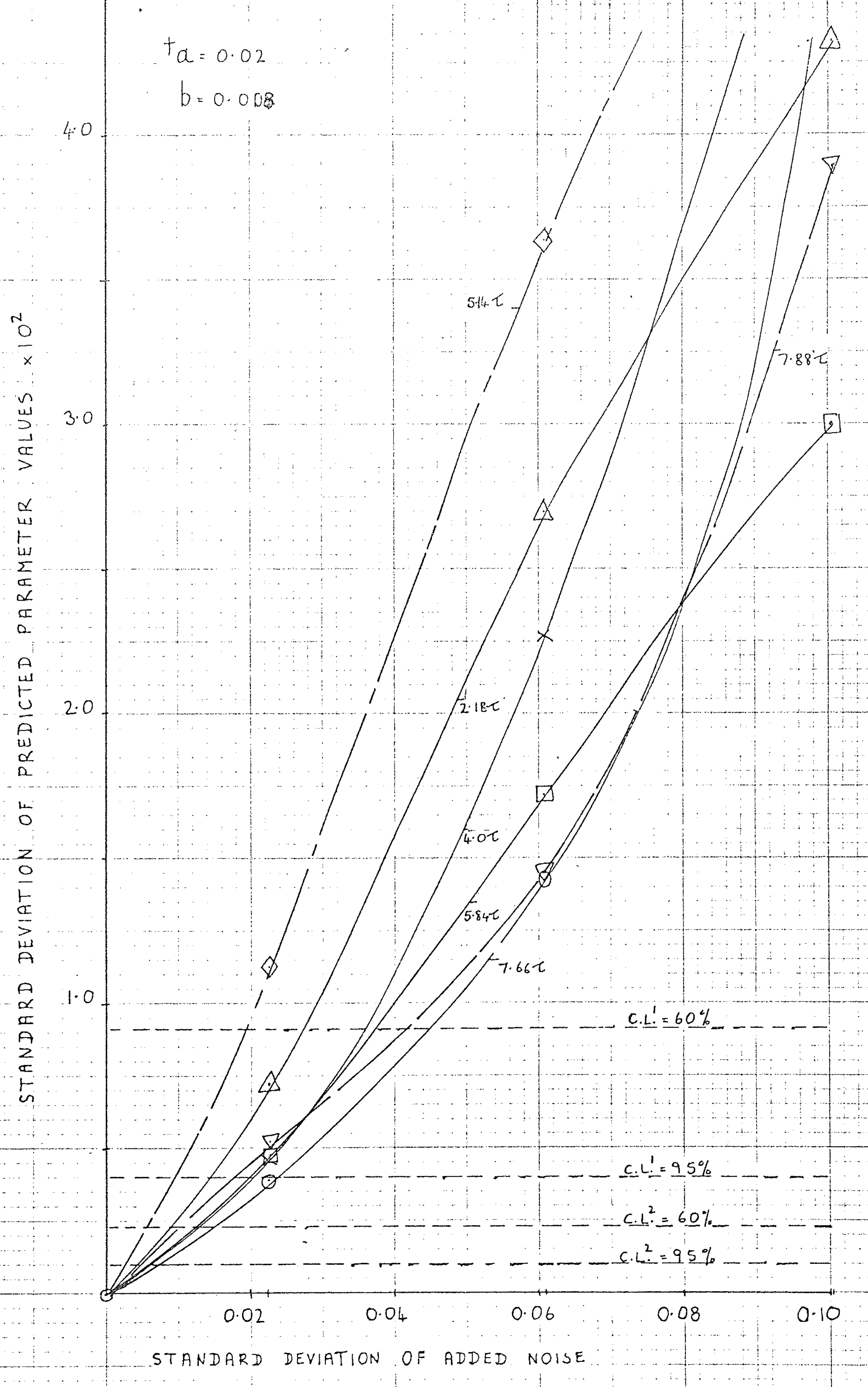

GRAPH 2 (RUNS 105, 107, 108)
ta = 0·01
b = 0·004
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10²
4·0
3·0
2·0
1·0
2·57τ
3·94τ
1·09τ
2·0τ
2·92τ
3·83τ
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE

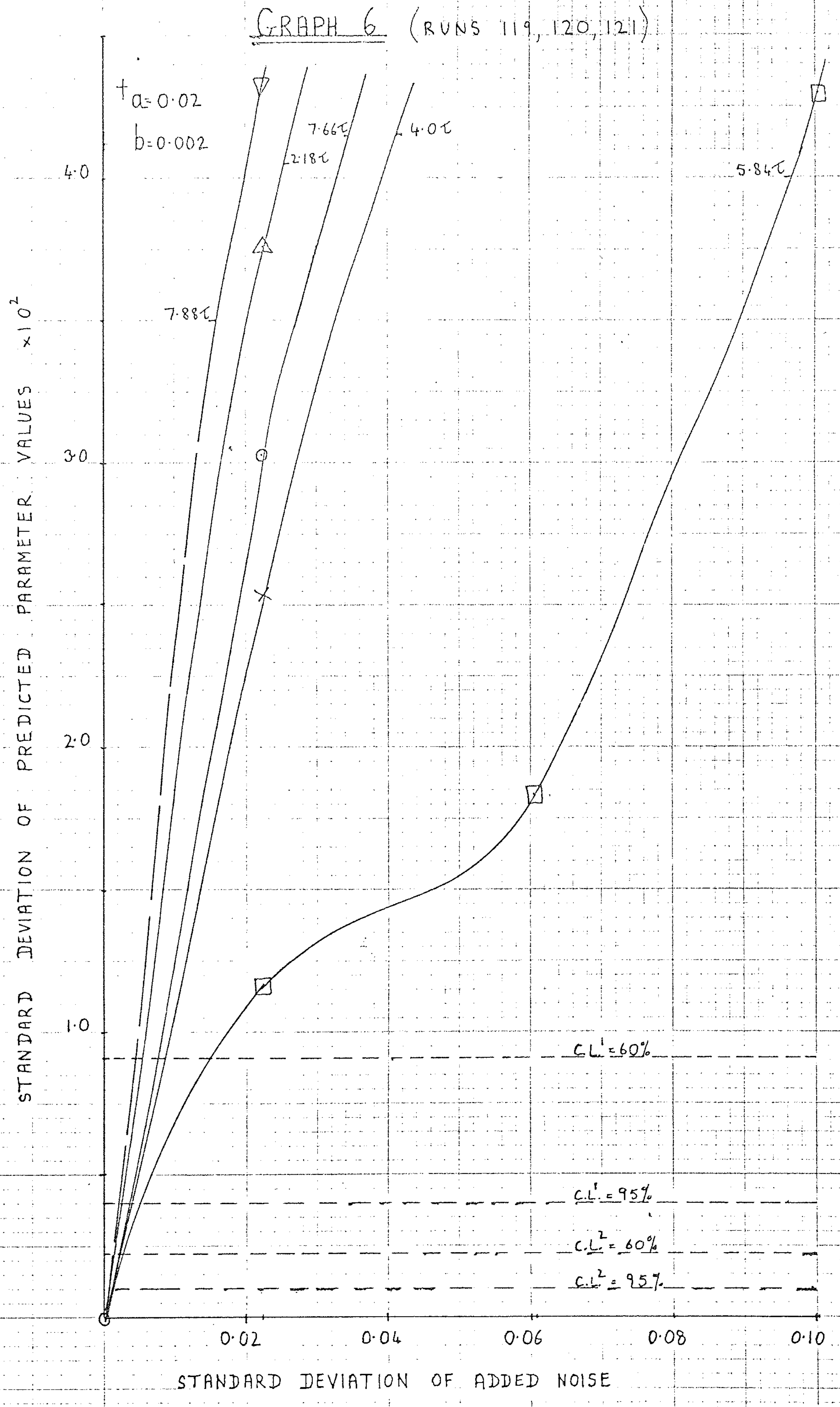


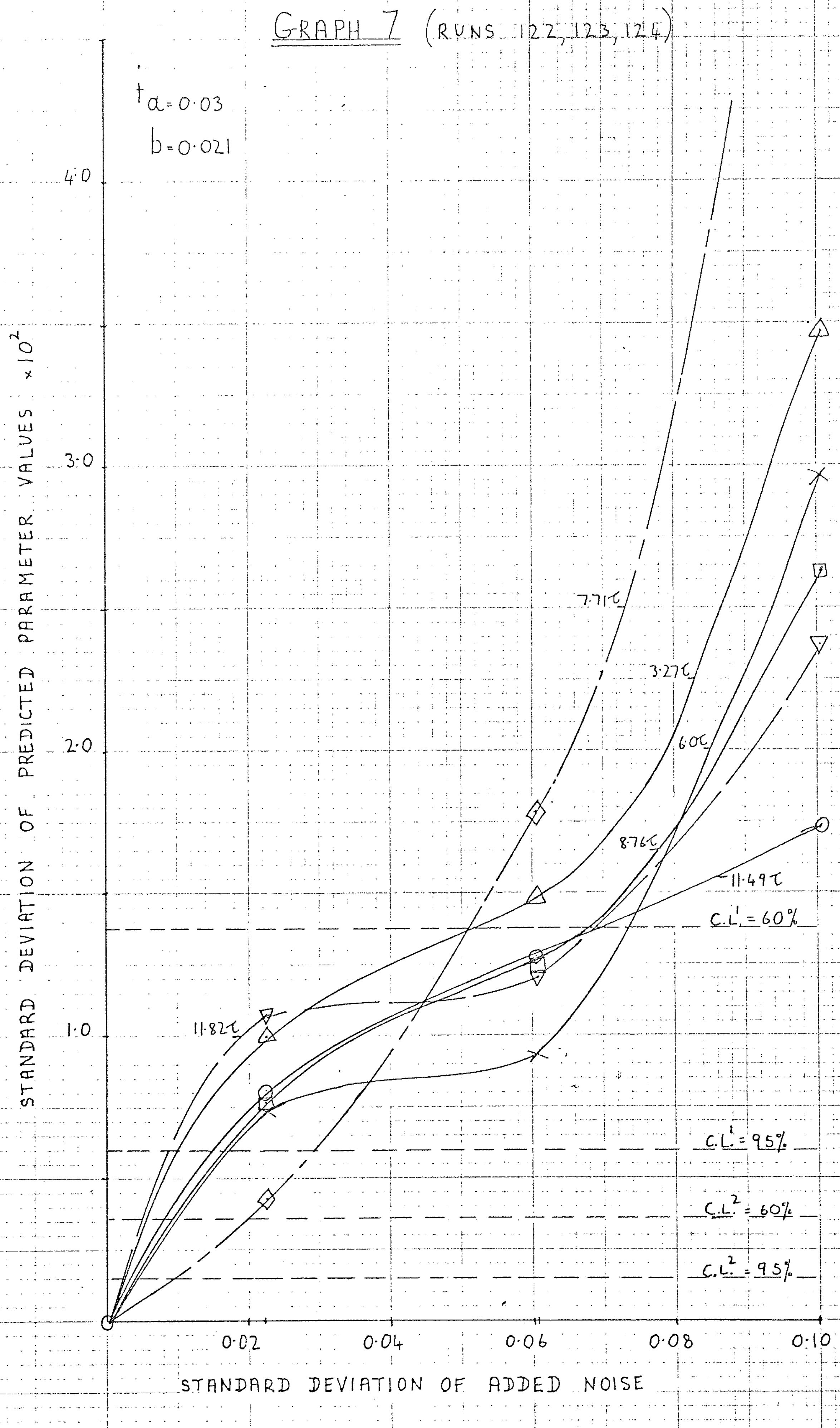
GRAPH 3 (RUNS 109, 110, 111)
+a=0·01
b=0·001
2·92τ
2·0τ
3·94τ
3·83τ
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10²
4·0
3·0
2·0
1·0
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE


GRAPH 4 (RUNS 113, 114, 115)
+a = 0·02
b = 0·014
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10²
4·0
3·0
2·0
1·0
5·14τ
2·18τ
7·66τ
4·0τ
5·84τ
7·88τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE

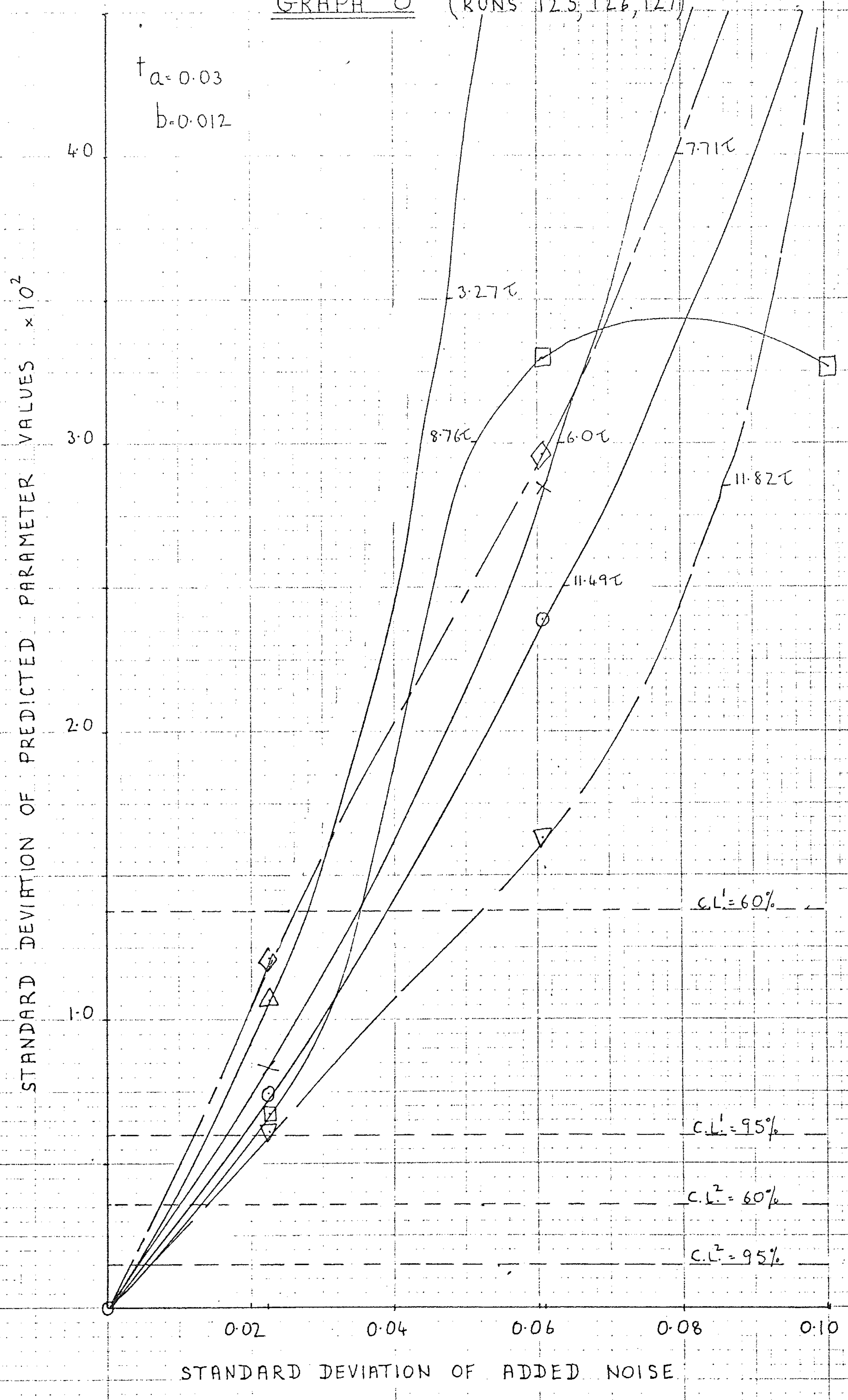
GRAPH 5 (RUNS 116, 117, 118)

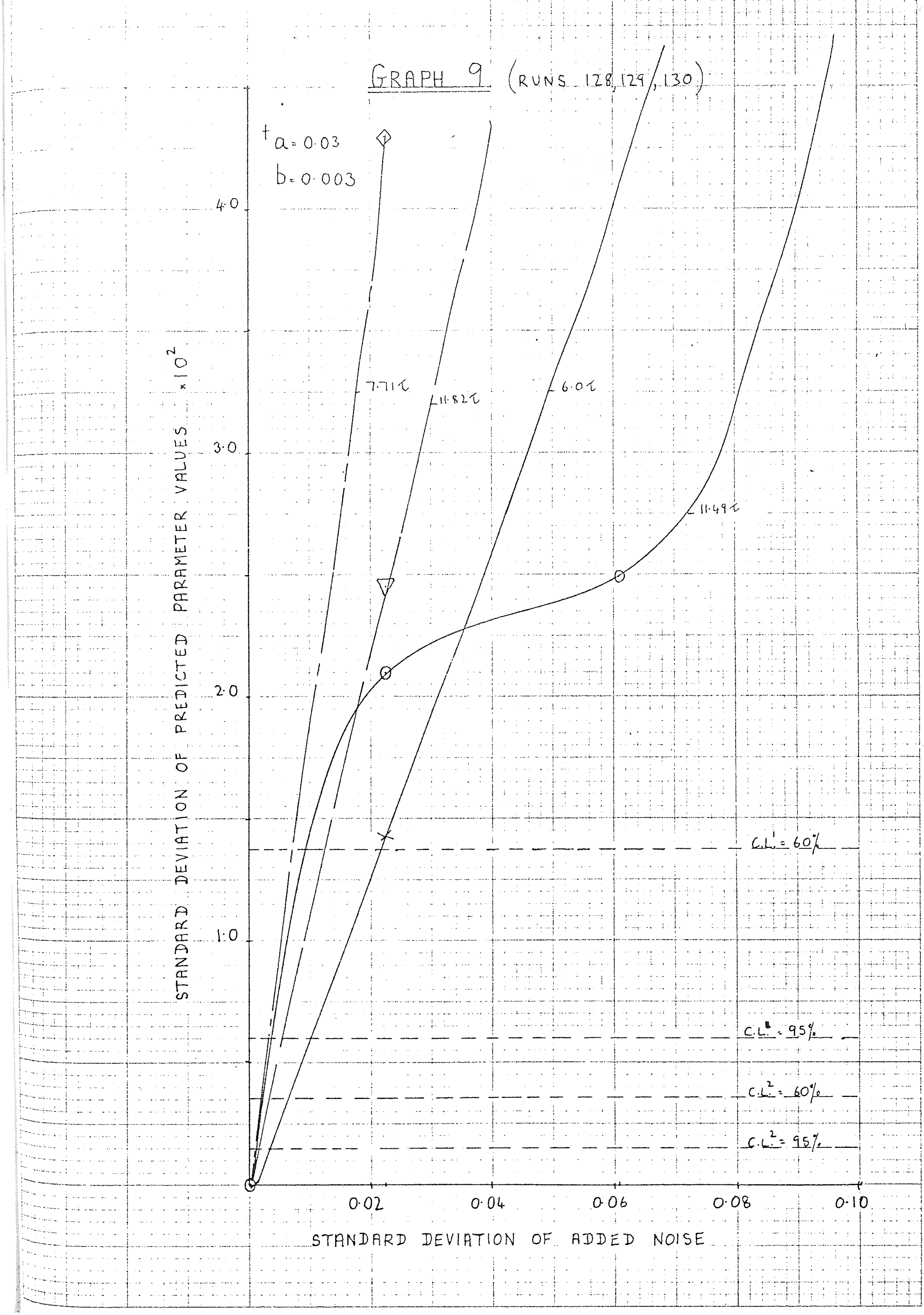


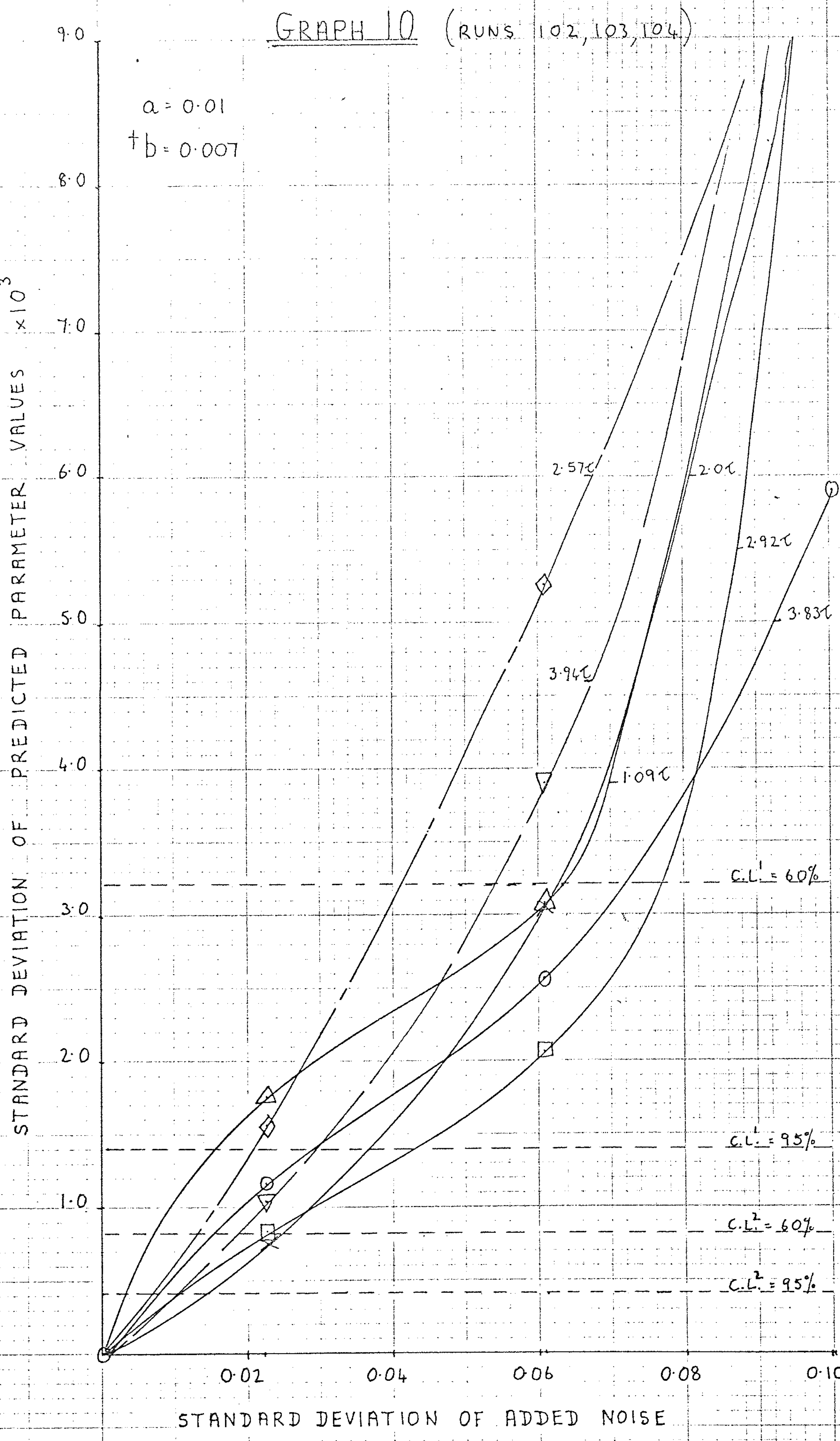

GRAPH 6 (RUNS 119, 120, 121)
a = 0·02
b = 0·002
7·88τ
7·66τ
2·18τ
4·0τ
5·84τ
4·0
3·0
2·0
1·0
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10²
STANDARD DEVIATION OF ADDED NOISE

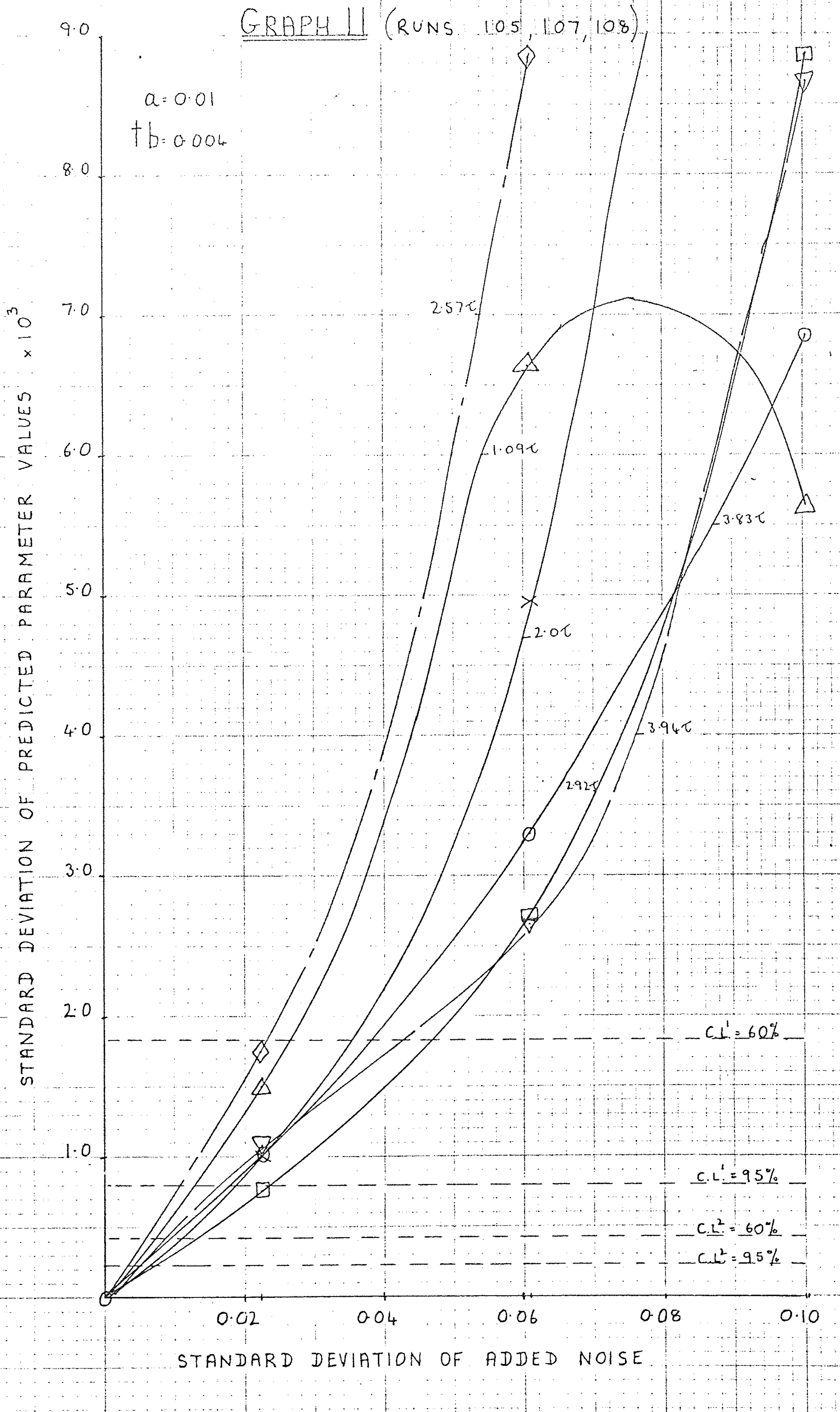

GRAPH 7 (RUNS 122, 123, 124)
a = 0·03
b = 0·021
4·0
3·0
2·0
1·0
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10²
7·71τ
3·27τ
6·0τ
8·76τ
11·49τ
11·82τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE

GRAPH 8 (RUNS 125, 126, 127)

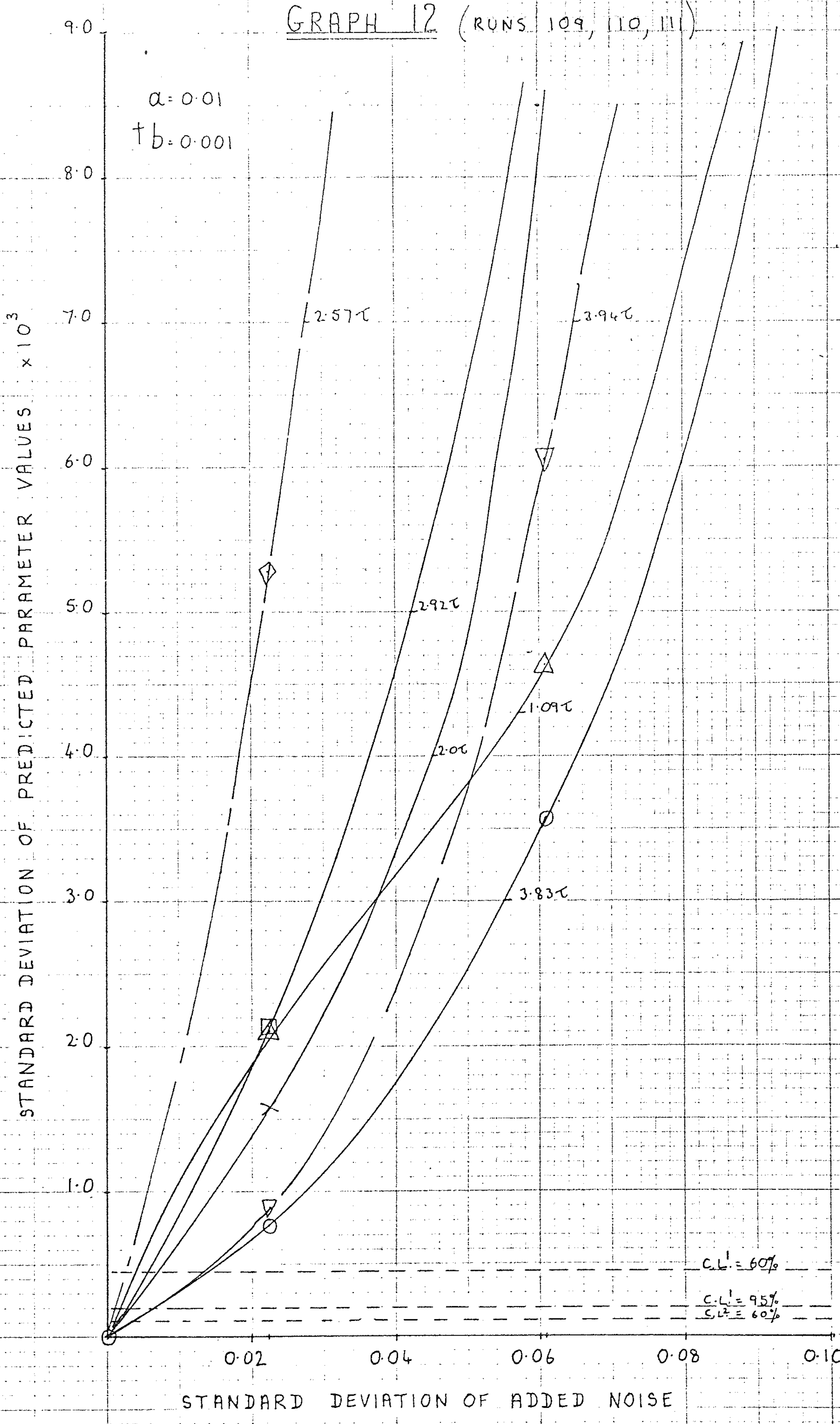



GRAPH 9 (RUNS 128, 129, 130)
a = 0.03
b = 0.003
7.71τ
11.82τ
6.0τ
11.49τ
C.L.[1] = 60%
C.L.[1] = 95%
C.L.[2] = 60%
C.L.[2] = 95%
4.0
3.0
2.0
1.0
0.02
0.04
0.06
0.08
0.10
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10²
STANDARD DEVIATION OF ADDED NOISE

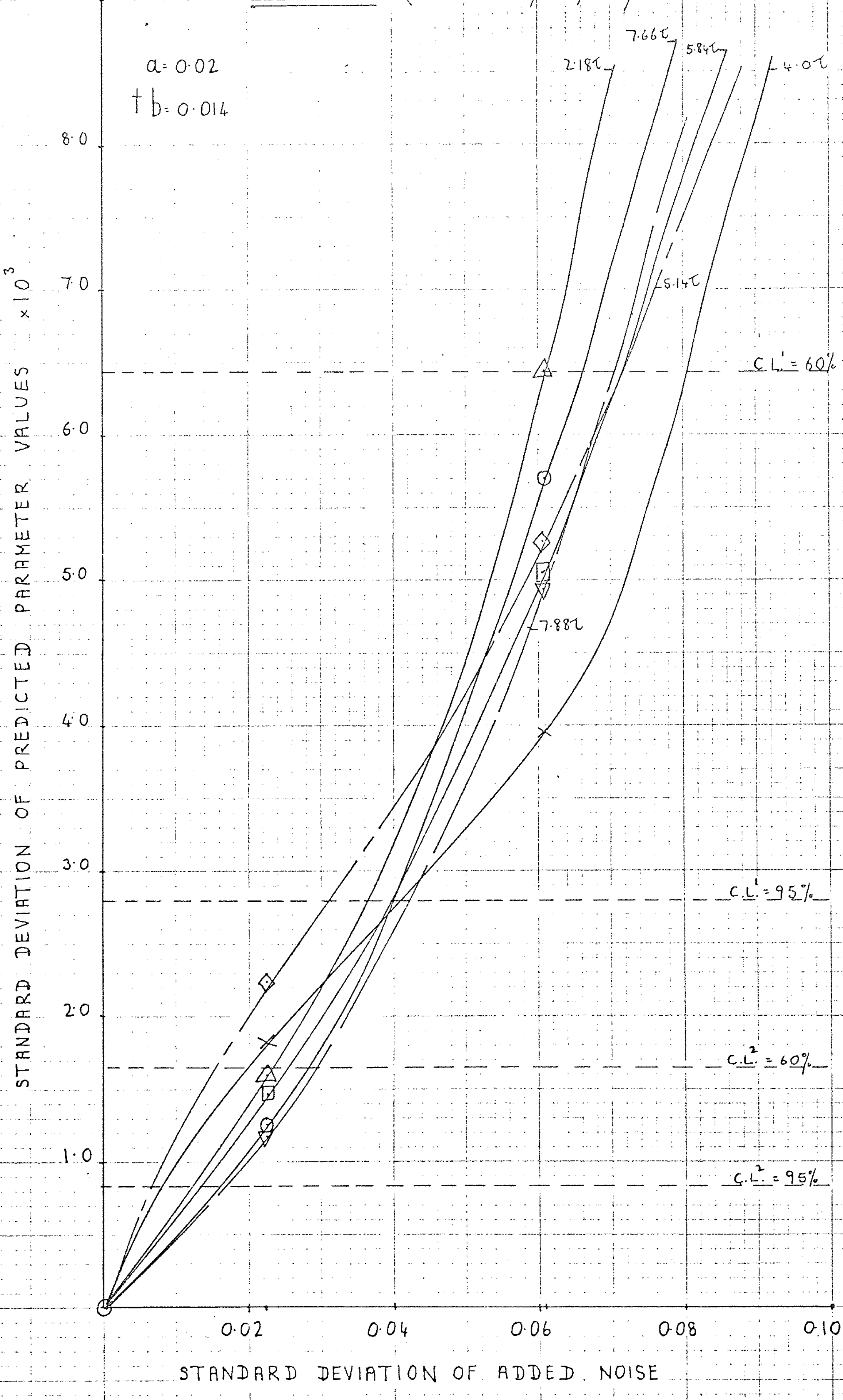

GRAPH 10 (RUNS 102, 103, 104)
a = 0·01
†b = 0·007
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10³
STANDARD DEVIATION OF ADDED NOISE
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0·02
0·04
0·06
0·08
0·10
2·57τ
2·0τ
2·92τ
3·83τ
3·94τ
1·09τ
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%

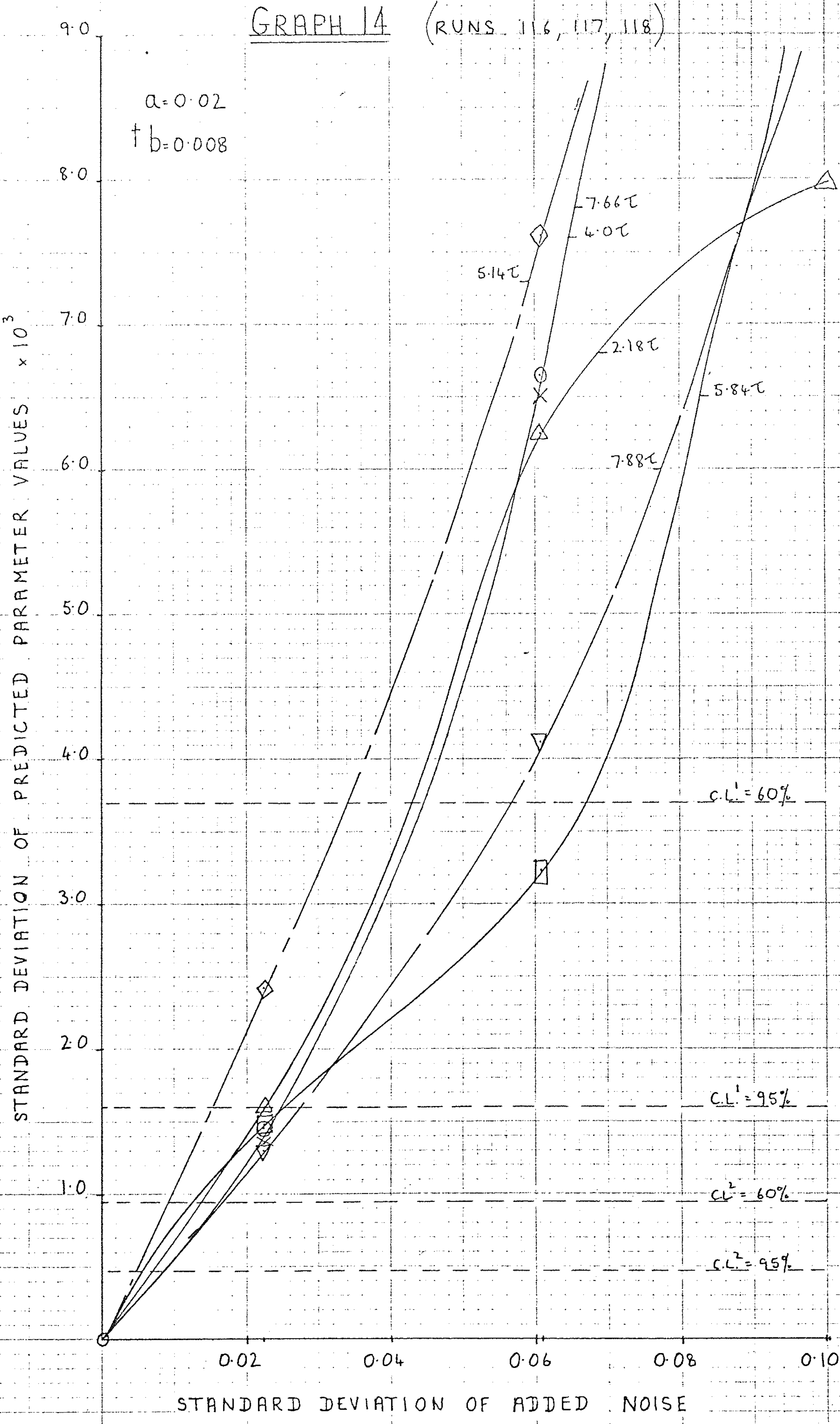


GRAPH 11 (RUNS 105, 107, 108)
a = 0·01
tb = 0·004
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10³
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0
2·57τ
1·09τ
2·0τ
3·83τ
3·94τ
2·92τ
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE

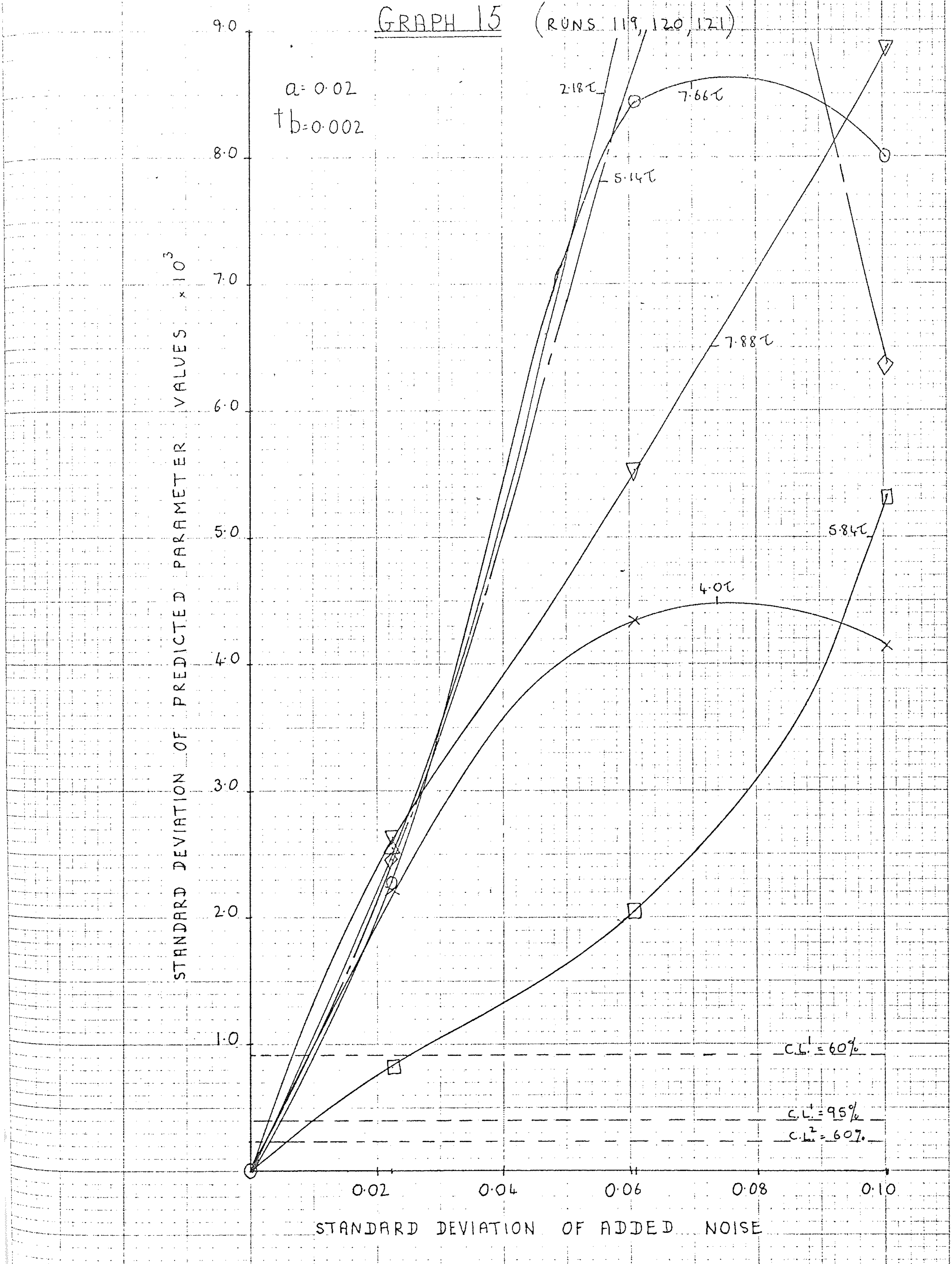

GRAPH 12 (RUNS 109, 110, 111)
a = 0.01
tb = 0.001
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10^3
STANDARD DEVIATION OF ADDED NOISE
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.02
0.04
0.06
0.08
0.10
2.57τ
2.92τ
3.94τ
1.09τ
2.0τ
3.83τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%

GRAPH 13 (RUNS 113, 114, 115)

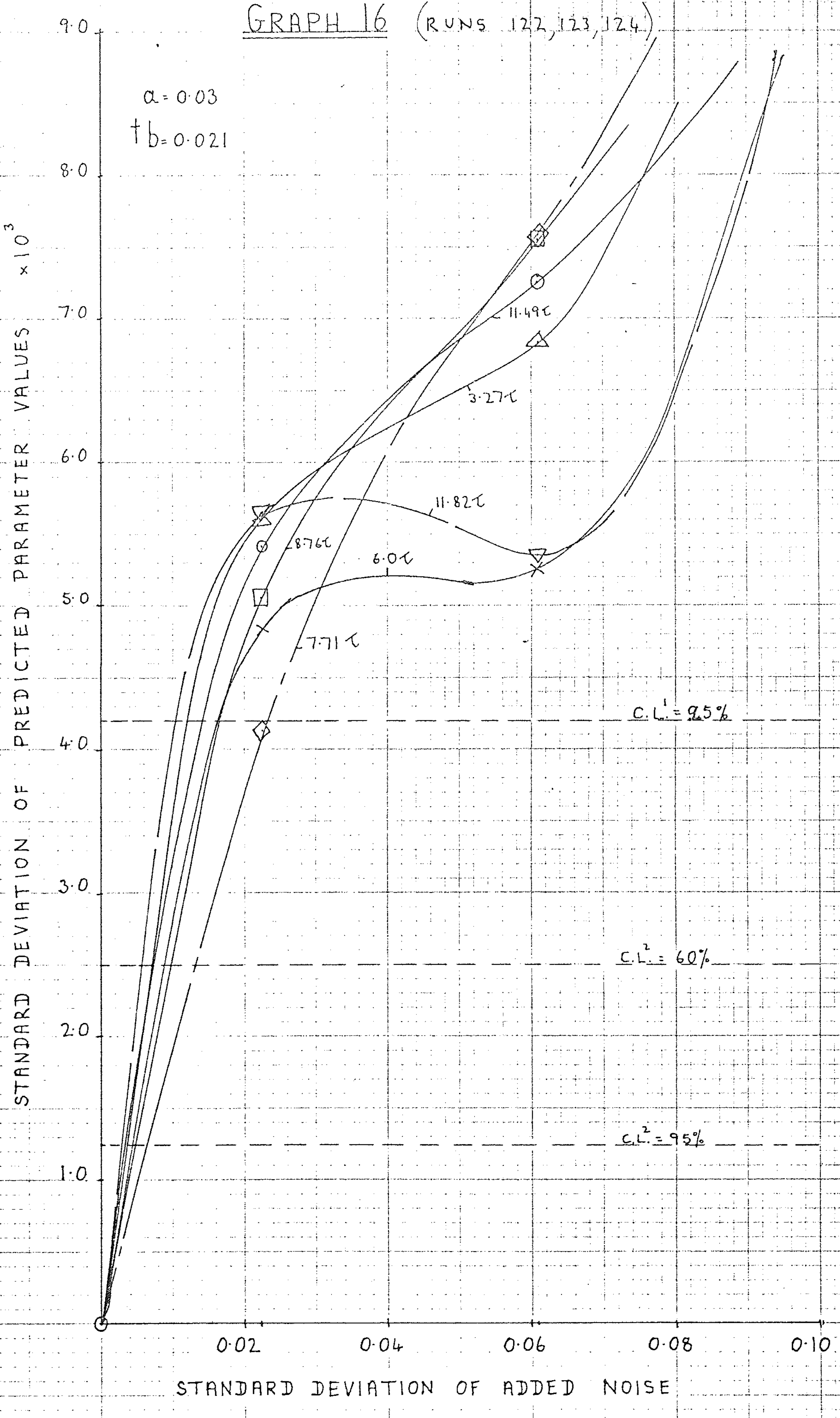




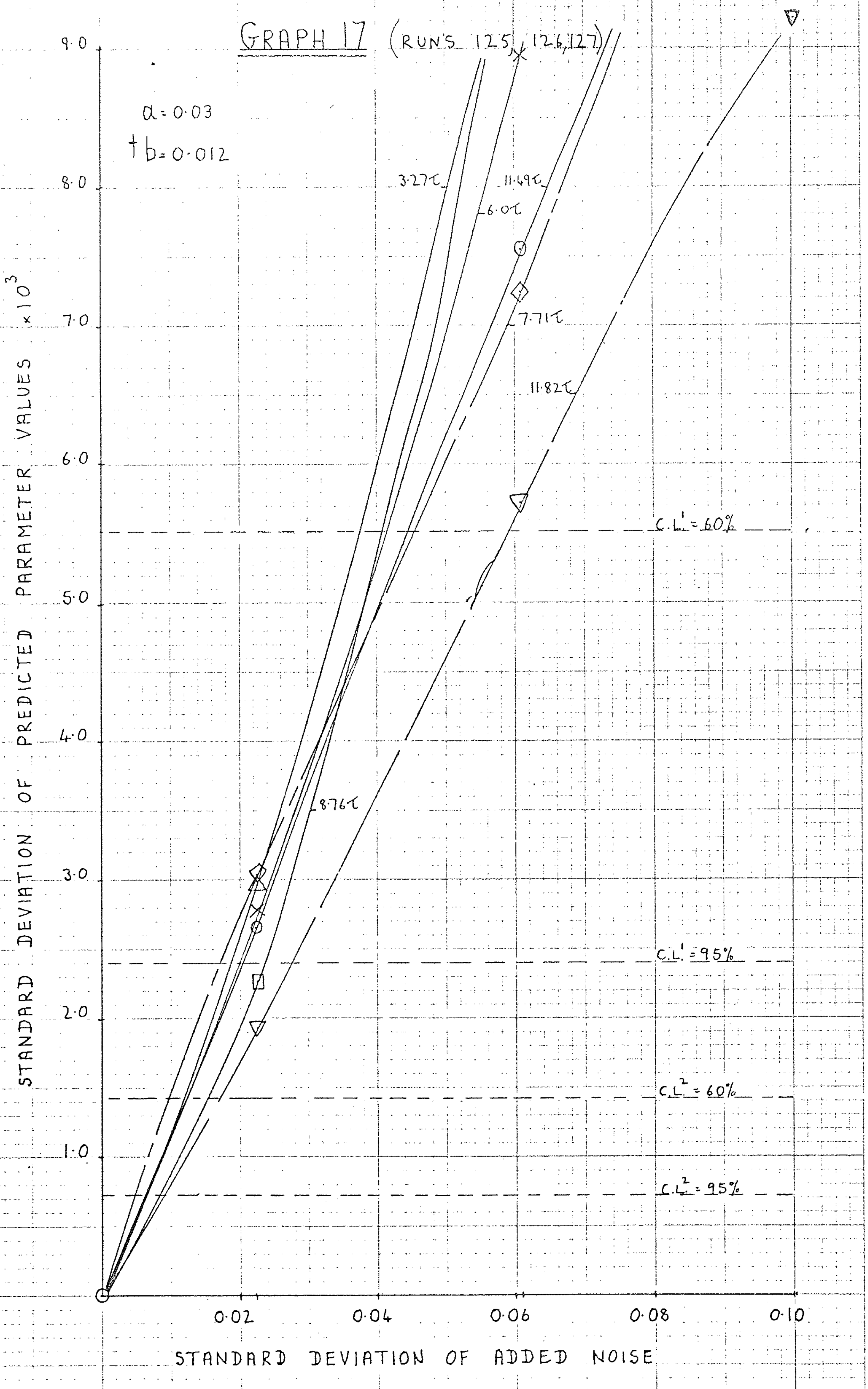
GRAPH 14 (RUNS 116, 117, 118)
a = 0.02
† b = 0.008
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10^3
STANDARD DEVIATION OF ADDED NOISE
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.02
0.04
0.06
0.08
0.10
7.66τ
4.0τ
5.14τ
2.18τ
5.84τ
7.88τ
C.L¹ = 60%
C.L¹ = 95%
CL² = 60%
C.L² = 95%



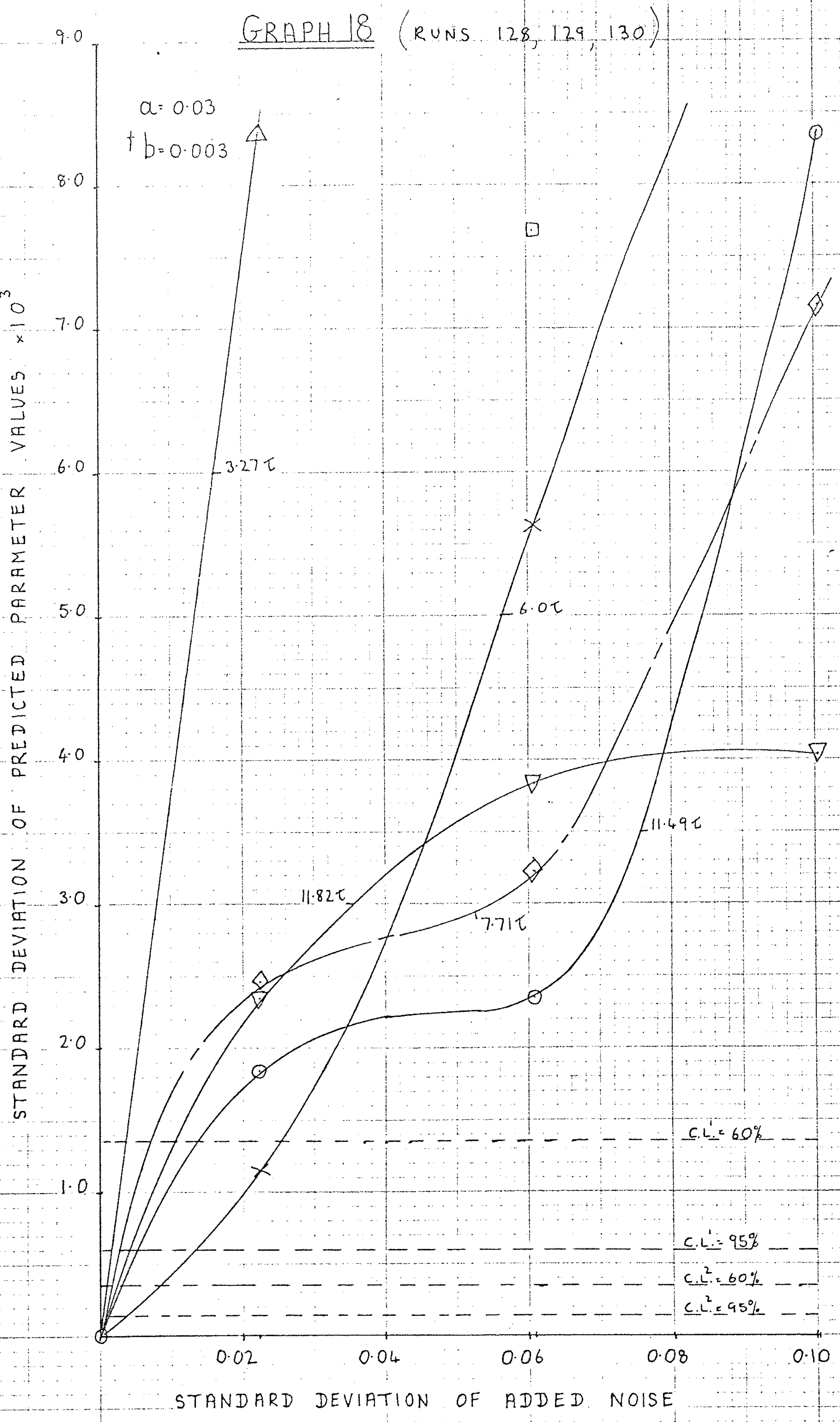
GRAPH 15 (RUNS 119, 120, 121)
a = 0.02
†b = 0.002
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10³
STANDARD DEVIATION OF ADDED NOISE
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.02
0.04
0.06
0.08
0.10
2.18τ
7.66τ
5.14τ
7.88τ
5.84τ
4.0τ
C.L.¹ = 60%
C.L.† = 95%
C.L.² = 60%



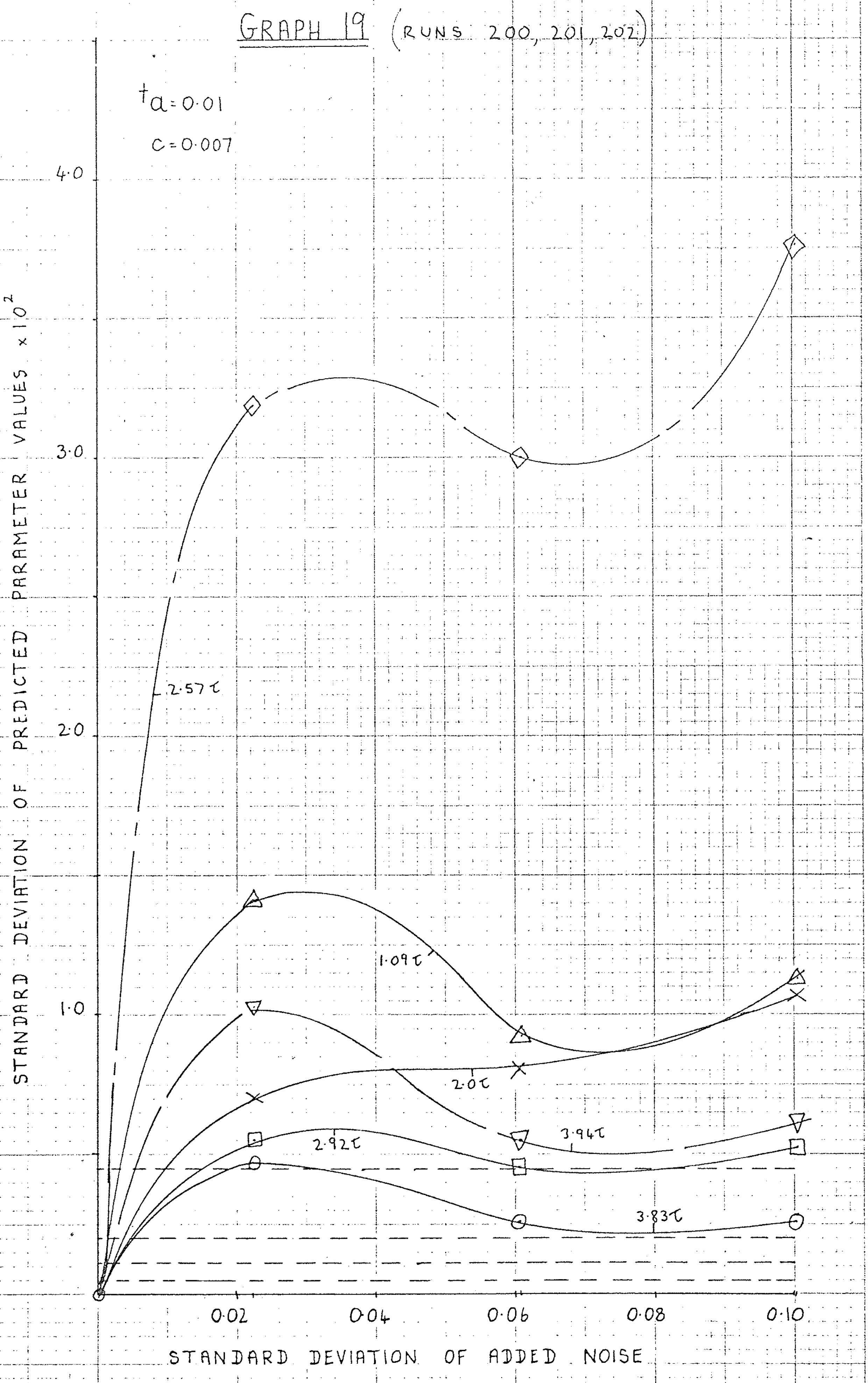
GRAPH 16 (RUNS 122, 123, 124)
a = 0·03
tb = 0·021
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10³
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
11·49τ
3·27τ
11·82τ
8·76τ
6·0τ
7·71τ
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE



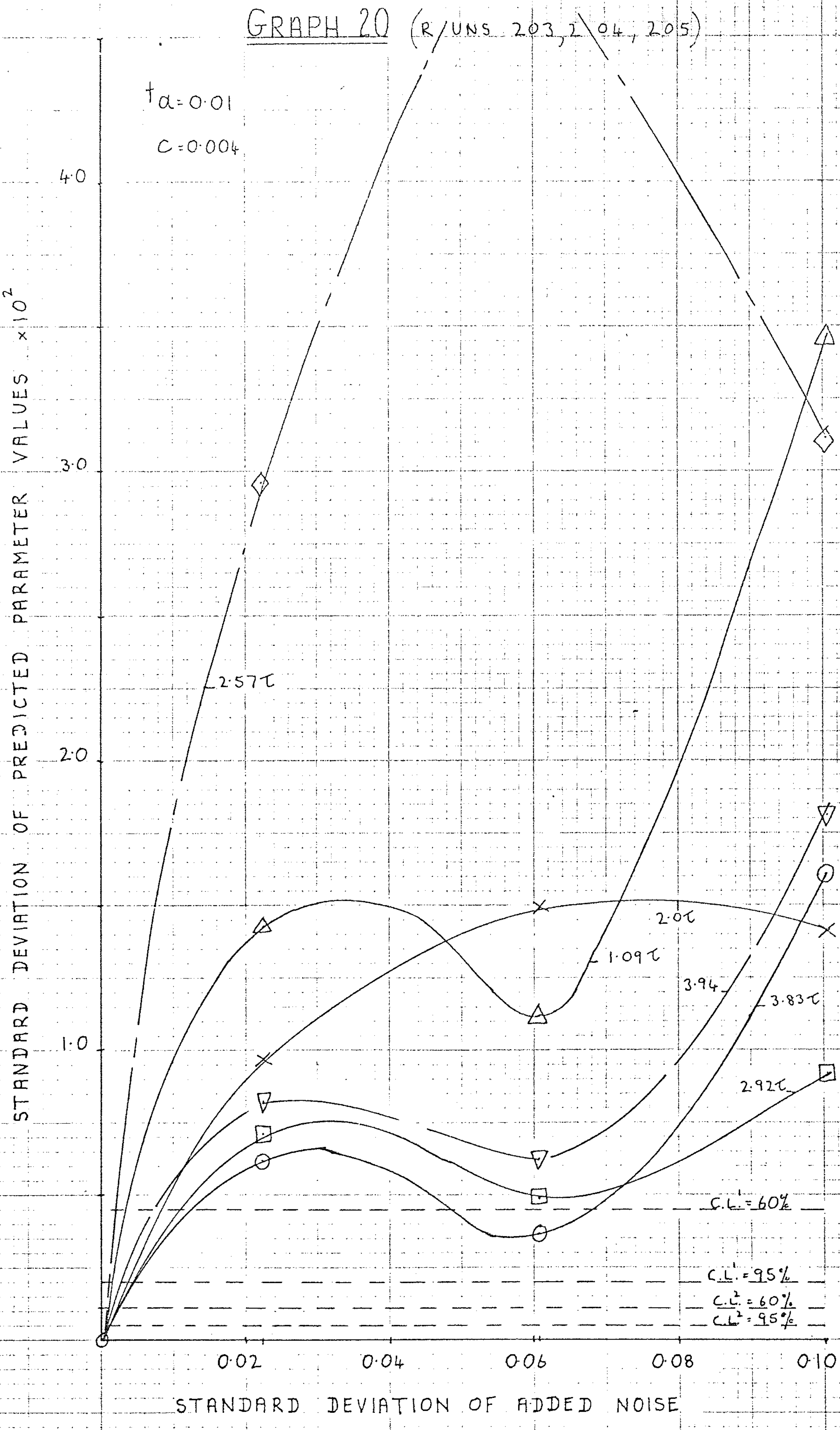
GRAPH 17 (RUN'S 125, 126, 127)
α = 0.03
tb = 0.012
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10³
STANDARD DEVIATION OF ADDED NOISE
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.02
0.04
0.06
0.08
0.10
3.27τ
11.49τ
6.0τ
7.71τ
11.82τ
8.76τ
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%



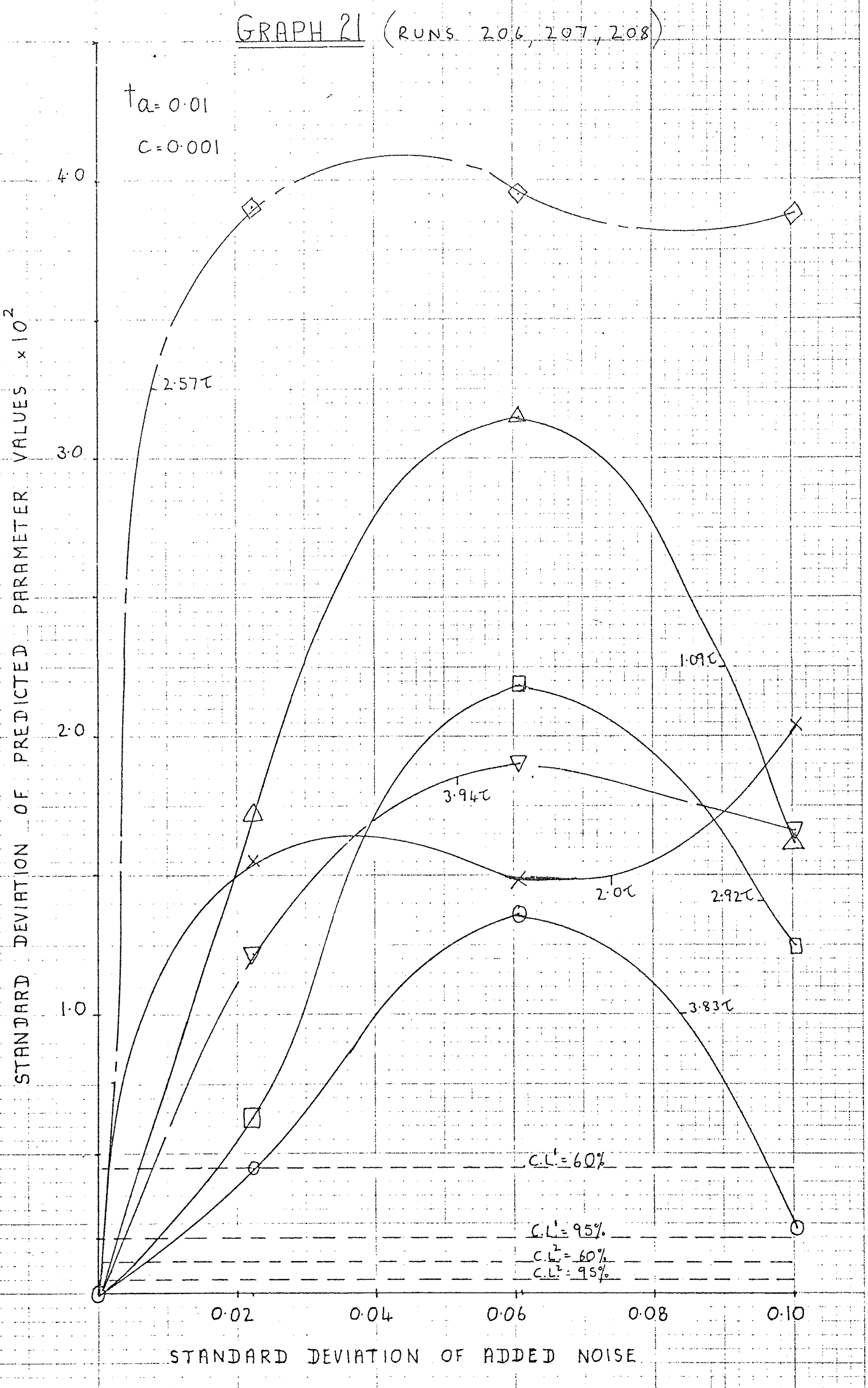
GRAPH 18 (RUNS 128, 129, 130)
a = 0·03
b = 0·003
3·27τ
6·0τ
11·49τ
11·82τ
7·71τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10³
9·0
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE



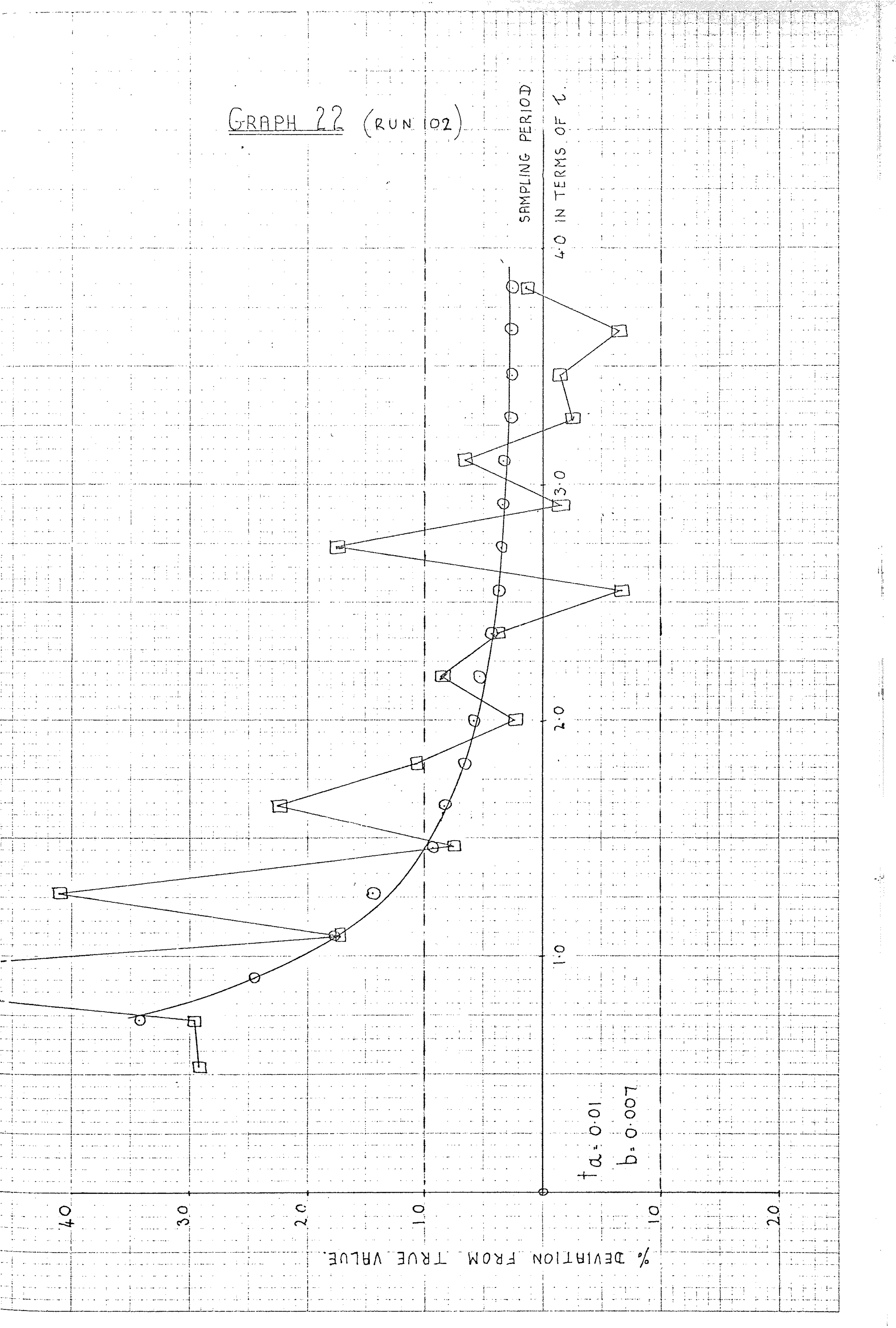
GRAPH 19 (RUNS 200, 201, 202)
t_a = 0·01
C = 0·007
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10²
4·0
3·0
2·0
1·0
2·57τ
1·09τ
2·0τ
3·94τ
2·92τ
3·83τ
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE



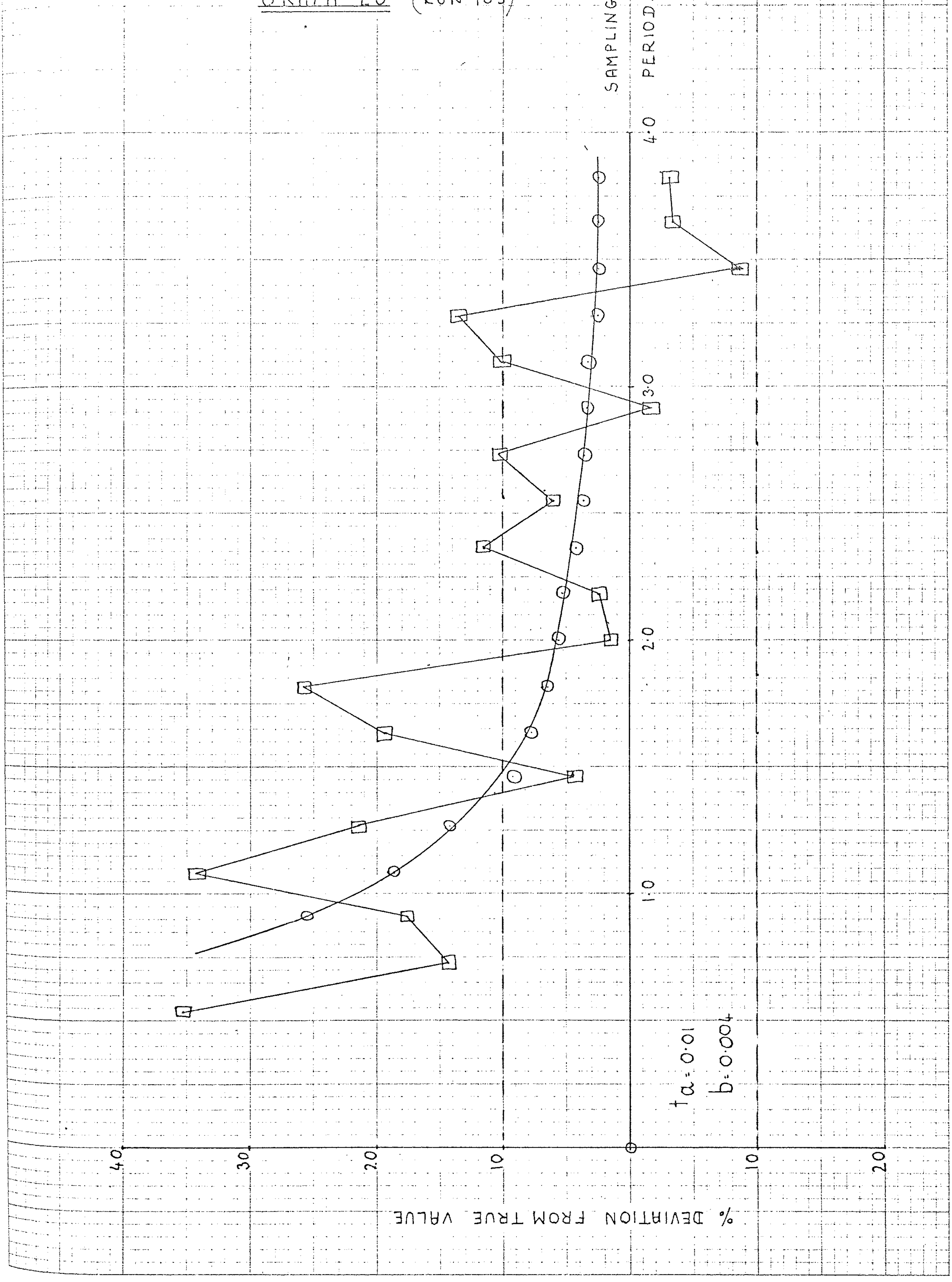
GRAPH 20 (RUNS 203, 204, 205)
t_a = 0·01
c = 0·004
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES ×10²
4·0
3·0
2·0
1·0
2·57τ
2·0τ
1·09τ
3·94
3·83τ
2·92τ
C.L.¹ = 60%
C.L.¹ = 95%
C.L.² = 60%
C.L.² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE



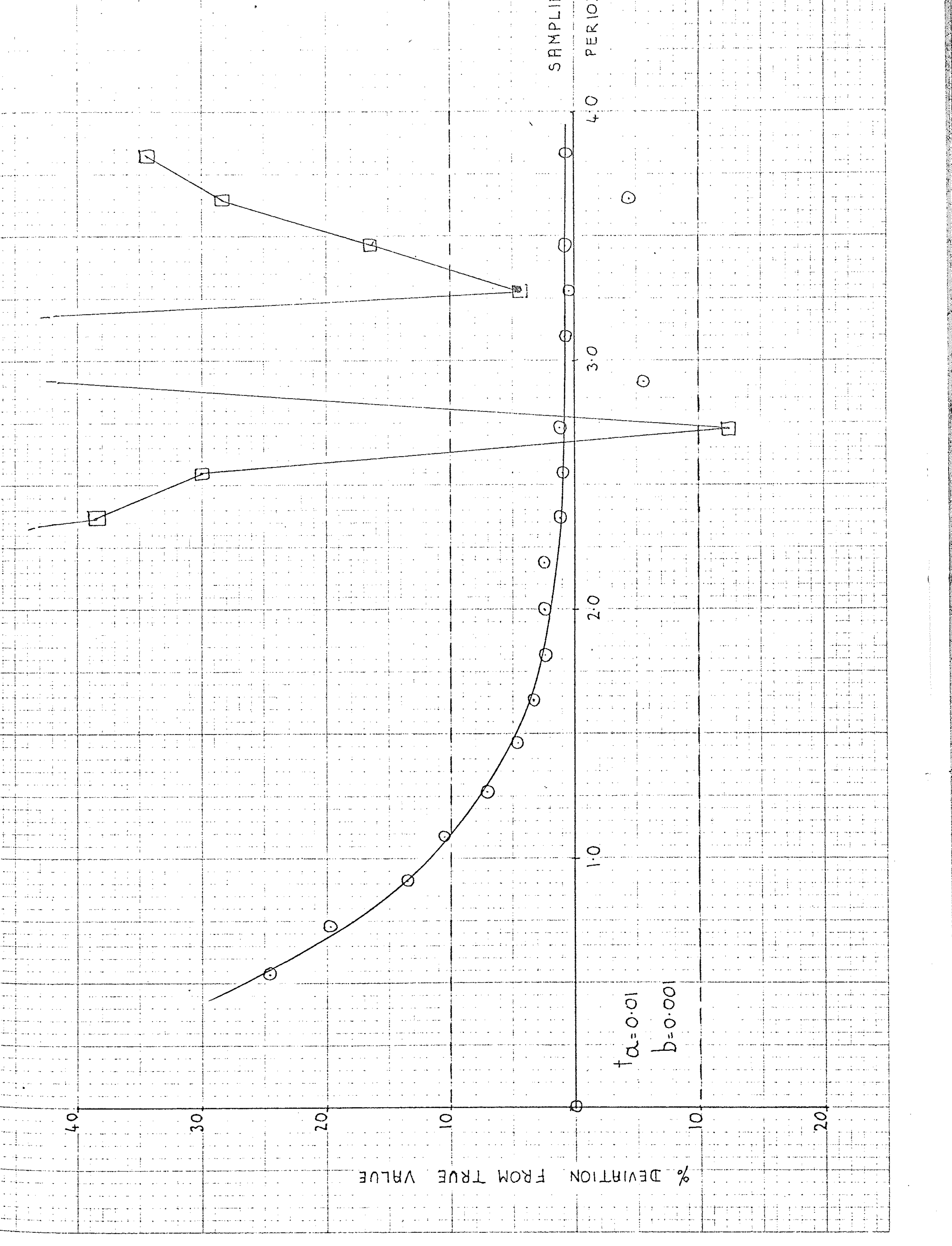
GRAPH 21 (RUNS 206, 207, 208)
ta = 0·01
C = 0·001
STANDARD DEVIATION OF PREDICTED PARAMETER VALUES × 10²
4·0
3·0
2·0
1·0
2·57τ
1·09τ
3·94τ
2·0τ
2·92τ
3·83τ
C.L¹ = 60%
C.L¹ = 95%
C.L² = 60%
C.L² = 95%
0·02
0·04
0·06
0·08
0·10
STANDARD DEVIATION OF ADDED NOISE


GRAPH 22 (RUN 102)
SAMPLING PERIOD
4·0 IN TERMS OF τ
3·0
2·0
1·0
% DEVIATION FROM TRUE VALUE
4·0
3·0
2·0
1·0
1·0
2·0
+a = 0·01
b = 0·007

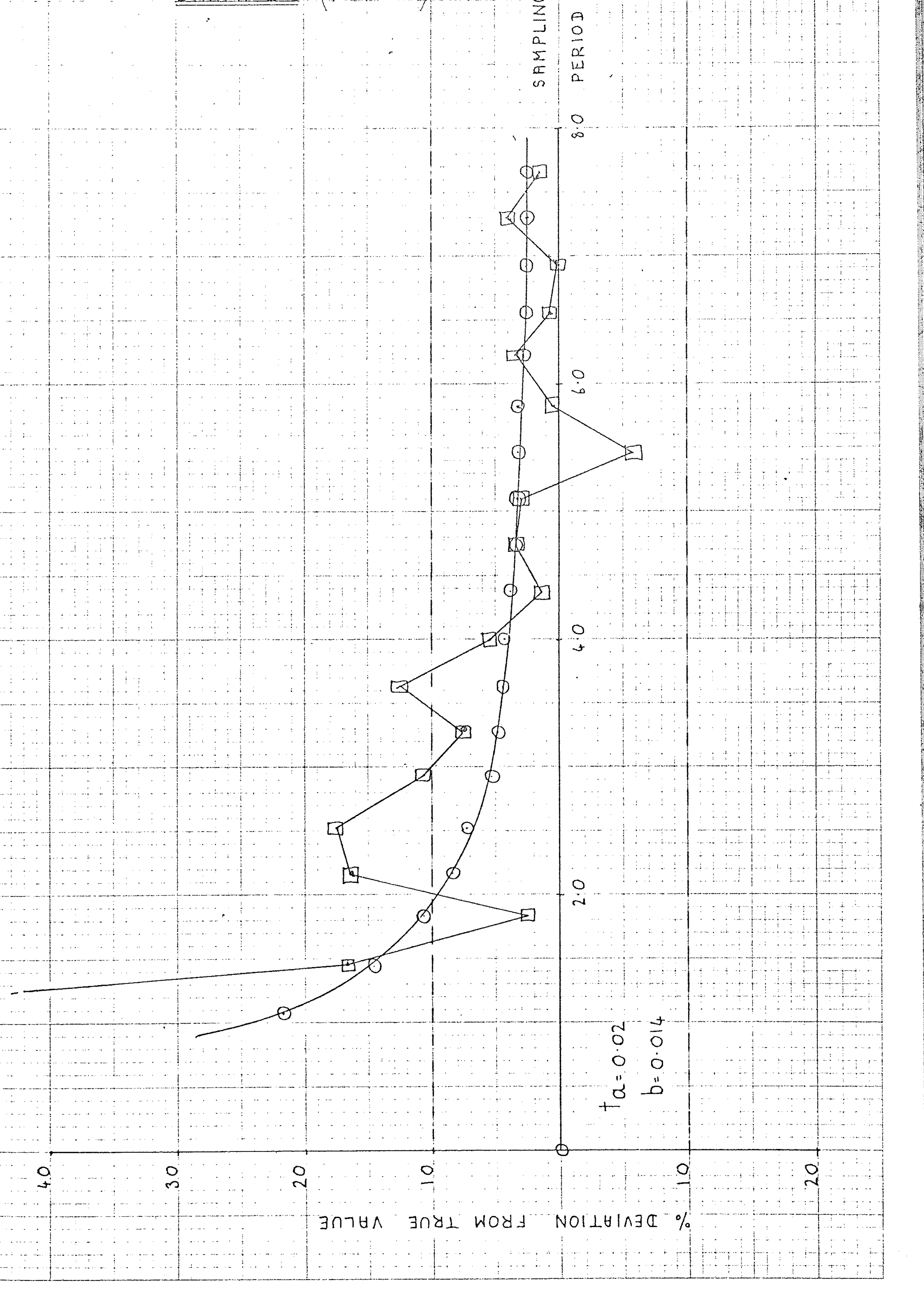
GRAPH 23 (RUN 105)



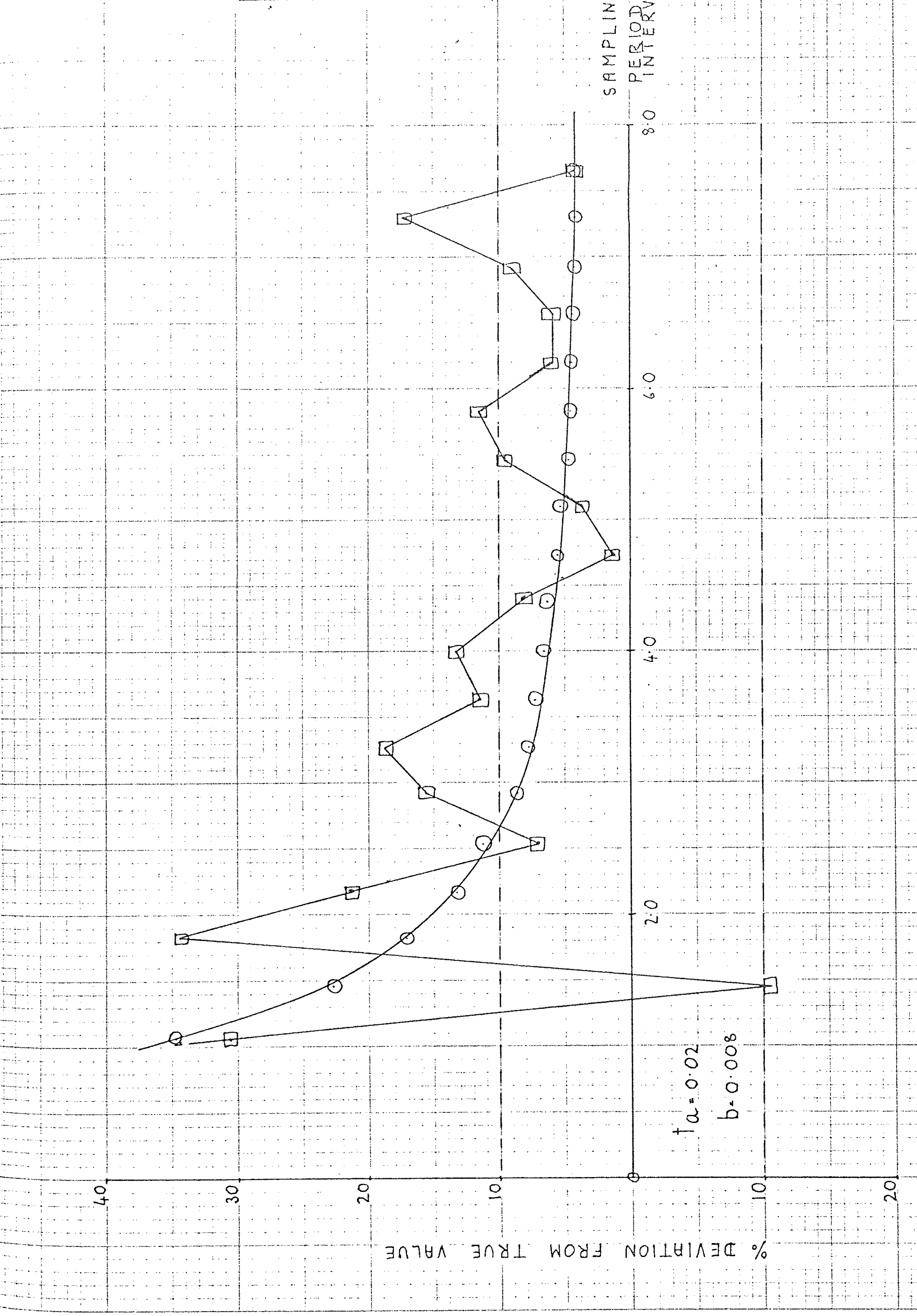
GRAPH 24 (RUN 109)



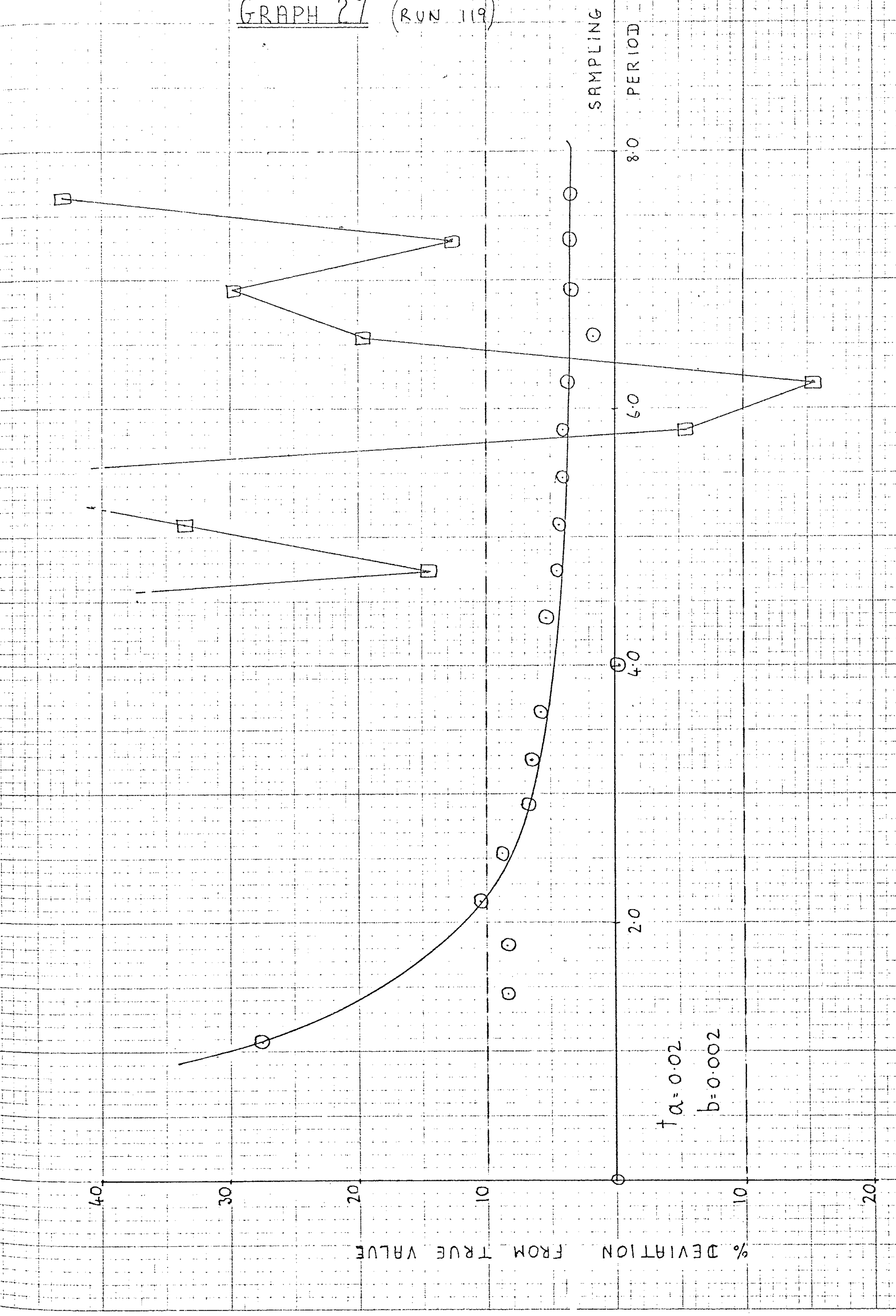
GRAPH 25 (RUN 113)



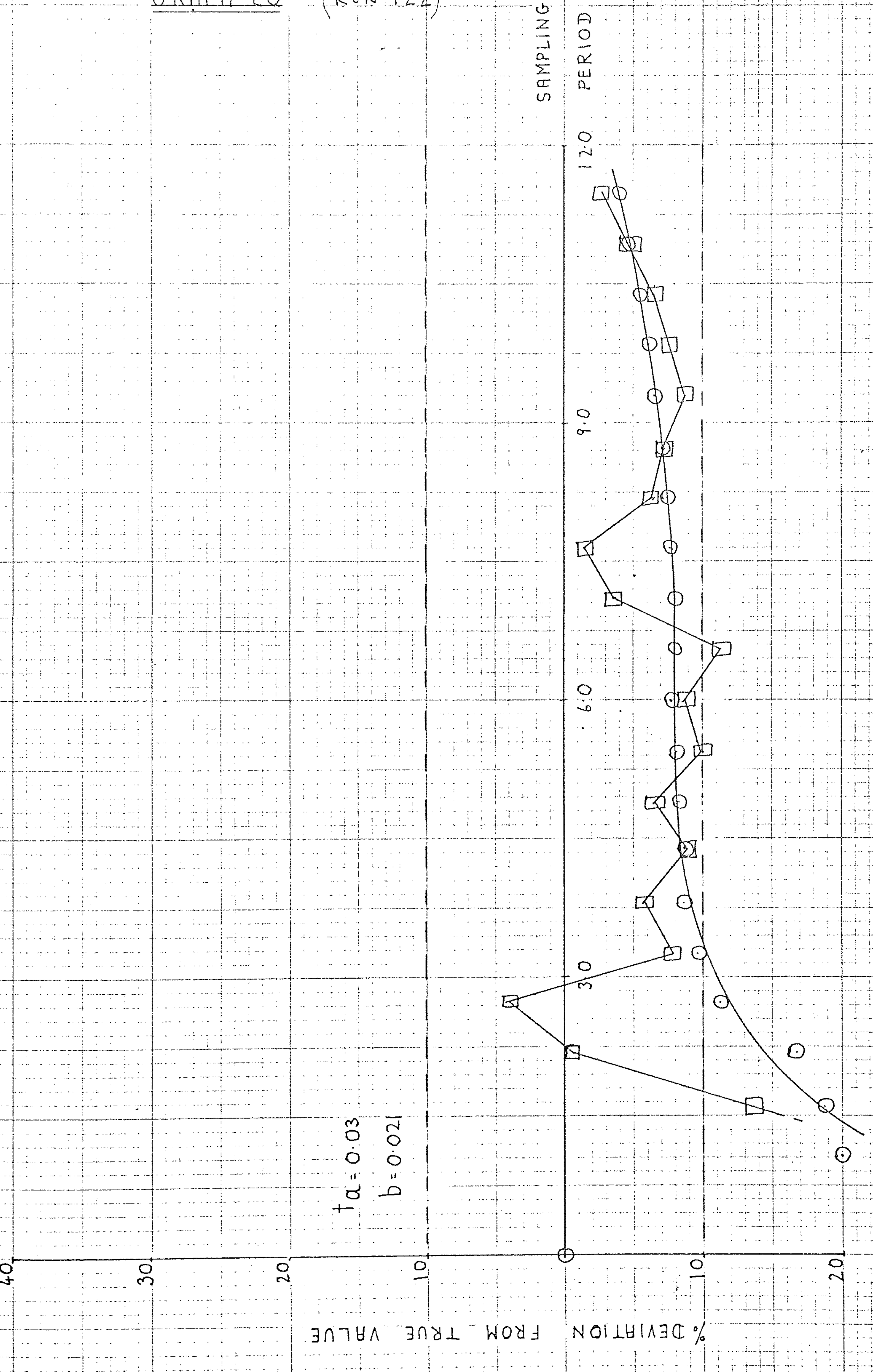
GRAPH 26 (RUN 116)



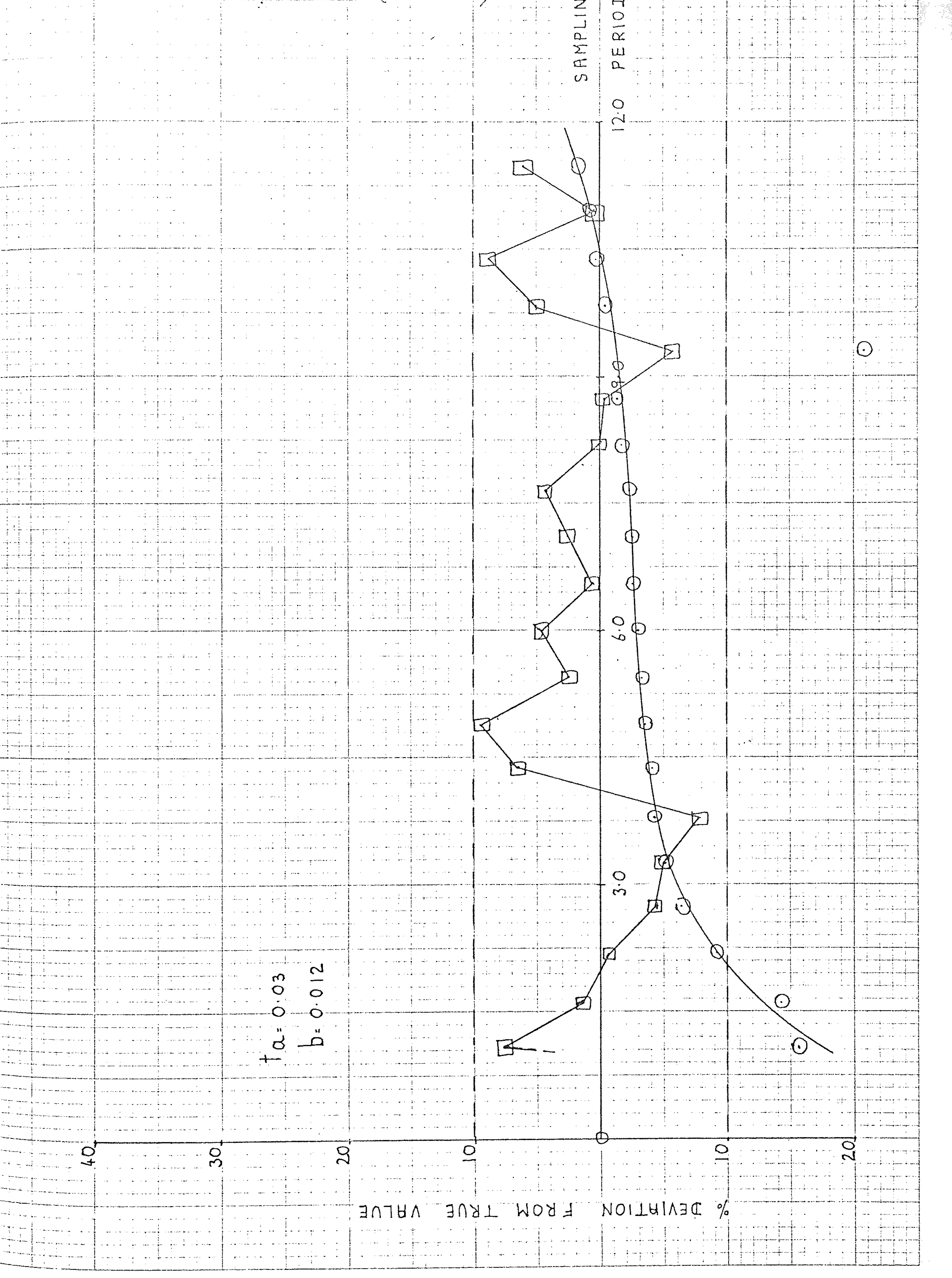
GRAPH 27 (RUN 119)



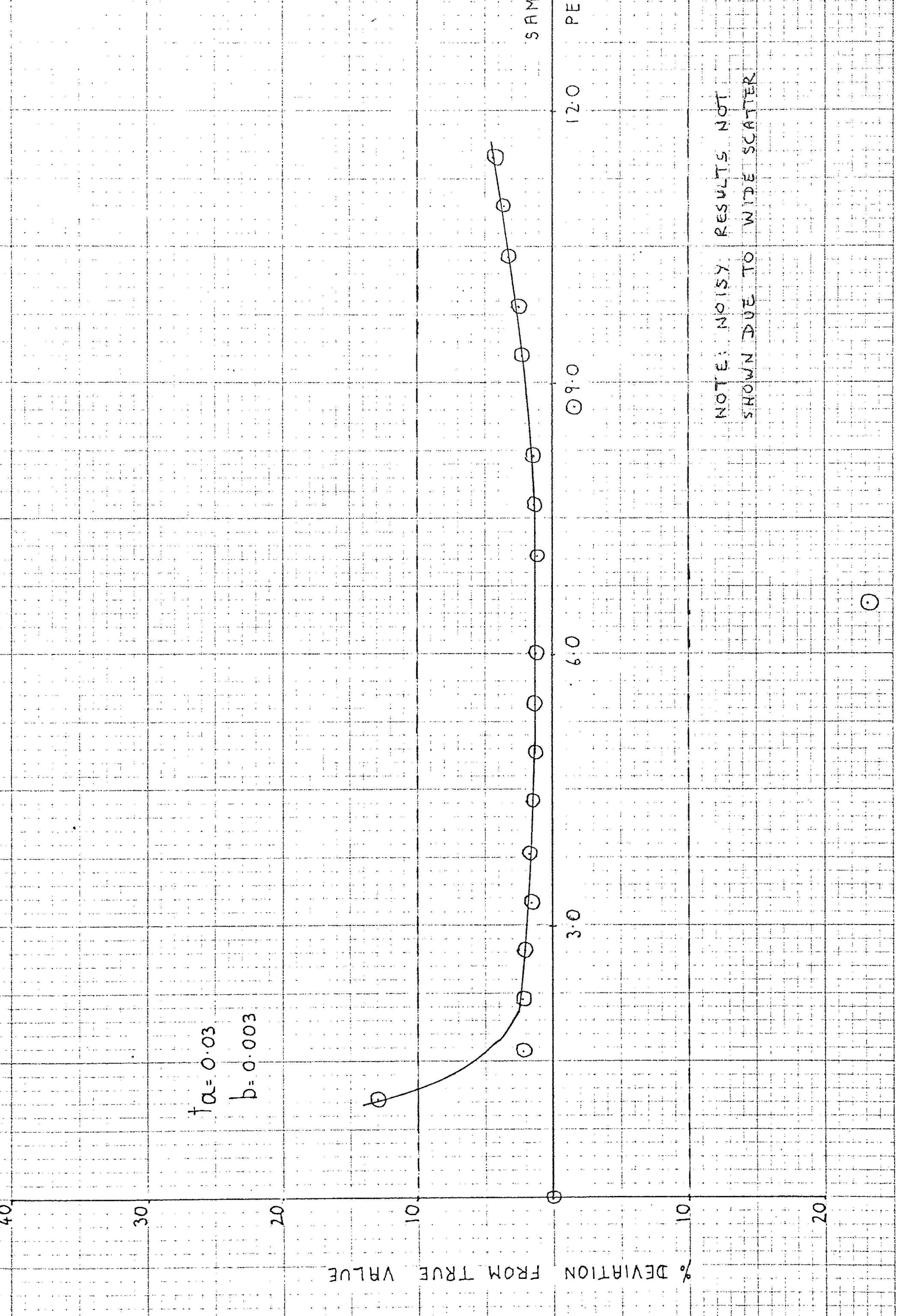
GRAPH 28 (RUN 122)

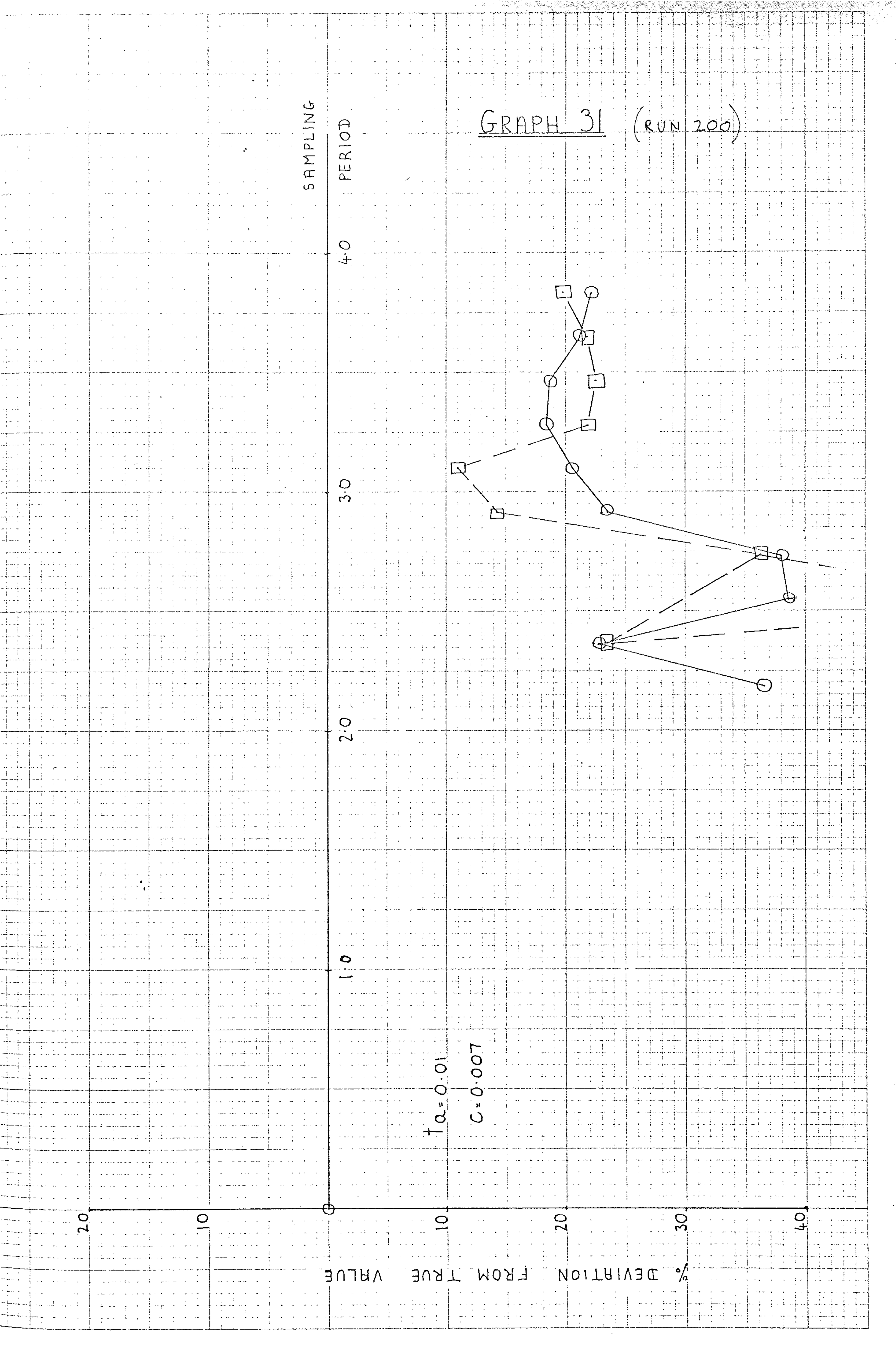


GRAPH 29 (RUN 125)



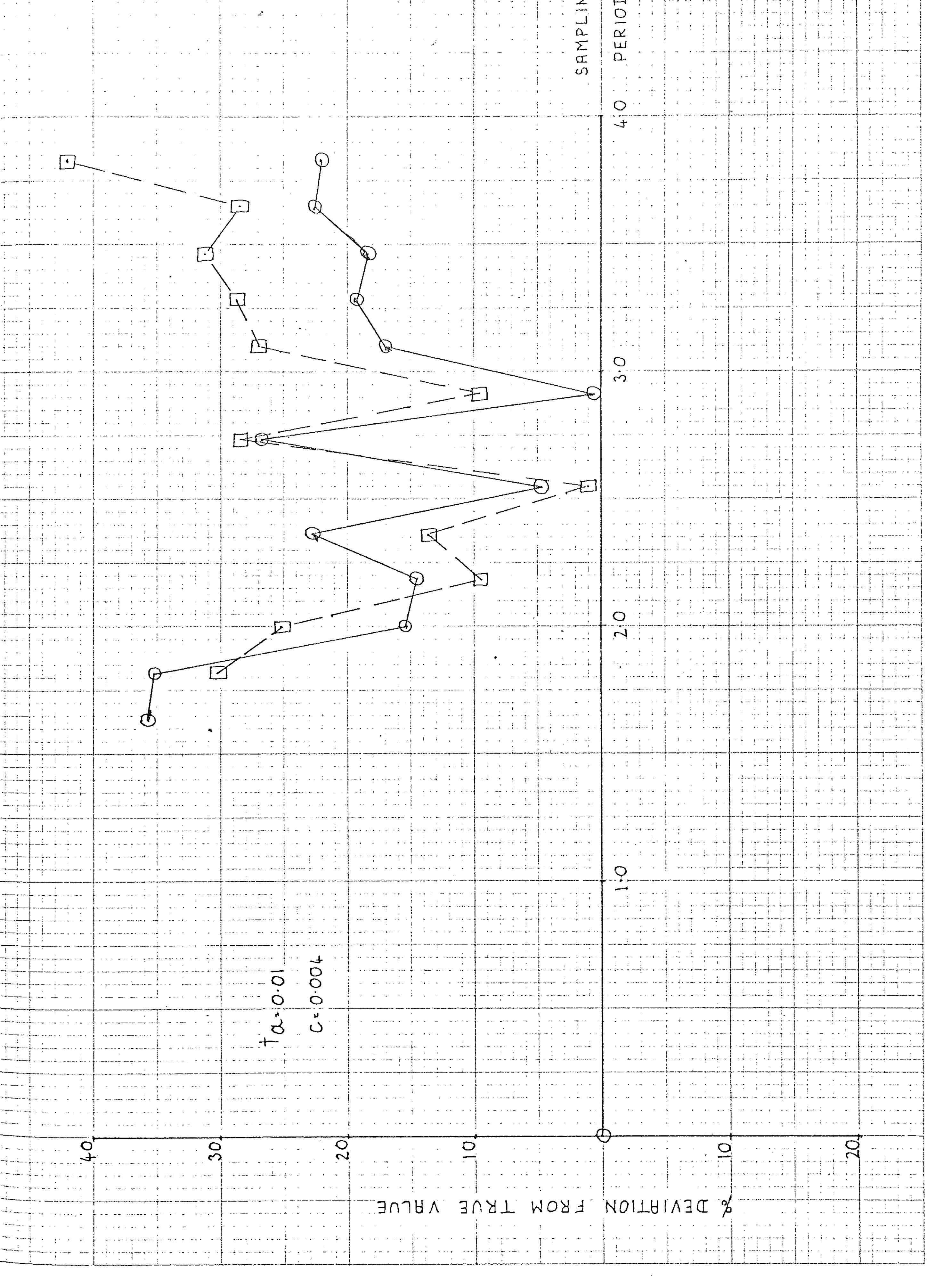
GRAPH 30 (RUN 128)



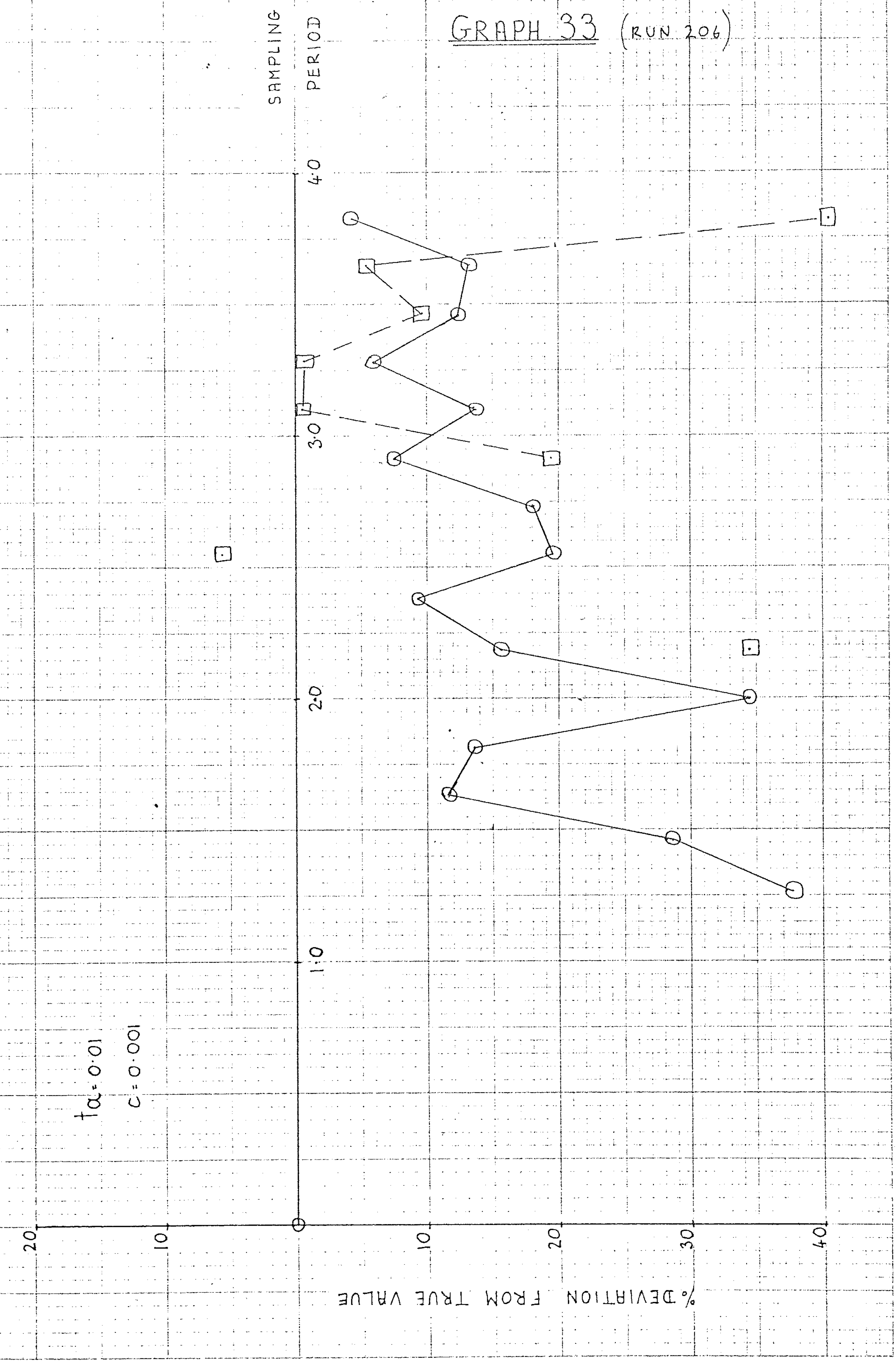


GRAPH 31 (RUN 200)
SAMPLING PERIOD
% DEVIATION FROM TRUE VALUE
$t_a = 0.01$
$C = 0.007$
1.0
2.0
3.0
4.0
20
10
0
10
20
30
40

GRAPH 32 (RUN 203)



GRAPH 33 (RUN 206)



Appendix V

Tables are given of $w_i r_i^{s-1}$ and t_i for N = 3 - 15. The former tables are taken from Price (3), whilst the latter are taken from Bellman (1).

(a) Tables of $w_i r_i^{s-1}$ for N = 3 - 15

N= 3

.27777778	.44444444	.27777778
.03130602	.22222222	.24647176
.00352824	.11111111	.21869398

N= 4

.17392742	.32607258	.32607258	.17392742
.01207610	.10760704	.21846554	.16185132
.00083847	.03551134	.14636984	.15061368
.00005822	.01171908	.09806640	.14015630

N= 5

.11846344	.23931434	.28444444	.23931434	.11846344
.00555713	.05522545	.14222222	.18408888	.11290631
.00026069	.01274412	.07111111	.14160755	.10760987
.00001223	.00294090	.03555555	.10892944	.10256188
.00000057	.00067866	.01777778	.08379230	.09775069

N= 6

.08566225 .18038079 .23395697 .23395697
.18038079 .08566225

.00289241 .03055566 .08906518 .14489180
.14982513 .08270984

.00009766 .00517599 .03390626 .08973288
.12444546 .07997510

.00000330 .00087679 .01290779 .05557243
.10336498 .07727472

.00000011 .00014852 .00491387 .03441654
.08585544 .07466552

.00000000 .00002516 .00187066 .02131449
.07131193 .07214442

N= 7

.06474248 .13985270 .19091503 .20897959
.19091503 .13985270 .06474248

.00164744 .01807378 .05671654 .10448980
.13419849 .12177892 .06309504

.00004192 .00233575 .01684920 .05224490
.09433115 .10604089 .06148952

.00000107 .00030186 .00500552 .02612245
.06630749 .09233676 .05992486

.00000003 .00003901 .00148703 .01306122
.04660903 .08040367 .05840001

.00000000 .00000504 .00044176 .00653061
.03276254 .07001275 .05691396

.00000000 .00000065 .00013124 .00326531
.02302953 .06096470 .05546572

N= 8

.05061427	.11119052	.15685332	.18134189
.18134189	.15685332	.11119052	.05061427
.00100495	.01130438	.03721091	.07403875
.10730314	.11964241	.09988614	.04960932
.00001995	.00114928	.00882769	.03022874
.06349312	.09125919	.08973104	.04862432
.00000040	.00011684	.00209423	.01234187
.03756998	.06960942	.08060838	.04765888
.00000001	.00001188	.00049682	.00503897
.02223081	.05309572	.07241318	.04671261
.00000000	.00000121	.00011786	.00205733
.01315435	.04049962	.06505117	.04578513
.00000000	.00000012	.00002796	.00083997
.00778366	.03089174	.05843763	.04487606
.00000000	.00000001	.00000663	.00034295
.00460573	.02356317	.05249646	.04398505

N= 9

.04063719	.09032408	.13030535	.15617354
.16511968	.15617354	.13030535	.09032408
.04063719			
.00064694	.00740517	.02518989	.05276687
.08255984	.10340667	.10511547	.08291891
.03999025			
.00001030	.00060711	.00486956	.01782852
.04127992	.06846832	.08479515	.07612085
.03935361			
.00000016	.00004977	.00094136	.00602378
.02063996	.04533470	.06840303	.06988012
.03872711			
.00000000	.00000408	.00018198	.00203527
.01031998	.03001732	.05517975	.06415104
.03811057			
.00000000	.00000033	.00003518	.00068766
.00515999	.01987527	.04451272	.05889165
.03750386			
.00000000	.00000003	.00000680	.00023234
.00257999	.01315995	.03590777	.05406345
.03690680			
.00000000	.00000000	.00000131	.00007850
.00129000	.00871355	.02896629	.04963109
.03631925			
.00000000	.00000000	.00000025	.00002652
.00064500	.00576948	.02336669	.04556211
.03574105			

N= 10

.03333567	.07472567	.10954318	.13463336
.14776211	.14776211	.13463336	.10954318
.07472567	.03333567		
.00043492	.00504162	.01755925	.03814194
.06288206	.08488005	.09649142	.09198393
.06968405	.03290075		
.00000567	.00034015	.00281466	.01080570
.02676027	.04875825	.06915518	.07723935
.06498259	.03247150		
.00000007	.00002295	.00045118	.00306128
.01138818	.02800855	.04956336	.06485825
.06059832	.03204785		
.00000000	.00000155	.00007232	.00086727
.00484638	.01608915	.03552194	.05446178
.05650986	.03162973		
.00000000	.00000010	.00001159	.00024570
.00206244	.00924221	.02545850	.04573182
.05269723	.03121707		
.00000000	.00000001	.00000186	.00006961
.00087770	.00530907	.01824604	.03840123
.04914184	.03080979		
.00000000	.00000000	.00000030	.00001972
.00037352	.00304973	.01307690	.03224569
.04582632	.03040782		
.00000000	.00000000	.00000005	.00000559
.00015895	.00175188	.00937218	.02707686
.04273449	.03001110		
.00000000	.00000000	.00000001	.00000158
.00006765	.00100634	.00671702	.02273657
.03985127	.02961955		

N= 11

.02783428	.06279018	.09314511	.11659688
.13140227	.13646254	.13140227	.11659688
.09314511	.06279018	.02783428	

.00030299	.00354568	.01256751	.02803595
.04799184	.06823127	.08341043	.08856093
.08057760	.05924450	.02753129	

.00000330	.00020022	.00169566	.00674130
.01752799	.03411563	.05294657	.06726629
.06970575	.05589904	.02723159	

.00000004	.00001131	.00022879	.00162096
.00640172	.01705782	.03360898	.05109198
.06030077	.05274249		

.00000000	.00000064	.00003087	.00038976
.00233809	.00852891	.02133402	.03880681
.05216475	.04976419	.02664195	

.00000000	.00000004	.00000416	.00009372
.00085394	.00426445	.01354223	.02947564
.04512647	.04695407	.02635193	

.00000000	.00000000	.00000056	.00002253
.00031188	.00213223	.00859622	.02238816
.03903783	.04430264	.02606507	

.00000000	.00000000	.00000008	.00000542
.00011391	.00106611	.00545664	.01700489
.03377069	.04180093	.02578134	

.00000000	.00000000	.00000001	.00000130
.00004160	.00053306	.00346372	.01291603
.02921421	.03944048	.02550069	

.00000000	.00000000	.00000000	.00000031
.00001519	.00026653	.00219867	.00981034
.02527251	.03721333	.02522310	

.00000000	.00000000	.00000000	.00000008
.00000555	.00013326	.00139565	.00745143
.02186264	.03511194	.02494853	

N= 12

.02358767	.05346966	.08003916	.10158371
.11674627	.12457352	.12457352	.11674627
.10158371	.08003916	.05346966	.02358767
.00021747	.00256341	.00920840	.02096088
.03690166	.05448638	.07008714	.07984461
.08062282	.07083076	.05090625	.02337020
.00000201	.00012289	.00105941	.00432509
.01166403	.02383143	.03943220	.05460699
.06398703	.06268178	.04846574	.02315473
.00000002	.00000589	.00012188	.00089244
.00368682	.01042347	.02218521	.03734658
.05078388	.05547033	.04614222	.02294125
.00000000	.00000028	.00001402	.00018415
.00116534	.00455905	.01248177	.02554191
.04030508	.04908854	.04393010	.02272974
.00000000	.00000001	.00000161	.00003800
.00036835	.00199405	.00702245	.01746852
.03198849	.04344097	.04182403	.02252018
.00000000	.00000000	.00000019	.00000784
.00011643	.00087217	.00395095	.01194699
.02538795	.03844314	.03981893	.02231255
.00000000	.00000000	.00000002	.00000162
.00003680	.00038147	.00222287	.00817074
.02014938	.03402031	.03790996	.02210684
.00000000	.00000000	.00000000	.00000033
.00001163	.00016685	.00125062	.00558810
.01599173	.03010632	.03609250	.02190302
.00000000	.00000000	.00000000	.00000007
.00000368	.00007298	.00070362	.00382179
.01269198	.02664263	.03436218	.02170108
.00000000	.00000000	.00000000	.00000001
.00000116	.00003192	.00039587	.00261378
.01007311	.02357743	.03271481	.02150100
.00000000	.00000000	.00000000	.00000000
.00000037	.00001396	.00022272	.00178761
.00799461	.02086488	.03114641	.02130277

N= 13

.02024200	.04606075	.06943676	.08907299
.10390802	.11314159	.11627578	.11314159
.10390802	.08907299	.06943676	.04606075
.02024200			

.00016008	.00189774	.00688889	.01592851
.02865301	.04353358	.05813789	.06960801
.07525501	.07314448	.06254787	.04416301
.02008192			

.00000127	.00007819	.00068345	.00284842
.00790117	.01675045	.02906894	.04282487
.05450317	.06006440	.05634244	.04234346
.01992310			

.00000001	.00000322	.00006781	.00050937
.00217878	.00644509	.01453447	.02634711
.03947372	.04932336	.05075265	.04059887
.01976554			

.00000000	.00000013	.00000673	.00009109
.00060081	.00247988	.00726724	.01620951
.02858870	.04050309	.04571743	.03892617
.01960922			

.00000000	.00000001	.00000067	.00001629
.00016567	.00095419	.00363362	.00997256
.02070526	.03326012	.04118176	.03732238
.01945414			

.00000000	.00000000	.00000007	.00000291
.00004569	.00036714	.00181681	.00613541
.01499571	.02731236	.03709608	.03578467
.01930029			

.00000000	.00000000	.00000001	.00000052
.00001260	.00014127	.00090840	.00377468
.01086059	.02242822	.03341574	.03431031
.01914766			

.00000000	.00000000	.00000000	.00000009
.00000347	.00005435	.00045420	.00232230
.00786574	.01841749	.03010054	.03289670
.01899623			

.00000000	.00000000	.00000000	.00000002
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.00569674	.01512397	.02711423	.03154133
.01884600			

.00000000	.00000000	.00000000	.00000000
.00000026	.00000805	.00011355	.00087901
.00412584	.01241942	.02442420	.03024180
.01869695			

.00000000	.00000000	.00000000	.00000000
.00000007	.00000310	.00005678	.00054079
.00298812	.01019852	.02200106	.02899581
.01854909			

.00000000	.00000000	.00000000	.00000000
.00000002	.00000119	.00002839	.00033271
.00216414	.00837476	.01981831	.02780116
.01840239			

N= 14

.01755973	.04007904	.06075929	.07860158
.09276920	.10259923	.10763193	.10763193
.10259923	.09276920	.07860158	.06075929
.04007904	.01755973		

.00012043	.00143413	.00524956	.01228964
.02248500	.03492927	.04800088	.05963105
.06766996	.07028420	.06631194	.05550973
.03864491	.01743930		

.00000083	.00005132	.00045356	.00192153
.00544982	.01189146	.02140708	.03303724
.04463214	.05324902	.05594384	.05071372
.03726210	.01731970		

.00000001	.00000184	.00003919	.00030044
.00132090	.00404837	.00954697	.01830354
.02943740	.04034275	.04719682	.04633209
.03592876	.01720092		

.00000000	.00000007	.00000339	.00004697
.00032015	.00137824	.00425769	.01014066
.01941562	.03056465	.03981743	.04232903
.03464314	.01708296		

.00000000	.00000000	.00000029	.00000734
.00007760	.00046921	.00189881	.00561821
.01280569	.02315652	.03359183	.03867183
.03340352	.01696580		

.00000000	.00000000	.00000003	.00000115
.00001881	.00015974	.00084972	.00311264
.00844607	.01754394	.02833963	.03533061
.03220826	.01684945		

.00000000	.00000000	.00000000	.00000018
.00000456	.00005438	.00037766	.00172449
.00557066	.01329172	.02390863	.03227807
.03105576	.01673389		

.00000000	.00000000	.00000000	.00000003
.00000110	.00001851	.00016842	.00095541
.00367416	.01007013	.02017043	.02948926
.02994451	.01661913		

.00000000	.00000000	.00000000	.00000000
.00000027	.00000630	.00007511	.00052933
.00242332	.00762938	.01701671	.02694141
.02887302	.01650515		

.00000000	.00000000	.00000000	.00000000
.00000006	.00000215	.00003350	.00029326
.00159831	.00578020	.01435609	.02461369
.02783987	.01639196		

.00000000	.00000000	.00000000	.00000000
.00000002	.00000073	.00001494	.00016247
.00105418	.00437922	.01211146	.02248708
.02684368	.01627954		

.00000000	.00000000	.00000000	.00000000
.00000000	.00000025	.00000666	.00009002
.00069529	.00331780	.01021779	.02054421
.02588315	.01616790		

.00000000	.00000000	.00000000	.00000000
.00000000	.00000008	.00000297	.00004987
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.02495698	.01605701		

N= 15

.01537662	.03518302	.05357961	.06978534
.08313460	.09308050	.09921574	.10128912
.09921574	.09308050	.08313460	.06978534
.05357961	.03518302	.01537662	

.00009232	.00110346	.00406652	.00961580
.01783353	.02819635	.03962706	.05064456
.05958868	.06488415	.06530107	.06016954
.04951309	.03407956	.01528430	

.00000055	.00003461	.00030864	.00132497
.00382554	.00854136	.01582716	.02532228
.03578879	.04522916	.05129308	.05187871
.04575521	.03301072	.01519254	

.00000000	.00000109	.00002342	.00018257
.00082063	.00258739	.00632142	.01266114
.02149464	.03152815	.04029000	.04473028
.04228254	.03197539	.01510133	

.00000000	.00000003	.00000178	.00002516
.00017604	.00078378	.00252479	.00633057
.01290962	.02197751	.03164724	.03856685
.03907344	.03097254	.01501066	

.00000000	.00000000	.00000013	.00000347
.00003776	.00023743	.00100841	.00316528
.00775348	.01531998	.02485846	.03325268
.03610789	.03000114	.01492054	

.00000000	.00000000	.00000001	.00000048
.00000810	.00007192	.00040276	.00158264
.00465672	.01067919	.01952598	.02867075
.03336742	.02906020	.01483096	

.00000000	.00000000	.00000000	.00000007
.00000174	.00002179	.00016086	.00079132
.00279681	.00744420	.01533738	.02472018
.03083494	.02814878	.01474192	

.00000000	.00000000	.00000000	.00000001
.00000037	.00000660	.00006425	.00039566
.00167976	.00518917	.01204730	.02131396
.02849467	.02726594	.01465342	

.00000000	.00000000	.00000000	.00000000
.00000008	.00000200	.00002566	.00019783
.00100886	.00361725	.00946299	.01837708
.02633202	.02641079	.01456544	

.00000000	.00000000	.00000000	.00000000
.00000002	.00000061	.00001025	.00009892
.00060592	.00252149	.00743305	.01584488
.02433351	.02558246	.01447799	

.00000000	.00000000	.00000000	.00000000
.00000000	.00000018	.00000409	.00004946
.00036391	.00175767	.00583855	.01366160
.02248667	.02478011	.01439107	

.00000000	.00000000	.00000000	.00000000
.00000000	.00000006	.00000163	.00002473
.00021856	.00122523	.00458610	.01177915
.02078001	.02400292	.01430467	

.00000000	.00000000	.00000000	.00000000
.00000000	.00000002	.00000065	.00001236
.00013127	.00085408	.00360232	.01015609
.01920288	.02325011	.01421879	

.00000000	.00000000	.00000000	.00000000
.00000000	.00000001	.00000026	.00000618
.00007884	.00059536	.00282957	.00875667
.01774544	.02252091	.01413342	

(b) Tables of t_i for N = 3 - 15

N = 3

2.183011
0.693147
0.119574

N = 4

2.667410
1.108634
0.400492
0.071960

N = 5

3.059523
1.466354
0.693147
0.262359
0.048046

N = 6

3.388323
1.775520
0.965769
0.479150
0.185601
0.034348

N = 7

3.671195
2.046127
1.213762
0.693147
0.352509
0.138382
0.025775

N = 8

3.919296
2.286055
1.438709
0.895796
0.524726
0.270804
0.107214
0.020055

N = 9

4.140187
2.501226
1.643438
1.085084
0.693147
0.412298
0.214821
0.085541
0.016048

N = 10

4.339217
2.696097
1.830738
1.261241
0.854343
0.554365
0.333101
0.174705
0.069852
0.013133

N = 11

4.520308
2.874069
2.003044
1.425235
1.007232
0.693147
0.454490
0.275032
0.144938
0.058126
0.010945

N = 12

4.686415
3.037776
2.162400
1.578225
1.151746
0.826945
0.575157
0.379921
0.231101
0.122223
0.049129
0.009262

N = 13

4.839821
3.189298
2.310507
1.721346
1.288247
0.955107
0.693147
0.485760
0.322624
0.197019
0.104484
0.042074
0.007940

N = 14

4.982325
3.330295
2.448775
1.855635
1.417266
1.077505
0.807498
0.590541
0.416188
0.277568
0.170022
0.090362
0.036438
0.006882

N = 15

5.115372
3.462117
2.578382
1.982016
1.539381
1.194272
0.917784
0.693147
0.509831
0.360861
0.241453
0.148258
0.078931
0.031866
0.006022

Appendix VI

In this appendix all Assembler language listings for the PDS. 1020 computer are given.

General Data-Logging Program

```
BGN
    JMP A0      /START.
    JMP R1      /CHANNEL RANGE.
    JMP R3      /GAINS.
    JMP R5      /CHANNEL PRINT-OUT.
    JMP R8      /INPUT MODE AND FILTER.
    JMP RL      /SCALE.
    JMP A5      /RETURN.
    ELA
    STA VL
    JMP A6+2
A0  OUT 403
    BCI GENERAL DATA LOGGING PROGRAM.
    OUT 403
    OUT 403
    SWL 1
    JPL FR
    JPL IN
A1  TSW 22
    TOV A2
    JMP A1
A2  TSW 88
    TOV A6
    JMP JC
A5  TSW 22
    TOV A5
    JMP A1
A6  JPL CR
    JMP A8
    JPL CR
    JPL SH
    JPL SQ
    JMP **
A8  JPL GC
    JPL GH
    JPL GP
A9  JPL CH
    JMP CP
FR  OUT 403
    OUT 403
    BCI FILTER (IN OR NO?):
    LMW FW
    EIR
    TXH *
    LDH ZO
    ITY
    AND DD+1
    ALS 2
    CPY BB
    ITY
    AND DD+1
    ADD BB
    AND FO
    TOV F2
    LDA FA
    CPY FX
    RTN
F2  LDA ZO
    CPY FX
    RTN
CR  ELA
    STA CZ
    LMW UN
    EIR
JL  JPL **      /CHANNEL RANGE.
    CPX AZ
    JPL RR      /RANGE CHECK.
    TXL JL
    LDA AA
    SUB AZ
    TMI KK
    LDA AA
    CPY BB
    LDA AZ
    CPY AA
    LDA BB
    CPY AZ
KK  LDA AZ
    SUB AA
    CPY CC
    JPL BC      /BINARY CONVERSION.
    CPY CB
    OUT 403
    OUT 403
    BCI FIRST CHANNEL NO.:
    LDA AA
    JPL S1
    OUT 403
    OUT 403
    BCI LAST CHANNEL NO.:
    LDA AZ
    JPL S1
    OUT 403
    OUT 403
CZ  JMP **
RR  SUB TT
    TMI ER
    SUB TT
    TMI RS
    OUT 403
```

```
ER BCI CHANNEL OUTSIDE PERMITTED RANGE.
   HLT **
RS RTN
S1 ALS 23
   OTY
   ALS 1
   OTY
   RTN
BC CPY BB
   ARS 1
   IZE EN
   SUB UN
   EIR
   LDA BB
BD SUB T1
   BAD TB
   STA BB
   TXH BD
EN LMW BB
   RTN
SH ELA
   STA N2
   OUT 403
   OUT 403
   BCI CALIBRATION FACTORS(INPUT BASES,THEN GRADIENTS).
   OUT 403
   OUT 403
   JMP CN
SP ELA
   STA L3
   LDA CC
   CPY CO
   LMW **
   STA LL
   STA LC
   STA LA
V7 JPL LO
   JPL S2
   OUT 423
   SWL 1
   LDA CO
   SUB UN
   TMI L3
   CPY CO
   LMW LL
   BAD LO
   STA LL
   STA LC
   STA LA
   JMP V7
L3 JMP **
LO SWL 2
   ELA
   STA LA+1
   LDA ZO
   IDK
   ALS 5
LL CPY **
   LDA ZO
   IDK
   CPY EE
```

```
   LMW AT
   EIR
   LDA EE
L1 ARS 1
   TZE L2
   TXH L1
L2 EIR
   BRS
   STA *+2
   LDA EE
   ALS 0
LC ADD **
LA CPY **
   JMP **
SQ ELA
   STA *+9
   LMW QZ
   STA SP+4
   JPL SP
   OUT 403
   OUT 403
   LMW QY
   STA SP+4
   JPL SP
   JMP **
GC LMW AG
   STA G3
   LDA CC
   CPY CO
   LDA AA
GO ADD T3
   CPY BB
   LMW TH
   EIR
   LDA BB
   OPP
   IDP
   SSP
   AND DX
G5 ARS 1
   TZE G2
   TXH G5
G2 EIR
   ALS 3
   ADD FX
   ADD BB
G3 CPY **
   LDA CO
   SUB UN
   CPY CO
   TMI G4
   LMW G3
   BAD G5
   STA G3
   LDA CC
   SUB CO
   ADD AA
   JMP GO
G4 RTN
GH ELA
   STA N2
   OUT 403
```

```
   OUT 403
   BCI GAINS.
   OUT 403
   OUT 403
   JMP CN
GP ELA
   STA Q6
   LMW AG
   BAD CB
   STA Q1
   LMW CB
   EIR
Q1 LDX **
   SUB FX
TH ARS 3
   SUB UN
   TZE Q2
   SUB UN
   TZE Q3
   SUB UN
   TZE Q4
   LDA T3
   JPL S3
   JMP Q5
Q2 LDA UN
   JPL S3
   JMP Q5
Q3 LDA T1
   JPL S3
   JMP Q5
Q4 LDA T2
   JPL S3
Q5 OUT 423
   TXH Q1
Q6 JMP **
S3 ALS 21
   OTY
   JMP V6
RC LMW AC
   BAD CB
   STA C1
   LMW AG
   BAD CB
   STA G1
   LMW CB
   EIR
   LDA CL
   OPP
   IDP
G1 LDX **
   OPP
   IDP
C1 CPX **
   TXH G1
   RTN
CH ELA
   STA N2
   OUT 403
   OUT 403
   BCI CHANNEL READINGS.
   OUT 403
```

```
CI OUT 403
   JMP CN
CP TSW 88
   TOV A4
   JMP A5
A4 OUT 403
   OUT 403
   JPL RC
   LMW AC
   BAD CB
   STA Y1
   LMW AV
   STA Y6
   LMW A5
   STA Y2
   LMW CB
   EIR
Y1 LDX **
   JPL OV
   TSW 11
   TOV Y3
   JPL S4
   JMP Y5
Y3 SWL 2
Y2 MPY **
   ARS 3
Y6 ADD **
   JPL S2
   LMW Y6
   BAD Y3
   STA Y6
   LMW Y2
   BAD Y3
   STA Y2
   SWL 1
Y5 OUT 423
   TXH Y1
ZX JMP CP
S4 TMI V1
   JMP V2
V1 OUT 400
V2 ALS 21
   OTY
   OUT 41L
   TZE *+7
V6 ALS 1
   OTY
   ALS 1
   OTY
   ALS 1
   OTY
   RTN
CN LMW CB
   EIR
   LDA AA
N1 CPY BB
   JPL S1
   OUT 423
   LDA BB
   ADD UN
   TXH N1
```

```
    OUT 403
    OUT 403
N2  JMP **
S2  CPY EE
    EIR
    STA BB
    LMW 02
    BLS
    EIR
    LDA EE
    TMI V3
    JMP V4
V3  OUT 400
V4  ARS 5
U1  ARS 1
    TXE U2
    TXH U1
U2  EIR
    BRS
    STA *+7
    BLS
    COM 1
    BAD FW
    EIR
    LDA EE
    ALS 16
    ALS 0
U3  ALS 1
    OTY
    TXH U3
    OUT 41L
U4  ALS 1
    TZE U5
    OTY
    JMP U4
U5  LMW BB
    EIR
    RTN
JC  JPL **
    ROT
    JMP JC
H1  LDA ZO
    IDK
    RTN
J1  TSW 44
    TOV J2
    JMP J1
J2  LDA SS
    OPP
    IDP
    AND DX
J3  TSW 44
    TOV J3
    RTN
IN  OUT 403
    OUT 403
    BCI INPUT FROM SCAN OR K/BD? :
    SWL 2
    LMW TH
    BLS
    EIR
```

```
    LDA ZO
I1  ALS 2
    CPY EE
    ITY
    AND DD
    ADD EE
    TXH I1
    AND IP
    TOV I2
    LMW JK
    STA JL
    STA JC
    JMP I3
I2  LMW JS
    STA JL
    STA JC
I3  OUT 403
    OUT 403
    SWL 1
    RTN
JS  PZE J1
JK  PZE H1
QZ  PZE AV
QY  PZE AS
DX  HEX DDDD+
NX  DEC 9999+
WY  PZE R6
WZ  PZE CP
IP  HEX 1429+
    HEX 192L+
ZO  HEX +
DD  HEX +
    HEX 3D+
SS  HEX L000+
CL  HEX 9000+
FW  HEX 4+
AT  HEX 8+
UN  HEX 1+
T1  HEX 10+
T2  HEX 100+
T3  HEX 1000+
FO  HEX 182L+
FA  HEX 4000+
TT  HEX 20+
TB  HEX L+
EE  BSS 2
CC  BSS 1
CO  BSS 1
BB  BSS 1
CB  BSS 1
FX  BSS 1
AA  BSS 1
AZ  BSS 1
R1  ELA
    STA R2
    JPL CR
R2  JMP **
R3  ELA
    STA R4
    JPL GC
    JPL GH
```

```
   JPL GP
R4 JMP **
R5 ELA
   STA R7
   LMW WY
   STA ZX
   JPL CH
   JMP A4
R6 LMW WZ
   STA ZX
R7 JMP **
R8 ELA
   STA R9
   JPL FR
   JPL IN
R9 JMP **
RL ELA
   STA RA
   JPL SH
   JPL SQ
RA JMP **
OV CPY BB
   SSP
   AND NX
   TOV OL
   LDA BB
   RTN
OL OUT 403
   BCI OVERFLOW!
   OUT 403
   JMP A8
AS PZE *+4
AG PZE *+11
AC PZE *+30
AV PZE *+49

FIN
```

Off-Line Identification Program for the Model $\frac{dx}{dt} + ax = a$

```
BGN
   JMP HD
ZO HEX +
   HEX +
   HEX +
   HEX +
   HEX +
   HEX +
BB JMP E1      /INPUT MATRIX.
CC JMP E2      /INPUT TIME SCALE.
DD JMP E3      /COMPUTE X(T).
EE JMP E4      /INITIALISE STORAGE.
FF JMP E5      /COMPUTE X(S).
GG JMP E6      /PRINT X(S).
HH JMP E7      /COMPUTE AND PRINT ESTIMATED VALUES.
II JMP E8      /PRINT X(T).
   HEX +
HD OUT 403
   OUT 403
   BCI MODELLING TECHNIQUE TEST PROGRAM.
   OUT 403
   OUT 403
   OUT 403
   IIK
E8 LMW XT
   STA K2
   LMW NP
   EIR
   OUT 403
   OUT 403
   BCI VALUES OF X(T)
   OUT 403
   OUT 403
K1 JPL FO
K2 MZE **
   OUT 403
   TXH *+2
   IIK
   LMW K2
   BAD TH
```

```
    STA K2
    JMP K1
E6  LMW XS
    STA C2
    LMW NP
    EIR
    OUT 403
    OUT 403
    BCI VALUES OF X(S)
    OUT 403
    OUT 403
C1  JPL FO
C2  MZE **
    OUT 403
    TXH *+2
    IIK
    LMW C2
    BAD TH
    STA C2
    JMP C1
E5  SWL 1
    LDA NO
    CPY CO
    LMW MX
    STA A2
    LMW XS
AA  STA A3
    STA A4
    LMW XT
    STA A1
    LMW NP
    EIR
AO  JPL IT
A1  LDX **       /X(T)
A2  MPX **       /MATRIX
    MPX TS
A3  ADX **       /X(S)
A4  CPX **       /X(S)
    SWL 1
    LMW A2
    BAD TH
    STA A2
    TXH *+2
    JMP A5
    LMW A1
    BAD TH
    STA A1
    JMP AO
A5  LDA CO
    SUB UN
    TZE E7
    CPY CO
    LMW A3
    BAD TH
    JMP AA
E4  SWL 6
    LMW FT
    EIR
    LMW XS
    BAD FT
    STA *+2
```

```
    LDA ZO
    CPX **
    TXH *-1
    SWL 1
    JMP E5
IN  LMW SV
    EIR
    SWL 2
    LDA ZO
TH  IDK
    CPY BS+1
    ARS 1
    TZE *+2
    TXH *-2
    EIR
    BRS
    STA *+2
    LDA BS+1
    ALS 0
    CPY BS+1
    SWL 1
    LDA ZO
    IDK
    CPY BS
    RTN
E1  SWL 1
    OUT 403
    OUT 403
    OUT 403
    BCI NO. OF QUADRATURE POINTS:
    LDA ZO
UN  IDT
    CPY NO
    SUB UN
    JPL BC
    CPY NP
    LDA NO
    ALS 23
    OTY
    ALS 1
    OTY
    OUT 403
    LDA NO
    CPY CO
    LMW MX
    STA B2
BO  LMW NP
    EIR
B1  JPL IT
B2  SAV **       /MATRIX VALUES.
    SWL 1
    LMW B2
    BAD TH
    STA B2
    TXH B1
    LDA CO
    SUB UN
    TZE *+3
    CPY CO
    JMP BO
    LMW NP
```

```
    EIR
    LMW TI
    STA B4
B3  JPL IT
B4  SAV **      /TIMES.
    SWL 1
    TXH *+2
    JMP E2
    LMW B4
    BAD TH
    STA B4
    JMP B3
BC  CPY CO
    ARS 1
    TZE EN
    SUB UN
    EIR
    LDA CO
BD  SUB TN
    BAD TB
    STA CO
    TXH BD
EN  LMW CO
    RTN
E2  OUT 403
    OUT 403
    BCI TIME SCALE:
    JPL IN
    JPL IT
    LDX BS
    CPX TS
    SWL 1
    JPL FO
    MZE TS
    OUT 403
E3  SWL 1
    OUT 403
    OUT 403
    BCI INPUT TIME CONSTANT
    OUT 403
    OUT 403
    JPL IN
    JPL IT
    LDX BS
    CPX TC
    SWL 1
    LMW NP
    EIR
    LMW TI
    STA D1
    LMW XT
    STA D2
CO  JPL IT
D1  LDX **
    MPX TS
    MPX TC
    CNP **
    CPX BS
    SWL 1
    JPL EX
    PZE BS
    PZE BS
    IIK
    JPL IT
    LDX UM
    SUX BS
D2  CPX **
    SWL 1
    TXH *+2
    JMP E4
    LMW D1
    BAD TH
    STA D1
    LMW D2
    BAD TH
    STA D2
    JMP DO
E7  SWL 1
    LMW XS
    STA F2
    LMW NP
    EIR
    JPL IT
    LDX ZO
    CPX SS
    CPX ES
    CPX ET
    LDX UM
    DVX TS
    CPX UP
F1  JPL IT
    LDX SS
    ADX UP
    CPX SS
F2  MPX **
    CPX BS
    SUX UM
    CPX BT
    LDX BS
    MPX SS
    MPX BT
    ADX ES
    CPX ES
    LDX BT
    MPX BT
    ADX ET
    CPX ET
    SWL 1
    TXH *+7
    JPL IT
    LDX ES
    DVX ET
    CNP **
    CPX ES
    JMP *+5
    LMW F2
    BAD TH
    STA F2
    JMP F1
    OUT 403
    OUT 403
    BCI TRUE TIME CONSTANT:
```

```
    JPL FO
    MZE TC
    OUT 403
    OUT 403
    BCI ESTIMATED TIME CONSTANT:
    JPL FO
    MZE ES
    OUT 403
    OUT 403
    IIK
TI  HEX L00+
XS  HEX L30+
XT  HEX L60+
MX  HEX L90+
NO  BSS 1
NP  BSS 1
TS  BSS 3
CO  BSS 1
SV  HEX M+
FT  HEX 2L+
TN  HEX 10+
TB  HEX L+
SS  BSS 3
BS  BSS 3
TC  BSS 3
UP  BSS 3
ES  BSS 3
ET  BSS 3
BT  BSS 3
UM  HEX 1+
    HEX 1000+
    HEX +
IT  BSS 275
FO  BSS 70
EX  BSS 1

FIN
```

Off-Line Identification Program for the Model $\frac{dx}{dt} + ax = b$

```
BGN
    JMP HD
ZO  HEX +
    HEX +
    HEX +
    HEX +
    HEX +
    HEX +
BB  JMP E1      /INPUT MATRIX.
CC  JMP E2      /INPUT TIME SCALE.
DD  JMP E3      /COMPUTE X(T).
EE  JMP E4      /INITIALISE STORAGE.
FF  JMP E5      /COMPUTE X(S).
GG  JMP E6      /PRINT X(S).
HH  JMP E7      /COMPUTE AND PRINT ESTIMATED VALUES.
II  JMP E8      /PRINT X(T).
    HEX +
HD  OUT 403
    OUT 403
```

```
   BCI MODELLING TECHNIQUE TEST PROGRAM.
   OUT 403
   OUT 403
   OUT 403
   IIK
E8 LMW XT
   STA K2
   LMW NP
   EIR
   OUT 403
   OUT 403
   BCI VALUES OF X(T).
   OUT 403
   OUT 403
K1 JPL FO
K2 MZE **
   OUT 403
   TXH *+2
   IIK
   LMW K2
   BAD TH
   STA K2
   JMP K1
E6 LMW XS
   STA C2
   LMW NP
   EIR
   OUT 403
   OUT 403
   BCI VALUES OF X(S)
   OUT 403
   OUT 403
C1 JPL FO
C2 MZE **
   OUT 403
   TXH *+2
   IIK
   LMW C2
   BAD TH
   STA C2
   JMP C1
E5 SWL 1
   LDA NO
   CPY CO
   LMW MX
   STA A2
   LMW XS
AA STA A3
   STA A4
   LMW XT
   STA A1
   LMW NP
   EIR
A0 JPL IT
A1 LDX **      /X(T)
A2 MPX **      /MATRIX
   MPX TS
A3 ADX **      /X(S)
A4 CPX **      /X(S)
   SWL 1
   LMW A2
   BAD TH
   STA A2
   TXH *+2
   JMP A5
   LMW A1
   BAD TH
   STA A1
   JMP A0
A5 LDA CO
   SUB UN
   TZE E7
   CPY CO
   LMW A3
   BAD TH
   JMP AA
E4 SWL 6
   LMW FT
   EIR
   LMW XS
   BAD FT
   STA *+2
   LDA ZO
   CPX **
   TXH *-1
   SWL 1
   JMP E5
IM LMW SV
   EIR
   SWL 2
   LDA ZO
TH IDK
   CPY BS+1
   ARS 1
   TZE *+2
   TXH *-2
   EIR
   BRS
   STA *+2
   LDA BS+1
   ALS 0
   CPY BS+1
   SWL 1
   LDA ZO
   IDK
   CPY BS
   RTN
E1 SWL 1
   OUT 403
   OUT 403
   OUT 403
   BCI NO. OF QUADRATURE POINTS:
   LDA ZO
UN IDT
   CPY NO
   SUB UN
   JPL BC
   CPY NP
   LDA NO
   ALS 23
```

```
    OTY
    ALS 1
    OTY
    OUT 403
    LDA NO
    CPY CO
    LMW MX
    STA B2
BO  LMW NP
    EIR
B1  JPL IT
B2  SAV **      /MATRIX VALUES.
    SWL 1
    LMW B2
    BAD TH
    STA B2
    TXH B1
    LDA CO
    SUB UN
    TZE *+3
    CPY CO
    JMP BO
    LMW NP
    EIR
    LMW TI
    STA B4
B3  JPL IT
B4  SAV **      /TIMES.
    SWL 1
    TXH *+2
    JMP E2
    LMW B4
    BAD TH
    STA B4
    JMP B3
BC  CPY CO
    ARS 1
    TZE EN
    SUB UN
    EIR
    LDA CO
BD  SUB TN
    BAD TB
    STA CO
    TXH BD
EN  LMW CO
    RTN
E2  OUT 403
    OUT 403
    BCI TIME SCALE:
    JPL IN
    JPL IT
    LDX BS
    CPX TS
    SWL 1
    JPL FO
    MZE TS
    OUT 403
E3  SWL 1
    OUT 403
```

```
    OUT 403
    BCI INPUT TIME CONSTANTS!
    OUT 403
    OUT 403
    JPL IN
    JPL IT
    LDX BS
    CPX TC
    SWL 1
    JPL IN
    JPL IT
    LDX BS
    CPX TD
    SWL 1
    LMW NP
    EIR
    LMW TI
    STA D1
    LMW XT
    STA D2
DO  JPL IT
D1  LDX **
    MPX TS
    MPX TC
    CNP **
    CPX BS
    SWL 1
    JPL EX
    PZE BS
    PZE BS
    IIK
    JPL IT
    LDX UM
    SUX BS
    DVX TC
    MPX TD
D2  CPX **
    SWL 1
    TXH *+2
    JMP E4
    LMW D1
    BAD TH
    STA D1
    LMW D2
    BAD TH
    STA D2
    JMP DO
E7  SWL 1
    LMW XS
    STA F2
    STA F3
    LMW NP
    EIR
    JPL IT
    LDX ZO
    CPX SS
    CPX BS
    CPX BT
    CPX BU
    CPX BW
```

```
   CPX BV
   LDX UM
   DVX TS
   CPX UP
F1 JPL IT
   LDX SS
   ADX UP
   CPX SS
F2 MPX **
   CPX BZ
   ADX BS
   CPX BS
   LDX BZ
   MPX SS
   CPX BZ
   ADX BT
   CPX BT
   LDX BZ
F3 MPX **
   CPX BZ
   ADX BU
   CPX BU
   LDX BZ
   MPX SS
   ADX BV
   CPX BV
   LDX BW
   ADX UM
   CPX BW
   SWL 1
   TXH *+19
   JPL IT
   LDX BS
   MPX BX
   DVX BW
   CNP **
   ADX BU
   CPX BZ
   LDX BS
   MPX BT
   DVX BW
   SUX BV
   DVX BZ
   CPX ES
   MPX BS
   ADX BT
   DVX BW
   CPX ET
   JMP *+6
   LMW F2
   BAD TH
   STA F2
   STA F3
   JMP F1
   OUT 403
   OUT 403
   BCI TRUE TIME CONSTANTS:
   OUT 403
   OUT 403
   JPL FO
```

```
   MZE TC
   OUT 403
   JPL FO
   MZE TD
   OUT 403
   OUT 403
   BCI ESTIMATED TIME CONSTANTS:
   OUT 403
   OUT 403
   JPL FO
   MZE ES
   OUT 403
   JPL FO
   MZE ET
   OUT 403
   OUT 403
   IIK
TI HEX L00+
XS HEX L30+
XT HEX L60+
MX HEX L90+
NO BSS 1
NP BSS 1
TS BSS 3
CO BSS 1
SV HEX M+
FT HEX 2L+
TN HEX 10+
TB HEX L+
SS BSS 3
BS BSS 3
TC BSS 3
TD BSS 3
BU BSS 3
BV BSS 3
BW BSS 3
BZ BSS 3
UP BSS 3
ES BSS 3
ET BSS 3
BT BSS 3
UM HEX 1+
   HEX 1000+
   HEX +
IT BSS 275
FO BSS 70
EX BSS 1

FIN
```

On-Line Identification Program

```
BGN
    JMP *+10
ZO  HEX +
    HEX +
    HEX +
    HEX +
    HEX +
    HEX +
    JMP QU      /QUADRATURE INFORMATION.
    JMP CU      /CHANNEL INFORMATION.
    JMP AA
    SWL 1
    OUT 403
    BC1 MODEL PREDICTION PROGRAM.
    OUT 403
    OUT 403
    OUT 403
    JMP QU
AA  JPL ZZ
    TSW 22
    TOV *+2
    JMP *-2
    TSW II
    TOV *+2
    JMP C2
    LDA CC
    OPP
    LDA ZO
    IDP
C1  CPY CB
    LDA CC
    OPP
    LDA ZO
    IDP
    CPY BB
    SUB CB
    SSP
    SUB SB
    TMI *+2
    JMP C2
    LDA BB
    JMP C1
C2  JPL T1
    LMW MM
    BAD NR
    STA A2
    LMW DA
    STA A1
A6  LDA NC
    CPY NO
    LMW VV
    BAD NR
A5  STA A3
    STA A4
    LMW NR
    EIR
AO  SWL 1
A1  LDA **
TW  SWL 2
A2  MPX **
    ARS 5
    MPY TF      /TIME FACTOR.
    ARS 7
A3  ADX **
A4  CPX **
    SWL 1
    LDA CX
    TZE *+2
    JPL XX
    SWL 2
    TXH AO
    SWL 1
    LMW A1
    BAD UN
    STA A1
    LDA NO
    SUB UN
    TZE *+5
    CPY NO
    LMW A3
    BAD NT
    JMP A5
    LDA NN
    ADD UN
    CPY NN
    SUB NP
    TZE CN
    LMW A2
    BAD NT
    STA A2
    JPL T1+9
    JMP A6
ZZ  ELA
    STA Z2
    LMW NB
    ELA
    LMW NR
    BAD VV
    STA Z5
    LMW NR
    EIR
Z4  SWL 2
    LDA ZO
Z5  CPX **
    TXH Z5
    ELA
    EIR
    SWL 1
    TXH *+2
    JMP TH
    LMW Z5
    BAD NT
    STA Z5
    EIR
    ELA
    JMP Z4-2
TH  SWL 3
```

```
   LDA ZO
   CPY SC
   SWL 1
   LDA N1
   ADD WT
   CPY CH
   LMW DA
   STA DB
Z3 LMW TI
   STA TJ
   STA *+1
   LDA **
   CPY CX
Z2 JMP **
QU SWL 1
   LDA ZO
   CPY SW
   TSW 88
   TOV *+3
   LDA UN
   CPY SW
   LDA SW
   TZE *+4
   TSW 88
   TOV *+4
   JMP *-2
   TSW 88
   TOV *-1
   OUT 403
   BCI NO. OF QUADRATURE POINTS:
   LDA ZO
   JPL IN      /INPUT ROUTINE.
   CPY NP
   JPL PR      /PRINTOUT ROUTINE.
   OUT 403
   OUT 403
   OUT 403
   LDA NP
   SUB UN
   JPL BC      /BINARY CONVERSION.
   STA NQ
   BLS
   STA NR
   LDA NP
   JPL BC
   BLS
   STA NT
   LMW NR
   BAD MM
   STA Q1
   LMW NR
   STA IR
   LMW NR
   EIR
   SWL 2
   LDA ZO
   JPL IN
Q1 CPX **      /MATRIX
   TXH *-3
   LMW IR
   EIR
   TXH *+2
   JMP *+7
   EIR
   STA IR
   LMW Q1
   BAD NT
   STA Q1
   JMP Q1-5
   SWL 1
   LMW NQ
   BAD TI
   STA Q2
   LMW NQ
   EIR
   LDA ZO
   JPL IN
Q2 CPX **      /TIMES.
   TXH Q2-2
   IIK
CU OUT 403
   BCI FIRST CHANNEL NO.:
   SWL 1
   LDA ZO
   JPL IN
   CPY N1
   JPL PR
   OUT 403
   OUT 403
   BCI LAST CHANNEL NO.:
   LDA ZO
   JPL IN
   CPY N2
   JPL PR
   LDA N2
   SUB N1
   ADD UN
   CPY NC
   SUB UN
   JPL BC
   STA NB
   SWL 2
   OUT 403
   OUT 403
   BCI TIME FACTOR:
   LDA ZO
   JPL IN
   CPY SO
   DEC 2+
   MZE TF
   HEX 6+
   OUT 403
   OUT 403
   BCI TIME CORRECTION FACTOR:
   LDA ZO
   JPL IN
   CPY TC
   JPL SO
   DEC 2+
   MZE TC
```

```
   HEX 6+
   OUT 403
   SWL 1
   TSW 11
   TOV *+2
   JMP AA
   OUT 403
   OUT 403
   OUT 403
   BCI CONTROL CHANNEL NO.:
   LDA ZO
   JPL IN
   CPY BB
   JPL PR
   LDA BB
   ADD WT
   CPY CC
   OUT 403
   OUT 403
   BCI CONTROL SIGNAL INITIATE AMPLITUDE:
   LDA ZO
   JPL IN
   CPY BB
   JPL PR
   LDA BB
   CPY SB
   OUT 403
   OUT 403
   OUT 403
CT JMP AA
T1 LDA CL
   OPP
   LDA CO
   ADD UN
   CPY CO
   IDP
   ARS 4
   SUB CX
   TZE RC
   LDA SC
   SUB NN
   TZE T1
   TMI *+2
   RTN
   OUT 403
   BCI SCAN ERROR.
   OUT 403
   IIK
RC LDA ZO
   CPY CO
   LMW DB
   BAD NB
   STA R2
   LMW NB
   EIR
R1 LDA CH
   OPP
   ADD UN
   CPY CH
   IDP
R2 CPX **
   TXH R1
   LDA SC
   ADD UN
   CPY SC
   SUB NP
   TZE R3
   LMW DB
   BAD UN
   BAD NB
   STA DB
   LMW TJ
   BAD UN
   STA TJ
   STA *+1
   LDA **
   CPY CX
   LDA N1
   ADD WT
   CPY CH
   JMP T1
R3 LDA ZO
   CPY CX
   RTN
XX ELA
   STA *+6
   EIR
   STA IR
   JPL T1
   LMW IR
   EIR
   JMP **
IN TSW 44
   TOV *+3
   IDT
   RTN
   IDK
   RTN
PR CPY BB
   LMW TH
   EIR
   LDA BB
   ARS 1
   TZE *+2
   TXH *-2
   EIR
   STA *+6
   COM 1
   BAD TH
   EIR
   OUT 413
   LDA BB
   ALS 0
   ALS 20
   ALS 1
   OTY
   TXH *-2
   RTN
BC CPY BB
   ARS 1
   TZE EN
   SUB UN
```

```
   EIR
   LDA BB
BD SUB TN
   BAD TB
   STA BB
   TXH BD
EN LMW BB
   RTN
VV HEX SL7+
MM HEX CM5+
DA HEX LC9+
TI HEX LLL+
CL DEC 9000+
WT DEC 1000+
TN DEC 10+
TB HEX L+
UN HEX 1+
SW BSS 1
BB BSS 1
CC BSS 1
CB BSS 1
NP BSS 1
NQ BSS 1
NR BSS 1
NT BSS 1
CH BSS 1
N1 BSS 1
N2 BSS 1
NC BSS 1
NB BSS 1
SB BSS 1
IR BSS 1
NO BSS 1
SC BSS 1
NN BSS 1
CO BSS 1
DB BSS 1
CX BSS 1
TJ BSS 1
TC BSS 2
TF BSS 2
SO BSS 77
CN IIK 77

FIN
```

Parameter Estimation Routine for the On-Line Identification Program.

Model: $\frac{dx}{dt} + ax = a$

```
BGN
TW SWL 2
   LDA TC
   ALS 2
   JPL FL      /FLOAT ROUTINE.
   PZE F1
   SWL 2
   LDA TF
```

```
   ALS 2
   JPL FL
   PZE F2
   JPL IT        /FLOATING POINT INTERPRETER.
   LDX UM
   DVX F2
   CPX F3
   SWL 1
   LMW NB
   STA IR
   LMW VV
   STA L1
   LMW TK
LD STA L3
   STA L4
TH SWL 3
   LDA ZO
   CPY SS
   CPY BU
   CPY BV
LO LMW NQ
   EIR
   SWL 2
L1 LDA **
   ALS 2
   JPL FL
   PZE FB
   JPL IT
   LDX SS
   ADX F3
   CPX SS
   MPX FB
   CPX BT
   MPX SS
   MPX BT
   CPX BS
   LDX BT
   MPX SS
   SUX BS
   ADX BU
   CPX BU
   LDX BT
   MPX TU
   SUX UM
   CPX BS
   LDX BT
   MPX BT
   SUX BS
   MPX F1
   ADX BV
   CPX BV
   SWL 1
   LMW L1
   BAD TW
   STA L1
   TXH LO+2
   JPL IT
   LDX BU
   DVX BV
L3 CPX **
```

```
   SWL 1
   JPL FO     /FLOATING POINT OUTPUT.
L4 MZE **
   OUT 403
   LMW IR
   EIR
   TXH *+5
   OUT 403
   OUT 403
   OUT 403
   IIK
   EIR
   STA IR
   LMW L3
   BAD TH
   JMP LD
VV HEX SL7+
UM HEX 1+
   HEX 1000+
   HEX +
TU HEX 1+
   HEX 2000+
   HEX +
BU BSS 3
TK HEX L82+
BV BSS 3
BS BSS 3
BT BSS 3
F1 BSS 3
F2 BSS 3
F3 BSS 3
FB BSS 3
SS BSS 3
IR NSS 1
FO BSS 70
IT BSS 270
FL NSS 1
ZO SYN 1
NQ SYN 23D
NB SYN 246
TF SYN 252
TC SYN 250

FIN
```

On-Line Monitor Program (Single Cycle)

```
BGN
   JMP AR
ZO HEX +
   HEX +
   HEX +
UN HEX 1+
JJ BSS 1
   JMP AZ        /INPUT SCAN INFORMATION
   JMP P1        /READ DATA
   JMP P2        /HEAD DATA TAPE
   JMP P3        /PUNCH DATA
   JMP P5        /END DATA TAPE
   JMP P6        /STOP CODE
AR OUT 403
   BCI DATA LOGGER SCANNER
   OUT 403
   OUT 403
   OUT 403
   IIK
AZ SWL 1
   BCI DATA VALUES PER CHANNEL:
   LDA ZO
   TH IDK
   CPY NN
   JPL PR
   OUT 403
   OUT 403
   BCI NO. OF CHANNELS:
   LDA ZO
   IDK
   CPY NC
   JPL PR
   OUT 403
   OUT 403
   BCI FIRST CHANNEL:
   LDA ZO
   IDK
   CPY CC
   JPL PR
   LDA CC
   ADD TX
   CPY CC
   OUT 403
   OUT 403
   OUT 403
   OUT 403
   IIK
P1 SWL 1
   LDA NN
   CPY CO
   LDA NC
   JPL BC
   STA NB
   LDA NC
   SUB UN
   JPL BC
   STA IR
   EIR
   LMW S1
   BAD IR
   STA A4
   LDA CC
   CPY CM
   JPL CR
   CPY CD
   JPL CR
   AND DD
   SUB CD
   SSP
   SUB TN
   TMI *-5
   JMP A7
CR LDA CC
   OPP
   IDP
   RTN
A7 LDA CL
   OPP
   IDP
A6 LDA CM
   OPP
   ADD UN
   CPY CM
   IDP
A4 CPX **
   TXH A6
   LDA CO
   SUB UN
   TZE P1-1
   CPY CO
   LMW A4
   BAD NB
   STA A4
   LDA CC
   CPY CM
   LMW IR
   EIR
   JMP A7
P2 SWL 3
   LMW F1
   EIR
   LDA ST
   OPB
   ARS 2
   TXH *-2
   SWL 1
   LDA ZO
   IDK
   TMI *+3
   OPB
   JMP *-4
   LDA NL
   OPB
   LMW FI
   EIR
   LDA ZO
```

```
   OPB
   TXH *-1
   IIK
P3 SWL 1
   LDA NN
   MPY NC
   CPY CO
   LMW S1
   STA A2
   STA A3
A2 LDA **
   TMI *+2
   JMP *+3
   LDA SN
   OPB
   LMW UN
   EIR
   LDA NP
   OPB
   ARS 2
   TXH *-2
   LMW TH
   EIR
A1 EIR
   STA *+3
   EIR
A3 LDA **
   ARS 0
   AND FI
   BAD AD
   STA *+1
   LDA **
   OPB
   TXH A1
   JPL ZZ
   LDA CO
   SUB UN
   TZE P5+7
   CPY CO
   LMW A2
   BAD UN
   STA A2
   STA A3
   JMP A2
P5 SWL 3
   LMW FI
   EIR
   LDA TL
   OPB
   ARS 2
   TXH *-2
   IIK
P6 LMW SC
   OPB
   IIK
ZZ LMW UN
   EIR
   LDA SP
   OPB
   TXH *-1
```

```
   RTN
PR ALS 21
   OTY
   ALS 1
   OTY
   ALS 1
   OTY
   ALS 1
   OTY
   RTN
BC CPY JJ
   ARS 1
   TZE EN
   SUB UN
   EIR
   LDA JJ
BD SUB TN
   BAD NL
   STA JJ
   TXH BD
EN LMW JJ
   RTN
TN DEC 10+
TX HEX 1000+
NN BSS 1
NC BSS 1
IR BSS 1
CC BSS 1
NB BSS 1
CO BSS 1
CM BSS 1
CD BSS 1
CL HEX 9000+
ST HEX 5LS4+
   HEX LOA3+
   HEX AD44+
NP HEX 2M30+
DD HEX DDDD+
NL HEX L+
FI HEX D+
SN HEX 25+
SC HEX 84+
SP HEX LO+
TL HEX OLOL+
   HEX LLLL+
   HEX LLLL+
AD PZE *+1
   HEX 30+
   HEX CI+
   HEX C2+
   HEX 33+
   HEX C4+
   HEX 35+
   HEX 36+
   HEX C7+
   HEX C8+
   HEX 39+
SI PZE *+1

FIN
```

On-Line Monitor Program (Repetitive Operation)

```
BGN
   JMP AR
ZO HEX +
   HEX +
   HEX +
UN HEX 1+
   HEX +
   JMP AZ       /INPUT SCAN INFORMATION.
   JMP P2       /HEAD DATA TAPE.
   JMP P5       /END DATA TAPE.
   JMP P6       /STOP CODE.
   JMP P3       /CONTROL PROGRAM.
   JMP P8       /COUNTER SET.
AR OUT 403
   BCI DATA LOGGER SCANNER (MOD.).
   OUT 403
   OUT 403
   OUT 403
   IIK
P3 SWL 1
   LDA ZO
   IDK
   CPY BO
P7 JPL YY
   LDA LG
   OPP
   LDA ZO
FY IDP
   TMI P7
   JPL YY
   JPL P1       /READ DATA.
   LMW LG
   EIR
   LDA ZO
   OPB
   TXH *-1
   JPL CO       /SORT AND PUNCH DATA.
   LDA BO
   SUB UN
   TZE *+3
   CPY BO
   JMP P7
   IIK
YY LDA CL
   OPP
   IDP
   RTN
CO ELA
   STA R9
   SWL 1
   LDA UN
   CPY QS
R1 LDA QS
   MPY TH
   CPY QT
   SUB UN
   JPL EC
   BLS
   STA QU
   LMW QS
   BAD ST
   STA *+1
   LDA **
   TZE R6
   CPY SQ
   LMW QS
   BAD TI
   STA *+1
   LMW **
   STA R4+3
   SWL 2
   LMW QU
   EIR
   LDA ZO
   CPX TT+28
   TXH *-1
R4 SWL 2
   LMW QU
   EIR
   LDX **       /SAMPLE TIMES.
   ADX TT+28
   CPX TT+28
   TXH *-3
   LMW QU
   EIR
R3 LDX TT+28
   CPY BS
   ARS 4
   ALS 4
   SUB BS
   ADD FV
   TMI *+4
   TZE *+3
   LDA BS
   JMP *+3
   LDA BS
   ADD UN
   ARS 4
   JPL EC
   CPY JJ
   LDA ZO
   CPY BS
   LMW NC
   AND UN
   TZE *+3
   LDA JJ
   CPY BS
   LMW NC
   BRS
   TZE *+3
   LDA JJ
   BLS
   BAD BS
   CPX SU+14
   SWL 2
   EIR
   BLS
   EIR
```

```
    TXH R3
    SWL 1
    LMW QU
    BRS
R8  STA IR
    EIR
    LDX SU+14
    BAD S1
    STA R5+2
    STA R7
    LMW NB
R5  STA JR
    EIR
    LDX **
    TMI *+2
    JMP *+3
    LDA SN
    OPB
    LMW UN
    EIR
    LDA NP
    OPB
    ARS 2
    TXH *-2
    LMW TH
    EIR
A1  EIR
    STA *+4
    LMW JR
    EIR
R7  LDX **
    ARS 0
    AND FI
    BAD AD
    STA *+1
    LDA **
    OPB
    LMW *-6
    EIR
    TXH A1
    JPL ZZ
    LMW JR
    EIR
    TXH *+2
    JMP *+3
    EIR
    JMP R5
    LMW IR
    EIR
    TXH *+2
    JMP *+3
    EIR
    JMP R8
    LDA SQ
    SUB UN
    TZE *+3
    CPY SQ
    JMP R4
R6  LDA QS
    ADD UN
```

```
    CPY QS
    SUB FY
    TMI R1
    TZE R1
R9  JMP **
SQ  BSS 1
P8  SWL 1
    LDA UN
    CPY QS
    LMW QS
    BAD ST
    STA P9+2
    STA P9+4
    LMW QS
    BAD TI
    STA *+1
    LMW **
    STA P9
    TOV *+1
    LDA NN
    ALS 4
    SWL 2
P9  DVP **
    SWL 1
    CPY **        /NO. OF SETS.
    JPL PU
    PZE **
    LDA QS
    ADD UN
    CPY QS
    SUB FY
    TMI P8+3
    TZE P8+3
    IIK
ST  PZE *
    BSS 5
PU  ELA 5
    STA A2+3
    BAD UN
    STA A3
    LMW TH
    EIR
A2  EIR
    STA *+5
    EIR
    LMW **
    STA *+1
    LDA **
    ARS 0
    AND FI
    BAD AD
    STA *+1
    LDA **
    OPB
    TXH A2
    JPL ZZ
A3  JMP **
EC  SWL 1
    CPY JJ
    LMW TH
    EIR
```

```
   STA IR
   LDA ZO
   CPY VL
   LDA JJ
   ARS 1
   TZE *+2
   TXH *-2
   EIR
   COM 1
   BAD TH
ED STA JR
   STA *+2
   LDA JJ
   ARS 0
   AND FI
   TZE *+11
   SUB UN
   EIR
   LMW JR
   BAD S2
   STA *+2
   LDA ZO
   BAD **
   TXH *-1
   BAD VL
   STA VL
   LMW JR
   EIR
   TXH *+2
   JMP *+3
   EIR
   JMP ED
   LMW IR
   BRS
   EIR
   LMW VL
   RTN
AZ SWL 1
   BCI DATA VALUES PER CHANNEL:
   LDA ZO
TH IDK
   CPY NN
   JPL PR
   OUT 403
   OUT 403
   BCI NO. OF CHANNELS:
   LDA ZO
   IDK
   CPY NC
   JPL PR
   OUT 403
   OUT 403
   BCI FIRST CHANNEL:
   LDA ZO
   IDK
   CPY CC
   JPL PR
   LDA CC
   ADD TX
   CPY CC
   OUT 403
   OUT 403
   OUT 403
   OUT 403
   IIK
P1 SWL 1
   ELA
   STA EF
   LDA NN
   CPY CO
   LDA NC
   SUB UN
   STA NB
   LDA NC
   SUB UN
   JPL EC
   STA IR
   EIR
   LMW S1
   BAD UN
   BAD IR
   STA A4
   LDA CC
   CPY CM
   JPL CR
   CPY CD
   JPL CR
   AND DD
   SUB CD
   SSP
   SUB TN
   TMI *-5
   JMP A7
CR LDA CC
   OPP
   IDP
   RTN
A7 LDA CL
   OPP
   IDP
A6 LDA CM
   OPP
   ADD UN
   CPY CM
   IDP
A4 CPX **
   TXH A6
   LDA CO
   SUB UN
EF TZE **
   CPY CO
   LMW A4
   BAD NC
   STA A4
   LDA CC
   CPY CM
   LMW IR
   EIR
   JMP A7
P2 SWL 3
```

```
  LMW FI
  EIR
  LDA SZ
  OPB
  ARS 2
  TXH *-2
  SWL 1
  LDA ZO
  IDK
  TMI *+3
  OPB
  JMP *-4
  LDA NL
  OPB
  LMW FI
  EIR
  LDA ZO
  OPB
  TXH *-1
  IIK
5 SWL 3
  LMW FI
  EIR
  LDA TL
  OPB
  ARS 2
  TXH *-2
  IIK
6 LMW SC
  OPB
  IIK
Z LMW UN
  EIR
  LDA SP
  OPB
  TXH *-1
  RTN
R ALS 21
  OTY
  ALS 1
  OTY
  ALS 1
  OTY
  ALS 1
  OTY
  RTN
N DEC 10+
X HEX 1000+
N BSS 1
C BSS 1
R BSS 1
C BSS 1
B BSS 1
O BSS 1
O BSS 1
M BSS 1
D BSS 1
L HEX 9000+
Z HEX 5LS4+
  HEX LOA3+
  HEX AD44+
P HEX 2M30+
```

```
DD HEX DDDD+
NL HEX L+
FI HEX D+
SN HEX 25+
SC HEX 84+
SP HEX LO+
TL HEX OLOL+
   HEX LLLL+
   HEX LLLL+
AD PZE *+1
   HEX 30+
   HEX C1+
   HEX C2+
   HEX 33+
   HEX C4+
   HEX 35+
   HEX 36+
   HEX C7+
   HEX C8+
   HEX 39+
TT BSS 30
SU BSS 15
JJ BSS 1
QS BSS 1
QT BSS 1
QU BSS 1
JR BSS 1
VL BSS 1
BS BSS 2
LG HEX 1035+
FV HEX +
   HEX 5000+
S2 PZE *+1
   HEX 1+
   HEX L+
   HEX 64+
   HEX 3M7+
TI PZE *
   PZE K1
   PZE K2
   PZE K3
   PZE K4
   PZE K5
   HEX 1+
   HEX +
   HEX 5+
   HEX 7968+
K1 HEX 18+
   HEX 2566+
   HEX 1+
   HEX +
   HEX 5+
   HEX 4035+
   HEX 13+
   HEX 9499+
   HEX 28+
   HEX 1172+
   HEX 51+
   HEX 6921+
K2 HEX 98+
   HEX 6469+
   HEX 1+
   HEX +
```

```
   HEX 5+
   HEX 3303+
   HEX 13+
   HEX 3862+
   HEX 25+
   HEX 6916+
   HEX 43+
   HEX 1921+
   HEX 67+
   HEX 6149+
   HEX 102+
   HEX 4077+
   HEX 155+
   HEX 8590+
3  HEX 257+
   HEX 9877+
   HEX 1+
   HEX +
   HEX 5+
   HEX 3040+
   HEX 13+
   HEX 1962+
   HEX 24+
   HEX 9515+
   HEX 41+
   HEX 0193+
   HEX 62+
   HEX 0986+
   HEX 89+
   HEX 2863+
   HEX 124+
   HEX 3518+
   HEX 170+
   HEX 3979+
   HEX 233+
   HEX 4701+
   HEX 327+
   HEX 9827+
4  HEX 505+
   HEX 9830+
   HEX 1+
   HEX +
   HEX 5+
   HEX 2916+
   HEX 13+
   HEX 1071+
   HEX 24+
   HEX 6194+
   HEX 40+
   HEX 0952+
   HEX 59+
   HEX 9238+
   HEX 84+
   HEX 6614+
   HEX 115+
   HEX 1025+
   HEX 152+
   HEX 3936+
   HEX 198+
   HEX 3182+
   HEX 255+
   HEX 6262+
   HEX 329+
   HEX 1292+
   HEX 428+
   HEX 1604+
   HEX 574+
   HEX 9115+
K5 HEX 849+
   HEX 4474+
SI PZE *

FIN
```

-Line Statistical Analysis Program.

```
N
 OUT 403
 OUT 403
 BCI STATISTICAL CHECK.
 OUT 403
 OUT 403
 SWL 1
 LDA ZO
 BCI CHANNEL COMMAND?
 OUT 403
 OUT 403
 OUT 403
 IDK
 CPY CH
 SWL 3
 LDA ZO
 CPY CO
 CPY C1
 CPY C2
A SWL 1
 LDA CH
 OPP
 LDA ZO
 IDP
 ALS 4
 JPL FL
 PZE CC
 JPL IT
 LDX CO
 ADX UM
 CPX CO
 LDX CC
 ADX C1
 CPX C1
 LDX CC
 MPX CC
 ADX C2
 CPX C2
 TSW 88
 TRA *+2
 JMP AA
 LDX C1
 DVX CO
 CPX MN
 LDX C1
 MPX C1
 DVX CO
 CPX CC
 LDX CO
 SUX UM
 CPX CO
 LDX C2
 SUX CC
 DVX CO
 CPX VA
 SWL 1
 JPL SQ
 PZE VA
 BCI MEAN:
 JPL FO
 MZE MN
 OUT 403
 OUT 403
 BCI STANDARD DEVIATION:
 JPL FO
 MZE VA
 OUT 403
 OUT 403
 BCI SAMPLE SIZE:
 JPL FO
 MZE CO
 OUT 403
 OUT 403
 IIK
CH BSS 1
ZO HEX +
   HEX +
   HEX +
CO BSS 3
C1 BSS 3
C2 BSS 3
CC BSS 3
VA BSS 3
MN BSS 3
UM HEX 1+
   HEX 1000+
   HEX +
FL BSS 43
IT BSS 270
FO BSS 66
SQ BSS 1

FIN
```