CALIFORNIA STATE UNIVERSITY, NORTH RIDGE

EYE MOVEMENT STUDY

A project report submitted in partial satisfaction of the requirements for the degree of Master of Science in ENGINEERING

by

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ABSTRACT

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The purpose of this study was to develop a procedure for demonstrating a correlation between eye movements and the quality of visual and motor performance. This was to establish an improved capability for conducting test and evaluation of human task efficiency. The correlation between operator performance and eye movements is thought to be a function of task loading, task variables, and operator fatigue. These parameters were studied through laboratory experimentation. This report outlines the feasibility and motivation for eye movement research, the design of the experiment, and pertinent preliminary results.
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CHAPTER ONE
BACKGROUND

The Relationship of Fast Eye Movements and Mental State of a Subject

Vestibular nystagmus refers to the involuntary eye movements which occur in connection with stimulation of the semicircular canals (Wendt, 1936). The semi-circular canals are within the same bony cavity that contains the inner ear and they are the human vestibular apparatus (a sensory system providing information about the position and movement of the head to the Central Nervous System, see figure 1). The form of the eye movement has two components: the slow deviation and the fast phase. The slow deviation is believed to have its genesis in the canicular end organ (specifically, the hair cells of the cupula; the cupula transmits mechanical energy to the receptor hair cells which, during appropriate positioning or movement, are distorted resulting in excitation of the vestibular nerve fibers, see figure 2) and which serves to maintain the position of the eyes in space when the head moves relative to the earth (Camis, 1930; Guedry, 1965; McCabe, 1965; Wendt, 1936, 1950). Each semi-circular canal has an enlarged end containing receptor cells and fine terminal branches of the vestibular nerve. The top of each receptor cell has a number of hairs embedded in a tissue mass that covers the receptor tissue. This mass is called the cupula. The fast phase, which is a saccade, is presumably of more central origin (Gernandt, 1959; McCabe, 1965; Wolfe, 1966) and serves to return the eyes to the normal forward position.
Figure 1
Nystagmus can better be explained through an example. If the human body is rotated rapidly in a chair the eyes will undergo the rapid to-and-fro motion called nystagmus. The motion is jerky because the movement has two components; a slow phase opposite to the direction of rotation of the chair, and a fast phase (a saccade) bringing the eyes back to the front.

The finding that the fast phase of nystagmus is absent in persons with lesions in the pontine reticular formation (Daroff & Hoyt, 1971; the pontine reticular formation provides a link between the classical sensory systems of the brain and such nonspecific behavioral phenomena as "alertness," "attention," "arousal," "sleep," etc. which appear to be related to sensory activation but not necessarily to any specific type of stimulation) and the similar result reported by Barany sometime ago (1907, cited by McCabe, 1965) suggests that the fast phase should be examined for a relationship to arousal.

Kennedy (1972) examined characteristics of fast eye movements and operationally defined their disappearance as habituation. Because the fast eye movement of nystagmus which is "habituated" can be retrieved by alerting the subject (with a provocative stimulus such as clapping, etc., Guedry, 1965; Wendt, 1950, 1951) and because of Daroff & Hoyt's relationships, Kennedy hypothesized that some characteristics of the fast eye movements could be related to measures of mental work. He found a general correspondence existed between the quantity of the fast eye movements and alertness of the subject as measured by a vigilance task.
There are other studies which have shown other relationships between certain aspects of eye movements and the mental state of the subject. These studies include (a) the relationship of electroencephalogram alpha and ocular motor activity with the suggestion that the latter causes the former (Mulholland & Evans, 1965, 1966); (b) the changing pattern of small eye movements during inattention (Gaardner, 1966); (c) the increase in the number of fixations as interest increased (fixations are periods of time during which the eye does not move, usually 0.1 seconds in duration, Trehub, et.al., 1964); (d) the increase in the duration of fixations as cognitive activity increased (Gould & Schaffer, 1965); (e) the increase in the number of fixations as the stress in a driving task increased (Whalen, 1968); and (f) an increase in fixation duration and a decrease in frequency of movement when words associated with drugs were presented to addicts as compared to non-addict controls (Hall, et.al., 1973).

From Kennedy's study and those cited above, it is hypothesized that the fast eye movements can be used as a quantitative and independent index of mental work as shown via a vigilance task.

In a preliminary study conducted by the Human Factors Engineering Branch at the Pacific Missile Test Center, which took as its working hypothesis that some aspect of fast eye movement would be related to operator performance (Ketchum & Kennedy, 1976), the preliminary data showed that the velocity of fast eye movements are correlated with (1) performance on a task, and (2) task difficulty. As performance decreased, the number of fast eye movements in the 100 to 200 degree-
per-second range were observed to decrease for all task levels. The most difficult task had more fast eye movements than the least difficult task. Additionally, greater degradation in performance appeared to coincide with greater downward shift of fast eye movement densities per unit time. This finding was not conclusive and resulted in some speculation regarding the complex nature of the study effort.

**Relationship of Eye Movements to Navy Weapons Systems**

In an experimental situation independent variables are imposed on the organism and are systematically varied in the experimental situation. Dependent variables measure the responses of the organism. Eye movements are one aspect of human behavior that can function as both independent and dependent variables simultaneously (Kling & Riggs, 1971). Saccades are a type of fast eye movement under both voluntary (dependent) and involuntary (independent) control. Since voluntary eye movements are consequences, they are the responses of the visual system to the visual stimuli. In this mode, (voluntary) eye movements, in particular, saccades, should provide a means of comparative test and evaluation of display designs, cockpit configurations, and operator visual and motor performance in aircraft/flight situations and in airborne weapon systems.

Eye movements associated with specific visual tasks (monitoring, tracking, display interpretation, target acquisition) may be reflected in such parameters as (1) saccadic frequency and amplitude, (2) fixation duration and frequency, (3) line-of-sight and point-of-regard within a specific display (task), (4) scan and search patterns, (5) use of foveal and peripheral vision, etc. (foveal vision is the
highest resolution vision and peripheral vision is the lowest resolution vision). These parameters in turn indicate (1) where a person is looking (2) if visual masking occurs, for example, when two sound stimuli are presented simultaneously, the sensation of one stimulus (the masked tone) may be suppressed by the sensation of the other (the masking tone); the masked tone sensation remains obliterated unless its physical intensity is increased), (3) if the field of view is restricted, etc. Recent studies by Snyder (1973) and Greening (1973) have shown the importance of short-duration fixations for target acquisition and the distribution of search with the field-of-view. These eye movement parameters can be potentially valuable means for comparatively evaluating alternative display designs and cockpit configurations. They should provide a sensitive indication of individual display effectiveness as an integral part of a total configuration.

Another area where eye movement recordings may be an especially useful research tool is in the study of visual task loading in a simulated cockpit environment. Different eye movement characteristics have been shown to be related to performance. Enoch (1960) found that when display degradation was introduced, the characteristics representing various facets of the individual eye fixations changed markedly. In a simulated air-to-ground search task, Enoch found that increasing the amount of blur increased search time as well as duration of fixation and also reduced inter-fixation distances (Enoch, 1958). In another simulated air-to-ground search task, Snyder (1973) found that median fixation duration increased as target
acquisition performance decreased.

There also is evidence that eye movement characteristics can be used to determine if complex visual environments become familiar (Hall & Cusack, 1972). Mourant and Rockwell (1972) studied the visual behavior of novice and experienced automobile drivers and found that novice drivers need to obtain information foveally whereas experienced drivers are able to obtain the same information through peripheral vision. This finding is consistent with Mackworth’s (1965) discovery that "visual noise causes tunnel vision" (i.e., he found that by increasing the complexity of stimulus patterns, that is by adding extraneous visual stimuli, he degraded peripheral recognition).

The pattern of eye movements and their duration, amplitude, and spacing, etc., appear to be a useful means for evaluation of the level of visual task loading upon a pilot in a simulated flight environment. Thus, measurement of aircraft pilot eye movement patterns while "flying" a flight simulator is an ideal method for preliminary evaluation of prototype advance display designs. The results from these tests can be used to identify the most promising designs for further development and eventual flight test. This approach is more cost effective than waiting until flyable hardware has been developed to discover an inadequate design which could have been detected much sooner in the development cycle.

Problem Summary

At the conclusion of the first Human Factors Engineering Branch eye movement study it was realized that a procedure was required for
collecting additional data for correlative research. Thus, the purpose of this study is to develop a procedure for demonstrating a correlation between eye movements and visual and motor performance to acquire an improved capability to perform test and evaluation of operator task efficiency. Specifically, to study the correlation of operator performance and eye movements as a function of task loading, task variables and operator fatigue is the objective of this study.
CHAPTER TWO
DESIGN OF EXPERIMENT

Procedure

The procedure developed is summarized in figure 3. Steps three and seven were eliminated in the second and third sessions. Each step is described in more detail below.

Each subject attended three experimental sessions. The first session began with an introductory interview in which instructions were given to the subject (Step One). These instructions included the following:

1. The experiment will harm you in no way;
2. You will be wearing a helmet with an infrared sensing system on it. Adjustments will be made to make you as comfortable as possible;
3. The experiment will take place in the dark. Please keep as quiet as possible. In order to keep your facial muscles calm please do not grind your teeth, chew gum, whistle, etc.;
4. You cannot fail the task so please stay alert and try your best;
5. You will have a learning period to familiarize yourself with the task.

The second and third sessions did not include rereading the above instructions but a reminder that the same instructions applied was verbally given to the subjects.
Figure 3
The helmet was then put on the subject, and adjustments were made to the infrared sensors so that they were correctly positioned over each eye of the subject (Step Two). In the first session only, the subject was instructed to blink several times. These blinks were recorded in order to identify a typical blink and to distinguish it from a saccade (Step three). The chin rest was adjusted to the correct height for the subject and a calibration was recorded (Step Four). The eyes of the subject are light adapted for this first calibration. The calibration consisted of an array of lights that were displayed sequentially in front of the subject. The subject then followed with his eyes the appearance of these lights. The response box was then shown and described to the subject for familiarization (Step Five, see "Apparatus and Laboratory Set Up"). A response to the high, medium, and low tone buttons is required by feel in this experiment because the subject cannot see the labels in the dark. The twenty minute dark adaptation period then began with several things happening during that period (Step Six). In the first session two questionnaires were verbally given to the subject by the experimenter (see figures 4 and 5). The second questionnaire (figure 5) was given in all three sessions. After the questionnaires were given the task was explained to the subject, and he was given a learning period to familiarize himself with its requirements. In the first session the dark adaptation period was followed by a ten minute baseline test where the subject's eye movements were recorded without performing any task (Step Seven). This was to record the random eye
Subject
Date
Time

Age
Sex
Eye Color
Eye correction R
L
None

What hand do you write with? Right__Left__Both_
What hand do you eat with? Right__Left__Both_
What eye do you sight through a rifle with? Right__Left__Both_
What eye do you look through a monocular microscope with? Right__Left__Both_

Do you smoke?____ If yes, which of the following? Cigarettes____Pipe____Cigars____

Figure 4
Subject________________
Date _________________
Time _________________

1. Have you been ill in the past week? Yes No. If yes, specify: A) severity B) time course C) where localized, etc.

2. Are you in your usual state of fitness? Yes No

3. How many hours since your last meal?____

4. Approximately how many cups of fluid have you had in the past two hours?____

5. How many caffeine drinks (soft drinks, coffee, tea, etc.) have you consumed in the past 24 hours? In the past 2 hours? In the past hour?____

6. How much alcohol have you consumed in the past 24 hours? In the past 2 hours? In the past hour?____

7. How many cigarettes/pipefuls/cigars have you smoked in the past 24 hours? In the past 2 hours? In the past hour?____

8. Have you taken any drugs or medications of ANY kind in the past 24 hours? Yes No. If yes, when was the last dosage?____

   1. Sedative Tranquilizer Name
   2. Antihistamine (allergy, etc.) Name
   3. Analgesic (aspirin) Name
   4. Other (specify)

9. How many hours sleep did you have last night?____ Was this sufficient? Insufficient?____

10. So far has this day been much better better than usual usual usual____

    worse than much worse usual than usual____?

11. How concerned are you regarding your performance on this test? None Minimal Moderate Great Very great

12. Do you expect to perform better less well same as the average?

Figure 5
movements when no mental loading was imposed. When the dark adaptation period was concluded another calibration check was performed (Step Eight). The vigilance task (Step Nine, see following section) and a final calibration check (Step Ten) followed. Readaptation concluded each session (Step Eleven).

Vigilance Task

The vigilance task was an auditory task which consisted of three tones, a high, medium and low at 1800 Hz, 900 Hz, and 100 Hz, respectively. All subjects who received the vigilance task heard the same auditory signals for 60 minutes each session. The tones were presented to the subject through earphones at a comfortable listening level from a magnetic tape player. The tones occurred at different times for a total of eight per minute for the low tone, six per minute for the medium tone, and five per minute for the high tone. The period between the tones was periodic except for the space between the high tones. These were slightly aperiodic with one of the intervals between the tone occurrences twice as long as the others (see figure 6 for a diagram of the time sequence of the tones). The test is perceived as being random by the subjects due to the time sequence of the tones.

The vigilance task was for the subject to keep track of the tones and push a response key every fourth time the tone being counted occurred. Any silent method or memory aid available to the subject was allowed, but he was told not to count out loud. In the first session the subject had to keep track of the low tone only. In the second session the low and medium tones were counted independently.
Finally, the last and most difficult task required the subject to count all three tones and respond independently.

The task was performed in the dark because there are no specific visual stimuli to attract the subject's attention in the dark. This also reduced the complexity of the visual system because the light dependent parts of the eye would be at a low steady-state level. Thus, the motor behavior of the eye would not be encumbered by visually induced effects.

Subjects

Subjects were six males all from the Technical Professional program at the Pacific Missile Test Center. They ranged in age from 21 years to 33 years old and none of them wore corrective lenses. All reported that they were in their "usual state of fitness" and all expected to do "average" or "better than average" on the task.

The subjects attended each of their three sessions at the same time of the day. This was to minimize any of the effects that personal eating, drinking, and/or smoking habits might have had at different times of the day. This way any habits should have the same effect at the same time of day assuming consumption was fairly consistent.

Apparatus and Laboratory Set Up

Figure 7 depicts the laboratory set up. The eye movement data was collected on the Biometrics, Inc. model SCH/V-2 Eye Movement Monitor instrument (see "Eye Movement Recording" section), and was recorded simultaneously on an eight-channel Sanborn thermal chart recorder and a Tandberg Instrumentation recorder series 100 four-channel tape recorder. The auditory task was pre-recorded on a
Figure 7
magnetic cassette tape and was presented to the subject through headphones. The portion of the laboratory in which the subject was located was light proofed with black-out curtains.

Eye Movement Recording

The Biometrics, Inc. model SGH/V-2 Eye Movement Monitor instrument was the device used to convert eye movement data into electrical signals (see figures 8, 9, and 10). The eye movement monitor employs a photoelectric sensing and processing technique to determine magnitude and direction of eye movements while minimizing the effects of changes in ambient illumination or other artifacts disassociated from eye movements. Eye illumination and sensing is accomplished with infrared light to minimize distraction to the subject.

The eye movement monitor consists of a sensor assembly mounted on a regulation Navy pilot's helmet and a signal processing unit (see figure 9). The electronics inside the case perform the processing and amplification of the sensor signals for output to the peripheral recording equipment. Eye movements are detected by a pair of Silicon photodiodes and a Gallium Arsenide infrared (IR) light source mounted in front of each eye. The sensor configuration is such as to minimize obstruction of the field of view while maintaining the capability to accurately monitor eye movements and position. The IR sources are modulated with a 2kHz square wave to optimize the signal to noise ratio and minimize the amount of infrared energy radiated into the eye.

The eye movement monitoring capability of the device is based on the principle of electro-optical sensing. Photocells exposed to
Figure 8
Figure 9
Eye Movement Monitor Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power:</strong></td>
<td>Rechargeable NICAD batteries</td>
</tr>
<tr>
<td><strong>Weight:</strong></td>
<td>Total: 18 pounds; Sensor Assembly: 4.5 Oz.</td>
</tr>
<tr>
<td><strong>Dimensions:</strong></td>
<td>14(\frac{1}{2})&quot; x 12(\frac{1}{4})&quot; x 7(\frac{1}{4})&quot; (instrument case)</td>
</tr>
<tr>
<td><strong>Eye illumination:</strong></td>
<td>Gallium Arsenide infrared emitters (radiated power: less than 2.0 mw peak, 1.0 mw time averaged)</td>
</tr>
<tr>
<td><strong>Sensors:</strong></td>
<td>Silicon photodiodes</td>
</tr>
<tr>
<td><strong>Electronics:</strong></td>
<td>Solid state, printed circuit board construction</td>
</tr>
<tr>
<td><strong>Output signal:</strong></td>
<td>Typical range: ± 7 volts DC</td>
</tr>
<tr>
<td></td>
<td>Typical scale: 300 mv/degree</td>
</tr>
<tr>
<td></td>
<td>Output impedance: 4K</td>
</tr>
<tr>
<td><strong>Resolution:</strong></td>
<td>Horizontal: (\pm 4^\circ)</td>
</tr>
<tr>
<td></td>
<td>Vertical: (1^\circ)</td>
</tr>
<tr>
<td><strong>Accuracy:</strong></td>
<td>Horizontal: (1^\circ)</td>
</tr>
<tr>
<td></td>
<td>Vertical: (2^\circ)</td>
</tr>
<tr>
<td><strong>Range:</strong></td>
<td>(from center) (\pm 20^\circ)</td>
</tr>
<tr>
<td></td>
<td>(+10^\circ) (up), (-20^\circ) (down)</td>
</tr>
<tr>
<td><strong>Drift:</strong></td>
<td>(max., electronics only) (50) mv/hour</td>
</tr>
<tr>
<td><strong>Response time:</strong></td>
<td>Filter in: 16 milliseconds</td>
</tr>
<tr>
<td></td>
<td>Filter out: 2 milliseconds</td>
</tr>
<tr>
<td></td>
<td>Crosstalk: approx. 10%</td>
</tr>
<tr>
<td></td>
<td>Artifacts: blinks (easily distinguished) and squinting</td>
</tr>
</tbody>
</table>

Figure 10
varying amounts of light produce electrical signals that vary in proportion to the light changes. The operating principle of the monitor depends on detecting the changes in reflected light between the white sclera of the eye and the left and right sides of the iris (see figure 11). The modulated IR light source illuminates the eye with invisible light. The photodiodes are placed close to the eye, each facing the eye, one from the left side and the other from the right side. The photodiodes are fast-response devices which are sensitive in the near-infrared region. When the eye is centered both photodiodes receive the same amount of reflected IR light resulting in no net current flow from the differentially connected diodes. When the eye moves slightly toward one side, then one diode receives less reflected light than the other, resulting in a net current which is a function of the deflection of the eye from the central position. An amplifier-demodulator acts on the current regulated by the diodes to yield a single-ended, low-impedance, output voltage proportional to the angular displacement of the eye.
PHOTOELECTRIC SENSING TECHNIQUE.

Figure 11
CHAPTER THREE
RESULTS

Task Results

The percentage of correct task responses per five minute time interval was calculated for each task each subject performed. After a slight learning or warmup period, performance remained at a fairly constant level. The two-channel task represents a nearly 'normal' amount of mental activity and the performance data suggest that perhaps arousal is remaining fairly constant throughout the task (see figures 12-18).

There is a good correlation between task difficulty and levels of performance. The overall results follow the trend that the more difficult the task the lower the percent correct. The more difficult task, the three-channel task, has the least percent correct from beginning to end, overall. The one-channel task shows a decrement over time consistent with the current theories (Kennedy, 1972) of vigilance and under-stimulation or boring tasks. The two tone task more nearly equates with a normal level of mental activity or arousal since performance is nearly constant throughout the session. Consequently, this task does delineate three levels of mental work or arousal and correlation of the fast eye movements, saccades, with these separate levels should result in relationship of quantity of fast eye movement and operator performance.
Figure 13

Subject 1

PERCENT CORRECT

1-channel 2-channel 3-channel

1 2 3 4 5 6 7 8 9 10 11 12

5-MINUTE TIME INTERVAL

Figure 13
Figure 14: 

1-channel 
2-channel 
3-channel 

Subject 2

5-MINUTE TIME INTERVAL 

Percent Correct

Figure 14
Figure 15

1-channel
2-channel
3-channel

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%

5-MINUTE TIME INTERVAL

Subject 3

PERCENT CORRECT
Figure 16
Subject 6

1-channel
2-channel
3-channel

PERCENT CORRECT

5-MINUTE TIME INTERVAL

Figure 18
Eye Movement Results

The eye movement data was digitized on a NOVA computer. This computer is the only one now available to the Human Factors Engineering Branch at the Pacific Missile Test Center to do the analog to digital conversion at the required sampling rate as well as being capable of graphical display for the digital data analysis. Descriptive plans of the analysis are outlined below.

a. Calibration

A calibration phase is included so that the output voltage of the eye movements can be equated proportionally to the angular displacement of the eye. During the experiment the subject looked at an array of points (see figure 19). These points are arranged so that the total desired horizontal viewing angle is generated when the subject looks from the leftmost to the rightmost point. The signals recorded during the experiment (see figure 20) are then converted into actual horizontal positions in the computer by linear interpolation with the calibration matrix analog data. Every subject's eyes are different therefore a separate calibration is needed for each individual to derive angular position data independently for each subject.

b. Calibration Procedure and Routine

After the data is digitized, a few seconds of it are graphically displayed on a CRT in order to get an idea of the range of that particular subject's eye movements (it will be within the ±10 volt range). Appendix A shows a hard copy of the data that was graphically displayed for subject 5. It was determined that his eye movements were seen in the most detail in a ±1.5 volt range. Each display contains
Figure 20
five seconds worth of data digitized at a rate of 100 points per second. Thus there are 500 points per display.

The data must be graphically displayed until it is evident that the calibration portion of the data has been reached. This is done by visually comparing the displayed data with the data originally recorded on the chart recorder (see figure 20). From the displayed data it can be shown that degrees -30, -20, -10, 0, 20, 30 are equal to X1, X2, X3, X4, X5, X6, X7 volts, respectively. These degrees are equated to the array of points the subject was viewing when the calibration was recorded (figure 19).

A FORTRAN function was then written to convert each data point voltage into degrees based upon the given seven points (see Appendix B). A linear interpolation algorithm was used for extrapolation outside the ±30 degree range based upon a value obtained by extending the line formed from the 20° to 30° points. This was done so that any data lying on the endpoints could be distinguished from data outside the endpoints. Using this technique the endpoints can be treated as good data, and values outside the endpoints can be investigated rather than completely discarded. Since the resolution of the points outside of the angle of vision determined by the -30 to +30 degree range is small, the rough estimation of the degrees obtained by extending the lines from the last two data points was acceptable for this experiment.

c. Analysis Routine

The calibration routine will be used in conjunction with the analysis program. The analysis program will detect saccadic eye movements in the data and will determine the duration, velocity, and
amplitude of those movements. The same constraints will be imposed on
the data to determine the saccadic factors as were used in the first
Human Factors Engineering Branch experiment. These constraints are (1)
that the velocity of the saccade must be within the 50–1100 degree per
second range, (2) that the duration of the saccade must be within the
20–100 millisecond range, and (3) that there be no reversal of direct-
ion.
This Appendix shows the digitized eye movement data for Subject 5 from the two tone task. The data shown here includes sample blinks, sample saccades and the first calibration from which the voltage values were determined.
APPENDIX B

FORTRAN INTERPOLATION FUNCTION

This Appendix contains the FORTRAN interpolation function which is used to calibrate all data points (voltages) to their respective angular degree values as determined by linear interpolation on the seven predetermined data points.
FUNCTION INTERP(X,Y)  
C LINEAR INTERPOLATION FUNCTION, X IS VOLTS IN, Y IS DEGREES OUT  
DIMENSION XTAB(7), YTAB(7)  
DATA IPTS/7/  
DATA XTAB/ values of X1 to X7 go here /  
DATA YTAB/30.0, 20.0, 10.0, 0.0, -10.0, -20.0, -30.0/  
IX=1  
IF(X.GE.XTAB(IX)) GO TO 10  
Y=(YTAB(1)-YTAB(2)/XTAB(1)-XTAB(2))*X-XTAB(2))+YTAB(2)  
GO TO 99  
10 IF(X.LE.XTAB(IPTS)) GO TO 20  
Y=(YTAB(IPTS-1)-YTAB(IPTS)/XTAB(IPTS-1)-XTAB(IPTS))*  
(X-XTAB(IPTS))+YTAB(IPTS)  
GO TO 99  
20 IF(X.GT.XTAB(IX+1)) GO TO 30  
GO TO 40  
30 IX=IX+1  
GO TO 20  
40 XFACT=(X-XTAB(IX))/XTAB(IX+1)-XTAB(IX))  
Y=XFACT*(YTAB(IX+1)-YTAB(IX))+YTAB(IX)  
99 RETURN  
END
References


