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TWO EVALUATIVE MODELS FOR A FAMILY
OF SUBMARINE VERSUS SUBMARINE EXPANDING
SQUARE SEARCH PLANS

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September 1973

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Two Evaluative Models for a Family of Submarine Versus Submarine Expanding Square Search Plans		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1973
7. AUTHOR(s) Thomas Joseph Smith		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1973
		13. NUMBER OF PAGES 94
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Expanding Square Search DATUM Search Submarine Search Reproduced by NATIONAL TECHNICAL INFORMATION SERVICE U S Department of Commerce Springfield VA 22151		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This thesis investigates the effectiveness of a search plan developed by B. O. Koopman in a submarine versus submarine search situation. Two computer simulation models allow probability of target detection as a function of sonar range to be used as a measure of effectiveness. The Koopman search plan is analyzed and a family of alternate search plans are developed. The choice of a particular alternate search plan is		

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Two Evaluative Models for a Family
of
Submarine Versus Submarine Expanding Square Search Plans

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1973

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ABSTRACT

This thesis investigates the effectiveness of a search plan developed by B. O. Koopman in a submarine versus submarine search situation. Two computer simulation models allow probability of target detection as a function of sonar range to be used as a measure of effectiveness. The Koopman search plan is analyzed and a family of alternate search plans are developed. The choice of a particular alternate search plan is dependent on the parameters of the problem. These parameters are target speed, searcher speed, time late to the search area and total time available to conduct the search. By use of the computer programs a search plan can be chosen so as to maximize the probability of target detection at a particular sonar range for each combination of input parameters.

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I. INTRODUCTION

During World War II a great deal of analytical and statistical work was done in the field of military operations. In particular the Navy benefited greatly from the work of the Operations Research Group (ORG) headed by Bernard O. Koopman. The Group's research has been compiled into a single volume entitled Search and Screening (OEG Report No. 56). This volume explores the application of the scientific method to tactical problems of naval warfare. It is intended to serve as a theoretical framework and foundation for more immediate practical studies. Philip M. Morse in the forward to Search and Screening (OEG Report No. 56) stated:

"Although the tactical doctrines presented apply to instruments, weapons and conditions prevailing during World War II, it is believed that the methods and systematic processes of analysis which led to the doctrines have wide application--not only to submarine warfare but to many other military and civilian problems."

The analysis performed and the tactical applications devised by the Operations Research Group have withstood the test of time very well. Although extensive progress has been made in the methods of operations research since World War II, many of the tactical applications derived by the Operations Research Group are still considered the best available by current practitioners of the art.

In particular the methods developed by Dr. J.M. Dobbie for constructing expanding square searches for targets in transit have been widely applied. However, some of these applications may be inappropriate. One use they

have been applied to is that of a submerged submarine searching for another submerged submarine. In this particular situation the use of the search plan developed by Koopman and Dobbie is questionable. This thesis will investigate the appropriateness of the Koopman search plan in the submarine versus submarine search situation.

II. DISCUSSION OF THE KOOPMAN SEARCH PLAN

A. BASIC ASSUMPTIONS OF THE KOOPMAN SEARCH PLAN

In planning a search the nature of the target is usually known. The general position of the target is usually a random variable. Unless a fairly accurate estimate of its motion can be made, the search plan will have to be designed so as to be effective against a target having any one of many different sorts of motion. This plan assumes that the target speed is known exactly and that the target's course is a constant. When the object of search has had its approximate location disclosed at a certain time, the searcher has the problem of disposing its subsequent searching effort (which is always limited) in such a manner as to maximize its chance of detecting the target. This is subject of course to the searcher's limitations and the practical limitations of navigation.

It is assumed that information regarding the point of fix is received by the searcher. The time of this position information is also assumed known. It is further assumed that the searcher is airborne and has a considerable speed advantage over the target.

The information concerning the target's position is not exact. Only a probability distribution of target positions is actually given. This distribution will have its greatest density at the point of fix and fall continuously to zero at a distance. The distribution will be assumed to be circular normal in form. Therefore, the probability that the target at the time of fix will be in a certain small region $dx dy$ at the point (x,y) a distance r from the origin (point of fix) is given by the following:

$$f(x,y) = f(r) = \frac{1}{2\pi\sigma^2} e^{-r^2/2\sigma^2} dx dy$$

where σ is the standard deviation of the circular normal distribution.

It is assumed that the target's speed is known. The target's course is unknown but is assumed to be distributed uniformly between zero and 360 degrees. The target location distribution at a particular time, T hours after the initial fix at a distance r from the origin (point of fix), can be expressed by the following probability density:

$$f(x,y;T) = f(r;T) = \frac{1}{2\pi\sigma^2} e^{-\frac{(+r^2 + St^2T^2)}{2\sigma^2}} I_0\left(\frac{St rT}{\sigma^2}\right)$$

The derivation of these relationships are shown in chapter two of Koopman [Ref. 1] where St is the estimated target speed. In this equation I_0 is the ordinary Bessel function of zeroth order value for pure imaginary arguments of the function.

Figure 1 is a graph of $2\pi\sigma^2 f(r;T)$ this function plotted for various values of t as a function of r . It is obvious from figure one that when StT is greater than three sigma (3σ) the distribution has its maximum at $r = StT$.

Because of this a search plan can be constructed for large values of time which have elapsed from the time of fix to the time of initiation of the search. This time interval is called time late.

Theoretically the searcher should head for a position at a distance r where $r = StT$ from the point of fix. This will place him on the peak

of the target location distribution which is circular in form. The search pattern should then be constructed so as to maintain the searcher's position at the point of maximum density of the target location distribution. This would result in a search plan that resembled an equiangular or logarithmic spiral. There are practical considerations which make this infeasible, namely navigation problems and the undesirability of constant helming. Therefore, a search plan was constructed which approximates the theoretically optimal plan.

B. CONSTRUCTION OF THE KOOPMAN SEARCH PLAN

The theoretically optimal search plan was approximated by an expanding square search plan. Each circuit or square consists of four legs with 90 degree turns. The shape of the squares are shown in figure 2. The leg lengths are $L_1, L_2, L_3, \text{ etc.}$, and the corresponding distances of the search legs from the point of fix are $r_1, r_2, r_3, \text{ etc.}$ The time required for the searcher to go from point A to point B is $(r_1 + r_2)/S_0$, where S_0 is the searcher's speed. The time required for the target to move from a distance r_1 from the point of fix to a distance r_2 from the point of fix is $(r_2 - r_1)/St$ where St is the target speed. The searcher will just keep up with the target if these times are equal. By this reasoning

$$r_2 = mr_1$$

$$r_3 = mr_2$$

$$r_4 = mr_3$$

where

$$m = \frac{S_0 + St}{S_0 - St}$$

If we were to make $r_5 = mr_4$, the fifth leg would duplicate the position of the first leg in space relative to the target. That is to say that the searcher would be on the highest density point of the target location distribution. However, having traveled the first circuit (four legs) so as to be at this point of maximum density and not having detected the target has imparted additional information to the searcher. The first circuit being unsuccessful has altered the target location distribution. The target location distribution after one circuit is no longer unimodal. It is now a bimodal distribution with a depression where the peak of the initial target distribution function had been. This is caused by the fact that one circuit has been completed without detecting the target. Therefore, the second circuit should be flown either inside or outside the original peak. This will place the second circuit on one of the modal points of the new distribution. If the second circuit is constructed outside the peak, the third circuit should be constructed inside the peak, so as to be on the other modal value of the distribution.

In order to accomplish this objective the fifth leg was moved a distance S outside the position of the first leg in space relative to the target. This distance S is called the sweep spacing. A complete analytical development of an appropriate value for S is given in Ref. 1, chapter two and chapter seven. The final results of this development obtain the following form for the sweep spacing such that

$$S = 0.75 \sqrt{E \sigma}$$

where

$$E = W/2 \ln 2$$

W = sweep width

= 2 x Sonar Range

σ = the standard deviation of the circular normal distribution.

Therefore, r_5 is determined so that

$$\frac{r_5 + r_4}{S_0} = \frac{r_5 - r_4 - S}{St}$$

so that

$$r_5 = mr_4 + A$$

where

$$A = \frac{S_0 \times S}{S_0 - St}$$

A first approximation to r_1 is $St \times T$. However, the approximation to the spiral by straight search legs requires that r_1 be slightly less than this value. Therefore, a reasonable first approximation to r_1 is obtained by setting $r_1 = 0.9 \times St \times T$. Since any change in target course will reduce the outward component of velocity and since the second circuit is to be outside, the first r_1 was reduced further and taken so that

$$r_1 = 0.8 \times St \times T$$

Continuing we obtain the following:

$$r_2 = mr_1$$

$$r_3 = mr_2$$

$$r_4 = mr_3$$

$$r_5 = mr_4 + A$$

$$r_6 = mr_5$$

$$r_7 = mr_6$$

$$r_8 = mr_7$$

$$r_9 = mr_8 - 2A$$

$$r_{10} = mr_9$$

$$r_{11} = mr_{10}$$

$$r_{12} = mr_{11}$$

$$r_{13} = mr_{12} + 3A \text{ etc.}$$

Using the relationship between the lengths of the legs and their distances from the point of fix the following equations were obtained for the various search leg values:

$$L_1 = mr_1$$

$$L_2 = mL_1 + r_1$$

$$L_3 = mL_2$$

$$L_4 = mL_3 + A$$

$$L_5 = mL_4$$

$$L_6 = mL_5 + A$$

$$L_7 = mL_6$$

$$L_8 = mL_7 - 2A$$

$$L_9 = mL_8$$

$$L_{10} = mL_9 - 2A$$

$$L_{11} = mL_{10}$$

$$L_{12} = mL_{11} + 3A \text{ etc.}$$

This search plan was developed for large values of T where it was true that the maximum point of the distribution was located at a distance $r = StT$. The question arises as to what is the smallest value of T for which this search plan may be used for all values of T larger

than this lower bound without any essential decrease in the probability of detection for a given amount of search effort. By observing figure 1 it is seen that when T is less than $\frac{6}{St}$ the distribution resembles the original circular normal distribution. For T larger than $\frac{26}{St}$ the distribution has its maximum at approximately $r = St \times T$ and moves outward at St the speed of the target. However, there is a very rapid change in the distribution as T increases from $\frac{6}{St}$ to $\frac{26}{St}$. This change of the distribution from a stationary distribution to a distribution moving at the speed of the target makes the decision on a lower bound for T most difficult. Koopman and his associates, by an empirical method of testing the search plan against various values of T , concluded that a reasonable lower bound on T was $\frac{6}{St}$. Therefore, for values of $T \geq \frac{6}{St}$ this search plan was considered optimal by Koopman and Dobbie. For values of $T < \frac{6}{St}$ the plan for large values of T is sufficient and may be used.

C. ANALYSIS OF THE KOOPMAN SEARCH PLAN

It is necessary to evaluate the assumptions used in constructing the Koopman search plan when applied to its use by a submerged submarine searching for another submerged submarine. The assumptions of constant detectability over time and detectability being independent of target aspect are acceptable for the submarine application. However, the searcher obviously is not airborne nor does he possess a considerable speed advantage over the target. The pertinent question is this: Does the inapplicability of this assumption invalidate the search plan as devised by Koopman?

In order to analyze this problem, a computer simulation model was designed. Various combinations of target speed, time late and searcher speed were used to construct the Koopman search plan. By observing figure

two, it is obvious that to be effective against a target whose course is assumed to be uniformly distributed between zero and 360 degrees, a minimum of one circuit or four search legs should be completed. The computer simulation constructed four legs of the search plan for each combination of target speed, searcher speed and time late. The program gave the time required to conduct one circuit of the search plan. In addition, it gives the probability of target detection as a function of actual sonar range as opposed to the estimated sonar range and resulting sweep width used in constructing the search plan. In constructing the simulation model, an option was included to allow the test of another of the basic assumptions of the Koopman search plan, namely, that of constant target speed. The program has two versions of target speed incorporated into it. In the first version the actual target speed is set equal to the estimated target speed used in constructing the search plan. The program can be changed so that the actual target speed is a random variable. In this case, the target speed is drawn from a uniform distribution. The mean of the distribution is the estimated target speed, and the end points of the interval are estimated target speed plus and minus two knots. This allows the evaluation of the search plan, when the assumption of constant target speed is not met, and an analysis of the resulting probabilities of target detection. Table I includes a tabulation of the amount of search time necessary to complete four legs of the Koopman search plan for various combinations of target speed, search speed and times late.

As previously stated, the amount of search time available is always limited. From Table I it is apparent that the amount of time necessary to complete one circuit, herein considered the minimum against a target whose course is uniformly distributed between zero and 360 degrees, is excessively large. The search time is particularly long for the most

probable cases that would be encountered in submarine versus submarine operations.

Tables I and II allow a comparison of the probability of target detection for the case where target speed is deterministic as opposed to the case where it is a random variable.

Because of the excessive amount of time required to complete the minimum number of legs of the Koopman search plan, it was decided to construct an alternate search plan that would not be susceptible to excessively long search times.

III. ALTERNATE SEARCH PLAN

A. BASIC ASSUMPTIONS OF THE ALTERNATE SEARCH PLAN

The Koopman search plan is obviously not universally applicable to submarine versus submarine search due to the excessive search time required to complete even a minimum number of search legs. The cause of this failure is obvious. By examining the multiplicative factor m where

$$m = \frac{S_0 + S_t}{S_0 - S_t}$$

the excessive time problem can be identified.

For the range of target speeds and searcher speed combinations used in compiling Tables I and II, the factor m ranges from a high value of 13 to a low value of 1.8. In the original design of the search plan, the searcher was airborne. Searcher speed was generally in the range of 140 to 160 knots. The target, either a surfaced submarine or a surface ship, generally had a top speed of approximately 25 to 30 knots. These two facts taken together show that the multiplier m was severely limited in size. In the submarine versus submarine search problem, this is not the case. By examining the formulae for the various search legs it can be seen that the formulae reduce to a common form such that

$$L_n = m^n r_1 + C_n$$

$$\text{where } C_n \geq 0 .$$

Therefore, for larger values of the factor m succeeding search legs become exponentially larger. This is the cause of the excessive times necessary to complete a minimum search plan. When target and searcher

speed are relatively close together and moderately large, this effect is even more pronounced. Therefore, an alternative search plan should not be limited in this manner.

Another assumption implicit in the Koopman search plan is that numerous circuits will be completed. This fact was used explicitly in arriving at the form of the r_1 distance. The sweep spacing S was also determined based on the assumption that more than one circuit would be completed. Since the searcher in the submarine application does not enjoy the prerequisite speed advantage to complete many circuits, this assumption should not be used in constructing an alternative search plan.

Intuitively then it seems that in an alternative search plan the multiplicative factor would be relatively "small" so as to allow the completion of the minimum search plan in a reasonable amount of time. Also the r_1 distance would be determined based on the assumption that few circuits could be completed. This is due to the limited amount of search effort available. In many cases tactical considerations will probably limit this time to that necessary to complete one circuit.

B. CONSTRUCTION OF AN ALTERNATE SEARCH PLAN

In order to test an alternative search plan against the Koopman search plan, a computer simulation model was developed. To allow a fair comparison of search plans, the search effort, that is search time, had to be equal for both plans. This time was set arbitrarily at four days (96 hours) for comparison purposes. The target speed was eight knots, the search speed 12 knots, and the time late was selected at four hours. The number of search legs of the Koopman search plan that could be completed in this time was then determined. The number of search legs for the alternate search plan

was likewise determined. The probability of detection as a function of actual sonar range was then calculated for both search plans and compared. In determining the best alternate search plan, it was hypothesized that the construction would be as shown in figure 3.

The distance r_1 would have the general form such that

$$r_1 = (\text{factor}) \times (\text{time late}) \times (\text{estimated target speed})$$

where the factor value was as yet undetermined. The search leg lengths would be obtained as follows:

$$L_n = (\text{multiplier})^n \times r_1$$

where the multiplier value was as yet undetermined. In determining comparison search plans, various combinations of factor values and multiplier values were used. The factor value ranged from 0.8 to 1.5 in 0.1 increments. The multiplier values used were 2.0, 3.0, 4.5 and 6.75. In all these values generated thirty-two different alternate search plans.

The computer program output allowed a direct comparison of each alternative search plan with the Koopman plan. The measure of comparison was the probability of detection as a function of actual sonar range. Although comparison values were available for all sonar ranges from zero to 60 nautical miles, the comparison was made at a sonar range of ten nautical miles. This is the sonar range estimate used in constructing the Koopman search plan values of Tables I and II.

The probability of target detection for different combinations of factor and multiplier values are shown in figure four. In this case, the actual target speed was equal to the estimated target speed. The Koopman search plan yielded a probability of target detection of .0870 under these values of target speed, searcher speed, time late and time available to

search. An alternate search plan using a factor value of 0.9 and a multiplier value of 2.0 produced the highest probability of target detection (.1490). This is considerably better than the results using the Koopman search plan.

However, this is not a fair comparison for the Koopman search plan. Koopman used the approximation for the r_1 offset distance as follows:

$$r_1 = 0.8 \times St \times TL$$

His previous approximation had been

$$r_1 = 0.9 \times St \times TL$$

The distance had been reduced because he felt that the target would not actually be on a constant course. The comparison is not fair because in the simulation model, the target's course is a constant. A better comparison would result if the Koopman search were computed using an r_1 offset of

$$r_1 = 0.9 \times St \times TL$$

based on the fact that the target course is a constant once its initial value is determined. When this is done, the probability of target detection at a sonar range of ten nautical miles is .1140 for the Koopman search plan. Therefore, using a better comparison, the best alternate search plan is still better than the Koopman search plan.

The question arises as to whether or not this particular alternate search plan is best or even better than the Koopman search plan when target speed is a random variable as opposed to being a constant equal to the estimated target speed. The simulation was run again with the actual target speed a random variable. The Koopman search plan yielded the

following values for probability of target detection at a sonar range of ten nautical miles:

$$r_1 = 0.8 \times St \times TL \quad .0750$$

$$r_1 = 0.9 \times St \times TL \quad .0990$$

The combination of factor and multiplier values that maximized the probability of target detection at a range of ten nautical miles was the same, that is a factor value of 0.9 and a multiplier value of 2.0. They produced a probability of target detection equal to .1060.

In theory what should now be done is to run the simulation for all interesting values of search speed, target speed and time late. This would be done with a set limit on the amount of search effort available. For each combination of target and search speed, the simulation would have to be run twice--once for the case where the actual target speed equals the estimated target speed and another time for the case where the target speed was a random variable. Each run would produce a different combination of factor value and multiplier value that maximized the probability of target detection. These values might be the same for the case where the target speed is deterministic and the case where it is a random variable or they might be different. One combination of factor and multiplier values might be predominant for different target speed, search speed and time late combinations. This does not necessarily have to be the case.

However, if this is not done, what is the applicability of the alternate search plan that was found best for this particular combination of searcher and target speeds and time lates with other parameter combinations? This hypothesis was tested by using the search leg values that this plan produces in the first computer simulation mentioned. The amount

of time necessary to complete four legs of the search plan for various combinations of search speed, target speed, and time late are tabulated in Table I.

Tables I and II list the probability of target detection for various combinations of search speed, target speed and time late values, using this particular alternate search plan. In the majority of the combinations the alternate search plan produces probabilities of target detection that are greater than the Koopman search plan. This is especially significant in light of the fact that the alternate search plan requires less time to complete one circuit than the Koopman search plan in all but three cases.

Ideally, given a combination of search speed, target speed, and time late, the alternate search plan that maximizes the probability of target detection for this combination should be determined.

It is interesting to note a phenomenon exhibited by both the Koopman search plan and the alternate search plan. For some combinations of target speed, searcher speed and times late, the probability of target detection is higher when the target speed is a random variable than when the target speed is deterministic. This result occurs most often when target speed and search speed are close together and the time late is large.

It is obvious that for some combinations of target initial position and a fixed speed, the target will be undetected by the searcher. However, if the target speed becomes a random variable, the searcher may be able to detect the target. Therefore, in these cases where the search plan has a low probability of target detection, randomness in target speed may increase the probability of target detection.

IV. RECOMMENDATIONS

Since the amount of time required to conduct the minimum number of search legs using the Koopman search plan is excessive, it is recommended that an alternate search plan be used. The particular alternate to be used is dependent on the target speed, searcher speed and time late. The time available to conduct the search is also a deciding factor. The particular search plan to use can be determined by using the computer program described in appendix C. If this is not possible, the alternate search plan using a factor value of 0.9 and a multiplier value of 2.0 could be used. The resulting times to complete one circuit of the search plan and the probabilities of target detection are shown in Tables I and II for various combinations of searcher speed, target speed and time lates.

APPENDIX A

TABLE I

Constants for all Comparisons
 One Circuit (Four Legs)
 Actual Sonar Range - 10 nmi
 Estimated Sonar Range - 10 nmi
 Standard Deviation of Circular
 Normal Distribution - 2 nmi
 Actual Target Speed - Estimated
 Target Speed

<u>Time</u> <u>Late</u> <u>(HRS)</u>	<u>Searcher</u> <u>Speed</u> <u>(KTS)</u>	<u>Target</u> <u>Speed</u> <u>(KTS)</u>	<u>Koopman Search</u> <u>Plan</u>		<u>Alternate Search</u> <u>Plan</u>	
			<u>Search</u> <u>Time</u> <u>(HRS)</u>	<u>Prob. of</u> <u>Detection</u>	<u>Search</u> <u>Time</u> <u>(HRS)</u>	<u>Prob. of</u> <u>Detection</u>
3	8	4	160.61	.4026	40.50	.4586
3	11	4	40.19	.4153	29.45	.4940
3	14	4	19.20	.4576	23.14	.4150
6	8	4	320.21	.1576	81.00	.1960
6	11	4	79.81	.1880	58.91	.2010
6	14	4	37.99	.2063	46.29	.1383
12	8	4	639.41	.0230	162.00	.0783
12	11	4	159.04	.0213	117.82	.0633
12	14	4	75.59	.0216	92.57	.0600
3	11	8	3416.89	.1240	58.91	.1670
3	14	8	364.47	.1460	46.29	.1983
6	11	8	6832.44	.0216	117.82	.0576
6	14	8	728.27	.0236	92.57	.1006
12	11	8	13,663.53	.0000	235.64	.0096
12	14	8	1,455.87	.0000	185.14	.0273
3	14	12	64,026.36	.0773	69.43	.1190
6	14	12	128,050.69	.0000	138.86	.0656
12	14	12	256,099.63	.0000	277.71	.0123

TABLE II

Constants for all Comparisons
 One Circuit (Four Legs)
 Actual Sonar Range - 10 nmi
 Estimated Sonar Range - 10 nmi
 Standard Deviation of Circular
 Normal Distribution - 2 nmi
 Actual Target Speed - Uniform
 Random Variable

<u>Time</u> <u>Late</u> <u>(HRS)</u>	<u>Searcher</u> <u>Speed</u> <u>(KTS)</u>	<u>Target</u> <u>Speed</u> <u>(KTS)</u>	<u>Koopman Search</u>		<u>Alternate Search</u>	
			<u>Search</u> <u>Time</u> <u>(HRS)</u>	<u>Plan</u> <u>Prob. of</u> <u>Detection</u>	<u>Search</u> <u>Time</u> <u>(HRS)</u>	<u>Plan</u> <u>Prob. of</u> <u>Detection</u>
3	8	4	160.61	.3616	40.50	.4033
3	11	4	40.19	.4000	29.45	.4040
3	14	4	19.20	.4313	23.14	.4033
6	8	4	320.21	.1113	81.00	.1266
6	11	4	79.81	.1190	58.91	.1403
6	14	4	37.99	.1486	46.29	.1310
12	8	4	639.41	.0340	162.00	.0320
12	11	4	159.04	.0376	117.82	.0356
12	14	4	75.59	.0453	92.57	.0373
3	11	8	3416.89	.1290	58.91	.1903
3	14	8	364.47	.1373	46.29	.1786
6	11	8	6832.44	.0330	117.82	.0723
6	14	8	728.27	.0456	92.57	.0643
12	11	8	13,663.57	.0086	235.64	.0213
12	14	8	1,455.87	.0166	185.14	.0193
3	14	12	64,026.36	.0810	69.43	.1463
6	14	12	128,050.69	.0190	138.86	.1516
12	14	12	256,099.63	.0026	277.71	.0186

APPENDIX B

This appendix discusses the first of the two computer simulation models used. This simulation determines the amount of time necessary to complete one circuit (four legs) of the Koopman search plan. The output of the simulation is a graph of probability of detection as a function of actual sonar range and a listing of the sixty points plotted by the graph. The program was written in Fortran IV, level G and was run on an IBM 360 digital computer.

The basic program organization is discussed next. The basic input parameters that can be changed are as follows:

<u>ALPHANUMERIC</u> <u>NAME</u>	<u>PARAMETER</u>	<u>VALUES</u>	<u>UNITS</u>
NTRUN	Number of targets run against a particular search plane	>1	
RS	Sonar Range	$60 > RS > 0$	NMI
SIGMA	Standard deviation of circular normal distribution	>0	NMI
S0	Initial value of searcher speed	$ST < S0 \leq 14$	KTS
STE	Initial value of target speed estimate	$0 < ST < S0$	KTS
TL	Initial value of time late	$0 < TL \leq 12.0$	HRS
ULCT	Upper limit on target course	$0 < ULCT \leq 2\pi$	rad
LLCT	Lower limit on target course	$0 \leq LLCT < 2\pi$	rad

For this program the input parameters mentioned above were initialized as follows:

NTRUN = 3000
RS = 10.0
SIGMA = 2.0
SO = 8.0
STE = 4.0
TL = 4.0
ULCT = 2π
LLCT = 0.0

The program then uses these initial values to compute the parameters necessary for constructing the Koopman expanding square search plan. The four search leg lengths are then computed. These distances and the r_1 distance are then used to establish the (x, y) co-ordinates for each search leg end point. Using the search speed input, the time at which each of these co-ordinates is reached is determined as is the total search time necessary for the entire search plan. The headings entitled initial values for search legs one, two, three and four will be discussed after the determination of target motion is discussed. The target course is then obtained from a uniform distribution. The end points of this interval are variable as previously mentioned. In this case the target speed was selected uniformly between values of zero and 360 degrees. The target speed is then obtained from a uniform distribution. The actual target speed can be set at the estimated target speed by using the following input cards:

ULST = STE
LLST = STE

Or the actual target speed can be a random variable drawn from a uniform distribution whose end points are the estimated target speed plus or minus two knots. This is done by substituting the following cards in the input deck:

$$ULST = STE + 2.0$$

$$LLST = STE - 2.0$$

The direction and distance of the uncertainty in target position from the origin (point of fix) is then generated from a circular normal distribution. The program then uses the randomly selected target course to determine the target's velocity components in the x and y directions. Using the random target position uncertainty selected from the circular normal distribution, the initial (x, y) coordinates of the target are then determined.

The conceptual framework associated with the next section of the program is discussed in detail in this section. For each randomly selected target track there will be some time at which the target and searcher are at a minimum range. This range is called the closest point of approach or CPA range.

It is useful to think of each search leg as being extended in space past the point where the turn to the next search leg is made. At any time on any search leg the searcher's position is a function of time and his speed. That is to say:

$$(x_s, y_s) = (a_1 + a_2t, a_3 + a_4t)$$

where

a_1 = search leg initial x- coordinate

a_3 = search leg initial y- coordinate

a_2 = searcher x- velocity component

a_4 = searcher y- velocity component

In a similar manner the target's position can be expressed as follows;

$$(x_t, y_t) = (b_1 + b_2 t, b_3 + b_4 t)$$

where

b_1 = target's initial x- coordinate

b_3 = target's initial y- coordinate

b_2 = target's x- velocity component

b_4 = target's y- velocity component

It also can be shown that the searcher/target range is obtained as follows:

$$\text{Range} = (x_s - x_t)^2 + (y_s - y_t)^2 \quad 1/2$$

Now to minimize this range the derivative of the equation with respect to time is taken and then is set equal to zero. This procedure yields the time at which the CPA range occurs. This time is given by the following equation:

$$t_{\text{rcpa}} = \frac{(a_1 - b_1)(a_2 - b_2) + (a_3 - b_3)(a_4 - b_4)}{(a_2 - b_2)^2 + (a_4 - b_4)^2}$$

If this time actually occurs while the searcher is traversing this search leg, the range at this time is a candidate for a minimum range. If the minimum range on this search leg does not occur on the interior of the search leg interval, then it must be an end point solution. The target/searcher range, when the searcher is at the end points of each search leg, is then easily determined.

The target's speed is a constant once selected. Therefore, the x,y velocity components are constants. The target's initial position is also constant once determined. On a particular search leg the searcher x,y velocity components are constants. One is identically zero, depending

on the orientation of the search leg. Therefore, for each search leg there are at most three candidates for the CPA range and at the least two. If the solution to the time equation falls within the time frame that the searcher is on this particular search leg, then there are three candidates for a minimum on this search leg. These three are the search leg end point ranges and the range at the time equation solution. If the time value that satisfies the equation occurs when the searcher is not on this particular search leg then there are only two candidates for a minimum range, the search leg end point ranges. Using this procedure all possible candidates for minima can be obtained for the entire search plan. Once the CPA range for the iteration has been determined, it is placed in a tally box. There are sixty tally boxes. Each tally box corresponds to an interval of one nautical mile. Once the program has determined the CPA range for each target, this range is placed in the tally box for the interval into which it falls. All CPA ranges in excess of sixty nautical miles were placed in the last tally box. The program tests at this point to determine if the required number of targets have been run against this particular search plan. If not, the program generates another set of target parameters and repeats the above mentioned step. If the required number of runs has been obtained, the program sums all the tally box values and then determines the probability that the CPA range will fall in the interval of each of the individual tally boxes. This information allows the calculation of the probability that the CPA range will be less than or equal to a particular range. In essence this is the probability of target detection as a function of the actual sonar range. The output of the program is twofold. First, a print out of the probability of target detection as a function of sonar range is provided.

These values are listed for every nautical mile between one and sixty nautical miles. Secondly, the probability of target detection as a function of sonar range is plotted graphically for values of sonar range from zero to sixty nautical miles. The program then varies the searcher speed, target speed and time late to obtain all the combinations shown in Tables I and II.

The probability of target detection as a function of actual sonar range is in fact an empirical cumulative distribution function. The number of iterations performed of different target tracks (3000) ensures that the empirical cumulative distribution function will be within $\pm .025$ units of the population cumulative distribution function. This is with a probability of .95, that is to say $\alpha = .05$. The exact number of runs needed was arrived at using Kolmogorov's statistic. These values are tabulated in Table A21-b of Ref. 2.

The pseudorandom number generator used was tested for randomness using a separate computer program not described in the thesis. The statistical tests for randomness used were the frequency test, serial test, lagged product test, runs up and down test, and runs above and below the mean test. The pseudorandom number test passes all of these tests adequately, thereby justifying its use.

It should be noted that by replacing the r_1 distance calculation and the search leg length computations for the Koopman plan by those necessary for the alternate search plan, the same output can be obtained for the alternate search plan. The following card must be removed:

$$SM = (SO + STE)/(SO - STE)$$

$$r_1 = 0.8 * STE * TL$$

$$SL1 = SM * r_1$$

$$SL2 = SM * SL1 + r_1$$

$$SL3 = SM * SL2$$

$$SL4 = SM * SL3 + A$$

Once these cards have been removed the following cards have to be inserted in their places:

$$SM = 2.0$$

$$r_1 = 0.9 * STE * TL$$

$$SL1 = SM * r_1$$

$$SL2 = SM ** 2 * r_1$$

$$SL3 = SM ** 3 * r_1$$

$$SL4 = SM ** 4 * r_1$$

The program will then determine the values depicted by Tables I and II for the alternate search plan that was determined to be best.

APPENDIX C

This appendix describes the second computer simulation used in the analysis and comparison of search plans. The primary purpose of this simulation is to compare alternate search plans with the Koopman search plan. Therefore, the goal of this simulation is to compare search plans which require the same amount of search effort, that is search time.

With this goal in mind, the input variables were chosen as follows:

<u>ALPHANUMERIC NAME</u>	<u>PARAMETER</u>	<u>VALUES</u>	<u>UNITS</u>
STE	Estimated target speed	$0 < \text{STE} < S_0$	KTS
S ₀	Searcher speed	$\text{STE} < S_0$	KTS
TL	Time late	>0	HRS
TLimit	Amount of search time available	>0	HRS
NTRUNS	Number of target runs against a particular search plan	>0	
ULCT	Upper limit target course	$0 < \text{ULCT} < 2\pi$	RADIANS
LLCT	Lower limit target course	$0 \leq \text{LLCT} < 2\pi$	RADIANS
SIGMA	Standard deviation of circular normal distribution	>0	NMI
RS	Sonar Range	>0	NMI

The program was run with the following initial values for these parameters:

STE = 8.0
 S₀ = 12.0
 TL = 4
 NTRUNS = 3000
 ULCT = 2π
 LLCT = 0.0

SIGMA = 2.0

RS = 10.0

The program input considered next is the actual target speed input. There are two options available. First the following two cards may be used:

ULST = STE

LLST = STE

When used, these cards result in the actual target speed being a constant equal to the estimated target speed. The second option involves inserting the following cards into the deck:

ULST = STE + 2.0

LLST = STE - 2.0

This results in the actual target speed for each iteration being drawn from a uniform distribution. The mean of the distribution is the estimated target speed while the end points are the estimated target speed plus and minus two knots. The program then computes the parameters necessary for the calculation of the Koopman search plan. The (x,y) coordinate values for each of these search leg end points is then calculated. This having been done, the values for twenty search legs were computed. The values necessary to determine the searcher's initial position and velocity component for each of the search legs is computed. The program then determines the time that the searcher will reach each of the search leg end points. The procedure stops the first instance in which this time exceeds the limit of the search time available. By so doing, the number of search legs or parts of search legs that can be completed in the search time available has been determined. The target's course is then selected from a uniform distribution. The limits of this distribution are variable and have been

previously mentioned. The target's position uncertainty is then selected from a circular normal distribution. The next target parameter determined is target speed. This speed comes from a uniform distribution as mentioned before.

The target's initial (x,y) coordinates are then determined. The target's velocity components in the x,y direction are calculated next. The candidates for the minimum target/searcher range are then calculated using the procedure fully explained in appendix A. From these a CPA range for this target iteration is determined. This range is placed in a tally box and the procedure is repeated until the required number of target iterations has been performed. When this has occurred, the probability of target detection as a function of sonar range is calculated.

The input parameters for the alternate search plan are now listed. They are as follows:

$$\text{OMULT} = 2.0$$

$$\text{FACTOR} = 0.8$$

The factor value is used in determining the r_1 distance as follows:

$$r_1 = \text{FACTOR} * \text{STE} * \text{TL}$$

and the quantity OMULT is used in determining the search leg lengths where

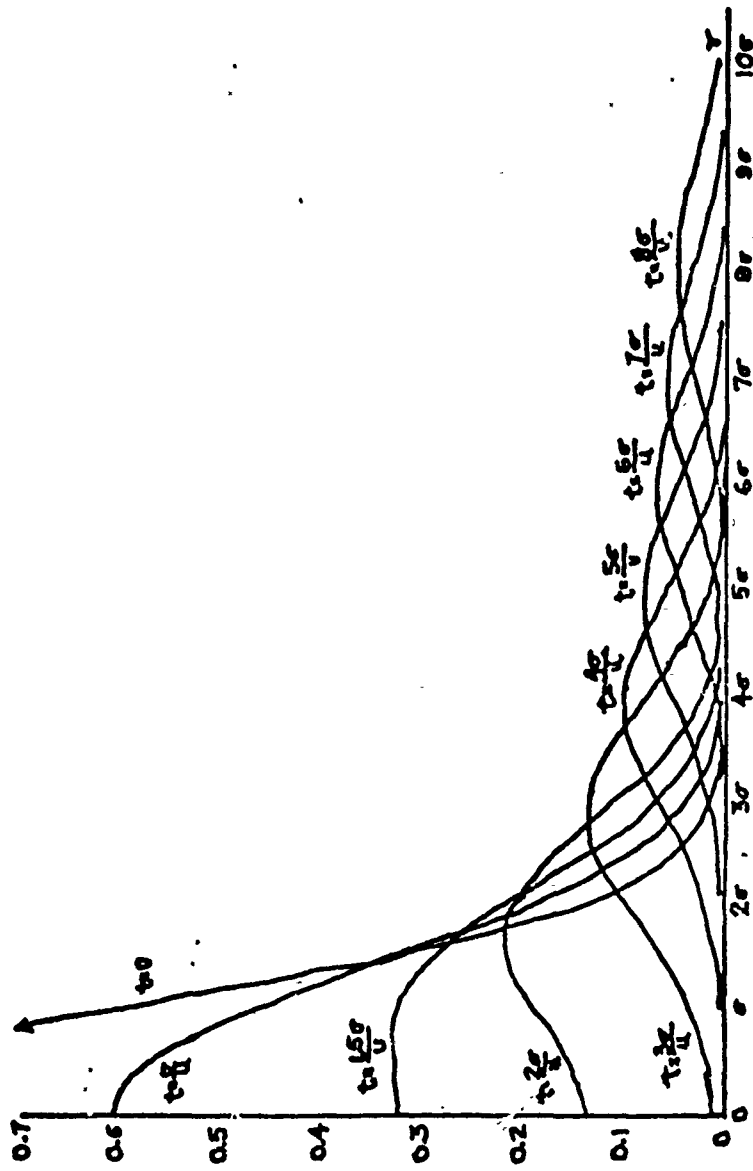
$$L_n = \text{OMULT}^n(r_1)$$

The value of twenty-four search leg's lengths for each FACTOR and OMULT combination are then determined. The (x,y) coordinates values for each search leg are calculated. The parameters necessary for the target/searcher minimum range calculation are determined at this point. The number of full and partial search legs that the target can complete in the allotted search time is then determined. The target course, speed

and position uncertainty values are then determined. The closest point of approach is determined for this iteration. This CPA range is placed in a tally box. The program tests to see if the desired number of targets have been run for this search plan. If they have not, it generates targets until the required number has been reached. For each target it computes the CPA range and places it in a tally box. The program then computes the values of probability of target detection as a function of sonar range.

These values are then printed for the Koopman search plan and the particular alternate search plan under consideration. The program then plots the graph of probability of detection as a function of sonar range. The values for the Koopman search plan and the particular alternate search plan under consideration are then plotted on the same graph. This is done to facilitate comparison. The factor value used in the r_1 determination and then the multiplier value used in the search leg length calculation are then varied. The entire alternate search is then recalculated. The required number of targets are run against this search plan and the probability of detection as a function of sonar range is calculated. Once these values are calculated they are printed out and plotted for easy comparison with the Koopman search plan.

APPENDIX D



Distance r from point of fix
 Distribution of a moving target about.
 a point of fix 0

figure 1

KOOPMAN SEARCH PLAN

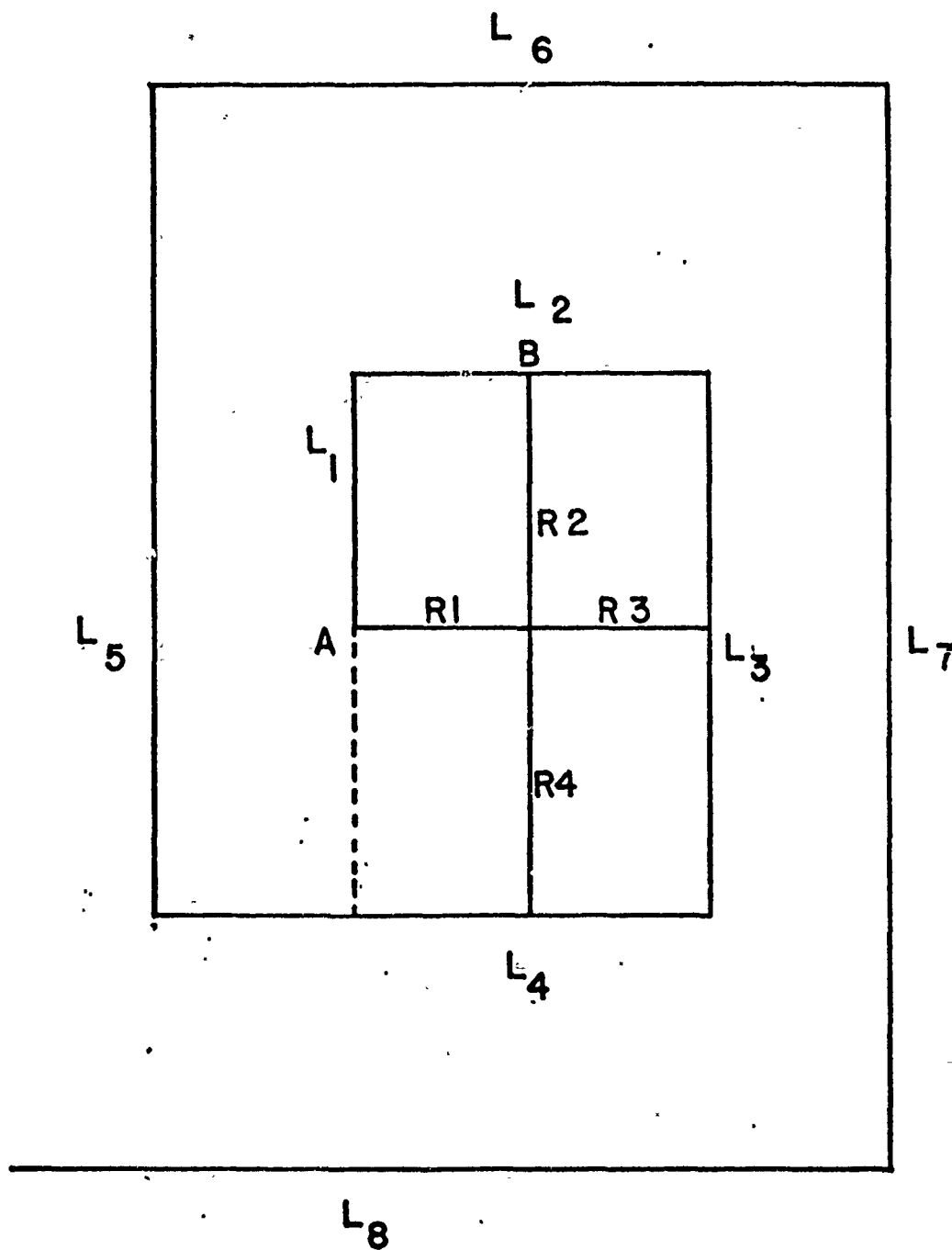


figure 2

ALTERNATE SEARCH PLAN

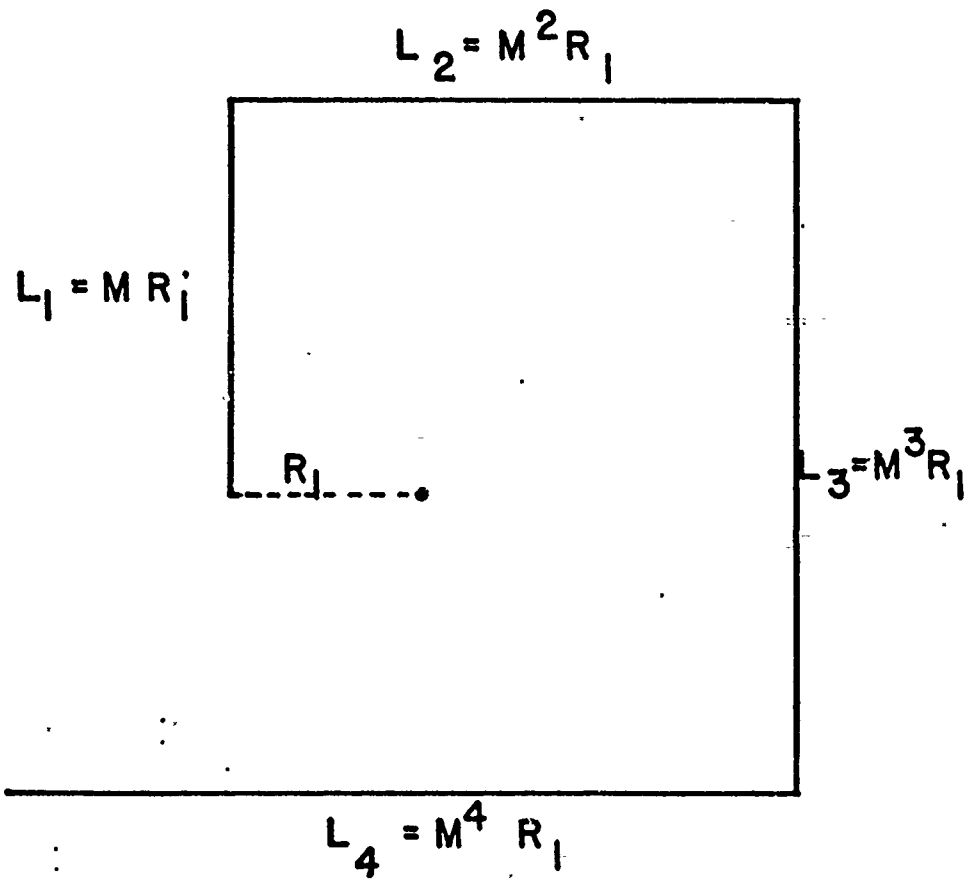


figure 3i

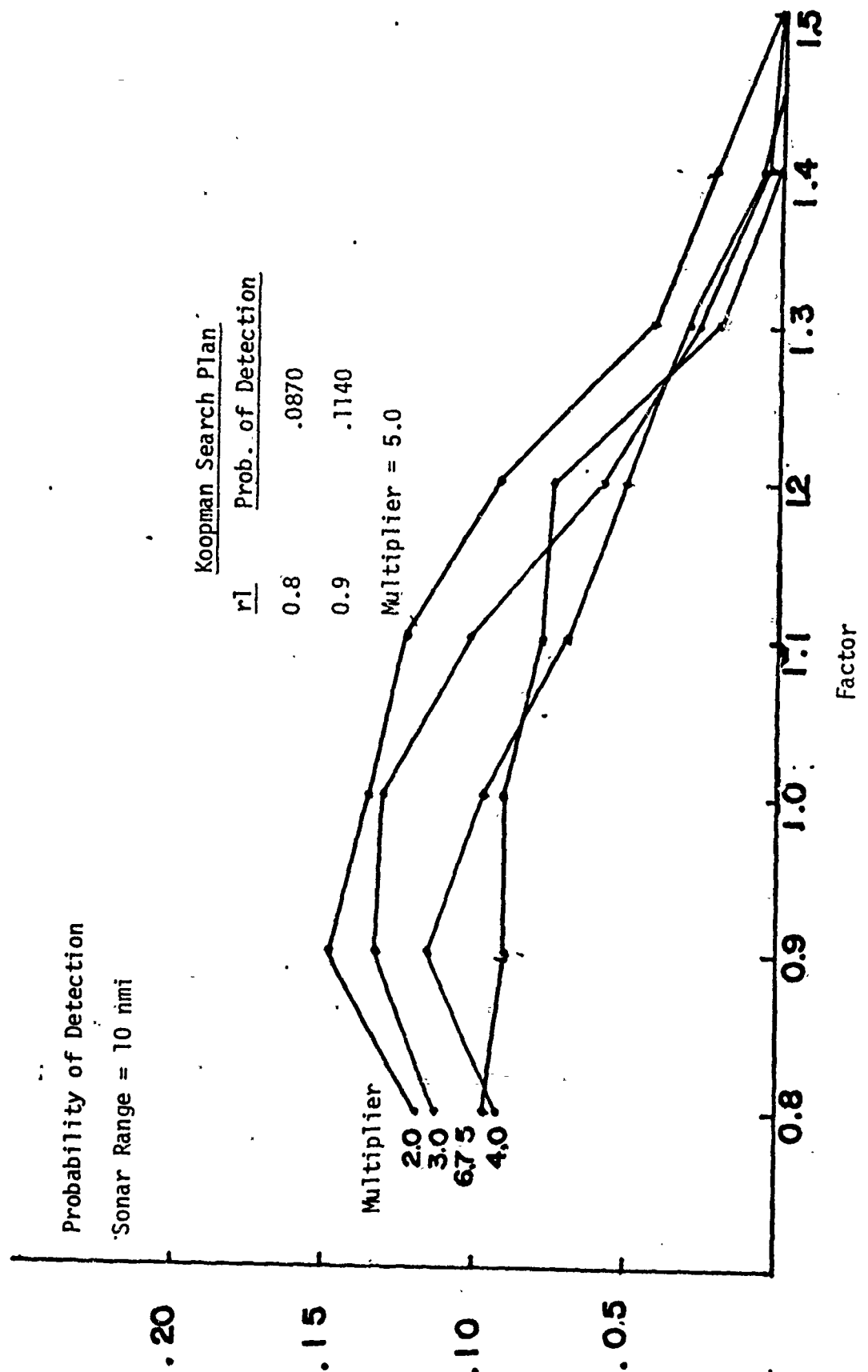


figure 4

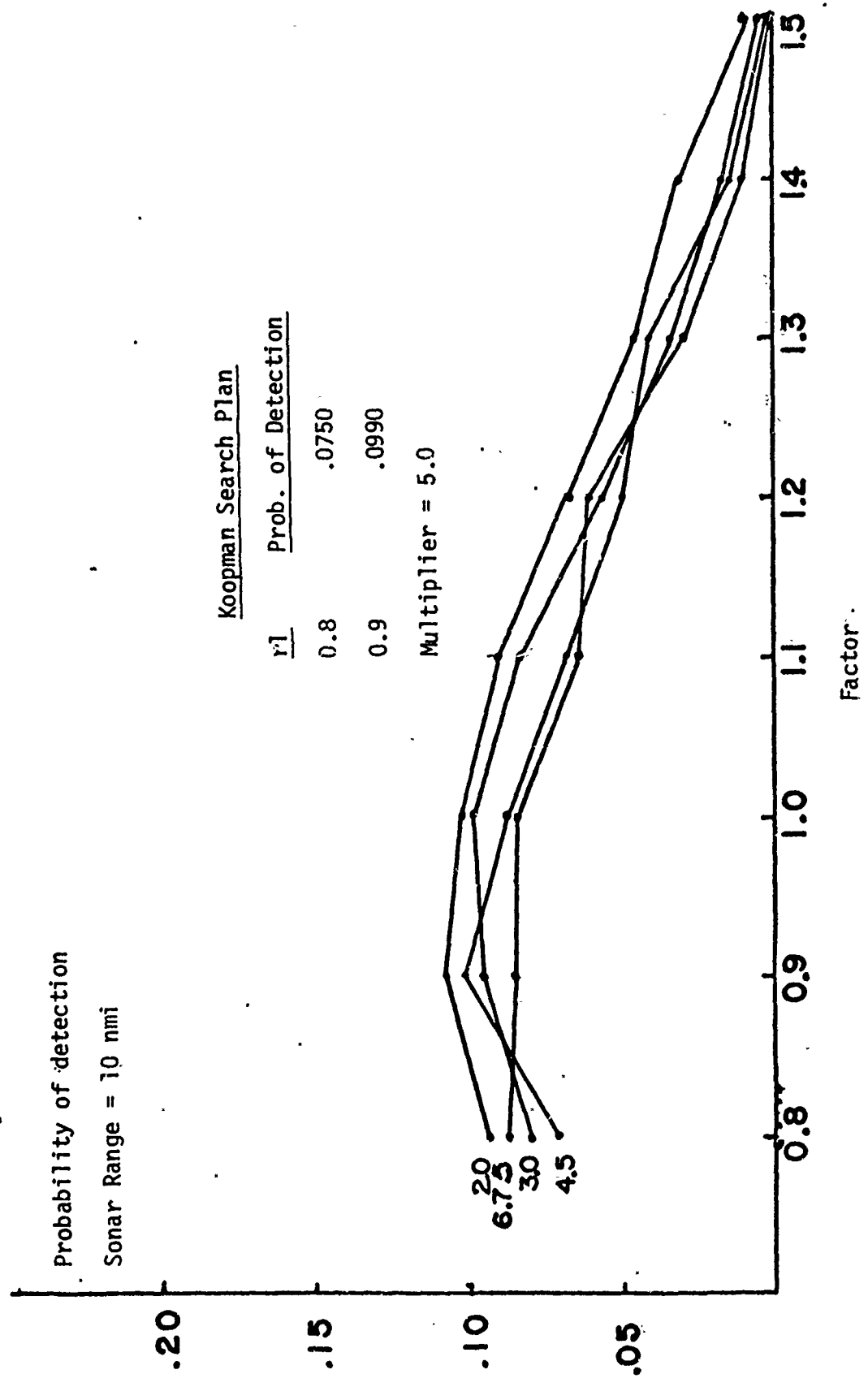


figure 5

COMPUTER OUTPUT

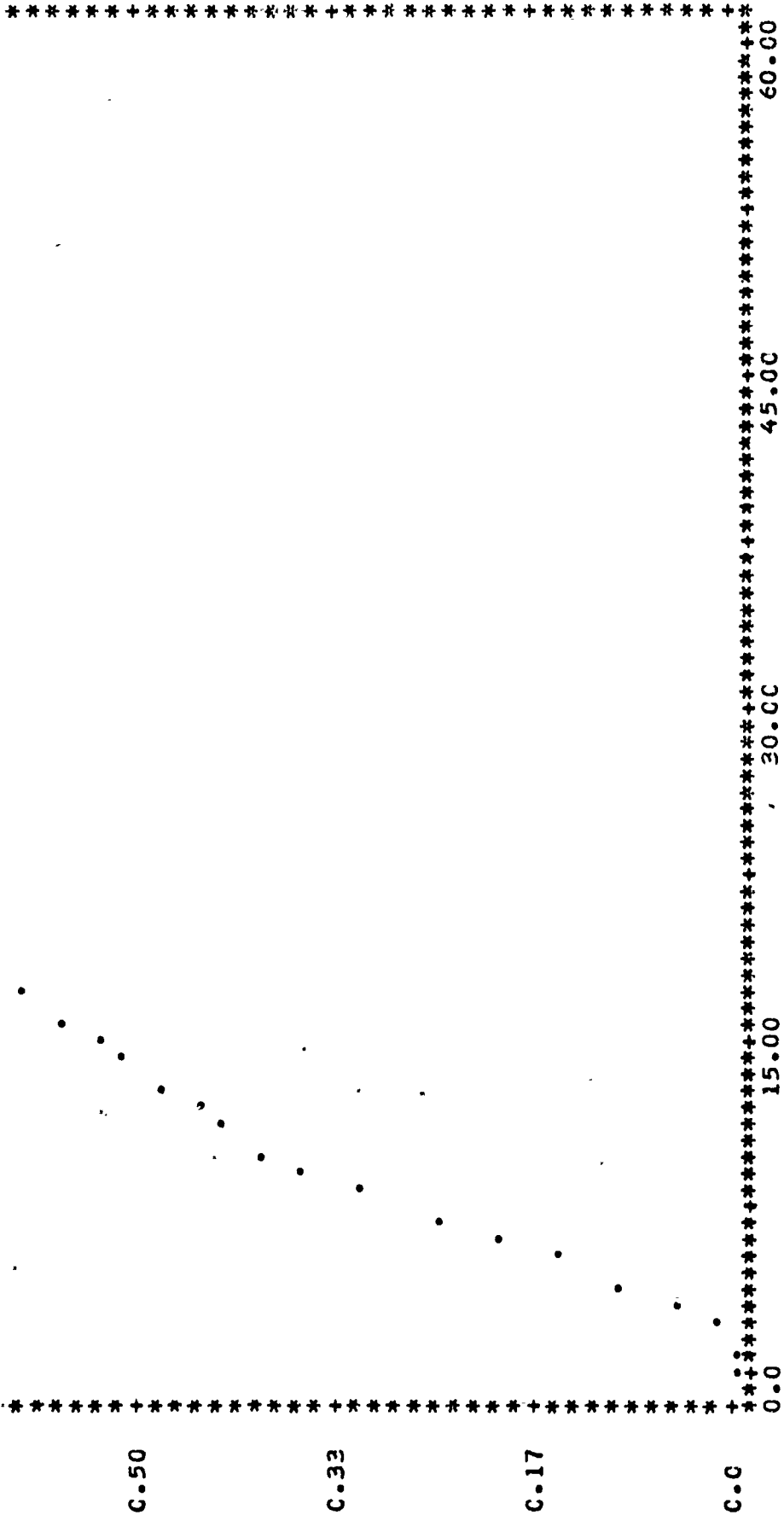
A sample of the computer output is included in this section for each of the programs used. The output for the first program consists of a listing of the probabilities of target detection for actual sonar ranges for a limited number of target speeds, searcher speeds and times late combinations. After each listing, the same information is presented in a graphical format. The x-axis represents actual sonar range in nautical miles, and the y-axis is the probability of target detection. In using the listing, a computer design feature made the following convention necessary:

Probability of Target Detection = CDF(x+1)
for Sonar Range of x nmi

The output of the second computer program consists of comparative listings and comparative graphs for the input parameters specified in the program explanation of Appendix C. The listings and graphical results are given for the Koopman search plan and the alternate search plans. The alternate search plans used a multiplier value of 2.0 and factor values of 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, and 1.5. The same convention is used for the listings. The axes of the graphs are also the same. In the graphical representation of the results, the Koopman search plan values are denoted by "." and the alternate search plan values are denoted by "+". In the case where the values of the Koopman search plan and the alternate search plan under consideration are the same, only the value for the alternate search plan (+) is printed. The exact probability of target detection at a particular sonar range can be obtained from the listings.

KCCPMAN SEARCH PLAN
SEARCHER SPEED= 8.0
ASSUMED TARGET SPEED= 4.0
TIME LATE= 3.0
TOTAL SEARCH TIME = 163.61

CCF 1=C.0
CCF 2=C.00300
CCF 3=C.01567
CCF 4=C.04967
CCF 5=C.10033
CCF 6=C.15333
CCF 7=C.20800
CCF 8=C.25667
CCF 9=C.30933
CCF 10=C.36267
CCF 11=C.40267
CCF 12=C.42933
CCF 13=C.45333
CCF 14=C.48200
CCF 15=C.51033
CCF 16=C.53967
CCF 17=C.57267
CCF 18=C.60700
CCF 19=C.66567
CCF 20=C.72700
CCF 21=C.80833
CCF 22=C.88433
CCF 23=C.95633
CCF 24=C.98567
CCF 25=C.99433
CCF 26=C.99933
CCF 27=1.00000
CCF 28=1.00000
CCF 29=1.00000
CCF 30=1.00000
CCF 31=1.00000
CCF 32=1.00000
CCF 33=1.00000
CCF 34=1.00000
CCF 35=1.00000
CCF 36=1.00000
CCF 37=1.00000
CCF 38=1.00000
CCF 39=1.00000
CCF 40=1.00000
CCF 41=1.00000
CCF 42=1.00000
CCF 43=1.00000
CCF 44=1.00000
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CCF 47=1.00000
CCF 48=1.00000
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CCF 51=1.00000
CCF 52=1.00000
CCF 53=1.00000
CCF 54=1.00000
CCF 55=1.00000
CCF 56=1.00000
CCF 57=1.00000
CCF 58=1.00000
CCF 59=1.00000
CCF 60=1.00000
CCF 61=1.00000

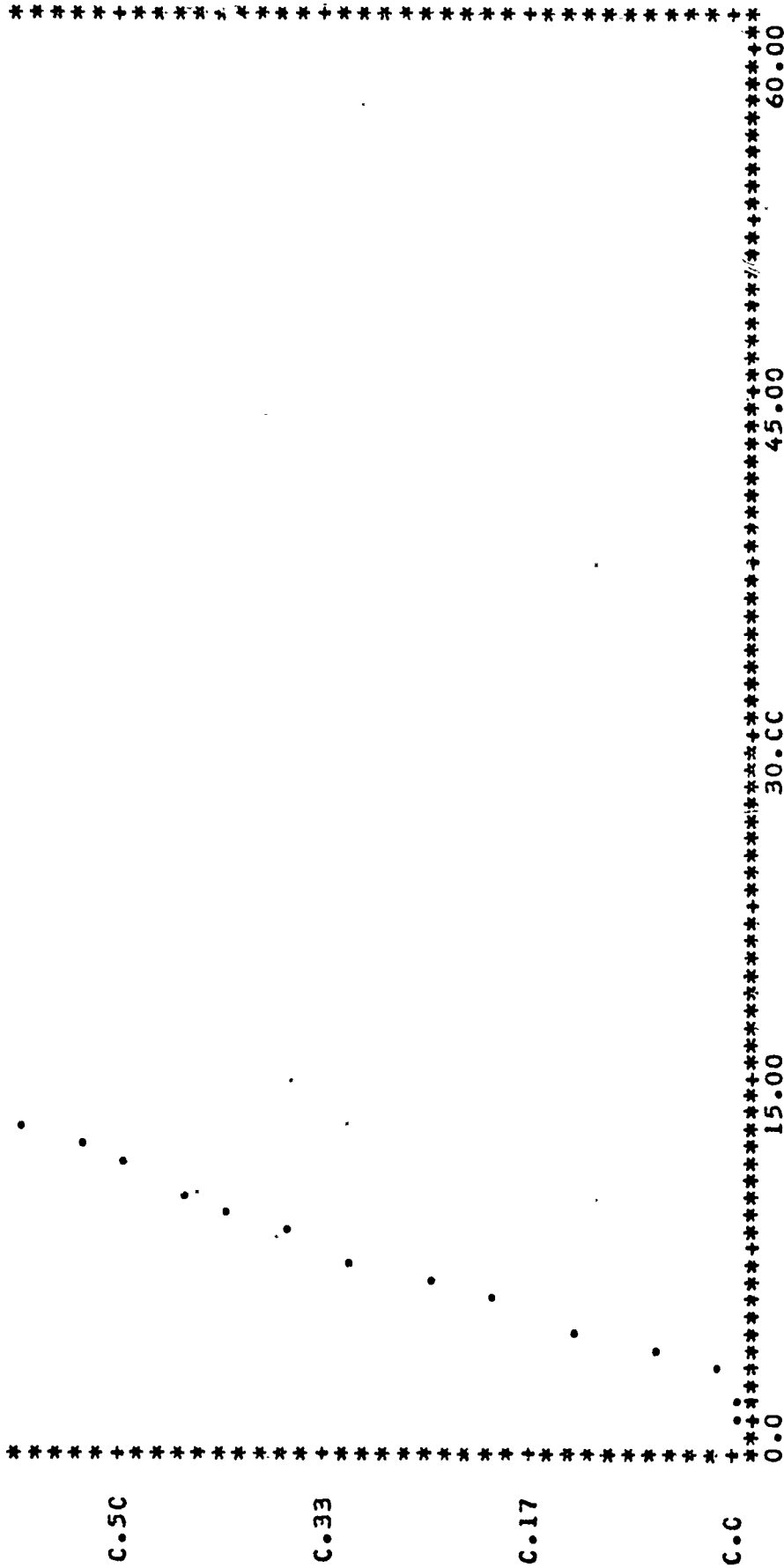


X-SCALE: **M= 0.75CE 00 UNITS
Y-SCALE: **M= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS
SEARCHER SPEED= 8.0
ASSUMED TARGET SPEED= 4.0
TIME LATE= 3.0

KCCPMAN SEARCH PLAN
SEARCHER SPEED=14.0
ASSUMED TARGET SPEED= 4.0
TIME LATE= 3.0
TCTAL SEARCH TIME = 22.20

CCF 1=C.0
CCF 2=0.00533
CCF 3=0.02200
CCF 4=C.06600
CCF 5=C.12833
CCF 6=C.19333
CCF 7=C.25467
CCF 8=C.32100
CCF 9=C.37333
CCF 10=C.41833
CCF 11=C.45767
CCF 12=C.49667
CCF 13=C.53833
CCF 14=C.58333
CCF 15=C.62500
CCF 16=C.68400
CCF 17=C.74400
CCF 18=C.79967
CCF 19=C.85167
CCF 20=C.88167
CCF 21=C.91067
CCF 22=C.94467
CCF 23=C.97967
CCF 24=C.99133
CCF 25=C.99733
CCF 26=C.99867
CCF 27=1.00000
CCF 28=1.00000
CCF 29=1.00000
CCF 30=1.00000
CCF 31=1.00000
CCF 32=1.00000
CCF 33=1.00000
CCF 34=1.00000
CCF 35=1.00000
CCF 36=1.00000
CCF 37=1.00000
CCF 38=1.00000
CCF 39=1.00000
CCF 40=1.00000
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CCF 43=1.00000
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CCF 45=1.00000
CCF 46=1.00000
CCF 47=1.00000
CCF 48=1.00000
CCF 49=1.00000
CCF 50=1.00000
CCF 51=1.00000
CCF 52=1.00000
CCF 53=1.00000
CCF 54=1.00000
CCF 55=1.00000
CCF 56=1.00000
CCF 57=1.00000
CCF 58=1.00000
CCF 59=1.00000
CCF 60=1.00000
CCF 61=1.00000



X-SCALE: **N= 0.750E 00 UNITS

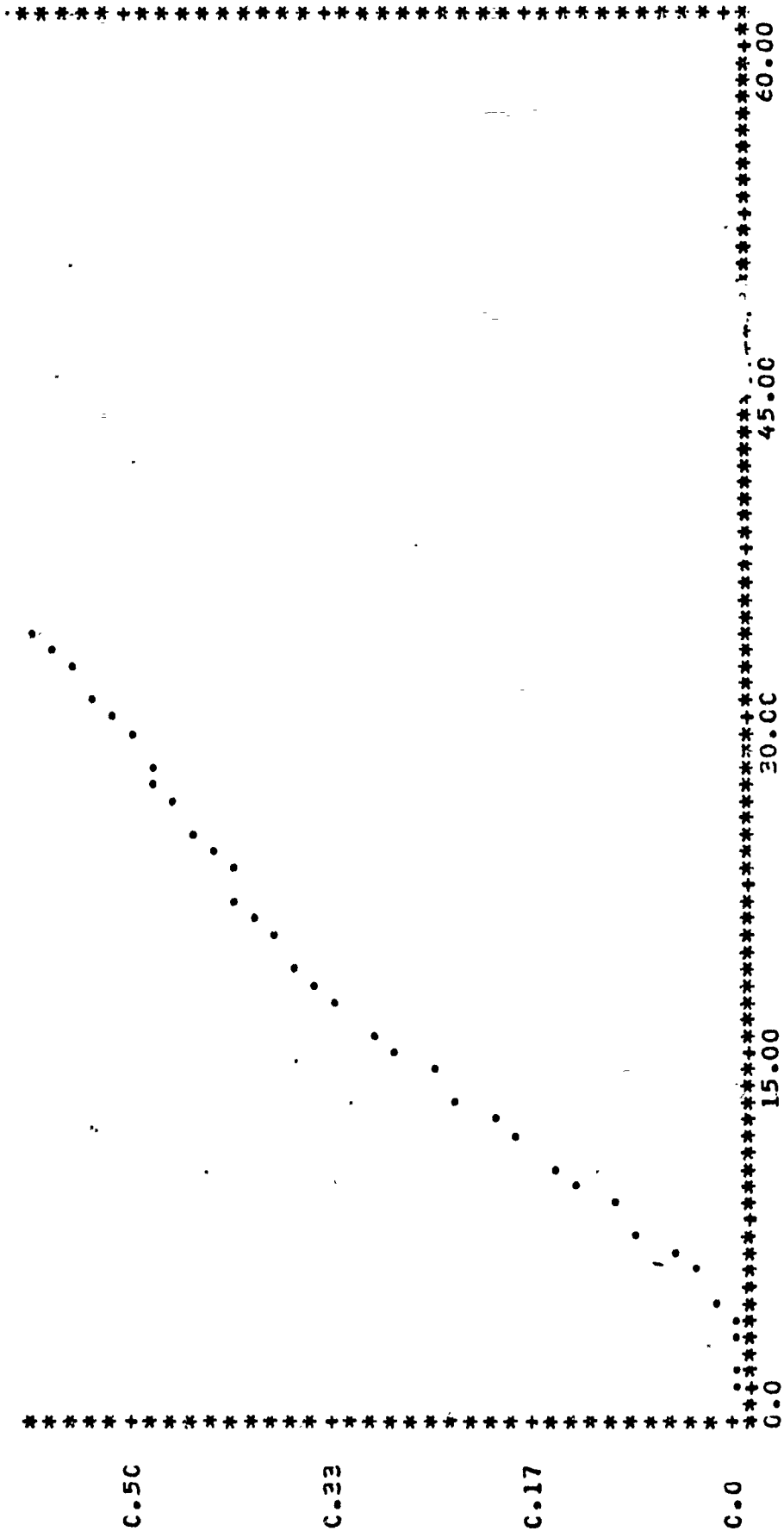
Y-SCALE: **N= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS

SEARCHER SPEED=14.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE= 3.0

KCCPMAN SEARCH PLAN
SEARCHER SPEED= 8.0
ASSUMED TARGET SPEED= 4.0
TIME LATE= 6.0
TCTAL SEARCH TIME = 326.21

CCF 1=C.0
CCF 2=C.0
CCF 3=C.0
CCF 4=C.00233
CCF 5=C.00900
CCF 6=C.02700
CCF 7=C.04933
CCF 8=C.07533
CCF 9=C.10067
CCF 10=C.13300
CCF 11=C.15767
CCF 12=C.18067
CCF 13=C.20567
CCF 14=C.23100
CCF 15=C.25700
CCF 16=C.28000
CCF 17=C.30333
CCF 18=C.32733
CCF 19=C.34800
CCF 20=C.36800
CCF 21=C.38500
CCF 22=C.39833
CCF 23=C.41233
CCF 24=C.42267
CCF 25=C.43733
CCF 26=C.45167
CCF 27=C.46667
CCF 28=C.47867
CCF 29=C.49100
CCF 30=C.50667
CCF 31=C.51700
CCF 32=C.53400
CCF 33=C.55233
CCF 34=C.56967
CCF 35=C.59067
CCF 36=C.62033
CCF 37=C.65400
CCF 38=C.68467
CCF 39=C.71500
CCF 40=C.75533
CCF 41=C.79800
CCF 42=C.84067
CCF 43=C.89067
CCF 44=C.94533
CCF 45=C.97633
CCF 46=C.99000
CCF 47=C.99600
CCF 48=C.99933
CCF 49=C.99967
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CCF 51=1.00000
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CCF 60=1.00000
CCF 61=1.00000

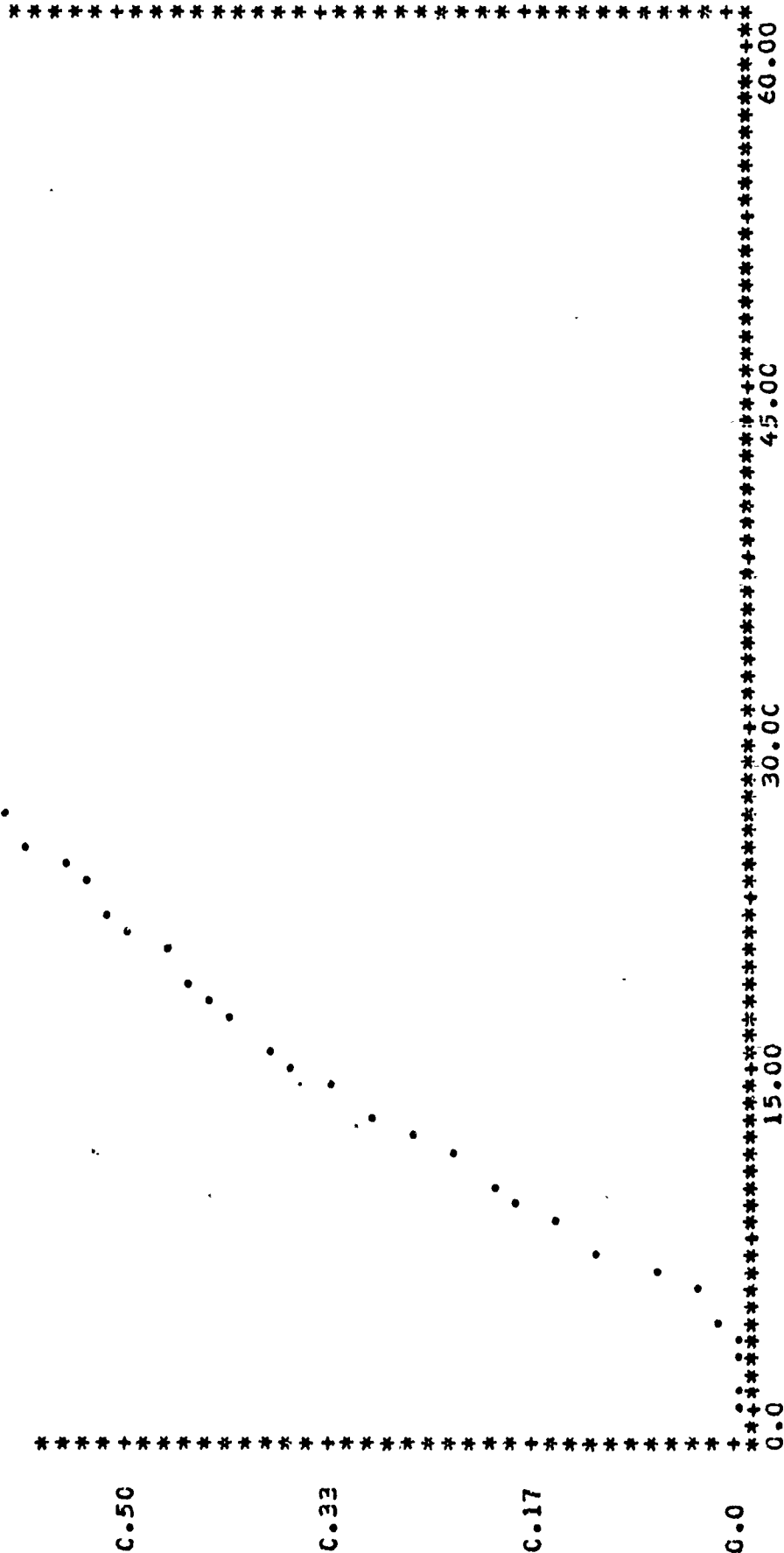


X-SCALE: **n= 0.75CE 00 UNITS
 Y-SCALE: **n= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS
 SEARCHER SPEED= 8.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE= 6.0

KCCFMAN SEARCH PLAN
 SEARCHER SPEED=14.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE= 6.0
 TCTAL SEARCH TIME = 43.99

CCF 1=C.0
 CCF 2=C.0
 CCF 3=0.00100
 CCF 4=0.00433
 CCF 5=0.01233
 CCF 6=C.03100
 CCF 7=0.06833
 CCF 8=C.10900
 CCF 9=C.14367
 CCF 10=C.17867
 CCF 11=C.20633
 CCF 12=C.22967
 CCF 13=C.25867
 CCF 14=0.29467
 CCF 15=0.32633
 CCF 16=C.36100
 CCF 17=C.38667
 CCF 18=C.41100
 CCF 19=C.43367
 CCF 20=C.45500
 CCF 21=C.47333
 CCF 22=C.49767
 CCF 23=C.52000
 CCF 24=0.53533
 CCF 25=C.55800
 CCF 26=C.58033
 CCF 27=C.59833
 CCF 28=C.62133
 CCF 29=C.64867
 CCF 30=C.66833
 CCF 31=C.69367
 CCF 32=C.72467
 CCF 33=C.75367
 CCF 34=C.78467
 CCF 35=C.81500
 CCF 36=C.84033
 CCF 37=C.86067
 CCF 38=C.87167
 CCF 39=C.87867
 CCF 40=C.88700
 CCF 41=C.90267
 CCF 42=C.92633
 CCF 43=C.95100
 CCF 44=C.97800
 CCF 45=C.99200
 CCF 46=C.99633
 CCF 47=0.99900
 CCF 48=C.99933
 CCF 49=0.99967
 CCF 50=1.00000
 CCF 51=1.00000
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 CCF 54=1.00000
 CCF 55=1.00000
 CCF 56=1.00000
 CCF 57=1.00000
 CCF 58=1.00000
 CCF 59=1.00000
 CCF 60=1.00000
 CCF 61=1.00000

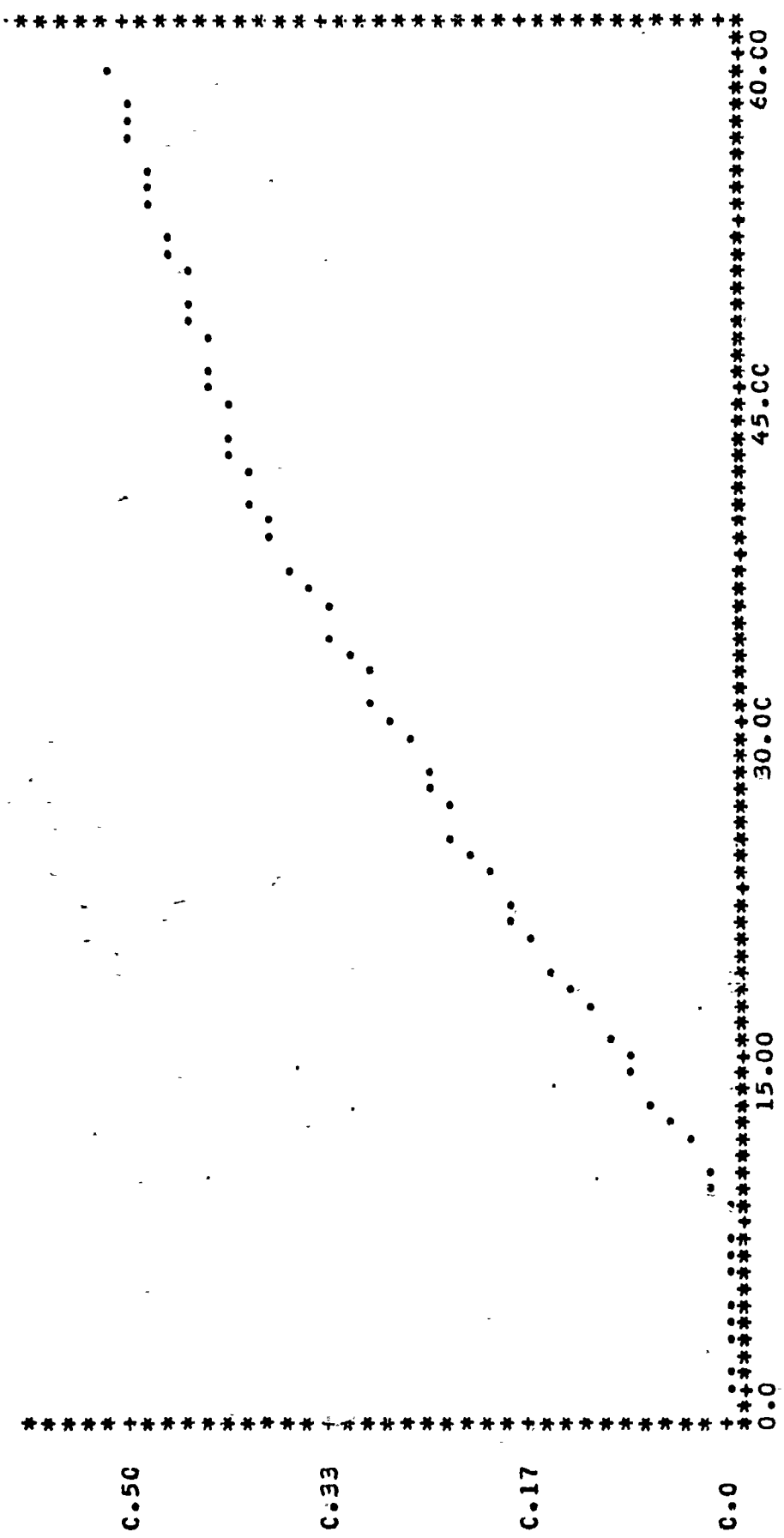


X-SCALE: **= C.75CE 00 UNITS
 Y-SCALE: **= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS
 SEARCHER SPEED=14.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE= 6.0

KCCPMAN SEARCH PLAN
 SEARCHER SPEED= 8.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE=12.0
 TCTAL SEARCH TIME = 651.41

CCF 1=0.0
 CCF 2=0.0
 CCF 3=0.0
 CCF 4=0.0
 CCF 5=0.0
 CCF 6=0.0
 CCF 7=0.0
 CCF 8=C.00133
 CCF 9=C.00333
 CCF 10=0.00867
 CCF 11=C.02300
 CCF 12=0.03533
 CCF 13=0.04600
 CCF 14=C.06100
 CCF 15=0.07700
 CCF 16=C.08833
 CCF 17=C.10267
 CCF 18=0.12133
 CCF 19=C.13633
 CCF 20=C.15233
 CCF 21=C.16700
 CCF 22=0.17567
 CCF 23=C.18567
 CCF 24=C.19900
 CCF 25=C.21100
 CCF 26=C.22533
 CCF 27=0.23567
 CCF 28=C.24567
 CCF 29=C.25633
 CCF 30=0.26700
 CCF 31=C.28033
 CCF 32=C.29400
 CCF 33=C.30467
 CCF 34=C.31733
 CCF 35=C.33033
 CCF 36=C.34000
 CCF 37=C.35033
 CCF 38=C.36267
 CCF 39=C.37767
 CCF 40=C.38833
 CCF 41=C.39767
 CCF 42=0.40433
 CCF 43=0.41100
 CCF 44=C.41633
 CCF 45=0.42233
 CCF 46=C.42833
 CCF 47=C.43467
 CCF 48=0.43867
 CCF 49=C.44400
 CCF 50=C.45000
 CCF 51=0.45733
 CCF 52=0.46433
 CCF 53=C.47000
 CCF 54=C.47667
 CCF 55=C.48533
 CCF 56=C.48900
 CCF 57=C.49400
 CCF 58=C.50000
 CCF 59=0.50733
 CCF 60=0.51367
 CCF 61=1.00000

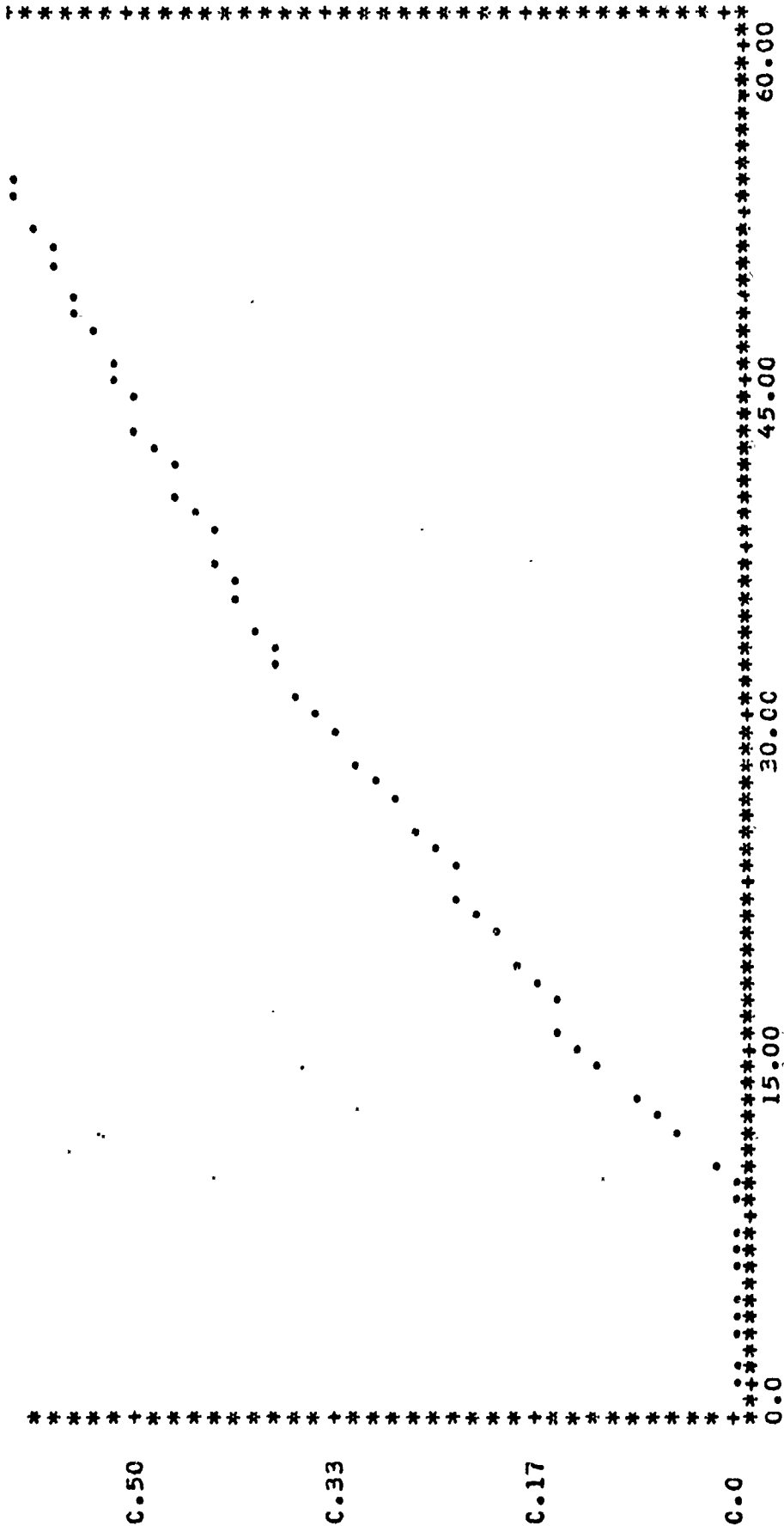


X-SCALE: "M"= 0.750E 00 UNITS
 Y-SCALE: "M"= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS
 SEARCHER SPEED= 8.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE=12.0

KCCPMAN SEARCH PLAN
SEARCHER SPEED=14.0
ASSUMED TARGET SPEED= 4.0
TIME LATE=12.0
TCTAL SEARCH TIME = 87.58

CCF 1=C.0
CCF 2=C.0
CCF 3=C.0
CCF 4=C.0
CCF 5=C.0
CCF 6=C.0
CCF 7=C.0
CCF 8=C.0
CCF 9=C.00333
CCF 10=C.00767
CCF 11=C.02167
CCF 12=C.04200
CCF 13=C.06533
CCF 14=C.08833
CCF 15=C.10900
CCF 16=C.12700
CCF 17=C.14300
CCF 18=C.15767
CCF 19=C.17267
CCF 20=C.18633
CCF 21=C.20000
CCF 22=C.21400
CCF 23=C.22600
CCF 24=C.24000
CCF 25=C.25400
CCF 26=C.26833
CCF 27=C.28200
CCF 28=C.29400
CCF 29=C.31267
CCF 30=C.32367
CCF 31=C.335067
CCF 32=C.34667
CCF 33=C.35767
CCF 34=C.36933
CCF 35=C.38300
CCF 36=C.41533
CCF 37=C.42400
CCF 38=C.43267
CCF 39=C.44133
CCF 40=C.44867
CCF 41=C.46033
CCF 42=C.47033
CCF 43=C.48133
CCF 44=C.49267
CCF 45=C.50267
CCF 46=C.51033
CCF 47=C.52033
CCF 48=C.53300
CCF 49=C.54267
CCF 50=C.55033
CCF 51=C.56033
CCF 52=C.57133
CCF 53=C.58333
CCF 54=C.59500
CCF 55=C.60600
CCF 56=C.62133
CCF 57=C.63567
CCF 58=C.64500
CCF 59=C.66100
CCF 60=C.67867
CCF 61=C.00000



X-SCALE: "M"= 0.75CE C0 UNITS
 Y-SCALE: "M"= 0.167E-01 UNITS

SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARAMETERS
 SEARCHER SPEED=14.0
 ASSUMED TARGET SPEED= 4.0
 TIME LATE=12.0

SEARCHER SPEED=12.0
 ASSUMED TARGET SPEED= 8.0
 TIME LATE= 4.0
 TCTAL SEARCH TIME= 96.00

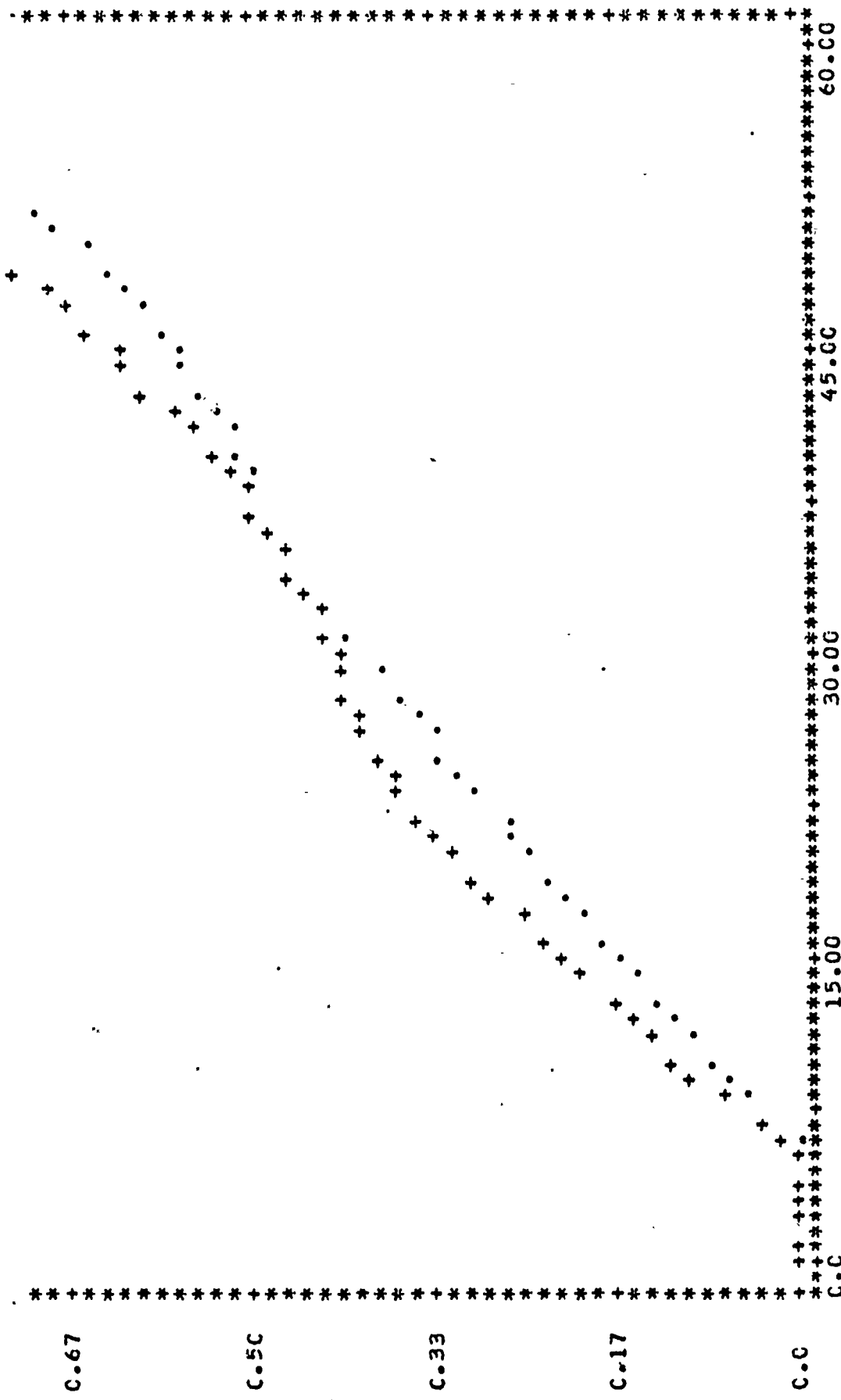
KCCFMAN
 SEARCH
 PLAN

ALTERNATE
 SEARCH
 PLAN

FACTOR= 0.8 MULTIPLIER= 2.00

CCF 1=0.0
 CDF 2=0.0
 CCF 3=0.0
 CDF 4=0.0
 CCF 5=0.0010
 CDF 6=0.0030
 CCF 7=0.0060
 CDF 8=0.0090
 CCF 9=0.0120
 CDF 10=0.0150
 CCF 11=0.0180
 CDF 12=0.0210
 CCF 13=0.0240
 CDF 14=0.0270
 CCF 15=0.0300
 CDF 16=0.0330
 CCF 17=0.0360
 CDF 18=0.0390
 CCF 19=0.0420
 CDF 20=0.0450
 CCF 21=0.0480
 CDF 22=0.0510
 CCF 23=0.0540
 CDF 24=0.0570
 CCF 25=0.0600
 CDF 26=0.0630
 CCF 27=0.0660
 CDF 28=0.0690
 CCF 29=0.0720
 CDF 30=0.0750
 CCF 31=0.0780
 CDF 32=0.0810
 CCF 33=0.0840
 CDF 34=0.0870
 CCF 35=0.0900
 CDF 36=0.0930
 CCF 37=0.0960
 CDF 38=0.0990
 CCF 39=0.1020
 CDF 40=0.1050
 CCF 41=0.1080
 CDF 42=0.1110
 CCF 43=0.1140
 CDF 44=0.1170
 CCF 45=0.1200
 CDF 46=0.1230
 CCF 47=0.1260
 CDF 48=0.1290
 CCF 49=0.1320
 CDF 50=0.1350
 CCF 51=0.1380
 CDF 52=0.1410
 CCF 53=0.1440
 CDF 54=0.1470
 CCF 55=0.1500
 CDF 56=0.1530
 CCF 57=0.1560
 CDF 58=0.1590
 CCF 59=0.1620
 CDF 60=0.1650
 CCF 61=1.0000

CCF 1=0.0
 CDF 2=0.0
 CCF 3=0.0
 CDF 4=0.0
 CCF 5=0.0
 CDF 6=0.0040
 CCF 7=0.0130
 CDF 8=0.0370
 CCF 9=0.0600
 CDF 10=0.0920
 CCF 11=0.1170
 CDF 12=0.1320
 CCF 13=0.1450
 CDF 14=0.1680
 CCF 15=0.1920
 CDF 16=0.2130
 CCF 17=0.2360
 CDF 18=0.2550
 CCF 19=0.2770
 CDF 20=0.2980
 CCF 21=0.3100
 CDF 22=0.3330
 CCF 23=0.3500
 CDF 24=0.3630
 CCF 25=0.3710
 CDF 26=0.3860
 CCF 27=0.3920
 CDF 28=0.3980
 CCF 29=0.4090
 CDF 30=0.4190
 CCF 31=0.4230
 CDF 32=0.4310
 CCF 33=0.4390
 CDF 34=0.4500
 CCF 35=0.4640
 CDF 36=0.4710
 CCF 37=0.4850
 CDF 38=0.4940
 CCF 39=0.5080
 CDF 40=0.5220
 CCF 41=0.5410
 CDF 42=0.5530
 CCF 43=0.5710
 CDF 44=0.5960
 CCF 45=0.6110
 CDF 46=0.6240
 CCF 47=0.6440
 CDF 48=0.6660
 CCF 49=0.6900
 CDF 50=0.7150
 CCF 51=0.7410
 CDF 52=0.7700
 CCF 53=0.7910
 CDF 54=0.8250
 CCF 55=0.8430
 CDF 56=0.8650
 CCF 57=0.8870
 CDF 58=0.9210
 CCF 59=0.9670
 CDF 60=0.9860
 CCF 61=1.0000



C.67

C.5C

C.33

C.17

C.C

X-SCALE: **n= 0.750E 00 UNITS
 Y-SCALE: **n= 0.167E-01 UNITS

SEARCHER SPEED=12.0
ASSUMED TARGET SPEED= 8.0
TIME LATE=4.0
TOTAL SEARCH TIME= 96.00

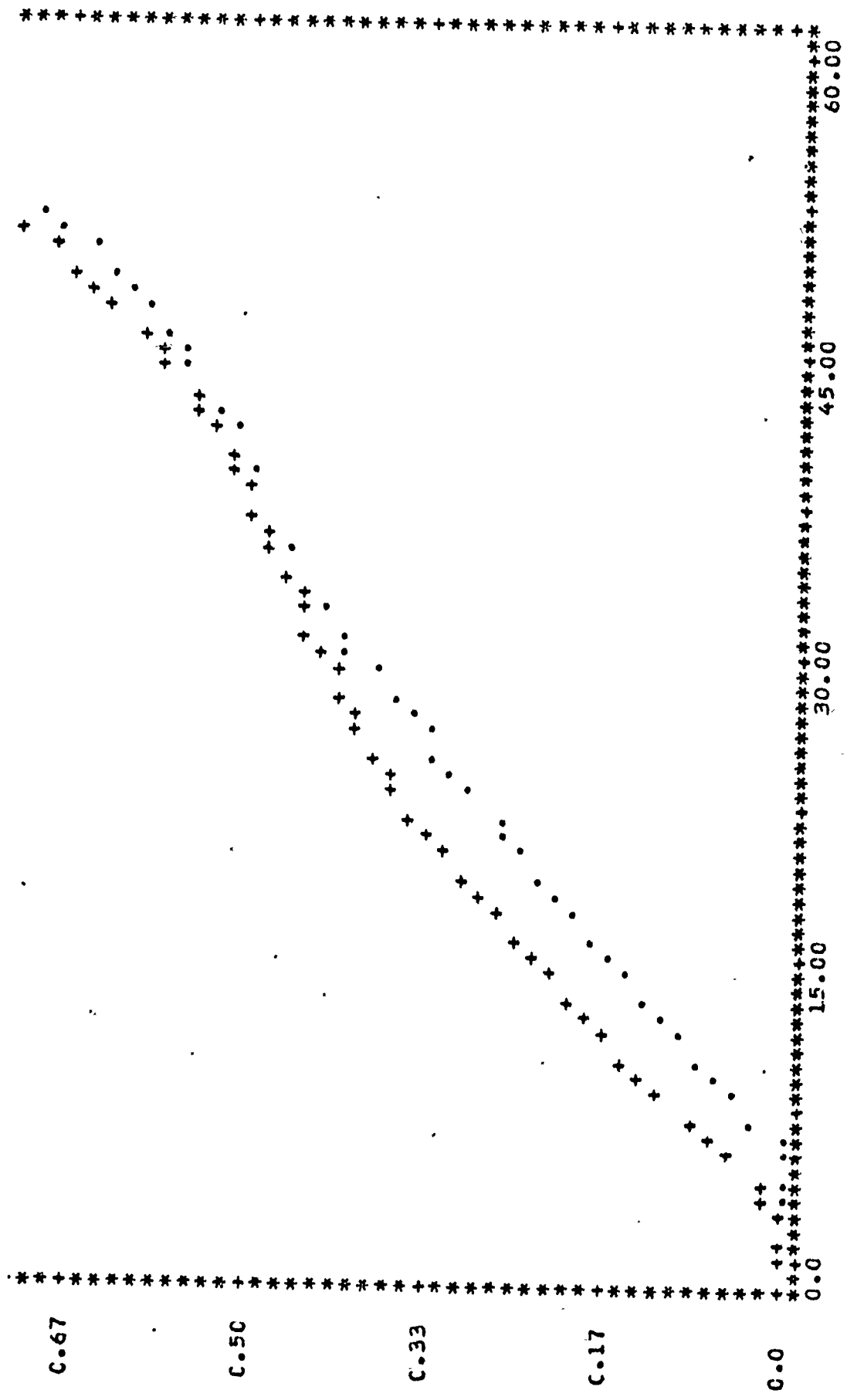
KCCFMAN
SEARCH
PLAN

ALTERNATE
SEARCH
PLAN

FACTOR= 0.9 MULTIPLIER= 2.00

CDF 1=0.0
CDF 2=0.0030
CDF 3=0.0050
CDF 4=0.0090
CDF 5=0.0140
CDF 6=0.0200
CDF 7=0.0270
CDF 8=0.0350
CDF 9=0.0440
CDF 10=0.0540
CDF 11=0.0650
CDF 12=0.0770
CDF 13=0.0900
CDF 14=0.1040
CDF 15=0.1190
CDF 16=0.1350
CDF 17=0.1520
CDF 18=0.1700
CDF 19=0.1890
CDF 20=0.2090
CDF 21=0.2290
CDF 22=0.2500
CDF 23=0.2710
CDF 24=0.2920
CDF 25=0.3140
CDF 26=0.3370
CDF 27=0.3610
CDF 28=0.3860
CDF 29=0.4110
CDF 30=0.4370
CDF 31=0.4640
CDF 32=0.4910
CDF 33=0.5190
CDF 34=0.5470
CDF 35=0.5760
CDF 36=0.6050
CDF 37=0.6340
CDF 38=0.6630
CDF 39=0.6920
CDF 40=0.7210
CDF 41=0.7500
CDF 42=0.7790
CDF 43=0.8080
CDF 44=0.8370
CDF 45=0.8660
CDF 46=0.8950
CDF 47=0.9240
CDF 48=0.9530
CDF 49=0.9820
CDF 50=1.0000
CDF 51=0.0030
CDF 52=0.0050
CDF 53=0.0090
CDF 54=0.0140
CDF 55=0.0200
CDF 56=0.0270
CDF 57=0.0350
CDF 58=0.0440
CDF 59=0.0540
CDF 60=0.0650
CDF 61=0.0770

CDF 1=0.0
CDF 2=0.0030
CDF 3=0.0050
CDF 4=0.0090
CDF 5=0.0140
CDF 6=0.0200
CDF 7=0.0270
CDF 8=0.0350
CDF 9=0.0440
CDF 10=0.0540
CDF 11=0.0650
CDF 12=0.0770
CDF 13=0.0900
CDF 14=0.1040
CDF 15=0.1190
CDF 16=0.1350
CDF 17=0.1520
CDF 18=0.1700
CDF 19=0.1890
CDF 20=0.2090
CDF 21=0.2290
CDF 22=0.2500
CDF 23=0.2710
CDF 24=0.2920
CDF 25=0.3140
CDF 26=0.3370
CDF 27=0.3610
CDF 28=0.3860
CDF 29=0.4110
CDF 30=0.4370
CDF 31=0.4640
CDF 32=0.4910
CDF 33=0.5190
CDF 34=0.5470
CDF 35=0.5760
CDF 36=0.6050
CDF 37=0.6340
CDF 38=0.6630
CDF 39=0.6920
CDF 40=0.7210
CDF 41=0.7500
CDF 42=0.7790
CDF 43=0.8080
CDF 44=0.8370
CDF 45=0.8660
CDF 46=0.8950
CDF 47=0.9240
CDF 48=0.9530
CDF 49=0.9820
CDF 50=1.0000
CDF 51=0.0030
CDF 52=0.0050
CDF 53=0.0090
CDF 54=0.0140
CDF 55=0.0200
CDF 56=0.0270
CDF 57=0.0350
CDF 58=0.0440
CDF 59=0.0540
CDF 60=0.0650
CDF 61=0.0770



X-SCALE: "M"= 0.75CE 00 UNITS
 Y-SCALE: "M"= 0.167E-01 UNITS

C.67
 C.50
 C.33
 C.17
 0.0

SEARCHER SPEED=12.0
ASSUMED TARGET SPEED= 8.0
TIME LATE= 4.0
TCTAL SEARCH TIME= 96.00

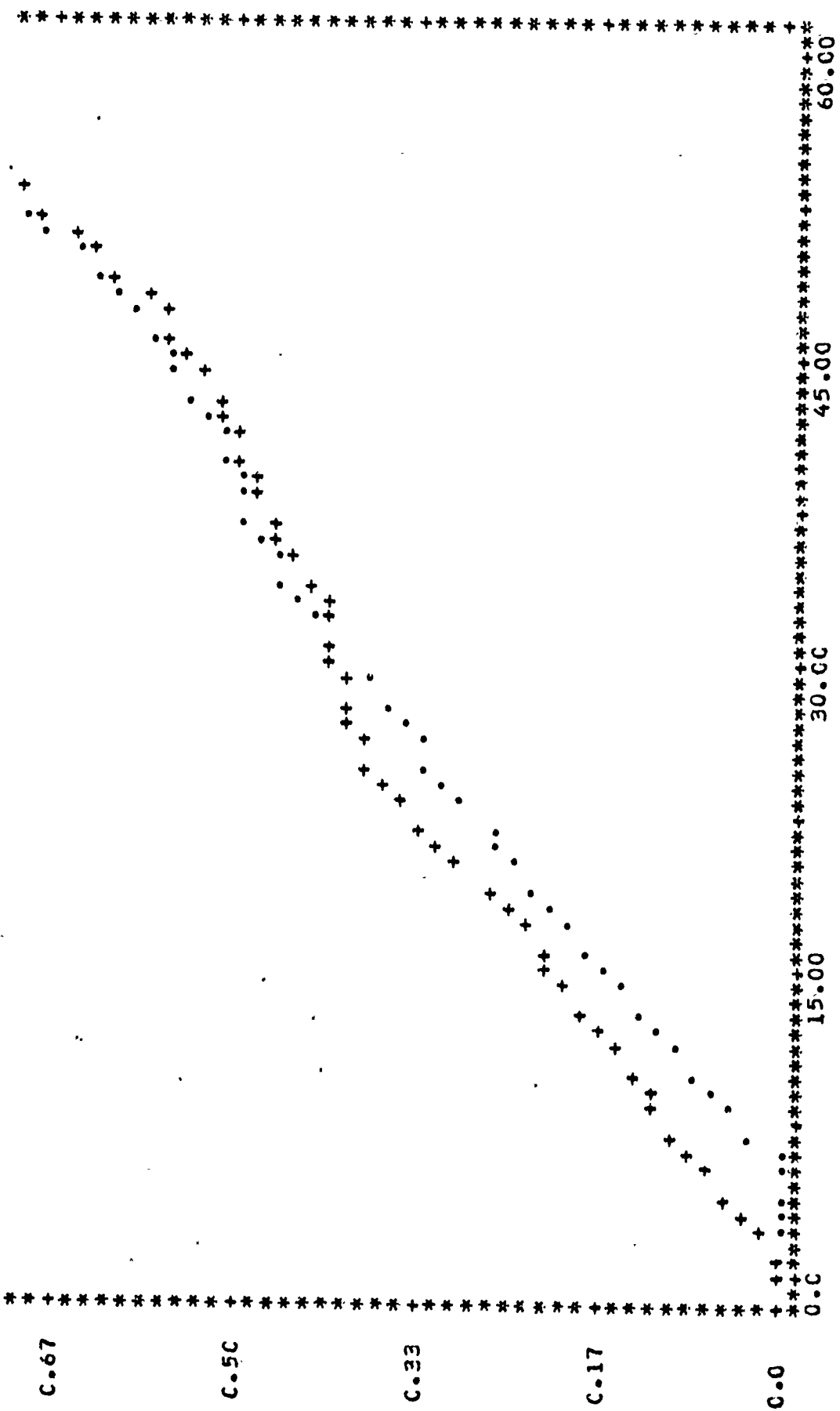
KCCPMAN
SEARCH
PLAN

ALTERNATE
SEARCH
PLAN

FACTOR= 1.0 MULTIPLIER= 2.00

CCF 1=C.0
CCF 2=C.0
CCF 3=C.0
CCF 4=C.0
CCF 5=C.0010
CCF 6=C.0030
CCF 7=C.0060
CCF 8=C.0125
CCF 9=C.0250
CCF 10=C.0500
CCF 11=C.0875
CCF 12=C.1250
CCF 13=C.1750
CCF 14=C.2250
CCF 15=C.2875
CCF 16=C.3625
CCF 17=C.4500
CCF 18=C.5500
CCF 19=C.6625
CCF 20=C.7875
CCF 21=C.9250
CCF 22=C.10750
CCF 23=C.12500
CCF 24=C.14375
CCF 25=C.16375
CCF 26=C.18500
CCF 27=C.20750
CCF 28=C.23125
CCF 29=C.25625
CCF 30=C.28250
CCF 31=C.31000
CCF 32=C.33875
CCF 33=C.36875
CCF 34=C.40000
CCF 35=C.43250
CCF 36=C.46625
CCF 37=C.50125
CCF 38=C.53750
CCF 39=C.57500
CCF 40=C.61375
CCF 41=C.65375
CCF 42=C.69500
CCF 43=C.73750
CCF 44=C.78125
CCF 45=C.82625
CCF 46=C.87250
CCF 47=C.92000
CCF 48=C.96875
CCF 49=C.101875
CCF 50=C.107875
CCF 51=C.114000
CCF 52=C.120250
CCF 53=C.126625
CCF 54=C.133125
CCF 55=C.139750
CCF 56=C.146500
CCF 57=C.153375
CCF 58=C.160375
CCF 59=C.167500
CCF 60=C.174750
CCF 61=1.0000

CCF 1=0.0
CCF 2=0.0080
CCF 3=0.0190
CCF 4=0.0330
CCF 5=0.0470
CCF 6=C.0600
CCF 7=0.0810
CCF 8=0.1000
CCF 9=0.1090
CCF 10=0.1230
CCF 11=0.1360
CCF 12=0.1560
CCF 13=0.1660
CCF 14=0.1810
CCF 15=0.1940
CCF 16=C.2100
CCF 17=0.2230
CCF 18=0.2330
CCF 19=0.2510
CCF 20=0.2740
CCF 21=0.2920
CCF 22=0.3140
CCF 23=C.3300
CCF 24=0.3470
CCF 25=0.3620
CCF 26=0.3760
CCF 27=0.3870
CCF 28=0.3960
CCF 29=0.3980
CCF 30=0.4060
CCF 31=0.4110
CCF 32=0.4170
CCF 33=0.4220
CCF 34=0.4250
CCF 35=0.4370
CCF 36=C.4500
CCF 37=C.4600
CCF 38=C.4700
CCF 39=0.4790
CCF 40=0.4890
CCF 41=0.4960
CCF 42=0.5040
CCF 43=0.5130
CCF 44=0.5240
CCF 45=0.5330
CCF 46=0.5470
CCF 47=0.5600
CCF 48=0.5730
CCF 49=0.5900
CCF 50=0.6190
CCF 51=0.6410
CCF 52=0.6550
CCF 53=0.6770
CCF 54=0.6930
CCF 55=0.7110
CCF 56=0.7440
CCF 57=C.7560
CCF 58=0.7800
CCF 59=0.8020
CCF 60=0.8190
CCF 61=1.0000



X-SCALE: "M"= C.75CE 00 UNITS
 Y-SCALE: "N"= 0.167E-01 UNITS

SEARCHER SPEED=12.0
ASSUMED TARGET SPEED= 8.0
TIME LATE= 4.0
TCTAL SEARCH TIME= 96.00

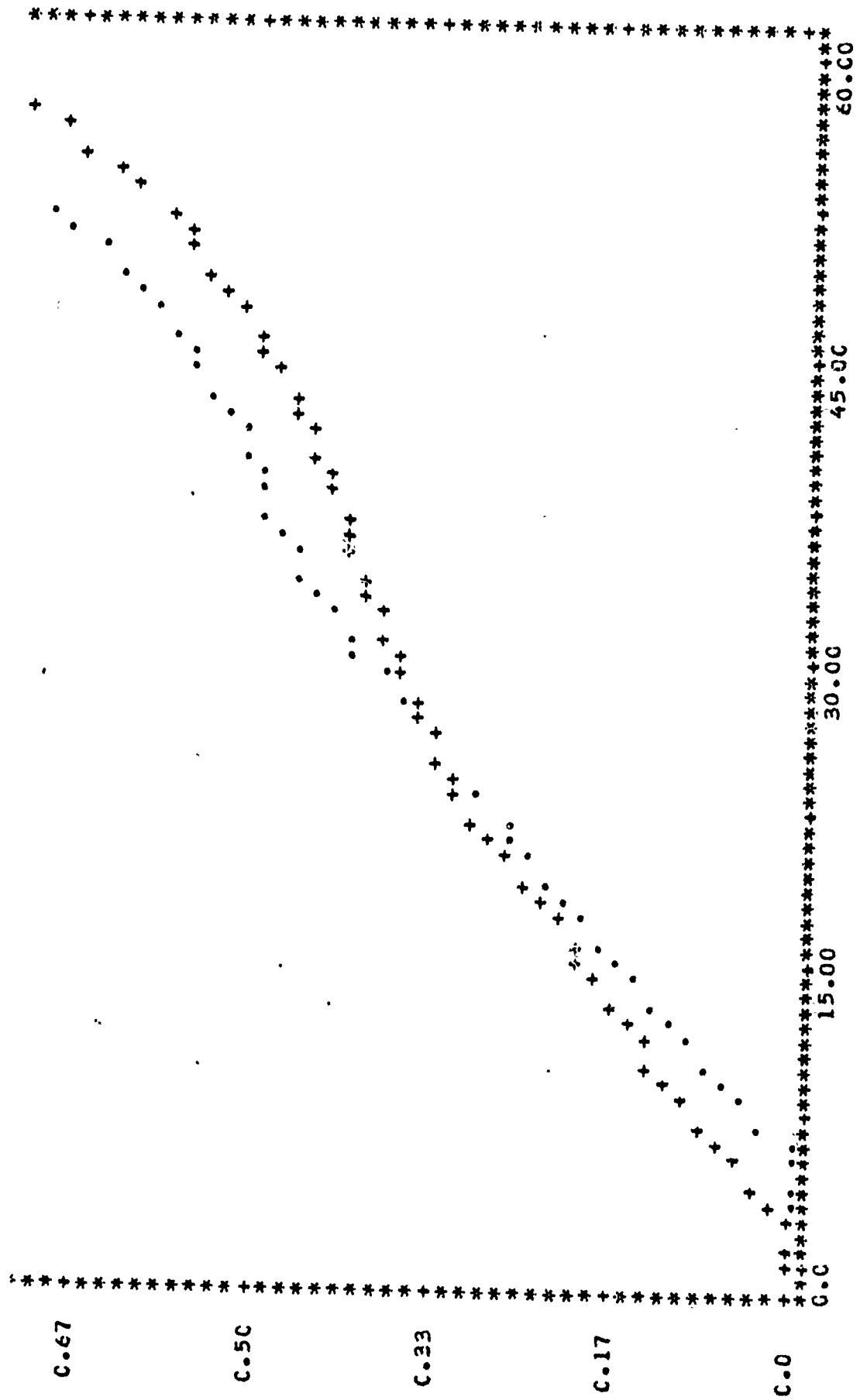
KCCPMAN
SEARCH
PLAN

ALTERNATE
SEARCH
PLAN

FACTOR= 1.1 MULTIPLIER= 2.00

CDF 1=C.0
CDF 2=C.0
CDF 3=C.0
CDF 4=C.0
CDF 5=C.0010
CDF 6=C.0030
CDF 7=C.0060
CDF 8=C.0130
CDF 9=C.0250
CDF 10=C.0450
CDF 11=C.0670
CDF 12=C.0870
CDF 13=C.1050
CDF 14=C.1200
CDF 15=C.1380
CDF 16=C.1550
CDF 17=C.1690
CDF 18=C.1880
CDF 19=C.2020
CDF 20=C.2140
CDF 21=C.2290
CDF 22=C.2440
CDF 23=C.2590
CDF 24=C.2740
CDF 25=C.2920
CDF 26=C.3120
CDF 27=C.3270
CDF 28=C.3410
CDF 29=C.3560
CDF 30=C.3720
CDF 31=C.3910
CDF 32=C.4030
CDF 33=C.4240
CDF 34=C.4390
CDF 35=C.4480
CDF 36=C.4600
CDF 37=C.4730
CDF 38=C.4800
CDF 39=C.4920
CDF 40=C.5060
CDF 41=C.5170
CDF 42=C.5220
CDF 43=C.5340
CDF 44=C.5460
CDF 45=C.5600
CDF 46=C.5680
CDF 47=C.5790
CDF 48=C.5930
CDF 49=C.6110
CDF 50=C.6320
CDF 51=C.6520
CDF 52=C.6760
CDF 53=C.7040
CDF 54=C.7270
CDF 55=C.7600
CDF 56=C.7940
CDF 57=C.8490
CDF 58=C.9100
CDF 59=C.9630
CDF 60=C.9920
CDF 61=1.0000

CDF 1=0.0
CDF 2=0.0020
CDF 3=0.0070
CDF 4=0.0140
CDF 5=0.0240
CDF 6=0.0540
CDF 7=C.0700
CDF 8=0.0880
CDF 9=0.0990
CDF 10=0.1130
CDF 11=0.1250
CDF 12=0.1370
CDF 13=C.1500
CDF 14=0.1630
CDF 15=0.1850
CDF 16=0.1960
CDF 17=0.2060
CDF 18=0.2170
CDF 19=0.2350
CDF 20=0.2470
CDF 21=0.2670
CDF 22=0.2780
CDF 23=0.2970
CDF 24=0.3100
CDF 25=0.3230
CDF 26=C.3300
CDF 27=0.3390
CDF 28=0.3490
CDF 29=0.3570
CDF 30=0.3660
CDF 31=0.3750
CDF 32=C.3820
CDF 33=0.3900
CDF 34=0.3980
CDF 35=0.4060
CDF 36=0.4120
CDF 37=0.4140
CDF 38=0.4170
CDF 39=0.4280
CDF 40=0.4380
CDF 41=0.4480
CDF 42=0.4550
CDF 43=0.4620
CDF 44=0.4700
CDF 45=0.4840
CDF 46=0.4950
CDF 47=0.5030
CDF 48=0.5230
CDF 49=0.5300
CDF 50=0.5470
CDF 51=0.5650
CDF 52=0.5750
CDF 53=0.5880
CDF 54=0.6170
CDF 55=0.6370
CDF 56=C.6620
CDF 57=0.6860
CDF 58=0.7110
CDF 59=0.7290
CDF 60=0.7590
CDF 61=1.0000



X-SCALE: "M"= 0.750E 00 UNITS
 Y-SCALE: "M"= 0.167E-01 UNITS

SEARCHER SPEED=12.0
 ASSUMED TARGET SPEED= 8.0
 TIME LATE= 4.0
 TCTAL SEARCH TIME= 96.00

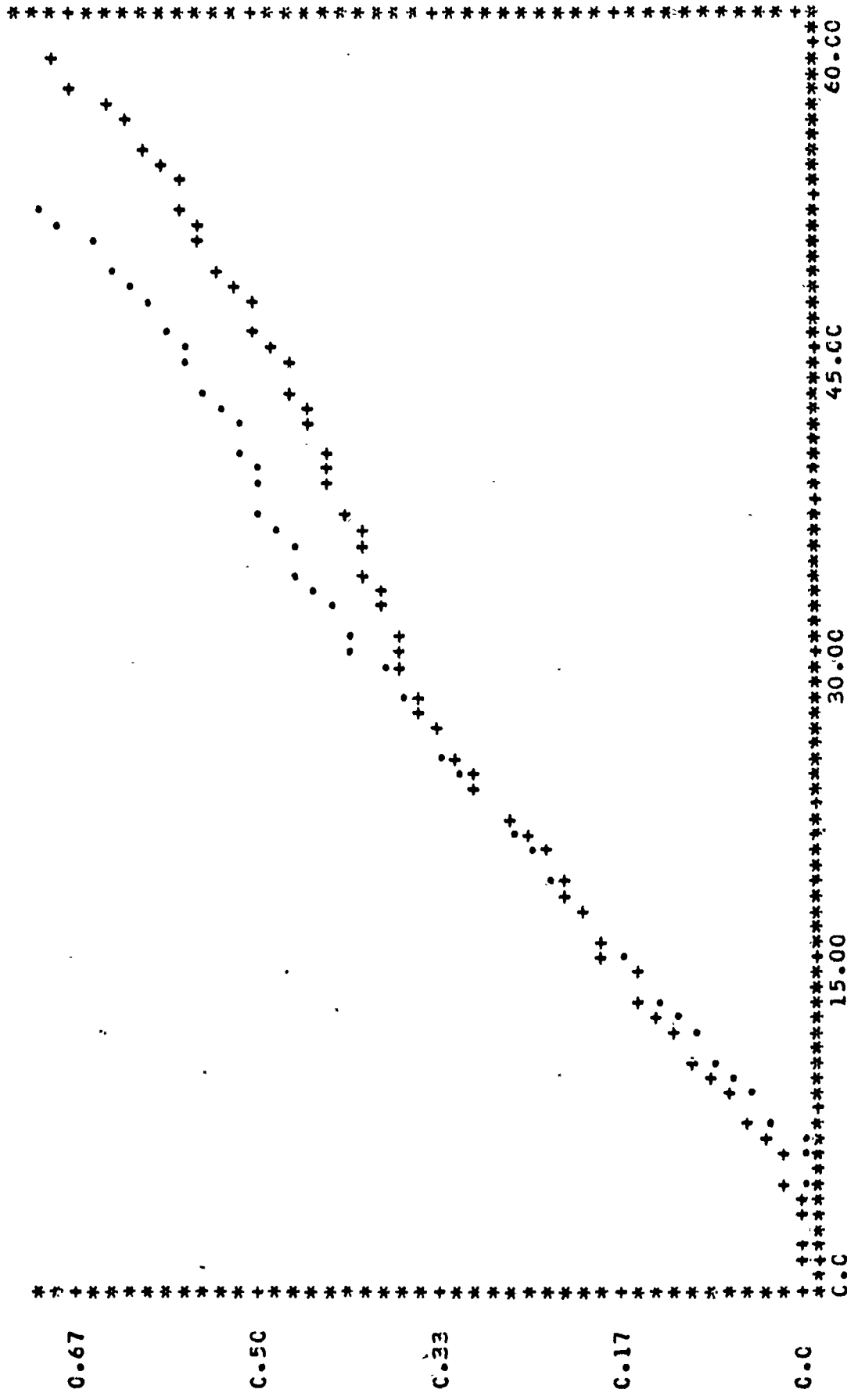
KCCFMAN
 SEARCH
 PLAN

ALTERNATE
 SEARCH
 PLAN

FACTOR= 1.2 MLLTIPLIER= 2.00

CCF 1=0.0000
 CCF 2=0.0000
 CCF 3=0.0000
 CCF 4=0.0000
 CCF 5=0.0010
 CCF 6=0.0030
 CCF 7=0.0060
 CCF 8=0.0100
 CCF 9=0.0150
 CCF 10=0.0200
 CCF 11=0.0260
 CCF 12=0.0330
 CCF 13=0.0400
 CCF 14=0.0480
 CCF 15=0.0560
 CCF 16=0.0650
 CCF 17=0.0740
 CCF 18=0.0840
 CCF 19=0.0940
 CCF 20=0.1050
 CCF 21=0.1160
 CCF 22=0.1270
 CCF 23=0.1390
 CCF 24=0.1510
 CCF 25=0.1630
 CCF 26=0.1760
 CCF 27=0.1890
 CCF 28=0.2020
 CCF 29=0.2160
 CCF 30=0.2300
 CCF 31=0.2440
 CCF 32=0.2590
 CCF 33=0.2730
 CCF 34=0.2880
 CCF 35=0.3030
 CCF 36=0.3180
 CCF 37=0.3340
 CCF 38=0.3490
 CCF 39=0.3650
 CCF 40=0.3810
 CCF 41=0.3970
 CCF 42=0.4140
 CCF 43=0.4310
 CCF 44=0.4480
 CCF 45=0.4660
 CCF 46=0.4840
 CCF 47=0.5020
 CCF 48=0.5200
 CCF 49=0.5390
 CCF 50=0.5580
 CCF 51=0.5770
 CCF 52=0.5970
 CCF 53=0.6170
 CCF 54=0.6370
 CCF 55=0.6570
 CCF 56=0.6780
 CCF 57=0.6990
 CCF 58=0.7200
 CCF 59=0.7410
 CCF 60=0.7630
 CCF 61=1.0000

CCF 1=0.0000
 CCF 2=0.0000
 CCF 3=0.0020
 CCF 4=0.0040
 CCF 5=0.0100
 CCF 6=0.0180
 CCF 7=0.0290
 CCF 8=0.0480
 CCF 9=0.0680
 CCF 10=0.0860
 CCF 11=0.0930
 CCF 12=0.1130
 CCF 13=0.1320
 CCF 14=0.1470
 CCF 15=0.1580
 CCF 16=0.1750
 CCF 17=0.1860
 CCF 18=0.2000
 CCF 19=0.2100
 CCF 20=0.2210
 CCF 21=0.2340
 CCF 22=0.2470
 CCF 23=0.2730
 CCF 24=0.2920
 CCF 25=0.3060
 CCF 26=0.3200
 CCF 27=0.3300
 CCF 28=0.3430
 CCF 29=0.3510
 CCF 30=0.3620
 CCF 31=0.3660
 CCF 32=0.3710
 CCF 33=0.3780
 CCF 34=0.3860
 CCF 35=0.3920
 CCF 36=0.3970
 CCF 37=0.4080
 CCF 38=0.4180
 CCF 39=0.4250
 CCF 40=0.4320
 CCF 41=0.4380
 CCF 42=0.4490
 CCF 43=0.4540
 CCF 44=0.4620
 CCF 45=0.4720
 CCF 46=0.4800
 CCF 47=0.4920
 CCF 48=0.5000
 CCF 49=0.5130
 CCF 50=0.5330
 CCF 51=0.5420
 CCF 52=0.5550
 CCF 53=0.5640
 CCF 54=0.5740
 CCF 55=0.5840
 CCF 56=0.6010
 CCF 57=0.6180
 CCF 58=0.6390
 CCF 59=0.6590
 CCF 60=0.6800
 CCF 61=1.0000



X-SCALE: "M"= 0.750E 00 UNITS
 Y-SCALE: "M"= 0.167E-01 UNITS

SEARCHER SPEED=12.0
 ASSUMED TARGET SPEED= 8.0
 TIME LATE= 4.0
 TCTAL SEARCH TIME= 96.00

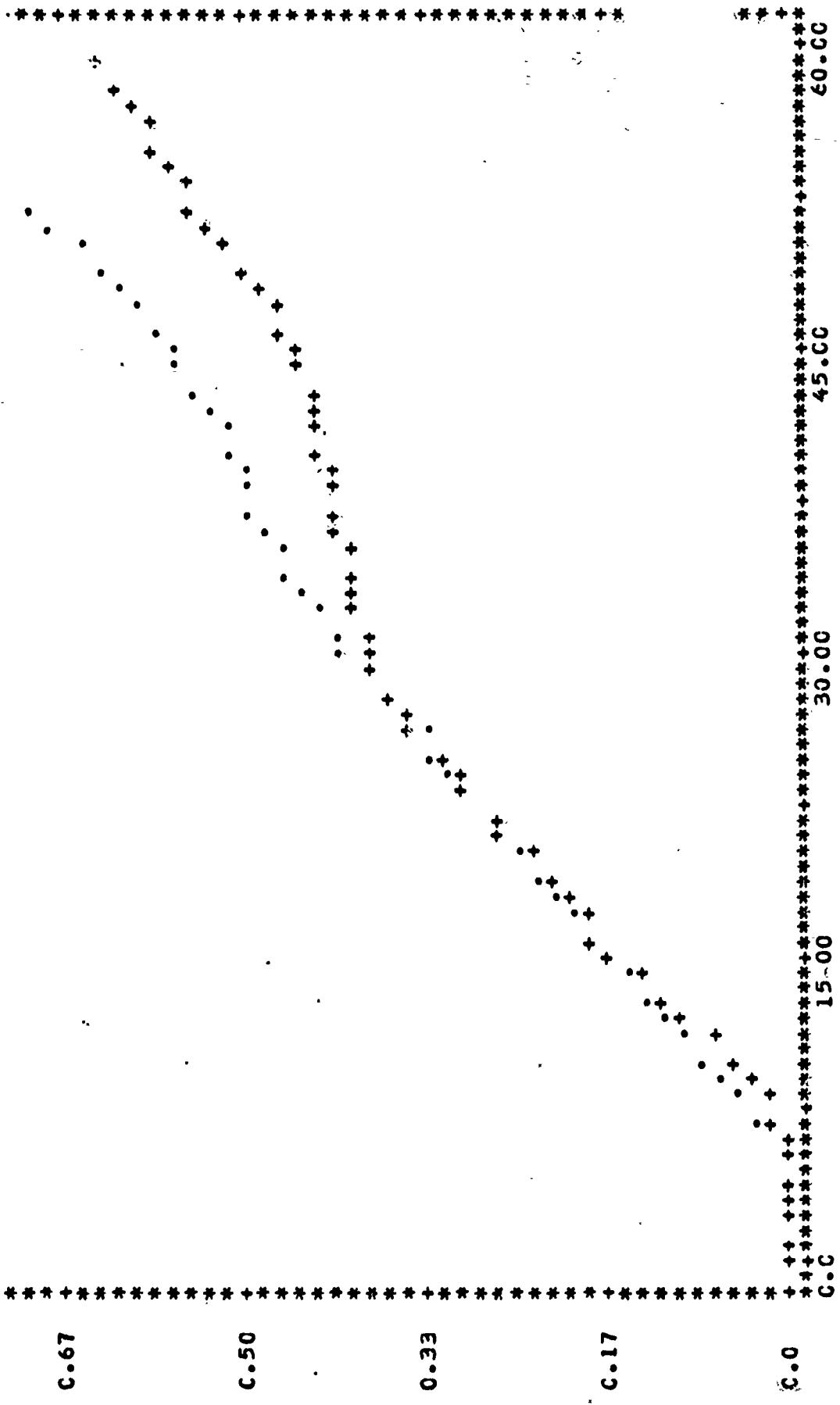
KCCFPAN
 SEARCH
 PLAN

ALTERNATE
 SEARCH
 PLAN

FACTOR= 1.3 MULTIPLIER= 2.00

CCCF 1=0.00000000
 CCF 2=0.00000000
 CCF 3=0.00000000
 CCF 4=0.00000000
 CCF 5=0.00000000
 CCF 6=0.00000000
 CCF 7=0.00000000
 CCF 8=0.00000000
 CCF 9=0.00000000
 CCF 10=0.00000000
 CCF 11=0.00000000
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 CCF 13=0.00000000
 CCF 14=0.00000000
 CCF 15=0.00000000
 CCF 16=0.00000000
 CCF 17=0.00000000
 CCF 18=0.00000000
 CCF 19=0.00000000
 CCF 20=0.00000000
 CCF 21=0.00000000
 CCF 22=0.00000000
 CCF 23=0.00000000
 CCF 24=0.00000000
 CCF 25=0.00000000
 CCF 26=0.00000000
 CCF 27=0.00000000
 CCF 28=0.00000000
 CCF 29=0.00000000
 CCF 30=0.00000000
 CCF 31=0.00000000
 CCF 32=0.00000000
 CCF 33=0.00000000
 CCF 34=0.00000000
 CCF 35=0.00000000
 CCF 36=0.00000000
 CCF 37=0.00000000
 CCF 38=0.00000000
 CCF 39=0.00000000
 CCF 40=0.00000000
 CCF 41=0.00000000
 CCF 42=0.00000000
 CCF 43=0.00000000
 CCF 44=0.00000000
 CCF 45=0.00000000
 CCF 46=0.00000000
 CCF 47=0.00000000
 CCF 48=0.00000000
 CCF 49=0.00000000
 CCF 50=0.00000000
 CCF 51=0.00000000
 CCF 52=0.00000000
 CCF 53=0.00000000
 CCF 54=0.00000000
 CCF 55=0.00000000
 CCF 56=0.00000000
 CCF 57=0.00000000
 CCF 58=0.00000000
 CCF 59=0.00000000
 CCF 60=0.00000000
 CCF 61=1.00000000

CCCF 1=0.00000000
 CCF 2=0.00000000
 CCF 3=0.00000000
 CCF 4=0.00000000
 CCF 5=0.00000000
 CCF 6=0.00000000
 CCF 7=0.00000000
 CCF 8=0.00000000
 CCF 9=0.00000000
 CCF 10=0.00000000
 CCF 11=0.00000000
 CCF 12=0.00000000
 CCF 13=0.00000000
 CCF 14=0.00000000
 CCF 15=0.00000000
 CCF 16=0.00000000
 CCF 17=0.00000000
 CCF 18=0.00000000
 CCF 19=0.00000000
 CCF 20=0.00000000
 CCF 21=0.00000000
 CCF 22=0.00000000
 CCF 23=0.00000000
 CCF 24=0.00000000
 CCF 25=0.00000000
 CCF 26=0.00000000
 CCF 27=0.00000000
 CCF 28=0.00000000
 CCF 29=0.00000000
 CCF 30=0.00000000
 CCF 31=0.00000000
 CCF 32=0.00000000
 CCF 33=0.00000000
 CCF 34=0.00000000
 CCF 35=0.00000000
 CCF 36=0.00000000
 CCF 37=0.00000000
 CCF 38=0.00000000
 CCF 39=0.00000000
 CCF 40=0.00000000
 CCF 41=0.00000000
 CCF 42=0.00000000
 CCF 43=0.00000000
 CCF 44=0.00000000
 CCF 45=0.00000000
 CCF 46=0.00000000
 CCF 47=0.00000000
 CCF 48=0.00000000
 CCF 49=0.00000000
 CCF 50=0.00000000
 CCF 51=0.00000000
 CCF 52=0.00000000
 CCF 53=0.00000000
 CCF 54=0.00000000
 CCF 55=0.00000000
 CCF 56=0.00000000
 CCF 57=0.00000000
 CCF 58=0.00000000
 CCF 59=0.00000000
 CCF 60=0.00000000
 CCF 61=1.00000000



X-SCALE: ***= 0.750E 00 UNITS
 Y-SCALE: ***= 0.167E-01 UNITS

C.67

C.50

0.33

C.17

C.0

SEARCHER SPEED=12.0
ASSUMED TARGET SPEED= 8.0
TIME LATE= 4.0
TCTAL SEARCH TIME= 96.00

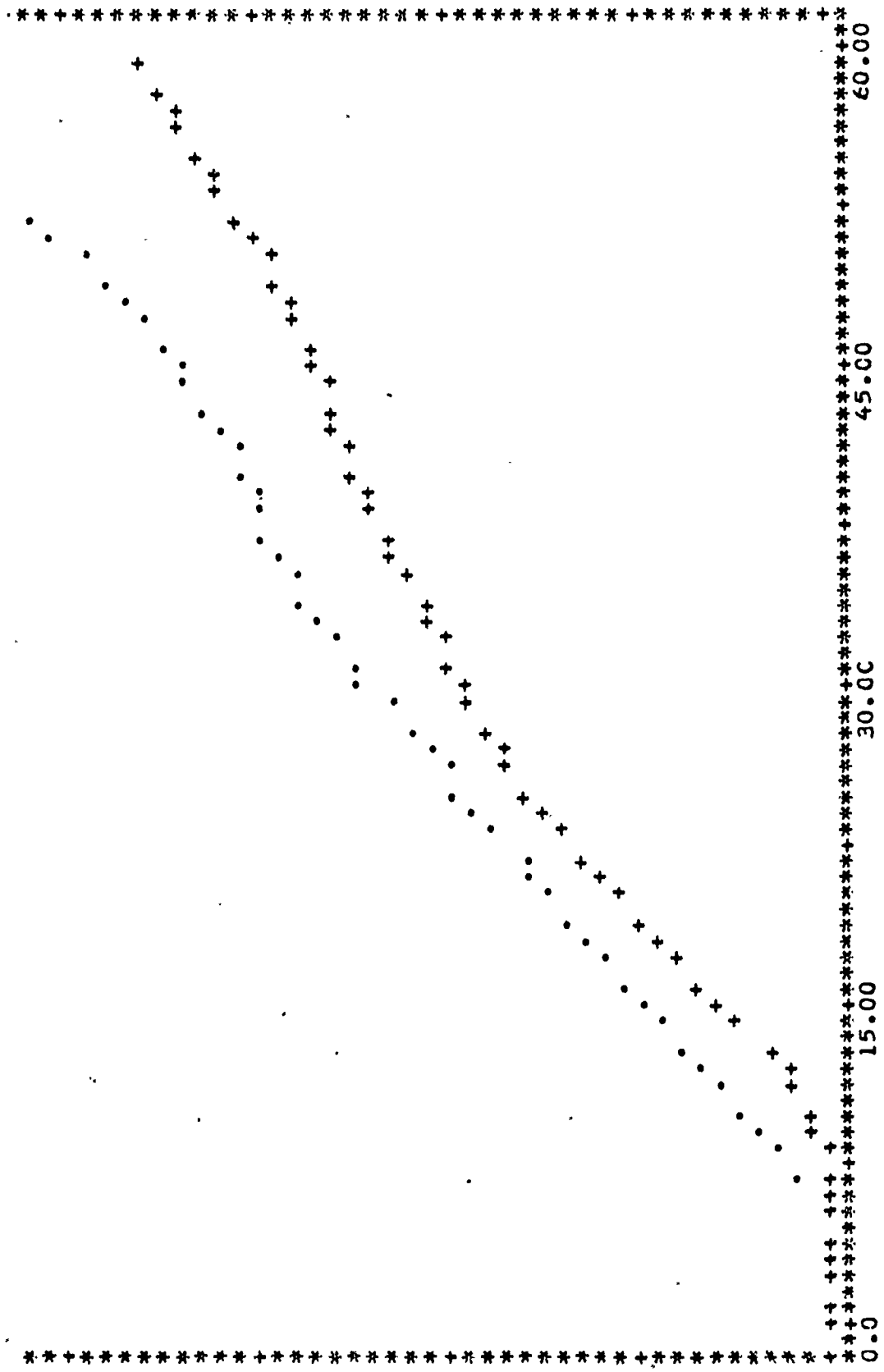
KCCFMAN
SEARCH
PLAN

ALTERNATE
SEARCH
PLAN

FACTOR= 1.4 MULTIPLIER= 2.00

CCF 1=0.0
CCF 2=C.0
CCF 3=C.0
CCF 4=C.0
CCF 5=C.0010
CCF 6=C.0030
CCF 7=C.0060
CCF 8=C.0250
CCF 9=C.0450
CCF 10=C.0670
CCF 11=C.0870
CCF 12=C.1050
CCF 13=C.1200
CCF 14=C.1380
CCF 15=C.1550
CCF 16=C.1690
CCF 17=C.1880
CCF 18=C.2020
CCF 19=C.2140
CCF 20=C.2290
CCF 21=C.2440
CCF 22=C.2550
CCF 23=C.2740
CCF 24=C.2920
CCF 25=C.3120
CCF 26=C.3270
CCF 27=C.3410
CCF 28=C.3550
CCF 29=C.3720
CCF 30=C.3910
CCF 31=C.4090
CCF 32=C.4240
CCF 33=C.4390
CCF 34=C.4480
CCF 35=C.4600
CCF 36=C.4730
CCF 37=C.4820
CCF 38=C.5010
CCF 40=C.5060
CCF 41=C.5170
CCF 42=C.5220
CCF 43=C.5340
CCF 44=C.5480
CCF 45=C.5600
CCF 46=C.5680
CCF 47=C.5790
CCF 48=C.5930
CCF 49=C.6110
CCF 50=C.6300
CCF 51=C.6520
CCF 52=C.6760
CCF 53=C.7040
CCF 54=C.7270
CCF 55=C.7600
CCF 56=C.7940
CCF 57=C.8490
CCF 58=C.9100
CCF 59=C.9630
CCF 60=C.9920
CCF 61=1.0000

CCF 1=0.0
CCF 2=0.0
CCF 3=0.0
CCF 4=0.0
CCF 5=0.0
CCF 6=0.0
CCF 7=0.0
CCF 8=0.0
CCF 9=0.0010
CCF 10=0.0140
CCF 11=0.0230
CCF 12=0.0290
CCF 13=0.0410
CCF 14=0.0560
CCF 15=0.0800
CCF 16=0.1040
CCF 17=0.1220
CCF 18=0.1360
CCF 19=0.1550
CCF 20=0.1690
CCF 21=0.1840
CCF 22=0.1960
CCF 23=0.2150
CCF 24=0.2340
CCF 25=0.2530
CCF 26=0.2650
CCF 27=0.2780
CCF 28=0.2880
CCF 29=0.3010
CCF 30=0.3110
CCF 31=0.3230
CCF 32=0.3330
CCF 33=0.3410
CCF 34=0.3460
CCF 35=0.3580
CCF 36=0.3670
CCF 37=0.3760
CCF 38=0.3870
CCF 39=0.3950
CCF 40=0.4060
CCF 41=0.4140
CCF 42=0.4190
CCF 43=0.4250
CCF 44=0.4320
CCF 45=0.4400
CCF 46=0.4460
CCF 47=0.4530
CCF 48=C.4600
CCF 49=0.4710
CCF 50=0.4790
CCF 51=0.4860
CCF 52=0.5050
CCF 53=0.5150
CCF 54=0.5270
CCF 55=C.5390
CCF 56=0.5490
CCF 57=0.5620
CCF 58=0.5710
CCF 59=0.5880
CCF 60=0.6020
CCF 61=1.0000



X-SCALE: "X"= 0.75CE CO UNITS
 Y-SCALE: "Y"= 0.167E-01 UNITS

SEARCHER SPEED=12.0
 ASSUMED TARGET SPEED= 8.0
 TIME LATE= 4.0
 TCTAL SEARCH TIME= 96.00

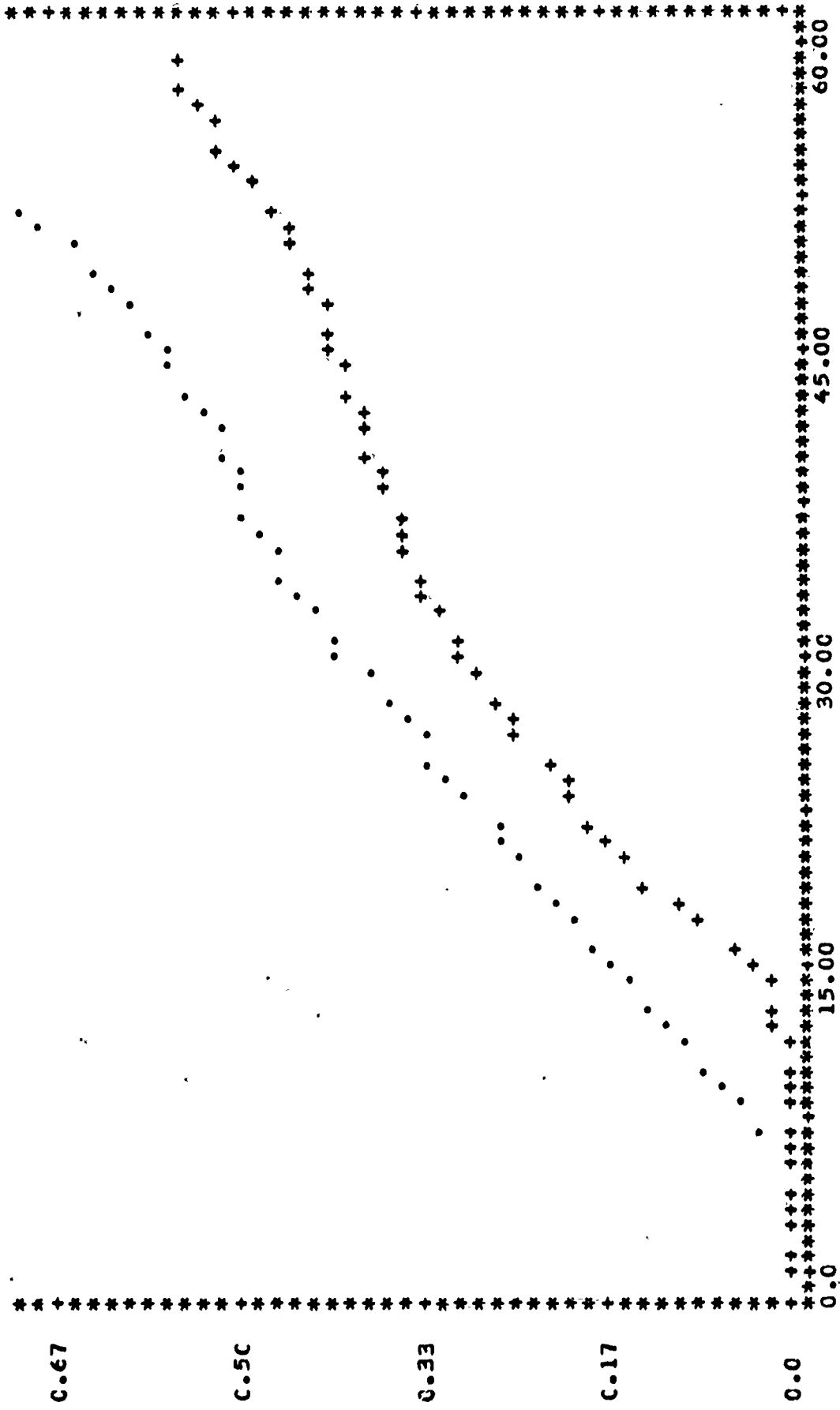
KCCFMAN
 SEARCH
 PLAN

ALTERNATE
 SEARCH
 PLAN

FACTOR= 1.5 MULTIPLIER= 2.00

CCCF 1=C.0
 CCCF 2=C.0
 CCCF 3=C.0
 CCCF 4=C.0
 CCCF 5=C.0
 CCCF 6=C.0010
 CCCF 7=C.0030
 CCCF 8=C.0060
 CCCF 9=C.0090
 CCCF 10=C.0120
 CCCF 11=C.0150
 CCCF 12=C.0180
 CCCF 13=C.0210
 CCCF 14=C.0240
 CCCF 15=C.0270
 CCCF 16=C.0300
 CCCF 17=C.0330
 CCCF 18=C.0360
 CCCF 19=C.0390
 CCCF 20=C.0420
 CCCF 21=C.0450
 CCCF 22=C.0480
 CCCF 23=C.0510
 CCCF 24=C.0540
 CCCF 25=C.0570
 CCCF 26=C.0600
 CCCF 27=C.0630
 CCCF 28=C.0660
 CCCF 29=C.0690
 CCCF 30=C.0720
 CCCF 31=C.0750
 CCCF 32=C.0780
 CCCF 33=C.0810
 CCCF 34=C.0840
 CCCF 35=C.0870
 CCCF 36=C.0900
 CCCF 37=C.0930
 CCCF 38=C.0960
 CCCF 39=C.0990
 CCCF 40=C.1020
 CCCF 41=C.1050
 CCCF 42=C.1080
 CCCF 43=C.1110
 CCCF 44=C.1140
 CCCF 45=C.1170
 CCCF 46=C.1200
 CCCF 47=C.1230
 CCCF 48=C.1260
 CCCF 49=C.1290
 CCCF 50=C.1320
 CCCF 51=C.1350
 CCCF 52=C.1380
 CCCF 53=C.1410
 CCCF 54=C.1440
 CCCF 55=C.1470
 CCCF 56=C.1500
 CCCF 57=C.1530
 CCCF 58=C.1560
 CCCF 59=C.1590
 CCCF 60=C.1620
 CCCF 61=C.1650

CCCF 1=0.0
 CCCF 2=0.0
 CCCF 3=0.0
 CCCF 4=0.0
 CCCF 5=0.0
 CCCF 6=0.0
 CCCF 7=0.0
 CCCF 8=0.0
 CCCF 9=0.0
 CCCF 10=0.0010
 CCCF 11=0.0010
 CCCF 12=0.0010
 CCCF 13=0.0010
 CCCF 14=0.0010
 CCCF 15=0.0020
 CCCF 16=0.0030
 CCCF 17=0.0040
 CCCF 18=0.0050
 CCCF 19=0.0060
 CCCF 20=0.0070
 CCCF 21=0.0080
 CCCF 22=0.0090
 CCCF 23=0.0100
 CCCF 24=0.0110
 CCCF 25=0.0120
 CCCF 26=0.0130
 CCCF 27=0.0140
 CCCF 28=0.0150
 CCCF 29=0.0160
 CCCF 30=0.0170
 CCCF 31=0.0180
 CCCF 32=0.0190
 CCCF 33=0.0200
 CCCF 34=0.0210
 CCCF 35=0.0220
 CCCF 36=0.0230
 CCCF 37=0.0240
 CCCF 38=0.0250
 CCCF 39=0.0260
 CCCF 40=0.0270
 CCCF 41=0.0280
 CCCF 42=0.0290
 CCCF 43=0.0300
 CCCF 44=0.0310
 CCCF 45=0.0320
 CCCF 46=0.0330
 CCCF 47=0.0340
 CCCF 48=0.0350
 CCCF 49=0.0360
 CCCF 50=0.0370
 CCCF 51=0.0380
 CCCF 52=0.0390
 CCCF 53=0.0400
 CCCF 54=0.0410
 CCCF 55=0.0420
 CCCF 56=0.0430
 CCCF 57=0.0440
 CCCF 58=0.0450
 CCCF 59=0.0460
 CCCF 60=0.0470
 CCCF 61=0.0480



X-SCALE: ***= 0.75CE 00 UNITS
 Y-SCALE: ***= 0.167E-01 UNITS

0.67

0.50

0.33

0.17

0.0

```

*****
* THIS PROGRAM CALCULATES ONE CIRCUIT OF THE KCCP MAIN
* SEARCH PLAN FOR VARIOUS COMBINATIONS OF TARGET SPEED
* SEARCHER SPEED AND TIME LATE. IT OUTPUTS A PRINTED A
* LISTING OF THE PROBABILITY OF TARGET DETECTION AS A
* FUNCTION OF ACTUAL SONAR RANGE. THIS DATA IS ALSO
* PRESENTED IN A GRAPHICAL FORMAT
*****
* DIMENSION R(5),SL(4),TCC(5),XC(5),A1(4),A2(4),A3(4),A4(4),
* IX(61),NTALLY(60),CDF(61),RSC(9)
* DATA NTALLY/60*0/
* NTRUN=3000
* STE=4.0
* ULCT=359.0 * 0.01745329
* LLCT=0.0
* BCXES=60.0
* RANGE=60.0
* DX=BOXES/RANGE
* X(1)=0.0
* CC 10 I=2,61
* II=I-1
* X(II)=FLCAT(II)
* CCONTINUE
10  RANDCM NUMBER GENERATOR
CC
KR=16807
IRS=27456385
ICCONTINUE
4C  ULST=STE
LL=3.0
5C  CCONTINUE
IF(STE-GE. 50) GO TO 700
100 CCONTINUE
MU=C.0
SIGMA=2.0
RS=10.0
CRXC=0.0
CRYC=0.0
CC
CCMPUTE PARAMETERS NECESSARY TO OBTAIN A SEARCH PLAN
CC

```

```

E=RS/O.69315
S=C.75 * SCRT( E * SIGMA)
SM=(SO+STE)/(SO-STE)
RATIO=SIGMA/STE
IF(RATIO .LE. TL) GO TO 200
R(1)=S/(SM**2+1.0)
GC TO 220
R(1)=0.8*STE*TL
220 A=(SO*S)/(SO-STE)
CC CALCULATE R(2) THRU R(5)
R(2)=SM * R(1)
R(3)=SM * R(2)
R(4)=SM * R(3)
R(5)=SM * R(4) +A
CC COMPUTE SEARCH LEG LENGTHS
SL(1)=SM * R(1)
SL(2)=SM * SL(1) +R(1)
SL(3)=SL(2) *SM
SL(4)=SM*SL(3)+A
CC COMPUTE TOTAL TIME SEARCHING
TSL=SL(1)+SL(2) +SL(3)+SL(4)
TST=TSL/SC
CC CALCULATE X AND Y COORDINATES OF THE SEARCH LEGS
XC(1)=ORXC -R(1)
YC(1)=ORYC
XC(2)=XC(1)
YC(2)=YC(1)+SL(1)
XC(3)=XC(2)+SL(2)
YC(3)=YC(2)
XC(4)=XC(3)-SL(3)
YC(4)=YC(3)-SL(4)
XC(5)=XC(4)
YC(5)=YC(4)
CC CALCULATION OF TIMES AT WHICH SEARCHER REACTS. SEARCH
LEG COORDINATES
TCC(1)=TL
TCC(2)=TL +SL(1)/SC
TCC(3)=TCC(2) +SL(2)/SC

```

TCC(4)=TCC(3)+ SL(3)/SO
TCC(5)=TCC(4)+ SL(4)/SC

C
C

DETERMINE INITIAL VALUES FOR SEARCH LEG ONE

A1(1)=XC(1)
A2(1)=0.0
A3(1)=YC(1)
A4(1)=SC

C
C

DETERMINE INITIAL VALUES FOR SEARCH LEG TWO

A1(2)=XC(2)
A2(2)=SC
A3(2)=YC(2)
A4(2)=0.0

C
C

DETERMINE INITIAL VALUES FOR SEARCH LEG THREE

A1(3)=XC(3)
A2(3)=0.0
A3(3)=YC(3)
A4(3)=-SC

C
C

DETERMINE INITIAL VALUES FOR SEARCH LEG FOUR

A1(4)=XC(4)
A2(4)=-SC
A3(4)=YC(4)
A4(4)=0.0

C
C

SELECT TGT COURSE UNIFORMLY BETWEEN UPPER AND LOWER LIMIT

153

CONTINUE

IC=IC*KR

RA1=0.5 +FLOAT(IC) * 2.328306E-10

CT=RNI*(ULCT-LLCT) +LLCT

C
C

GENERATE DIRECTION AND DISTANCE OF DATUM UNCERTAINTY

IC=IC*KR

RN2=0.5 +FLOAT(IC) *2.328306E-10

DDU=RN2*2.0*3.14159

Z=C.0

155

DD 160 J=1,12

IC=IC*KR

Z=Z+FLCAT(IC) *2.328306E-10

160

CONTINUE

```

C C      RN2=SIGMA *Z +FLOAT(MU)
C C      DSCU= ABS(RN3)
C C      GENERATE TARGET SPEED UNIFORMLY BETWEEN UPPER AND LOWER LIMITS
C C      IC=IC*KR
C C      RN4=0.5+FLCAT(IC)*2.328306E-10
C C      STA=RN4*(ULST-LLST)+LLST
C C      CALCULATE TARGET X AND Y VELOCITY COMPONENTS
C C      25C VTX=STA*SIN(CT)
C C          VTY=STA*COS(CT)
C C      CALCULATE INITIAL TARGET X AND Y COORDINATES
C C      TGTXC=ORXC + DSDU * CCS(ODU)
C C      TGTYC=ORYC + DSDU * SIN (ODU)
C C      DETERMINE CANDIDATES FOR MINIMUM FROM SEARCH LEG INTERVAL
C C      DC 300 K=1,4
C C      KK=(K)+1
C C      TIMERT=((A1(K)-TGTXC)*(A2(K)-VTX)+(A3(K)-TGTYC)*(A4(K)-VTY) )/
1 ((A2(K)-VTX)**2 + (A4(K)-VTY)**2)
C C      IF (TIMERT .LE. 0.0) GO TO 310
C C      IF (TIMERT .GT. TCC(K)) GO TO 310
C C      IF (TIMERT .LT. TCC(K)) GO TO 310
C C      SXC=A1(K)+A2(K)*TIMERT
C C      TYC=A3(K)+A4(K)*TIMERT +TGTYC
C C      TYC=VTY * TIMERT + TGTYC
C C      RSQ(K)=(SXC-TXC)**2 +(SYC-TYC)**2
C C      GC TO 300
C C      RSC(K)=9.9999E+10
C C      CCNTINUE
C C      DETERMINE END POINT CANDIDATES FOR MINIMUM
C C      DC 400 K=5,9
C C      KI=(K)-4
C C      TIME=TCC(KI)
C C      SXC=XCC(KI)
C C      TYC=YCC(KI) +VTX*TIME
C C      TYC=TGTYC + VTY * TIME
C C      RSC(K)=(SXC-TXC)**2 +(SYC-TYC)**2
C C      CCNTINUE
400

```


END

```

*****
** THIS PROGRAM COMPARES THE KOOPMAN SEARCH PLAN FOR A
** PARTICULAR TARGET SPEED AND TIME LATE
** AGAINST VARIOUS ALTERNATE SEARCH PLANS. THE AMOUNT OF
** SEARCH TIME AVAILABLE IS SET AT A FIXED VALUE. EACH
** SEARCH PLAN IS RUN FOR THIS FIXED AMOUNT OF TIME. ITS
** OUTPUT IS A LISTING OF THE PROBABILITY OF TARGET
** DETECTION AS A FUNCTION OF THE ACTUAL GRAPHICAL
** INFORMATION IS ALSO PRESENTED IN A GRAPHICAL FORMAT
*****
** DIMENSION X(61), R(5), SLK(20), XCK(21), YCK(21), A1(20), A2(20), A3(20),
** 1A4(20), TCK(21), RSC(150), XCO(101), YCO(101), P1(100), B2(100), B3(100),
** 2B4(100), SLC(100), TCO(101), CDF(61), CDF2(61), ATALLY(60)
** DATA NTALLY/60*0/
*****

```

INPUT CONSTANTS FOR THE MODEL

```

STE=8.0
SL=4.0
TL=12.0
TTLIMS=96.0
NTRUN=300
ULUCT=359.0*0.0174539
LUC=0.0
SIGMA=2.0
SRXC=0.0
ORS=0.0
BRXES=60.0
BRANGE=60.0
CX(I)=0.0
XC I=2,61
I(I)=FLCAT(I)
XC CONTINUE

```

10

RANDOM NUMBER GENERATOR

```

KR=16807
IRS=27456385
IC=KR*IRS

```

SET UPPER AND LOWER TARGET SPEED LIMITS


```

YCK(4)=YCK(3)-SLK(3)
CC 230 KK=1,4
KKC=4*(KK)
KK1=4*(KK)+1
KK2=4*(KK)+2
KK3=4*(KK)+3
KK4=4*(KK)+4
XCK(KK1)=XCK(KK0)-SLK(KK0)
YCK(KK1)=YCK(KK0)
XCK(KK2)=XCK(KK1)
YCK(KK2)=YCK(KK1)+SLK(KK1)
XCK(KK3)=XCK(KK2)
YCK(KK3)=YCK(KK2)
XCK(KK4)=XCK(KK3)-SLK(KK3)
YCK(KK4)=YCK(KK3)
CCNTINUE
230 XCK(21)=XCK(20)-SLK(20)
YCK(21)=YCK(20)

```

```

CC
CC DETERMINE INITIAL VALUES FOR SEARCH LEG ONE

```

```

LV=1
A1(LV)=XCK(LV)
A2(LV)=C.0
A3(LV)=YCK(LV)
A4(LV)=S0
LV=LV+4
IF(LV.EC.21) GO TO 315
GC TO 310
CCNTINUE

```

```

CC
CC DETERMINE INITIAL VALUES FOR SEARCH LEG TWO

```

```

LV=2
A1(LV)=XCK(LV)
A2(LV)=S0
A3(LV)=YCK(LV)
A4(LV)=C.0
LV=LV+4
IF(LV.EC.22) GO TO 325
GC TO 320
CCNTINUE

```

```

CC
CC DETERMINE INITIAL VALUES FOR SEARCH LEG THREE

```

```

LV=3
A1(LV)=XCK(LV)
A2(LV)=C.0

```



```

IC=IC*KR
Z=Z+FLCAT(IC)*2.328306E-10
380 CCNTINUE
RN3=SIGMA *Z +FLCAT(MU)
DSDU=ABS(RN3)
CC
GENERATE TARGET SPEED UNIFORMLY BETWEEN UPPER AND LOWER LIMITS
CC
IC=IC*KR
RN4=0.5*FLCAT(IC)*2.328306E-10
STA=RN4*(ULST-LLST)+LLST
CC
CALCULATE INITIAL TARGET X AND Y CCGRDINATES
CC
TGTXC=GRXC + DSDU * COS(DDU)
TGYC=ORYC + DSDU * SIN (DDU)
CC
CALCULATE TARGET X AND Y VELOCITY COMPONENTS
385 VIX=STA* SIN(CT)
VY=STA*COS(CT)
CC
DETERMINE CANDIDATES FOR MINIMUM FROM SEARCH LEG INTERVAL
CC
CC 400 K=1, NSL
KK=(K)+1
TIMERT=-((A1(K)-TGTXC)*(A2(K)-VTX)+(A3(K)-TGYC)*(A4(K)-VTY) )/
1( (A2(K)-VTX)**2 + (A4(K)-VTY)**2)
IF (TIMERT.LE.0.0) GO TO 410
IF (TIMERT.GT.1000) GO TO 410
IF (TIMERT.LT.1000) GO TO 410
IF (TIMERT.GT.1000) GO TO 410
SYC=A1(K)+A2(K)*TIMERT
SYC=A3(K)+A4(K)*TIMERT
TXC=VTX* TIMERT +TGTXC
TYC=VTY * TIMERT +TGYC
RSC(K)=(SYC-TXC)**2 +(SYC-TYC)**2
CC TO 400
410 RSC(K)=5.9995E+10
400 CCNTINUE
CC
DETERMINE END POINT CANDIDATES FOR MINIMUM
CC
KPLUS1=NSL+1
KPLUS2=2*NSL+1
DC 450 K=KPLUS1, KPLUS2
K1=(K)-NSL
TIME=TCK(K1)

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```

IF (TIME .GE. TLIMIT) GO TO 460
SXC=XCK(K1)
SYC=YCK(K1) +VTX*TIME
TYC=IGTYC + VTY * TIME
RSC(K)=(SXC-TXC)**2 +(SYC-TYC)**2
CCCONTINUE
CC TO 470
CCCONTINUE
KPLUS2=(K)-1
CCCONTINUE
C C C DETERMINE THE CLOSEST POINT OF APPROACH FOR THIS ITERATION
C C C
RSCM=RSC(1)
DC 500 K=2, KPLUS2
RMIN=AMIN1(RSQM,RSQ(K) )
RSCY=RMIN
CCCONTINUE
RCPA=SQRT(RSCM)
TALLY CPA RANGES INTO BOXES
C C
50C IF (RCPA .GE. 59.0) GG TO 610
LR=DX* RCPA +1.0
NTALLY(LR)=NTALLY(LR)+ 1
GC TO 1150
61C NTALLY(6C)=NTALLY(6C) +1
C C INCREMENT NUMBER OF RUNS
C C
115C NRUNS=NRUNS +1
C C TEST TO SEE IF DESIRED NUMBER OF RUNS OBTAINED
C C
120C IF (ARUNS .EQ. NTRUN) GO TO 1200
GC TO 373
CCCONTINUE
C C RESET ITERATION COUNTER TO ZERO
C C
ARUNS=0
C C COMPUTE TOTAL NUMBER OF TALLIES
C C
NTSUM=0.0
CC 650 L=1,60
NTSUM= NTSUM + NTALLY(L)
CCCONTINUE
65C

```

CC
CC
CC
COMPUTE INDIVIDUAL RANGE PROBABILITIES AND THE
CUMULATIVE PROBABILITIES

CCF(1)=0.0
SUMP=0.0
DC 670 M=1.60
NM=M+1
PBCX=FLGAT(NTALLY(M))/FLOAT(NTSUM)
SUMP=SUMP + PBOX
CCF(MM)=SUMP
CCCONTINUE

67C

CC
CC
CC

RESET ALL TALLY BCX VALUES TO ZERO

DC 680 I=1,60
NTALLY(I)=0
CCCONTINUE

68C

CC
CC
CC
CC

COMPUTE PARAMETERS FOR THE ALTERNATE SEARCH PLAN

CMULT=2.0
FACTOR=C.8
FACTOR=0.8
CCCONTINUE
XCIIST=FACTOR*STE*TL

685
68C

CC
CC

COMPUTE ALTERNATE SEARCH LEG LENGTHS

CC 700 MM=1.24
CMULT=CMULT*MM
SLC(MM)=CMULT*XDIIST
CCCONTINUE

70C

CC
CC

CALCULATE X AND Y COORDINATES OF THE SEARCH LEGS

XCC(1)=CRXC-XDIIST
YCC(1)=CRYC
XCC(2)=XCC(1)+SLO(1)
YCC(2)=YCC(1)+SLO(1)
XCC(3)=XCC(2)+SLO(2)
YCC(3)=YCC(2)+SLO(2)
XCC(4)=XCC(3)+SLO(3)
YCC(4)=YCC(3)+SLO(3)
DC 710 NN=1,5

```

NNC=4*(NN)+1
NN1=4*(NN)+2
NN2=4*(NN)+3
NN3=4*(NN)+4
NXC(NN1)=XCC(NNO)-SLC(NNO)
YXC(NN1)=YCC(NNO)
NXC(NN2)=XCC(NN1)+SLC(NN1)
YXC(NN2)=YCC(NN1)+SLC(NN2)
NXC(NN3)=XCC(NN2)
YXC(NN3)=YCC(NN2)
NXC(NN4)=XCC(NN3)
YXC(NN4)=YCC(NN3)
CONTINUE
XCC(25)=XCC(24)-SLC(24)
YCC(25)=YCC(24)

```

71C

C
C
C DETERMINE INITIAL VALUES FOR SEARCH LEG ONE

```

LV=1
B1(LV)=XCC(LV)
B2(LV)=0.0
B3(LV)=YCC(LV)
B4(LV)=50
IF(LV.EC.25) GO TO 815
GC TO 810
CONTINUE

```

81C

815

C
C
C DETERMINE INITIAL VALUES FOR SEARCH LEG TWO

```

LV=2
B1(LV)=XCC(LV)
B2(LV)=50
B3(LV)=YCC(LV)
B4(LV)=0.0
IF(LV.EC.26) GO TO 825
GC TO 820
CONTINUE

```

82C

825

C
C
C DETERMINE INITIAL VALUES FOR SEARCH LEG THREE

```

LV=3
B1(LV)=XCC(LV)
B2(LV)=50
B3(LV)=YCC(LV)
B4(LV)=50

```

83C

```

LV=LV+4
IF(LV.EC.27) GO TO 835
CC TO 830
CC CONTINUE
835
CC
CC DETERMINE INITIAL VALUES FOR SEARCH LEG FCUR
LV=4
B1(LV)=XCO(LV)
B2(LV)=-SO
B3(LV)=YCO(LV)
B4(LV)=C.O
LV=LV+4
IF(LV.EC.28) GO TO 850
CC TO 840
CC CONTINUE
850
CC
CC CALCULATION OF TIMES AT WHICH SEARCHER REACHES SEARCH
LEG COORDINATES
TCC(I)=TL
SLCSUM=TL
DC 860 III=2,25
NSLC=(III)-1
SLCSUM=SLCSUM + SLC(NSLC)/SC
TCC(III)=SLCSUM
IF(TCC(III).GT. TLIMIT ) GO TO 870
86C
87C
CC CONTINUE
CC
CC SELECT TGT CCURSE UNIFCRMLY BETWEEN UPPER AND LOWER LIMIT
CC CONTINUE
IC=IC*KR
RN1=0.5 +FLOAT(IC) * 2.328306E-1C
CT=RN1*(ULCT-LLCT) +LLCT
88C
CC
CC GENERATE DIRECTION AND DISTANCE OF DATUM UNCERTAINTY
IC=IC*KR
RN2=0.5 +FLOAT(IC) * 2.328306E-1C
DLC=RN2*2.0*3.14159
Z=C.O
LC 500 J=1,12
IC=IC*KR
Z=Z+ FL(CAT(IC) * 2.328306E-1C
RN3=SIGMA *Z +FL(CAT(MU)
DSCU= ABS(RN3)
89C

```

```

900 CCNTINUE
C
C GENERATE TARGET SPEED UNIFORMLY BETWEEN UPPER AND LOWER LIMITS
IC=IC*KR
RN4=0.5+FLCAT(IC)*2.328206E-10
STA=RN4*(ULST-LLST)+LLST
C
C CALCULATE TARGET X AND Y VELOCITY COMPONENTS
910 VTIX=STA*SIN(CT)
VTY=STA*CCS(CT)
C
C CALCULATE INITIAL TARGET X AND Y COORDINATES
TGTXC=ORXC + DSDU * CCS(DDU)
TGTYC=ORYC + DSDU * SIN (DDU)
C
C DETERMINE CANDIDATES FOR MINIMUM FROM SEARCH LEG INTERVAL
CC 1000 K=1, NSLO
KK=(K)+1
TIMERT=(( B1(K)-TGTXC)*(B2(K)-VTX)+(B3(K)-TGTYC)*(B4(K)-VTY)))/
1((B2(K)-VTX)**2 + (B4(K)-VTY)**2)
IF(TIMERT.LE.0) GO TO 1010
IF(TIMERT.GT.TCO(KK)) GO TO 101C
IF(TIMERT.LT.TCO(K)) GO TO 1010
IF(TIMERT.GT.TLIMIT) GC TC 1010
SXC=A1(K)+A2(K)*TIMERT
SYC=A3(K)+A4(K)*TIMERT
TXC=VTIX*TIMERT + TGTXC
TYC=VTY*TIMERT + TGTYC
RSC=(SXC-TXC)**2 + (SYC-TYC)**2
GC TO 1000
RSCC(K)=S.9999E+10
1010 CCNTINUE
C
C DETERMINE END POINT CANDIDATES FOR MINIMUM
KPLUS3=NSLO+1
KPLUS4=2 * NSLO +1
DC 1020 K=KPLUS3 , KPLUS4
K1=(K)-NSLO
TIME=TCO(K1)
IF(TIME.GE.TLIMIT) GO TO 1030
SXC=YCO(K1)
TYC=TGTXC +VTX*TIME

```

```

TYC=TGTYC + VTY * TIME
RSQ(K)=(SXC-TXC)**2 + (SYC-TYC)**2
102C CCNT INUE
CC TO 1040
1020 KFLUS4=(K)-1
104C CCNT INUE
CC
CC
DETERMINE THE CLOSEST POINT OF APPROACH FOR THIS ITERATION
CC
RSCM=RSQ(1)
CC 1050 K=2, KPLUS4
RMIN=AMIN(RSQM,RSQ(K) )
RSCM=RMIN
CCNT INUE
RCPA=SCRT(RSQM)
105C
CC
TALLY CFA RANGES INTO BOXES
CC
IF(RCPA.GE.59.0) GC TO 1060
LR=DX* RCPA +1.0
NTALLY(LR)=NTALLY(LR)+ 1
GC TO 1250
106C NTALLY(60)=NTALLY(60)+1
CC
CC INCREMENT NUMBER OF RUNS
CC 1250 NRUNS=NRUNS+1
CC
CC TEST TO SEE IF DESIRED NUMBER OF RUNS OBTAINED
CC
IF(NRUNS.EQ. NTRUN) GO TO 1300
GC TO 880
CCNT INUE
130C
CC
RESET ITERATION COUNTER TO ZERO
NRUNS=0
CC
CC COMPUTE TGTAL NUMBER OF TALLIES
NTSUM=0.0
DC 1310 L=1,60
NTSUM= NTSUM + NTALLY(L)
CCNT INUE
1310
CC
CC COMPUTE INDIVIDUAL RANGE PROBABILITIES AND THE
CC CUMULATIVE PROBABILITIES
CC

```

```

CCF2(1)=0.0
SUMP=0.0
CC 1320 M=1,60
MM=M+1
PBOX=FLOAT(INTALLY(M))/FLOAT(SUMP)
SUMP=SUMP + PBOX
CCF2(MM)=SUMP
CCCONTINUE
1320 WFORMAT(6,9710)
9720 WFORMAT(6,9730)
9730 WFORMAT(//,10X,'SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARA
METERS:')
1 WFORMAT(6,9740) SO,STE,TL
9740 WFORMAT(20X,'SEARCHER SPEED=',F4.1,/20X,' ASSUMED TARGET SPEED=',F4.
1,/20X,' TIME LATE=',F4.1)
CALL PLCTIP(X,CDF,61,1)
CALL PLCTIP(X,CDF2,61,1)
9700 WFORMAT(6,9700)SO,STE,TL,TLIMIT
2 WFORMAT(//,25X,'SEARCHER SPEED=',F4.1,/,25X,' ASSUMED TA
RGET SPEED=',F4.1,/,25X,' TIME LATE=',F4.1,/,25X,' TCTAL SEARCH TIME
=',F8.2,/)
WFORMAT(10X,'KOOPTMAN',14X,'ALTERNATE',/,10X,'SEARCH',15X,'SEARCH',/
,10X,'PLAN',17X,'PLAN',/)
9805 WFORMAT(6,9805) FACTOR,CMULT
WFORMAT(31X,'FACTOR=',F4.1,2X,'MULTIPLIER=',F6.2,/)
CC 1330 N=1,61
9810 WFORMAT(6,9810) N,CDF(N),N,CDF2(N)
1330 WFORMAT(11X,'CDF',I3,'=',F6.4,8X,'CDF',I3,'=',F6.4)
CCCONTINUE
CC RESET ALL TALLY BOX VALUES TO ZERO
CC
CC 1340 I=1,60
1340 WFORMAT(//,10X,'SEARCH PLAN WAS CALCULATED USING THE FOLLOWING PARA
METERS:')
CCCONTINUE
CC SUBROUTINE TO VARY THE X DISTANCE
CC
CC FACTR=FACTOR+0.1
IF(FACTOR.GE.1.5) GO TO 1350
GO TO 650
CC SUBROUTINE TO VARY THE MULTIPLIER
CC
CC 1350 CCNTINUE
CMULT=OMULT+ 0.5*OMULT

```

136C
IF (CMULT:GE. 8.0) GC TO 1360
GC TO 685
CCONTINUE
STCF
END

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