COPY NO. 21

# SRC-II DEMONSTRATION PROJECT
# PHASE ZERO
# TASK NUMBER 1

## DELIVERABLE NUMBER 3

# DEMONSTRATION PLANT
# SUPPLEMENTARY TECHNICAL STUDIES
# SECTION 10-CONFIDENCE ANALYSIS

JULY 31, 1979

THE PITTSBURG & MIDWAY COAL MINING CO.
DENVER, COLORADO

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
UNDER CONTRACT
DE-AC05-780R03055

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# SRC-II

# DEMONSTRATION PLANT

# CONFIDENCE ANALYSIS

PREPARED FOR
THE PITTSBURG & MIDWAY
COAL MINING CO.
BY
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GULF OIL CORPORATION
GULF MANAGEMENT SCIENCES GROUP
AUGUST, 1979

Table of Contents

# List of Illustrations

# I. Summary & Conclusions

The Gulf Management Sciences Group (GMSG) in Pittsburgh was asked to provide assistance in performing a confidence analysis for the SRC-II demonstration plant as required by the Department of Energy. Specifically, the contract says to "discuss confidence levels for plant operating and capital costs; plant operability and technical risk".

A preliminary meeting was held to determine which quantities should be analyzed in order to present a meaningful picture of the uncertainties in the project. The meeting resulted in the selection of the following key variables:

1) what modifications need to be made to the current plant design,
2) given that the above modifications have been made, what is the probability of building and operating a successful demonstration plant (defined as one that is able to produce liquid fuel from coal, regardless of the efficiency of the process), and what could cause the project to fail,
3) and given that the process works:
    a) what will be the duration of the project,
    b) what will be the on-stream factor for the last twelve months of the demonstration,
    c) what will be the design capacity factor for the last twelve months of the demonstration,
    d) what will be the total capital cost of the plant, and
    e) what will be the average direct annual operating costs.

A more detailed definition of each of these variables is presented in Chapter II.

It was decided that the best way to obtain estimates for these variables would be through interviews of people with substantial experience in the field. Of the eighteen participants, thirteen have operating and engineering experience, three have been involved in process development, one has commercial/economic background, and the other has a financial background. The graphs in Appendix C show the years of experience for each participant. Each subject was first asked what modifications he envisioned being made to the current plant design. Discussion was limited to major systems that might require partial redesign and comments concerning the plant in general. The table on page 5 summarized this portion of the interview, the X's indicating which subjects expressed concerns about a given area.

The interviewees were next asked to estimate the probability of success for the project, given that the modifications they envisioned were in fact made. These estimates, along with possible scenarios that could cause the project to fail, are summarized on page 6. Subjects B and J did not feel qualified to estimate the probability of success, which explains the missing numbers in the table. Most subjects, as shown, believe there is a very good chance that the project will be a success.

For the remaining five quantities, probability distributions were to be developed. The responses each subject gave to a series of questions provided a basis for deriving their probability distributions, which

were then mathematically combined as discussed in Chapter V to yield one probability curve for each variable. These combined distributions are shown on pages 7 through 11. Of particular interest in interpreting the graphs are the following items:

1. The mode of the distribution is the single point estimate of the most likely value and is graphically defined as the highest point on the probability curve.
2. The median represents the point where it is equally likely that the true value will be below this point as above it. This value corresponds to the .50 fractile which was estimated by each subject.
3. The shape and range of the distribution are also very important in that they show just how far above and below the median and mode the actual value of the variable might be as estimated by the participants. The end points of the curve represent the values that capture 90% of the probability distribution. In other words, for project duration, there is only a 5% chance that it will exceed 14.3 years.
4. The base cost estimate denotes the previously developed single point estimate of the mode for the stochastic variable. The following are the values for the base case estimates:

| | |
|---|---|
| Project Duration | 10.25 years |
| On-Stream Factor | 85% |
| Design Capacity Factor | 100% |

| | |
|---|---|
| Capital Costs (in 11/78 dollars) | $755 million |
| Direct Operating Costs (in 11/78 dollars) | $73 million |

The cumulative probability tables for each variable, presented on pages 12 through 16 are one of the most important results of the study. Each table shows the approximate probability that the true value of the variable will exceed or be less than a certain value. For example, there is about a 48% chance that the project will extend beyond eleven years, or conversely there is a 52% chance that the project duration will be less than eleven years.

In conclusion, the modes of the combined distributions indicate that the respondents in general felt that the base case estimates represented the most probable outcomes with the possible exception of the captial cost estimate. On the other hand, the respondents consistently judged that there is a chance that the demonstration plant will perform significantly worse that the base case for each of the variables that were projected. This conclusion is supported by the skewness of the distributions. These distributions can be expected to narrow and some of the skewness will disappear as the final design of the plant is determined.

The chapters that follow present a more detailed analysis of the methodology employed in this study.

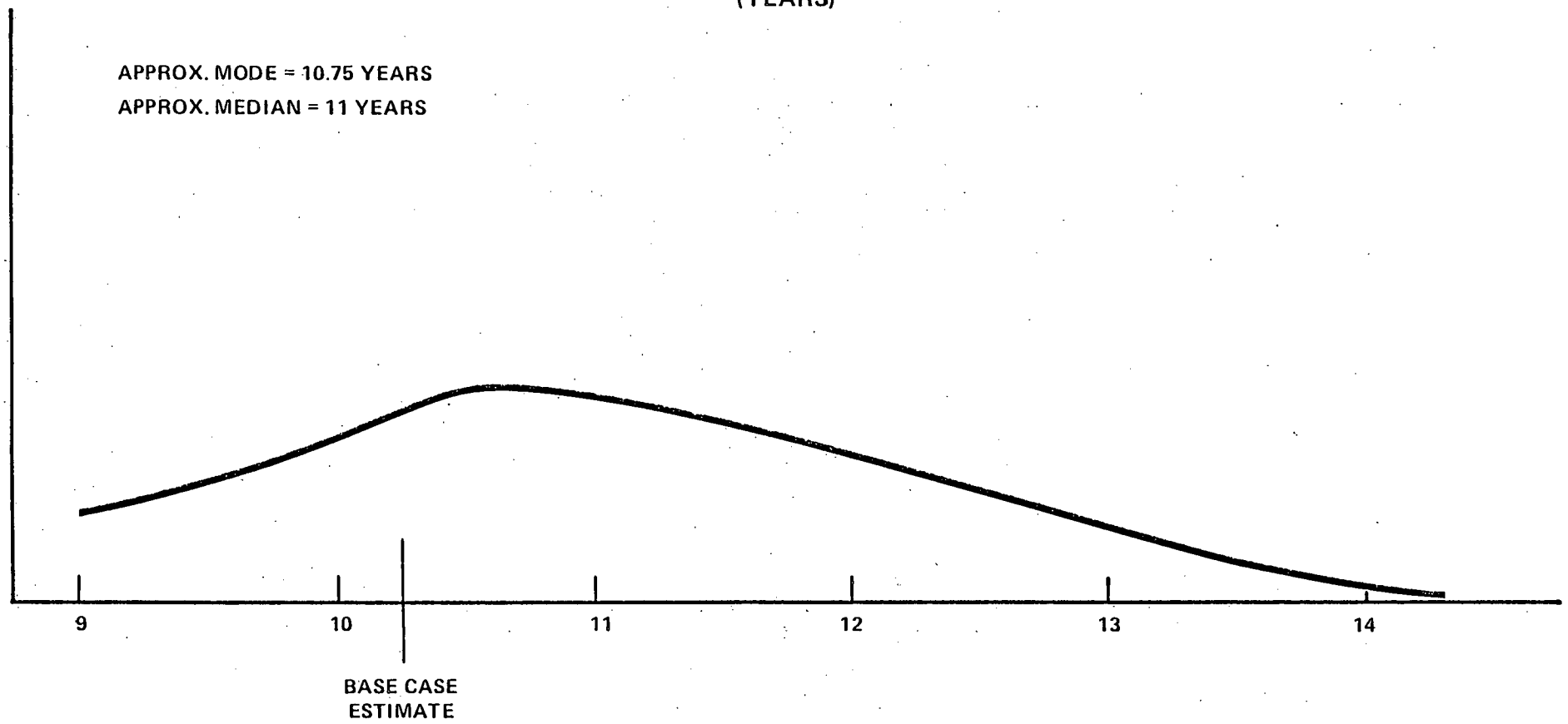
## Design Modifications and Comments

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Major Systems Requiring Partial Redesign:** | | | | | | | | | | | | | | | | | | |
| 1. Coal feed. | | | | | | | | | | | X | | | | | | | X |
| 2. Slurry mixing and preheating. | X | | | X | | | | | | | | X | X | | | | X | |
| 3. Dissolver. | | | | | | | | | | | | | | | | X | | |
| 4. Fractionation. | | | | | X | | | | | | X | | | X | | X | | X |
| 5. Pressure letdown. | | | | X | | X | | | | | | | X | | | | | |
| 6. Gasification. | | | X | | X | | | | | | | | X | X | | | | |
| 7. Recycle clean-up. | | | | | X | | | | | | | | | | | | | |
| **Other Comments:** | | | | | | | | | | | | | | | | | | |
| 1. Plant must be decoupled. | X | X | X | | | X | | X | X | | X | | | X | X | | X | |
| 2. Plant size should be reduced. | | | | | X | X | X | | | | | | | | X | | X | X |
| 3. Provide for an alternate source of hydrogen. | | | X | | | | | | | | X | | | | X | | X | |
| 4. There will be significant corrosion, erosion and abrasion problems. | | | | X | | | X | | | | X | | | | | | | |
| 5. Good sparing will be required. | X | | | | | | | | | | | | | | | | | |
| 6. Plant should have only one train. | | | | | | | | | | | | | | | X | | | |
| 7. Transfer lines between the bottoms and the gasifier need redesigned. | | | | | | | | | | | | X | | | | | | |

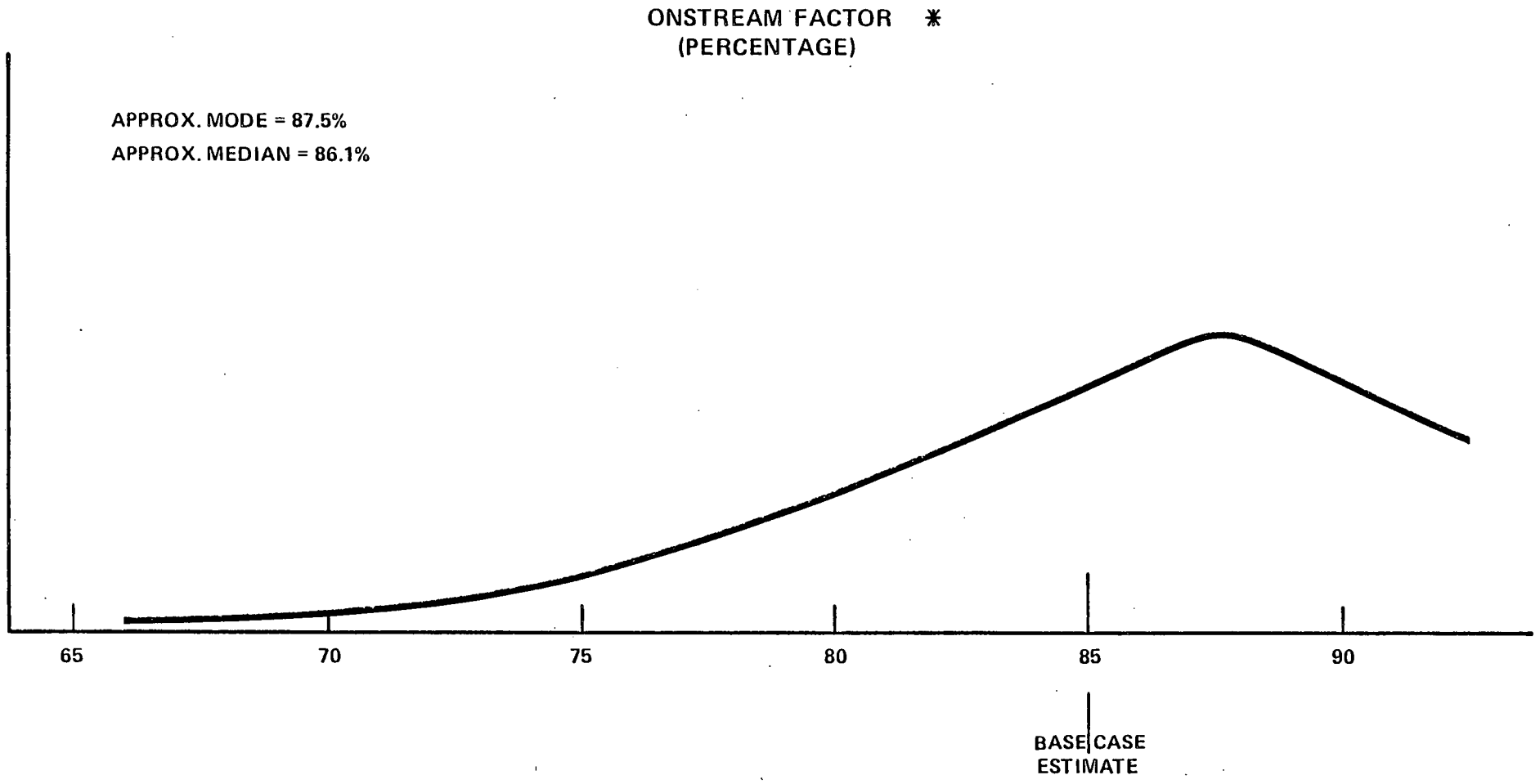
## Probability of Success

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| Probability of Success (%) | 90 | | 100 | 99 | 90 | 90 | 50 | 99 | 98 | | 90 | 100 | 99 | 90 | 85 | 80 | 10 | 0 |
| Possible Causes of a Failure: | | | | | | | | | | | | | | | | | | |
| 1. Compound equipment failures. | X | | | | | | | | | | | | | X | X | | | |
| 2. Much of the process has not been tested at the pilot plant stage. | | | | | | | X | | | | | | | | X | X | | X |
| 3. Excessive government regulation. | | | | | | X | | | | | | | | | | | X | X |
| 4. Environmental constraints. | | | | | | X | | | | | | | | | | | | |
| 5. The process is too highly integrated. | | X | | | | X | | | | | | | | | | | | |
| 6. Insurmountable abrasion and corrosion problems. | | | | | | | | | | | X | | | | | | X | |
| 7. SRC-II process itself is unproven. | | | | | | | X | | | | | | | | | | X | |
| 8. Plant is inadequately controlled. | | | | | | | | | | | | | | | X | | | |
| 9. Dissolver improperly designed. | | | | | | | | X | | | | | | | | | | |
| 10. Hydrogen production process is deficent. | | | | | | | | | X | | | | | | | | | |

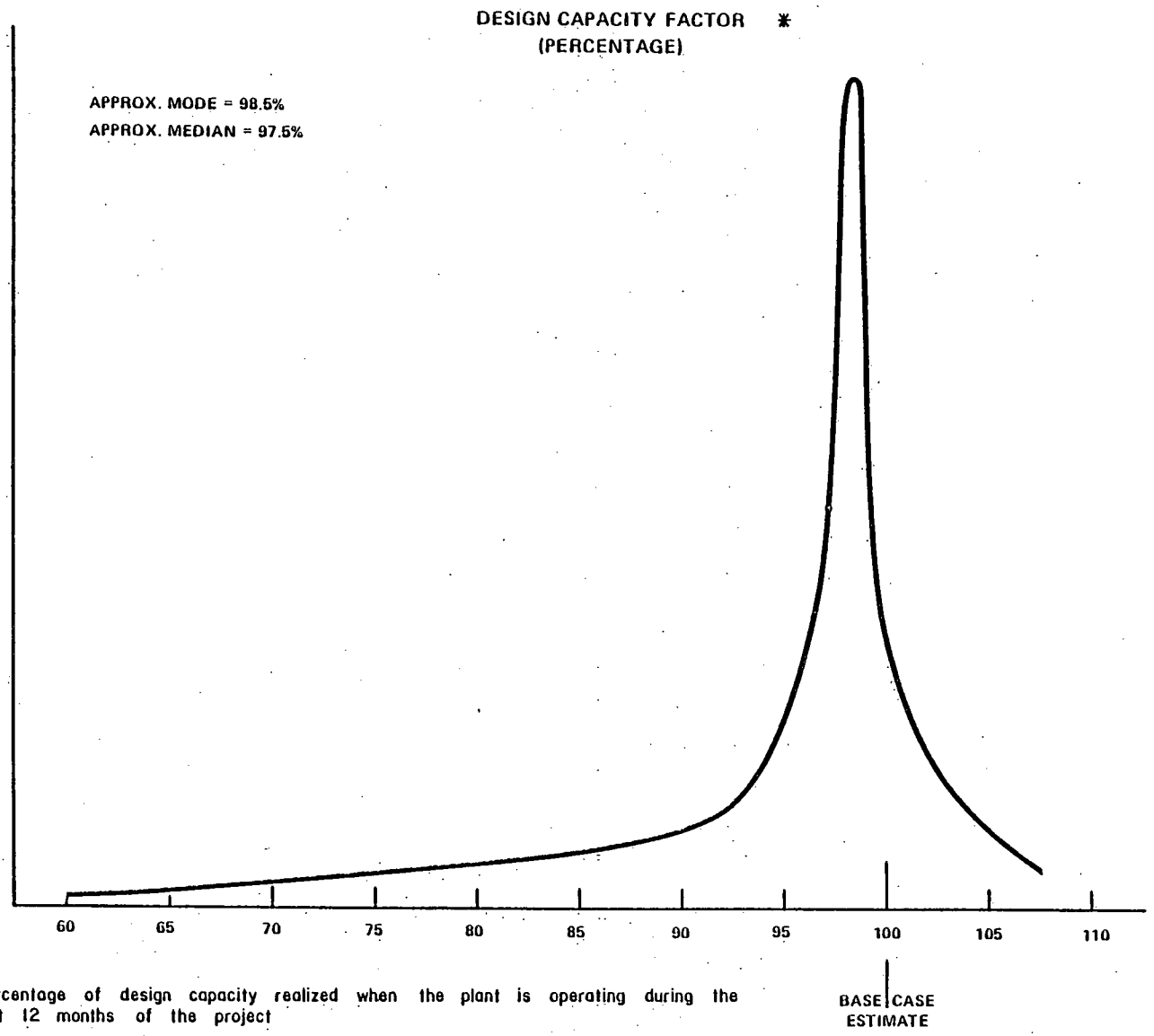
PROJECT DURATION ✱
(YEARS)




✱ Design, construction, and operation including 4 years of operation after shakedown

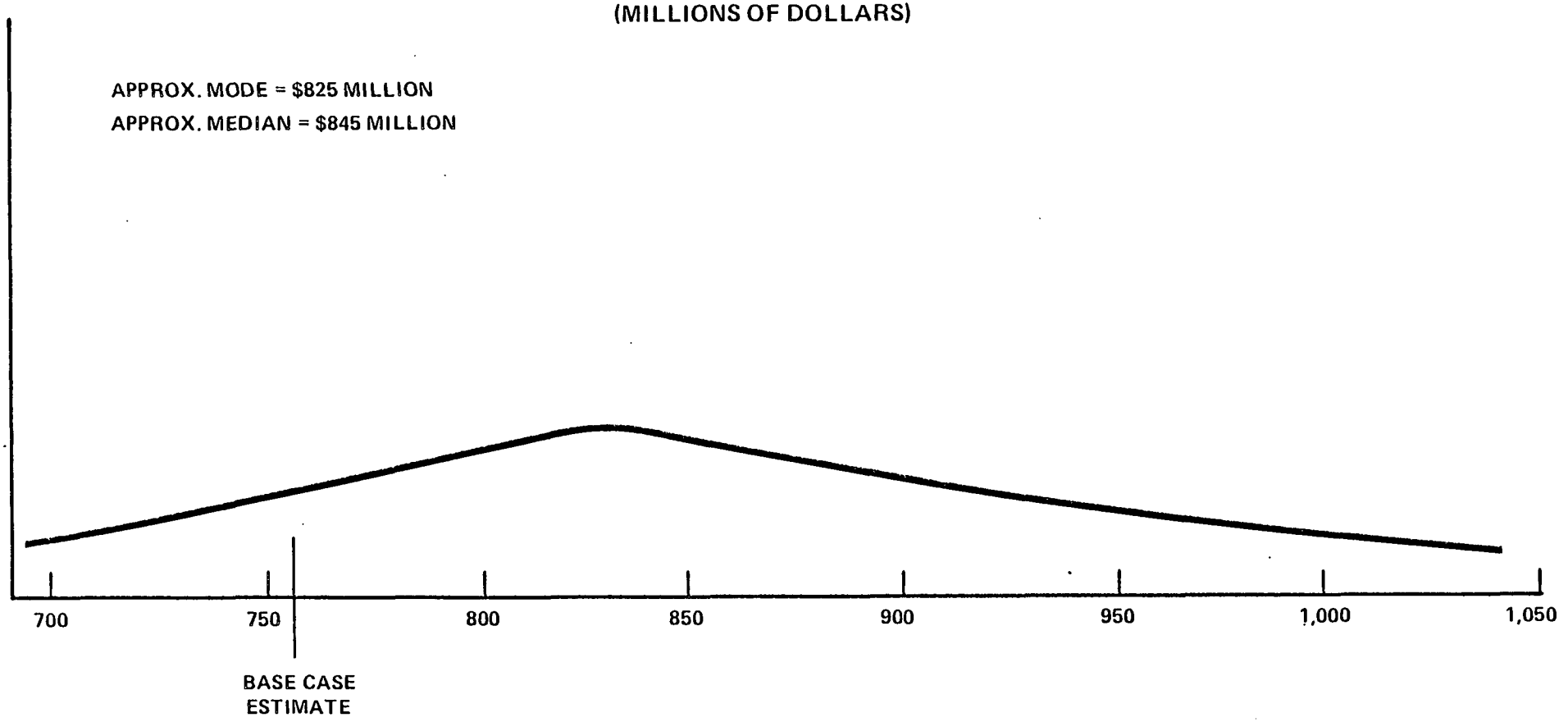



* Percentage of time the plant operates during the last 12 months of the project



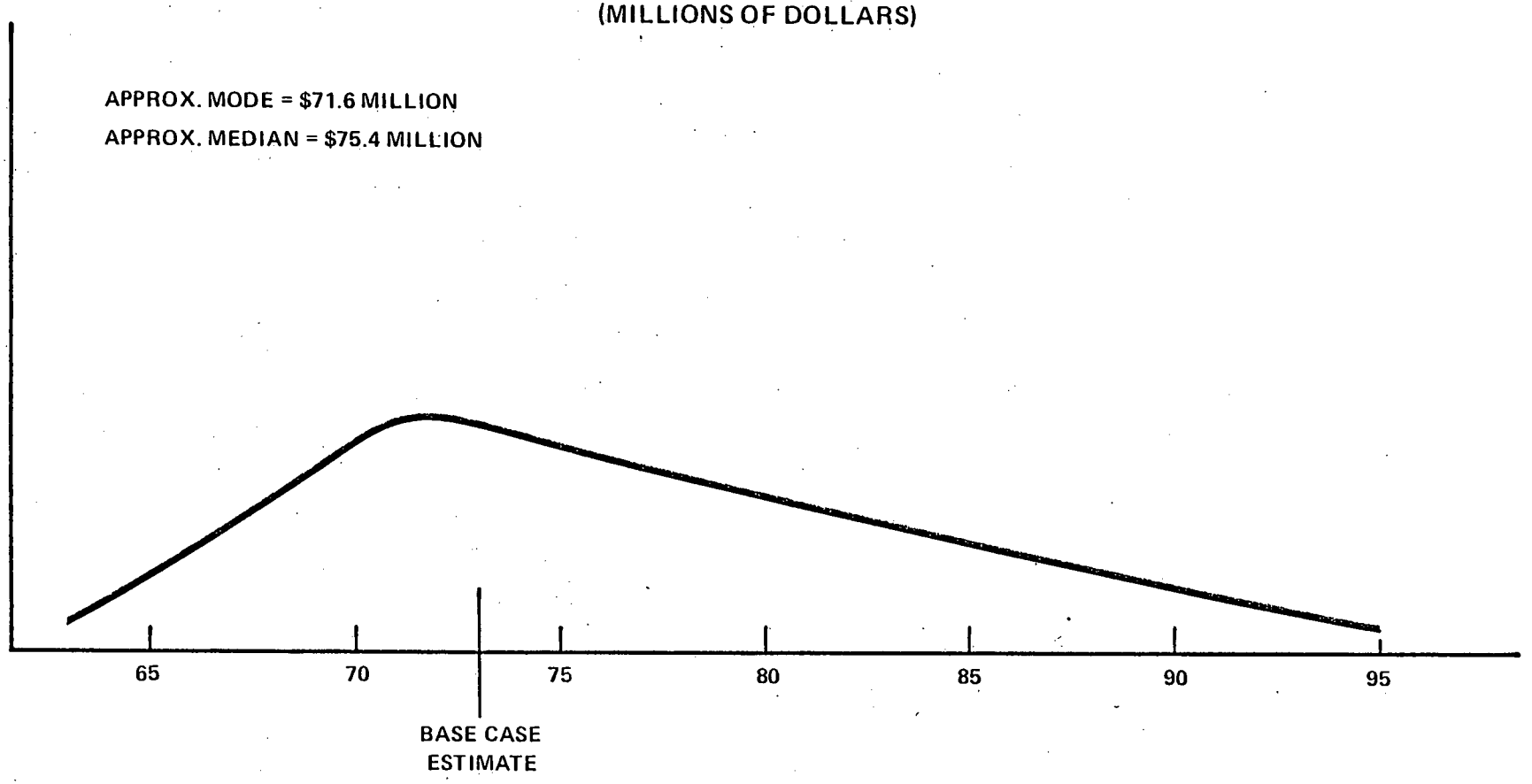

* Percentage of design capacity realized when the plant is operating during the last 12 months of the project

## CAPITAL COSTS *
## (MILLIONS OF DOLLARS)




* Total capital costs for phases I & II in 11/78 dollars

DIRECT ANNUAL OPERATING COSTS *
(MILLIONS OF DOLLARS)




* Average direct annual operating costs for phase III in 11/78 dollars

Project Duration

(years)

Cumulative Probability Table

| Value | Prob. of Being Less Than Value (%) | Prob. of Being More Than Value (%) |
|---|---|---|
| 8.98 | 5.0 | 95.0 |
| 9.25 | 8.6 | 91.4 |
| 9.50 | 12.9 | 87.1 |
| 9.75 | 17.9 | 82.1 |
| 10.00 | 23.6 | 76.4 |
| 10.25 | 30.0 | 70.0 |
| 10.50 | 37.0 | 63.0 |
| 10.75 | 44.6 | 55.4 |
| 11.00 | 52.1 | 47.9 |
| 11.25 | 58.5 | 41.5 |
| 11.50 | 64.8 | 35.2 |
| 11.75 | 70.4 | 29.6 |
| 12.00 | 75.7 | 24.3 |
| 12.25 | 80.3 | 19.7 |
| 12.50 | 84.3 | 15.7 |
| 12.75 | 87.7 | 12.3 |
| 13.00 | 90.5 | 9.5 |
| 13.25 | 92.8 | 7.2 |
| 13.50 | 93.5 | 6.5 |
| 13.75 | 94.2 | 5.8 |
| 14.00 | 94.8 | 5.2 |
| 14.25 | 94.9 | 5.1 |
| 14.31 | 95.0 | 5.0 |

Onstream Factor
(percentage)

Cumulative Probability Table

| Value | Prob. of Being Less Than Value (%) | Prob. of Being More Than Value (%) |
|---|---|---|
| 65.9 | 5.0 | 95.0 |
| 68.0 | 5.3 | 94.7 |
| 70.0 | 6.0 | 94.0 |
| 72.0 | 7.2 | 92.8 |
| 74.0 | 8.8 | 91.2 |
| 76.0 | 11.0 | 89.0 |
| 78.0 | 14.4 | 85.6 |
| 80.0 | 20.0 | 80.0 |
| 82.0 | 27.3 | 72.7 |
| 84.0 | 36.6 | 63.4 |
| 86.0 | 47.8 | 52.2 |
| 88.0 | 61.0 | 39.0 |
| 90.0 | 76.6 | 23.4 |
| 92.0 | 90.2 | 9.8 |
| 92.5 | 95.0 | 5.0 |

Design Capacity Factor

(percentage)

Cumulative Probability Table

| Value | Prob. of Being Less Than Value (%) | Prob. of Being More Than Value (%) |
|---|---|---|
| 59.8 | 5.0 | 95.0 |
| 64.0 | 5.7 | 94.3 |
| 68.0 | 7.1 | 92.9 |
| 72.0 | 8.7 | 91.3 |
| 76.0 | 11.0 | 89.0 |
| 80.0 | 13.9 | 86.1 |
| 84.0 | 17.5 | 82.5 |
| 88.0 | 22.4 | 77.6 |
| 92.0 | 28.9 | 71.1 |
| 96.0 | 41.0 | 59.0 |
| 100.0 | 79.0 | 21.0 |
| 104.0 | 91.2 | 8.8 |
| 107.8 | 95.0 | 5.0 |

## Capital Costs

(millions of 11/78 dollars)

Cumulative Probability Table

| Value | Prob. of Being Less Than Value (%) | Prob. of Being More Than Value (%) |
|---|---|---|
| 692 | 5.0 | 95.0 |
| 700 | 5.8 | 94.2 |
| 725 | 10.2 | 89.8 |
| 750 | 16.1 | 83.9 |
| 775 | 23.5 | 76.5 |
| 800 | 32.7 | 67.3 |
| 825 | 43.0 | 57.0 |
| 850 | 52.5 | 47.5 |
| 875 | 61.2 | 38.8 |
| 900 | 68.6 | 31.4 |
| 925 | 74.7 | 25.3 |
| 950 | 80.0 | 20.0 |
| 975 | 85.1 | 14.9 |
| 1000 | 89.3 | 10.7 |
| 1025 | 93.1 | 6.9 |
| 1041 | 95.0 | 5.0 |

Direct Annual Operating Costs
(millions of 11/78 dollars)

Cumulative Probability Table

| Value | Prob. of Being Less Than Value (%) | Prob. of Being More Than Value (%) |
|---|---|---|
| 62.9 | 5.0 | 95.0 |
| 64.0 | 6.8 | 93.2 |
| 66.0 | 10.4 | 89.6 |
| 68.0 | 16.0 | 84.0 |
| 70.0 | 23.4 | 76.6 |
| 72.0 | 33.1 | 66.9 |
| 74.0 | 43.7 | 56.3 |
| 76.0 | 52.0 | 48.0 |
| 78.0 | 59.1 | 40.9 |
| 80.0 | 65.5 | 34.5 |
| 82.0 | 71.1 | 28.9 |
| 84.0 | 76.3 | 23.7 |
| 86.0 | 81.2 | 18.8 |
| 88.0 | 85.3 | 14.7 |
| 90.0 | 89.0 | 11.0 |
| 92.0 | 91.8 | 8.2 |
| 94.0 | 93.9 | 6.1 |
| 94.9 | 95.0 | 5.0 |

SECTION II
IDENTIFICATION OF
VARIABLES

## II. Identification of Stochastic Variables

A planning meeting was held on August 1, 1979 with members of the SRC-II project team to determine what variables should be discussed in order to provide a meaningful confidence analysis report as requested by the Department of Energy. It was decided that the following items should be discussed with each interview subject:

1) Design Modifications

   Identify major design changes that are expected to be made, keeping in mind that there are both capital and time restrictions.

2) Probability of Success

   Given that the above modifications have been made, what is the probability of building and operating a sucessful demonstration plant. A successful plant is defined as a plant that is able to produce liquid fuel from coal, regardless of the efficiency of the process and quantity produced.

3) Failure Scenario

   As defined above, what could cause the project to fail.

For the remaining five variables, probability distributions would be developed.

4) Project Duration

   This variable was defined as the total elapsed time in years from the beginning of Phase I of the project to the end of Phase III. Additionally, it was assumed that during Phase

III, the plant would run for four years following the shake-down period (i.e., four years of operation were fixed). The only areas of uncertain duration would then be engineering design, construction, and start-up.

5) On-Stream Factor

On-stream factor represents the percentage of time that the plant is operating (producing any volume of product) during the last twelve months of Phase III. A value of 100% would represent operating the plant 365 days a year whereas an stream factor of 90% would represent 328 days operating time.

6) Design Capacity Factor

The plant has a design capacity of 6700 tons per stream day. Design capacity factor is defined as the percentage of the design capacity that will be realized, on the average, when the plant is operating (as defined above) for the last twelve months of Phase III.

7) Total Capital Costs (in 11/78 dollars)

Capital costs include all depreciable capital investments as well as engineering and testing; in other words, this is the total plant investment. Excluded, however, was the cost of modifying the Fort Lewis plant, the cost of site acquisition, the additional cost incurred should a modified engineering, procurement, construction approach <u>not</u> be used, as well as all Phase III capital costs.

8) Average Direct Annual Operating Costs (in 11/78 dollars)

This variable was defined to be the average operating costs incurred from the beginning of start-up to the end of Phase III. Direct annual operating costs include operating labor and benefits, maintenance labor and benefits, catalysts and chemicals, operating supplies, maintenance materials, electricity, and contract maintenance. Specifically excluded are overhead costs and coal expense.

## III. The Interview Process

In order to determine the underlying probability distributions, eighteen subjects were interviewed. The interview process involved six distinct steps. The first of these was a motivational exercise in which the subject was told the importance of what was about to be done and asked to carefully think through his answers. The motivational step was followed by a discussion of the methodology that was being used (i.e., what would take place in these interviews). If the subject was not familiar with probabilities, a brief explanation was provided.

The third step is called conditioning. At this juncture the importance of defining any assumptions that are being made and any particular scenarios that are envisioned when responding to questions about one of the variables was stressed. Anchoring was also discussed at this point. Anchoring is a common bias that is introduced when one has in mind a most likely or mean value for some variable and bases all the responses to questions concerning the variable on this central value. This tends to produce distributions that are closely centered around a value when in reality the true distribution covers a much wider range. By explaining this common bias, it was hoped that the subjects would consciously attempt to overcome their anchoring.

The last three steps in the process were repeated for each quantity that required a probability distribution. The first of these is structuring, which merely involves defining the quantity and stating any assumptions

that are to be made. At this point the subject would be sure to resolve any unanswered questions and would state any additional assumptions he was making.

The next step was to actually encode the distribution. The result of this step was a list of values that have .05, .10, .25, .50, .75, .90, and .95 probability of occurring. After obtaining this list of values, the final step is to verify the consistency of the answers. This was typically done by asking the subject if he felt that the unknown quantity was equally likely to fall in any of the four quartiles he had previously defined. The tails of the distribution were verified in a similar manner. If the subject felt there was a greater chance of the value falling in one quartile as opposed to another, the encoding process was repeated until a point of indifference was encountered.

## IV. Results of the Interview Process

Appendix A contains the actual forms used during the encoding process. At the top of each form is the code name (A, B, C, ...R) of the subject being interviewed and the quantity for which he is providing a distribution. Below this is a probability line on which the subject's responses to the questions were recorded. The seven points (responses) corresponding to probabilities for the occurrence of a value were then plotted on the upper half of the form and a curve was drawn through the points creating a cumulative density function.

The cumulative density function may be interpreted by selecting a point on the curve and drawing lines perpendicular to each axis from this point. The point at which the line intercepts the vertical axis denotes the probability that the actual value for the given quantity will be less than the value represented by the point at which the other perpendicular intercepts the horizontal axis. Variations of this analysis can be used to determine the cumulative probability associated with a certain value, or the value corresponding to a given cumulative probability.

In order to determine the approximate shape of the distribution, the cumulative density function was divided into intervals. The change in probability within an interval represented a point on the graph at the bottom of the page. After plotting one point for each interval, a curve was drawn through the points thereby approximating a probability distribution for the variable.

The remainder of the chapter will be devoted to presenting the scenarios envisioned by each subject that could cause the true value of the variable to be significantly higher or lower than the estimated median. The tables on pages 24 through 28 summarize each subjects comments for a particular variable, the X's indicating which subject made which comments. It should be noted that not all subjects felt qualified to comment on each of the five variables and of the subjects that did participate, only unusual scenarios were recorded.

## Project Duration Scenarios

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Possible causes of a significant decrease (optimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. few (if any) government delays. | | | | X | | | X | | X | | X | | | X | | | | |
| 2. early freeze of the plant design. | | | | | X | | | X | X | | X | | | X | | | | |
| 3. smooth start-up. | | | | X | | X | | | | | | X | | | | | | |
| 4. no environmental delays. | | | | | | | | | X | | | | | | | | | |
| 5. good contract management. | | | | | | | | | | | X | | | | | | | |
| 6. accelerate the construction activity. | | | | | X | | | | | | | | | | | | | |
| **Possible causes of a significant increase (pessimistic scenaros)** | | | | | | | | | | | | | | | | | | |
| 1. costly government delays. | | | | X | X | | X | X | | | | | X | X | | | | |
| 2. start-up problems. | | | X | | | | | X | | | | X | | X | X | | | |
| 3. environmental problems. | | | | | X | | | X | X | | X | | | | | | | |
| 4. design changes. | | | | | | | | | | | X | X | | X | | | | |
| 5. labor and mechanical problems. | | | | | | | | | | | X | | X | | | | | |
| 6. poor contract management. | | | | | | | | | | | X | | | | | | | |
| 7. long equipment lead times. | X | | | | | | | | | | | | | | | | | |

## Onstream Factor Scenarios

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Possible causes of a significant increase (optimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. lower maintenance than expected. | | | | X | | | | X | X | | | | X | | | | | |
| 2. good sparing. | | | | X | | X | | | | | X | | | | | | | |
| 3. basic design is good. | | | | | X | X | | | | | | | | | | | | |
| 4. good reliability on major pieces of equipment. | | | | X | | | | | | | X | | | | | | | |
| 5. consistent supply of coal. | | | | | | X | | | | | | | | | | | | |
| 6. good operators. | | | | | | | | | | | | | | X | | | | |
| **Possible causes of a significant decrease (pessimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. higher maintenance than expected. | X | | X | | | | X | X | | | X | X | | | | | | |
| 2. major equipment failure. | | | X | X | X | | | | X | | | | X | | | | | |
| 3. bottlenecks develop which are too costly to correct. | | | | | | X | | | | | | X | | X | | | | |
| 4. poor management. | | | | | | | | | | | X | | | | | | | |

## Design Capacity Factor Scenarios

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Possible causes of a significant increase (optimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. over design of the plant (safety margin) | | | X | X | X | X | X | X | X | | X | X | X | X | | | | |
| 2. better grade of coal is used. | | | | | | X | | | | | | | | X | | | | |
| 3. low down-time on parallel units. | | | | | | | X | | X | | | | | | | | | |
| 4. technological improvements. | | | | | | | | X | | | | | | | | | | |
| **Possible causes of a significant decrease (pessimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. only one train functions. | X | | | | | | | X | X | | | | | X | | | | |
| 2. bottlenecks. | | | | X | | X | | | | | X | X | | | | | | |
| 3. major equipment problems. | | | | X | X | X | | | | | | | | | | | | |
| 4. equipment performs at less than design. | | | X | | | | X | | | | | | X | | | | | |
| 5. repairs are uneconomical for a demo plant. | | | | | X | | | | | | | | | | | | | |

Capital Cost Scenarios

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Possible causes of a significant decrease (optimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. few (if any) government delays. | | | | | | | X | | X | X | | X | | X | | | | |
| 2. competitive vendor bidding for contracts. | | | | X | | | | | X | | | | X | | | | | |
| 3. no design changes. | | | | X | | | X | | | | | X | | | | | | |
| 4. pre-investment for commercial plant is eliminated. | | | | | | X | | X | | | | | | | | | | |
| 5. close control of construction. | | | | X | | | | | | | | | | | | | | |
| 6. less costly design is adopted. | | | | | | X | | | | | | | X | | | | | |
| **Possible causes of a significant increase (pessimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. government regulations and delays. | | | | X | | X | | | X | X | | | | X | | | | |
| 2. design changes. | | | | X | | | | X | | X | | | | X | | | | |
| 3. more sparing required. | | | | X | | | X | | | | | | | | | | | |
| 4. longer delivery schedules. | | | | | | | | X | X | | | | | | | | | |
| 5. lack of active bidding by vendors. | | | | | | | | X | | | | | X | | | | | |
| 6. technical problems and equipment failures | | X | | | | | | | X | | | X | | | | | | |
| 7. labor problems. | | | | | | | | | | | | X | | | | | | |

Direct Annual Operating Cost Scenarios

| | Interview Subjects | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| **Possible causes of a significant decrease (optimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. lower maintenance than expected. | | | | X | X | X | | | X | | | | X | | X | | | |
| 2. fewer people required. | | | | | X | | | | | | | | | | | | | |
| 3. little overtime. | | | | X | | | | | | | | | | | | | | |
| 4. waste disposal costs are minimal. | | | | | | | | | | | | | | X | | | | |
| 5. poor plant performance lowers power, catalyst and chemical requirements. | | | | | | | | | | | | | | X | | | | |
| **Possible causes of a significant increase (pessimistic scenario)** | | | | | | | | | | | | | | | | | | |
| 1. higher maintenance than expected. | | | | X | X | X | X | | X | | | | X | | X | | | |
| 2. inadequate instrumentation. | | | | | | X | | | | | | | | | | | | |
| 3. environmental and safety problems. | | | | | | | | | | | | | | X | | | | |
| 4. more electricity is consumed than expected. | | | | | | | | | | | | | | X | | | | |
| 5. additional operators are required. | | | | | | | | | | | | | | | X | | | |

## V. Combining Distributions

Due to the differing opinions demonstrated by the graphs of the stochastic variables shown in Appendix A, it became necessary to select a valid statistical method for combining the distributions in some defensible manner. The tables on pages 31 through 35 summarize the result of the following methodology:

1) Record all the data points (responses to the interview questions) for each subject (i.e., A, B, C, D, ... R) and for each variable (i.e., Project Duration, Onstream Factor, ... Operating Costs).
2) For each probability level (i.e., 5%, 10%, 25%, ... 95%) and for each variable, calculate a mean (simple average) and standard deviation (statistical measure of dispersion about the mean). Refer to the tables titled "Combined Distributions (First Pass)" on pages 31 through 35 for the results of this calculation.
3) In a similar manner, record in a second table all data points that fall within one standard deviation of the mean calculated in step 2. Be recording only those points within one standard deviation of the mean, outlier points (points significantly different from the mean) are dropped from consideration. The points dropped, therefore, represent points that appear to be either overly optimistic or overly pessimistic.
4) Calculate a new mean and standard deviation for these data points (refer to the "Second Pass" tables). This new mean now

becomes the point to be used in fitting a probability distribution. Each of these data points is placed on an encoding form as shown in Appendix B with the derived probability distributions appearing on pages 7 through 11.

## Combined Distributions for Project Duration

(years)

### First Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 10 | 10.5 | 11 | 12 | 13.5 | 14 | 15 |
| C | 9 | 9.25 | 9.5 | 10.25 | 11.25 | 12.25 | 13.25 |
| D | 10 | 10.5 | 11 | 12 | 13 | 14 | 15 |
| E | 8 | 8.25 | 8.5 | 10 | 11.5 | 13 | 15 |
| F | 8.75 | 9 | 9.25 | 10.25 | 12.25 | 13.25 | 14.25 |
| G | 9 | 9.25 | 9.5 | 10 | 10.5 | 11 | 11.5 |
| H | 10.25 | 11.25 | 11.5 | 11.75 | 12 | 12.5 | 13.25 |
| I | 7.5 | 8 | 9 | 10 | 10.5 | 12 | 15 |
| K | 9.5 | 9.75 | 10 | 11.5 | 12.5 | 13 | 14 |
| L | 8.25 | 9 | 9.25 | 9.75 | 10.75 | 11.75 | 12.75 |
| M | 8 | 9.25 | 9.75 | 11 | 11.75 | 12.5 | 14 |
| N | 8 | 8.5 | 9 | 12 | 14 | 15 | 17 |
| O | 12.25 | 12.75 | 13.25 | 14.25 | 15.25 | 17.25 | 17.5 |
| Mean | 9.12 | 9.63 | 10.04 | 11.13 | 12.21 | 13.19 | 14.42 |
| Std. Dev. | 1.29 | 1.32 | 1.31 | 1.29 | 1.43 | 1.61 | 1.63 |

### Second Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 10 | 10.5 | 11 | 12 | 13.5 | 14 | 15 |
| C | 9 | 9.25 | 9.5 | 10.25 | 11.25 | 12.25 | 13.25 |
| D | 10 | 10.5 | 11 | 12 | 13 | 14 | 15 |
| E | 8 | - | - | 10 | 11.5 | 13 | 15 |
| F | 8.75 | 9 | 9.25 | 10.25 | 12.25 | 13.25 | 14.25 |
| G | 9 | 9.25 | 9.5 | 10 | - | - | - |
| H | 10.25 | - | - | 11.75 | 12 | 12.5 | 13.25 |
| I | - | - | 9 | 10 | - | 12 | 15 |
| K | 9.5 | 9.75 | 10 | 11.5 | 12.5 | 13 | 14 |
| L | 8.25 | 9 | 9.25 | - | - | 11.75 | - |
| M | 8 | 9.25 | 9.75 | 11 | 11.75 | 12.5 | 14 |
| N | 8 | 8.5 | 9 | 12 | - | - | - |
| O | - | - | - | - | - | - | - |
| Mean | 8.98 | 9.44 | 9.73 | 10.98 | 12.22 | 12.83 | 14.31 |
| Std. Dev. | .86 | .68 | .74 | .89 | .76 | .77 | .74 |

## Combined Distributions for Onstream Factor

(percentage)

### First Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 60 | 70 | 75 | 80 | 82 | 85 | 92 |
| C | 75 | 80 | 85 | 88 | 90 | 92 | 93 |
| D | 75 | 80 | 84 | 88 | 90 | 91 | 92 |
| E | 50 | 70 | 85 | 90 | 92 | 96 | 97 |
| F | 60 | 75 | 80 | 85 | 90 | 93 | 95 |
| G | 60 | 70 | 77 | 80 | 82 | 85 | 90 |
| H | 75 | 80 | 85 | 90 | 91 | 92 | 94 |
| I | 50 | 65 | 80 | 85 | 92 | 94 | 97 |
| K | 75 | 80 | 85 | 88 | 90 | 91 | 92 |
| L | 75 | 78 | 80 | 85 | 90 | 91 | 92 |
| M | 70 | 75 | 81 | 85 | 89 | 90.5 | 92 |
| N | 30 | 50 | 65 | 85 | 90 | 92 | 93 |
| O | 0 | 25 | 50 | 80 | 83 | 85 | 86 |
| Mean | 58.1 | 69.1 | 77.8 | 85.3 | 88.5 | 90.6 | 92.7 |
| Std. Dev. | 22.1 | 15.7 | 10.1 | 3.5 | 3.6 | 3.5 | 2.9 |

### Second Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 60 | 70 | 75 | - | - | - | 92 |
| C | 75 | 80 | 85 | 88 | 90 | 92 | 93 |
| D | 75 | 80 | 84 | 88 | 90 | 91 | 92 |
| E | 50 | 70 | 85 | - | 92 | - | - |
| F | 60 | 75 | 80 | 85 | 90 | 93 | 95 |
| G | 60 | 70 | 77 | - | - | - | 90 |
| H | 75 | 80 | 85 | - | 91 | 92 | 94 |
| I | 50 | 65 | 80 | 85 | 92 | 94 | - |
| K | 75 | 80 | 85 | 88 | 90 | 91 | 92 |
| L | 75 | 78 | 80 | 85 | 90 | 91 | 92 |
| M | 70 | 75 | 81 | 85 | 89 | 90.5 | 92 |
| N | - | - | - | 85 | 90 | 92 | 93 |
| O | - | - | - | - | - | - | - |
| Mean | 65.9 | 74.8 | 81.5 | 86.1 | 90.4 | 91.8 | 92.5 |
| Std. Dev. | 10.2 | 5.3 | 3.5 | 1.6 | 1.0 | 1.1 | 1.4 |

## Combined Distributions for Design Capacity Factor

(percentage)

### First Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 50 | 85 | 95 | 100 | 103 | 105 | 110 |
| C | 89 | 92 | 95 | 100 | 102 | 103 | 104 |
| D | 75 | 85 | 90 | 95 | 100 | 103 | 105 |
| E | 50 | 70 | 80 | 85 | 90 | 95 | 100 |
| F | 50 | 75 | 85 | 95 | 100 | 105 | 110 |
| G | 60 | 70 | 75 | 85 | 95 | 105 | 110 |
| H | 50 | 75 | 90 | 100 | 105 | 110 | 120 |
| I | 50 | 70 | 90 | 100 | 102 | 104 | 108 |
| K | 90 | 93 | 95 | 100 | 105 | 107 | 110 |
| L | 80 | 90 | 96 | 100 | 104 | 110 | 120 |
| M | 78 | 83 | 88 | 90 | 93 | 97.5 | 99 |
| N | 55 | 65 | 70 | 95 | 97 | 100 | 105 |
| O | 30 | 50 | 65 | 80 | 85 | 90 | 100 |
| Mean | 62.1 | 77.2 | 85.7 | 94.2 | 98.5 | 102.7 | 107.8 |
| Std. Dev. | 18.4 | 12.4 | 10.2 | 7.0 | 6.2 | 5.8 | 6.7 |

### Second Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| A | 50 | 85 | 95 | 100 | 103 | 105 | 110 |
| C | - | - | 95 | 100 | 102 | 103 | 104 |
| D | 75 | 85 | 90 | 95 | 100 | 103 | 105 |
| E | 50 | 70 | 80 | - | - | - | - |
| F | 50 | 75 | 85 | 95 | 100 | 105 | 110 |
| G | 60 | 70 | - | - | 95 | 105 | 110 |
| H | 50 | 75 | 90 | 100 | - | - | - |
| I | 50 | 70 | 90 | 100 | 102 | 104 | 108 |
| K | - | - | 95 | 100 | - | 107 | 110 |
| L | 80 | 90 | - | 100 | 104 | - | - |
| M | 78 | 83 | 88 | 90 | 93 | 97.5 | - |
| N | 55 | 65 | - | 95 | 97 | 100 | 105 |
| O | - | - | - | - | - | - | - |
| Mean | 59.8 | 76.8 | 89.8 | 97.5 | 99.6 | 103.3 | 107.8 |
| Std. Dev. | 12.8 | 8.4 | 5.0 | 3.5 | 3.8 | 2.9 | 2.7 |

## Combined Distributions for Capital Costs

(millions of dollars)

### First Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| B | 800 | 900 | 950 | 1000 | 1150 | 1200 | 1300 |
| C | 600 | 650 | 700 | 750 | 800 | 850 | 900 |
| D | 630 | 660 | 710 | 750 | 800 | 870 | 950 |
| E | 750 | 775 | 850 | 900 | 1000 | 1100 | 1300 |
| F | 675 | 690 | 700 | 725 | 750 | 800 | 900 |
| G | 750 | 800 | 850 | 900 | 1000 | 1100 | 1300 |
| H | 660 | 680 | 700 | 760 | 850 | 975 | 1100 |
| I | 550 | 650 | 700 | 770 | 840 | 900 | 950 |
| J | 690 | 700 | 750 | 850 | 950 | 1000 | 1100 |
| L | 750 | 825 | 860 | 900 | 950 | 1000 | 1100 |
| M | 675 | 710 | 750 | 800 | 875 | 920 | 950 |
| N | 775 | 800 | 825 | 875 | 925 | 950 | 975 |
| O | 650 | 675 | 700 | 850 | 1000 | 1100 | 1200 |
| Mean | 689 | 732 | 773 | 833 | 915 | 982 | 1079 |
| Std. Dev. | 73 | 79 | 84 | 81 | 110 | 117 | 155 |

### Second Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| B | - | - | - | - | - | - | - |
| C | - | - | 700 | - | - | - | - |
| D | 630 | 660 | 710 | - | - | 870 | 950 |
| E | 750 | 775 | 850 | 900 | 1000 | - | - |
| F | 675 | 690 | 700 | - | - | - | - |
| G | 750 | 800 | 850 | 900 | 1000 | - | - |
| H | 660 | 680 | 700 | 760 | 850 | 975 | 1100 |
| I | - | - | 700 | 770 | 840 | 900 | 950 |
| J | 690 | 700 | 750 | 850 | 950 | 1000 | 1100 |
| L | 750 | - | - | 900 | 950 | 1000 | 1100 |
| M | 675 | 710 | 750 | 800 | 875 | 920 | 950 |
| N | - | 800 | 825 | 875 | 925 | 950 | 975 |
| O | 650 | 675 | 700 | 850 | 1000 | - | 1200 |
| Mean | 692 | 721 | 749 | 845 | 932 | 945 | 1041 |
| Std. Dev. | 47 | 55 | 63 | 56 | 64 | 50 | 96 |

## Combined Distributions for Direct Annual Operating Costs

(millions of dollars)

### First Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| C | 60 | 62 | 65 | 67 | 70 | 75 | 80 |
| D | 65 | 68 | 72 | 75 | 80 | 85 | 90 |
| E | 50 | 59 | 68 | 73 | 80 | 90 | 95 |
| F | 60 | 65 | 70 | 73 | 80 | 85 | 90 |
| G | 75 | 80 | 90 | 100 | 105 | 115 | 125 |
| I | 63 | 65 | 67 | 75 | 79 | 83 | 84 |
| M | 57 | 58 | 60 | 65 | 70 | 77 | 85 |
| N | 70 | 75 | 80 | 85 | 93 | 100 | 110 |
| O | 65 | 67 | 70 | 80 | 90 | 100 | 110 |
| Mean | 62.8 | 66.6 | 71.3 | 77.0 | 83.0 | 90.0 | 96.6 |
| Std. Dev. | 7.3 | 7.2 | 8.8 | 10.5 | 11.3 | 12.8 | 15.1 |

### Second Pass

| Subject | Observations | | | | | | |
|---|---|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | .75 | .90 | .95 |
| C | 60 | 62 | 65 | 67 | - | - | - |
| D | 65 | 68 | 72 | 75 | 80 | 85 | 90 |
| E | - | - | 68 | 73 | 80 | 90 | 95 |
| F | 60 | 65 | 70 | 73 | 80 | 85 | 90 |
| G | - | - | - | - | - | - | - |
| I | 63 | 65 | 67 | 75 | 79 | 83 | 84 |
| M | 57 | - | - | - | - | - | 85 |
| N | 70 | - | 80 | 85 | 93 | 100 | 110 |
| O | 65 | 67 | 70 | 80 | 90 | 100 | 110 |
| Mean | 62.9 | 65.4 | 70.3 | 75.4 | 83.7 | 90.5 | 94.9 |
| Std. Dev. | 4.3 | 2.3 | 4.9 | 5.7 | 6.2 | 7.7 | 11.0 |

## VI. Sources of Error

There are five possible sources of error that can be identified with this study as discussed below.

1) Inappropriate choice of subjects to be interviewed.
   Care was taken to select subjects of substantial experience who are currently involved in the SRC-II project, but there still exists the possibility that a nonrepresentative group was chosen.

2) Bias.
   Inherent biases that a subject may have are difficult to overcome, but every effort was made during the interviews to cut through biases and check the consistency of the responses.

3) Reliance on base case numbers.
   The subjects were aware of the estimated values for each quantity that were used in the base case. As a result, the probability distributions for each quantity often reflect the subject's feelings towards these base case estimates.

4) Inaccurate estimate of future costs.
   It is most difficult to estimate in 1978 what the cost will be for a plant that may not be completed for perhaps five to six years.

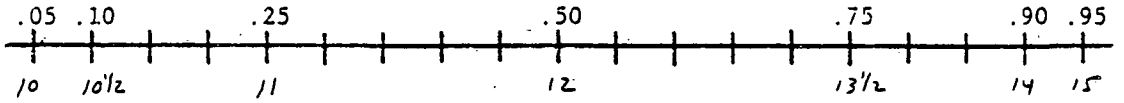
5) Inaccurate estimate of technological improvements.
   As with future costs, it is equally difficult to envision technological advances and engineering developments over the next five year period.

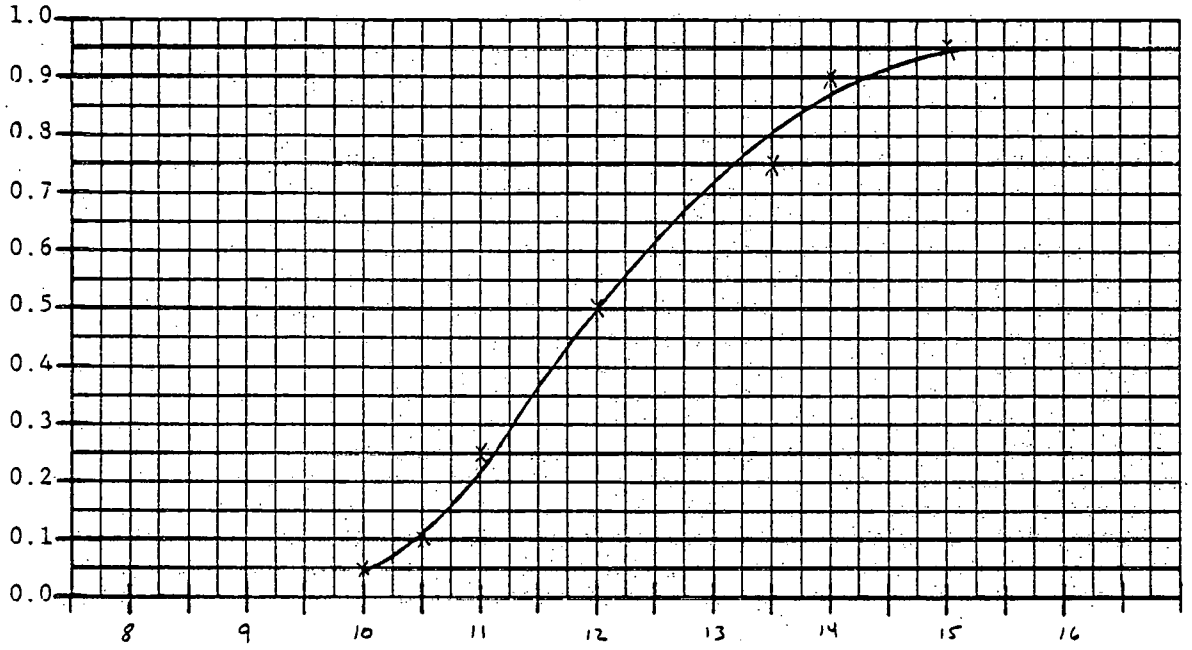
APPENDIX A

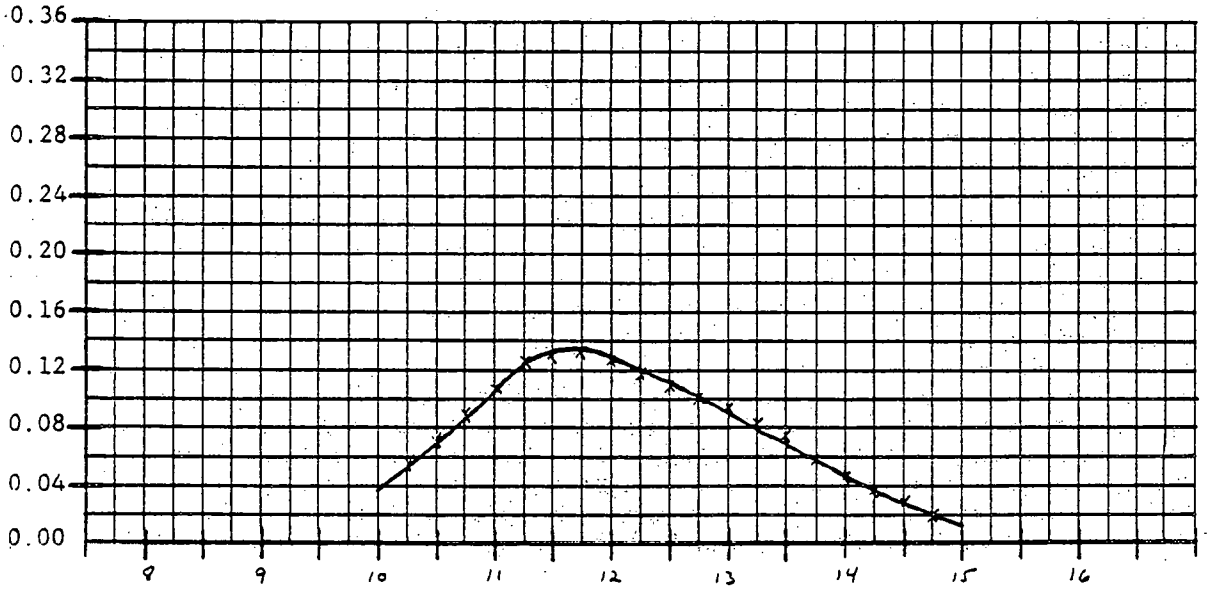
# APPENDIX

# A

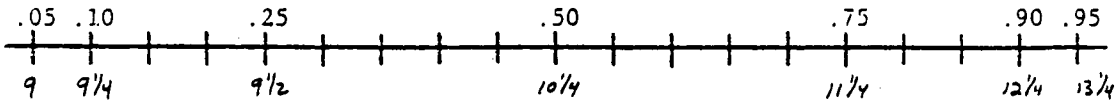
QUANTITY PROJECT DURATION
SUBJECT A
DATE 8/7/79

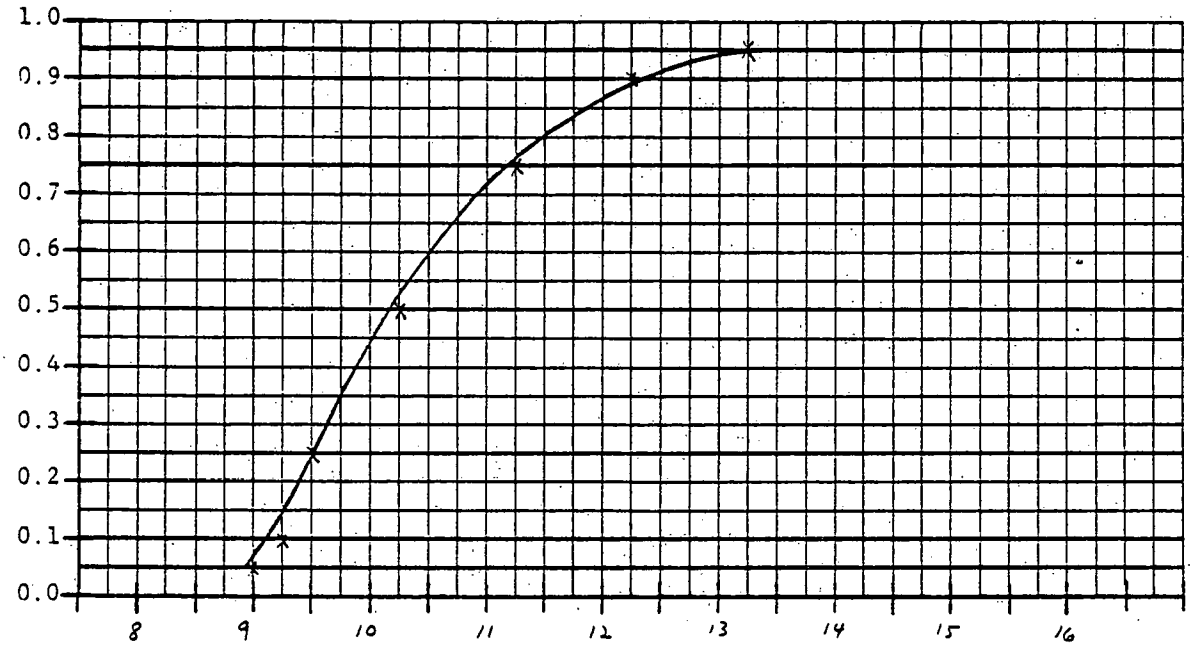


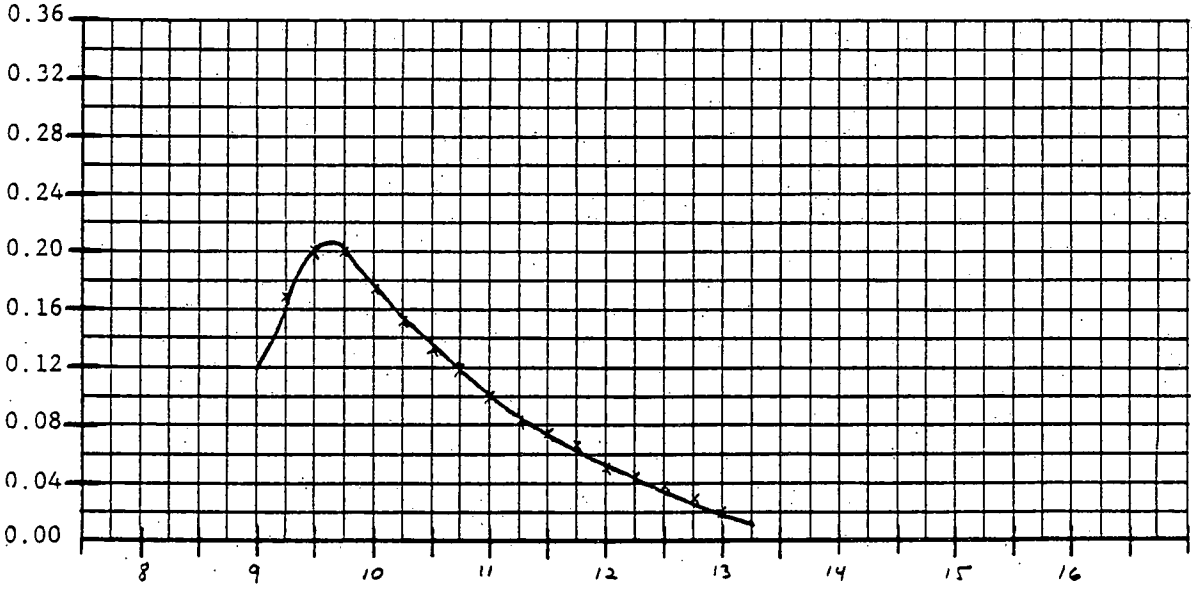



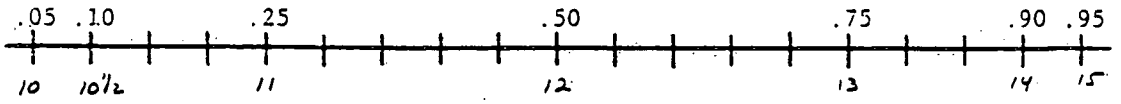
QUANTITY PROJECT DURATION
SUBJECT C
DATE 8/8/79

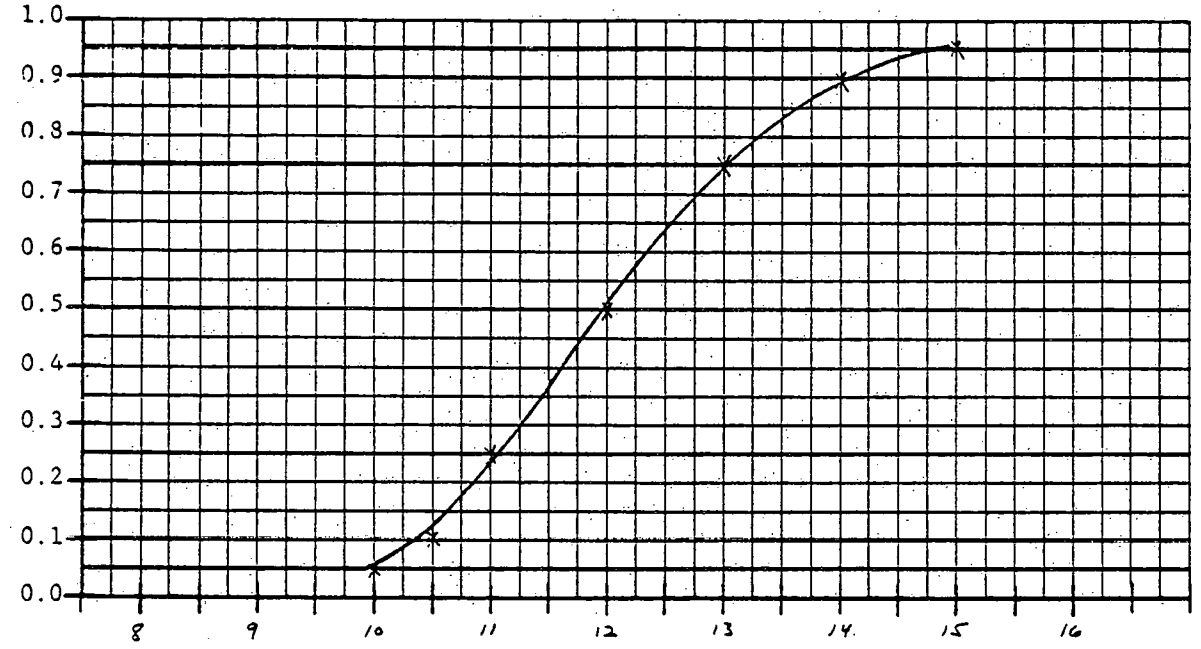


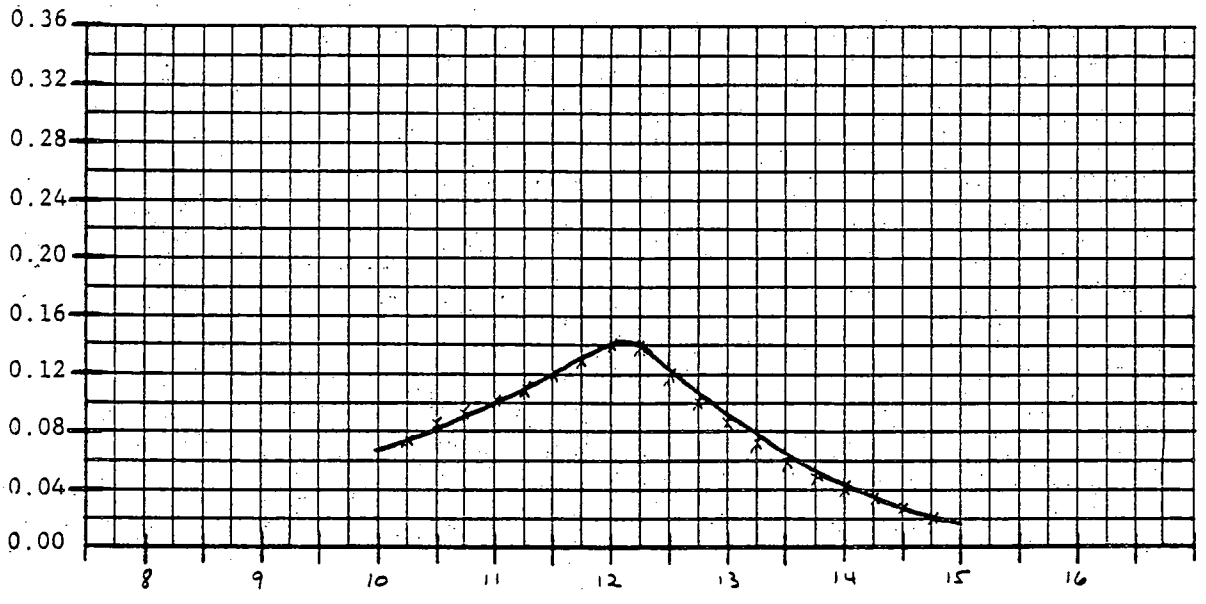



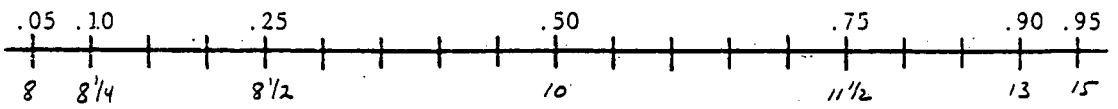
QUANTITY PROJECT DURATION
SUBJECT D
DATE 8/8/79

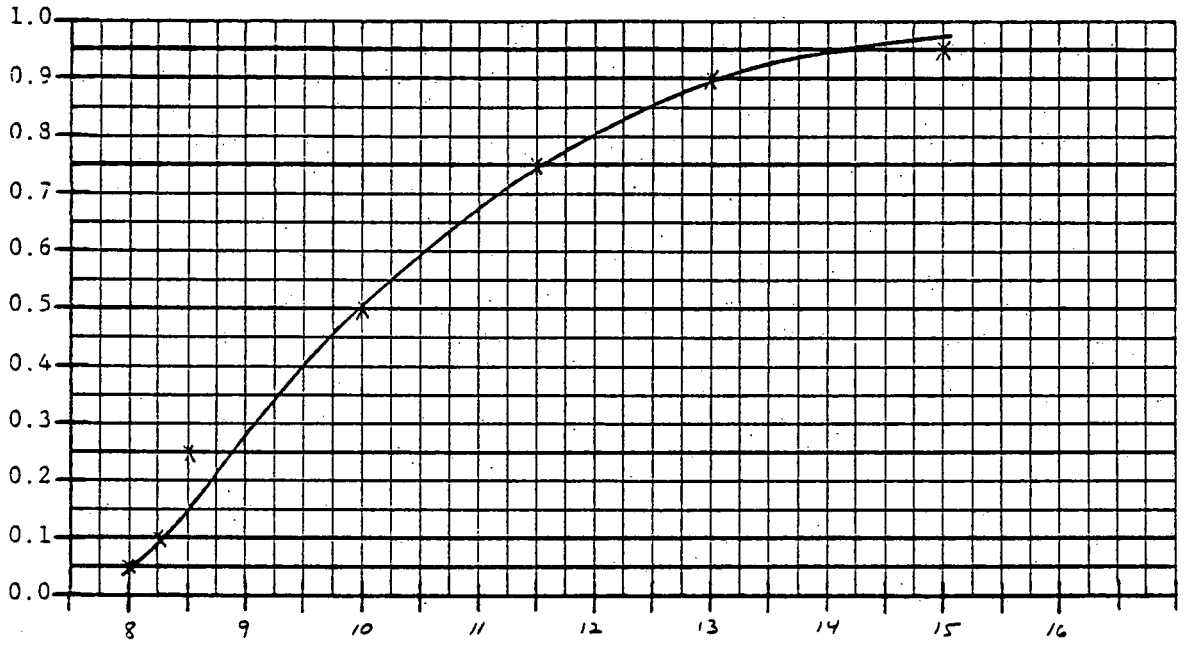


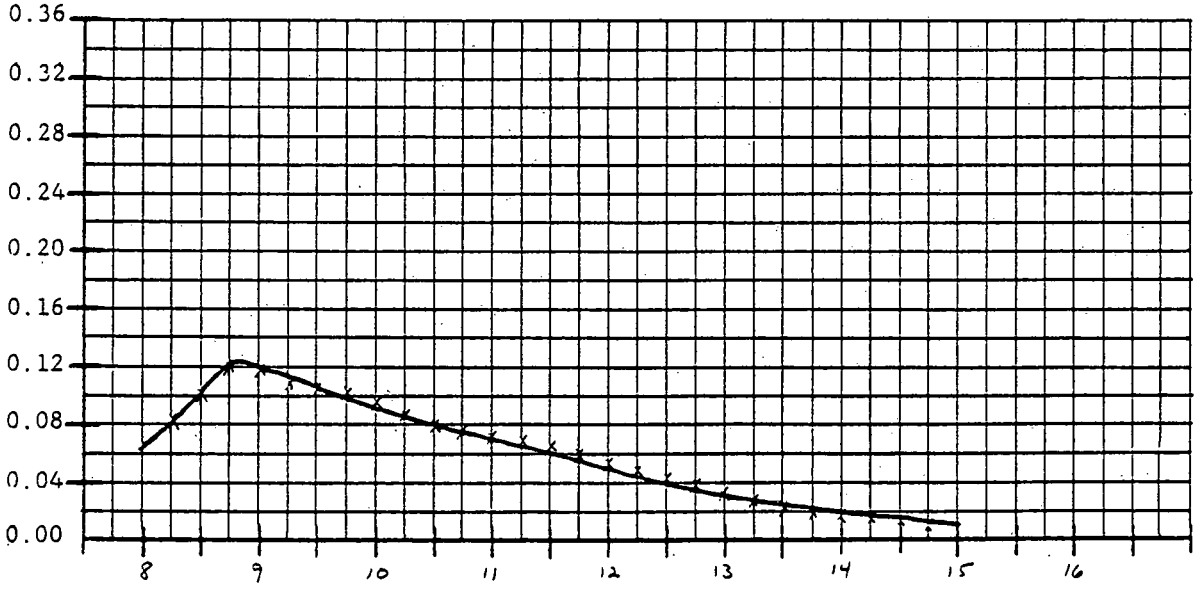



QUANTITY PROJECT DURATION
SUBJECT E
DATE 8/8/79

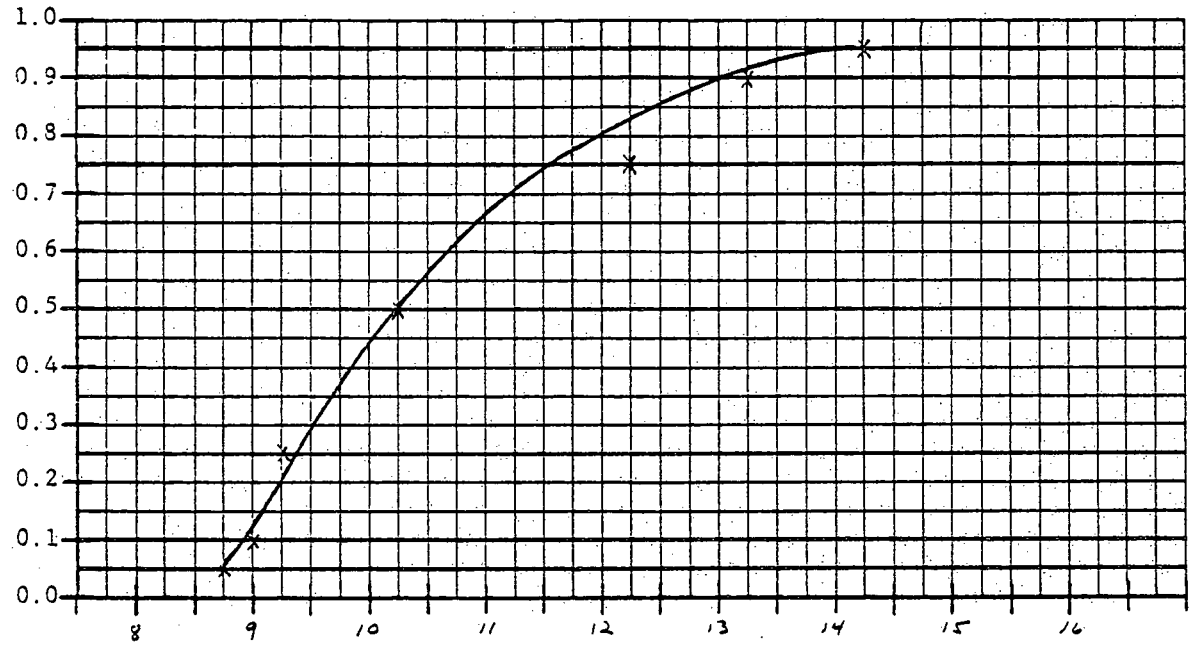


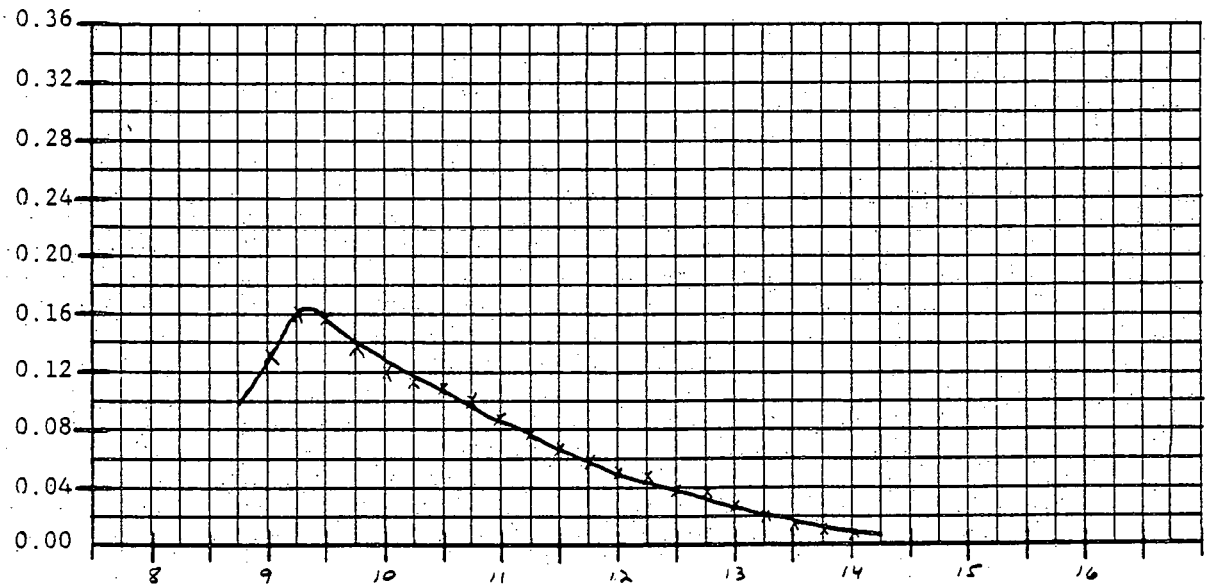



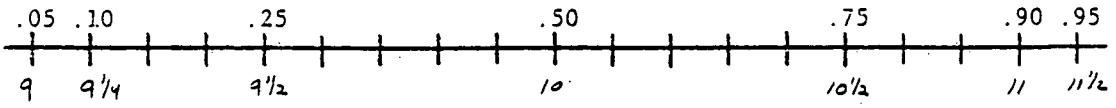
QUANTITY Project Duration
SUBJECT F
DATE 8/9/79

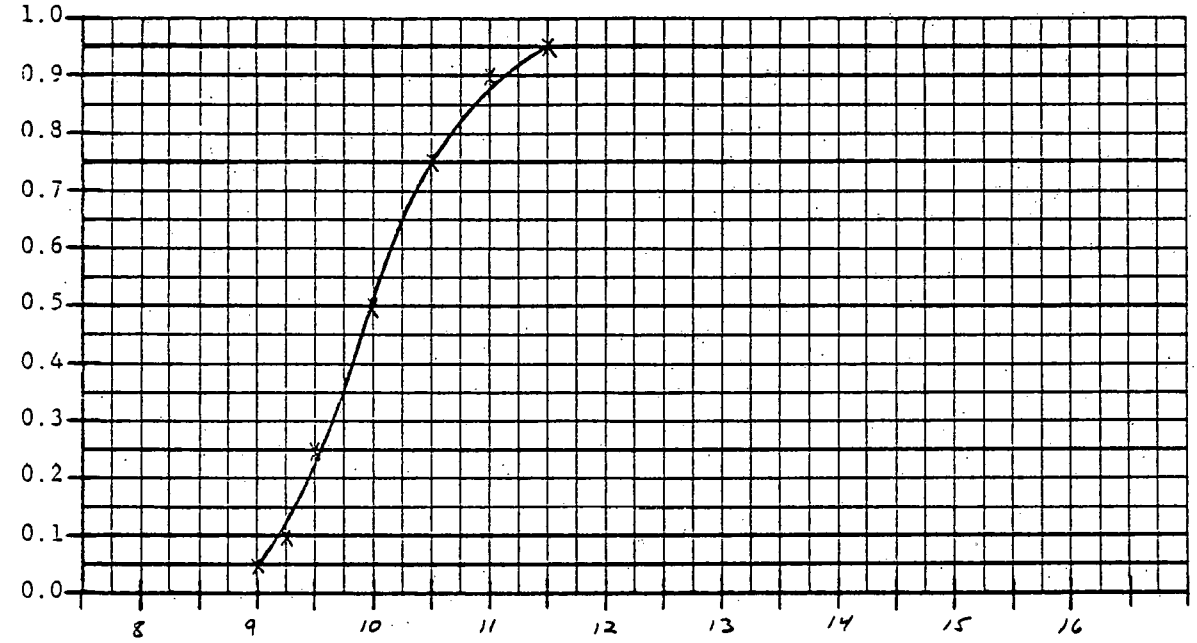
| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 8¾ | 9 | 9¼ | 10¼ | 12¼ | 13¼ | 14¼ |

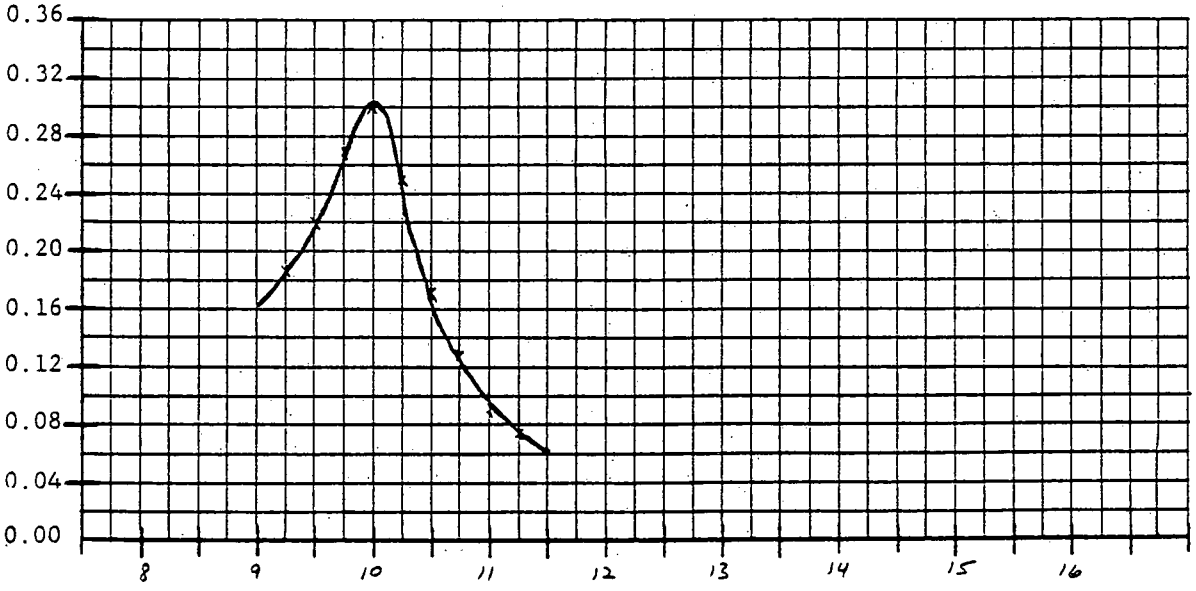


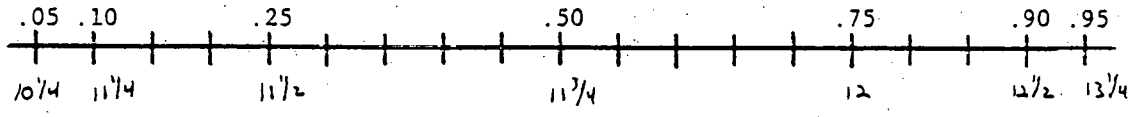
QUANTITY PROJECT DURATION
SUBJECT G
DATE 8/10/79

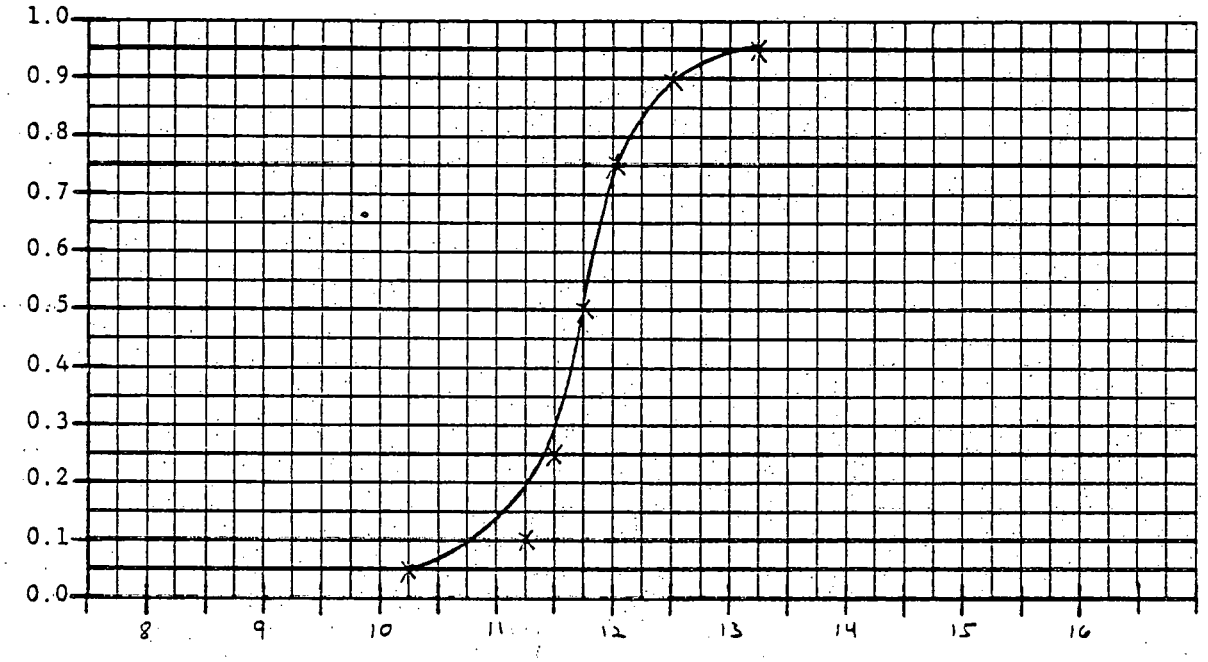


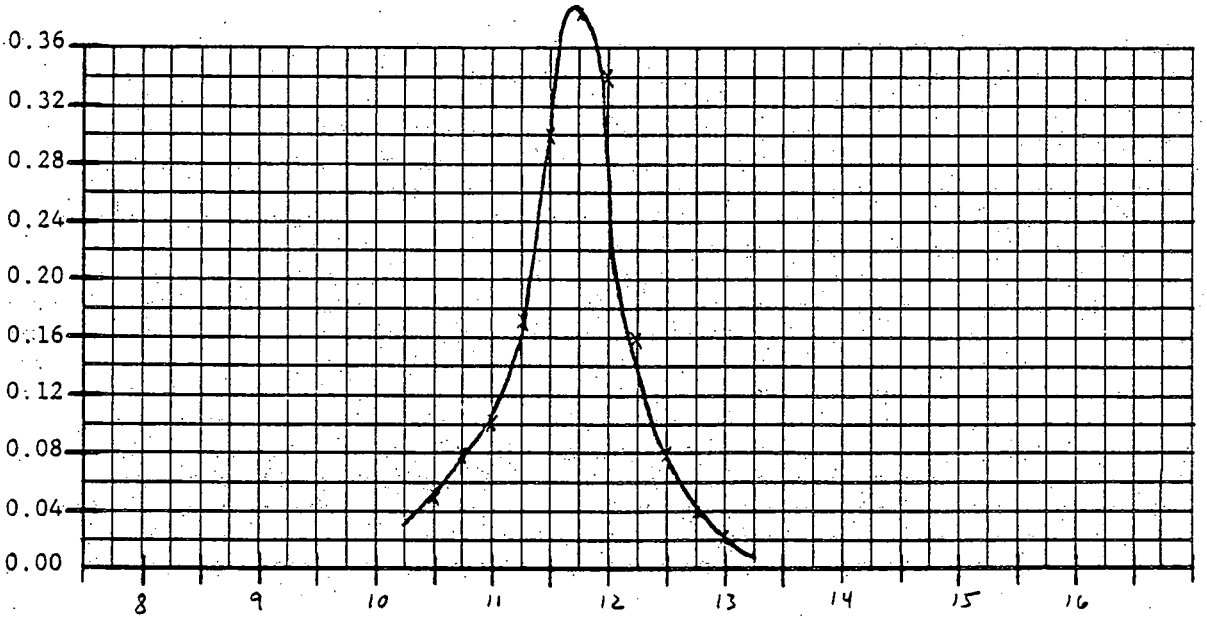



QUANTITY PROJECT DURATION
SUBJECT H
DATE 8/10/79

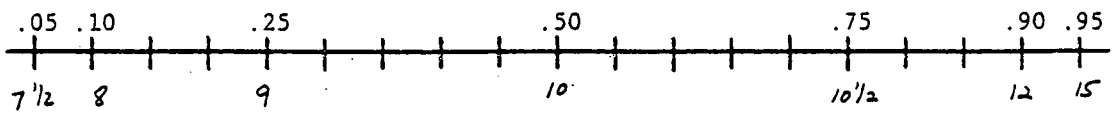


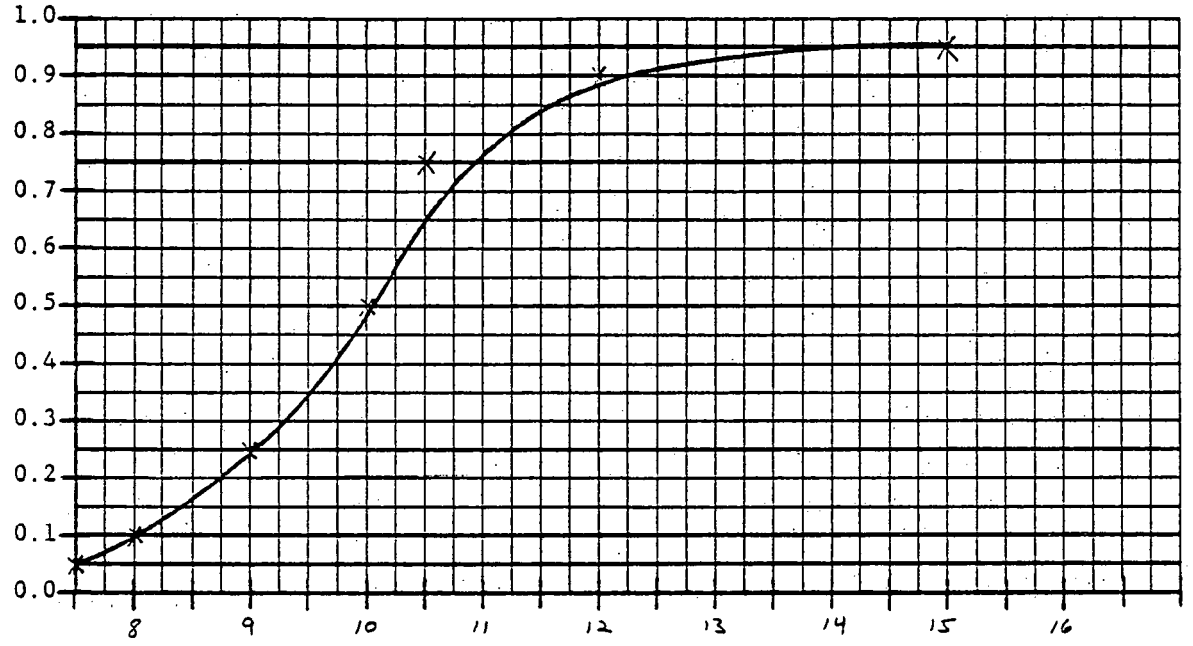



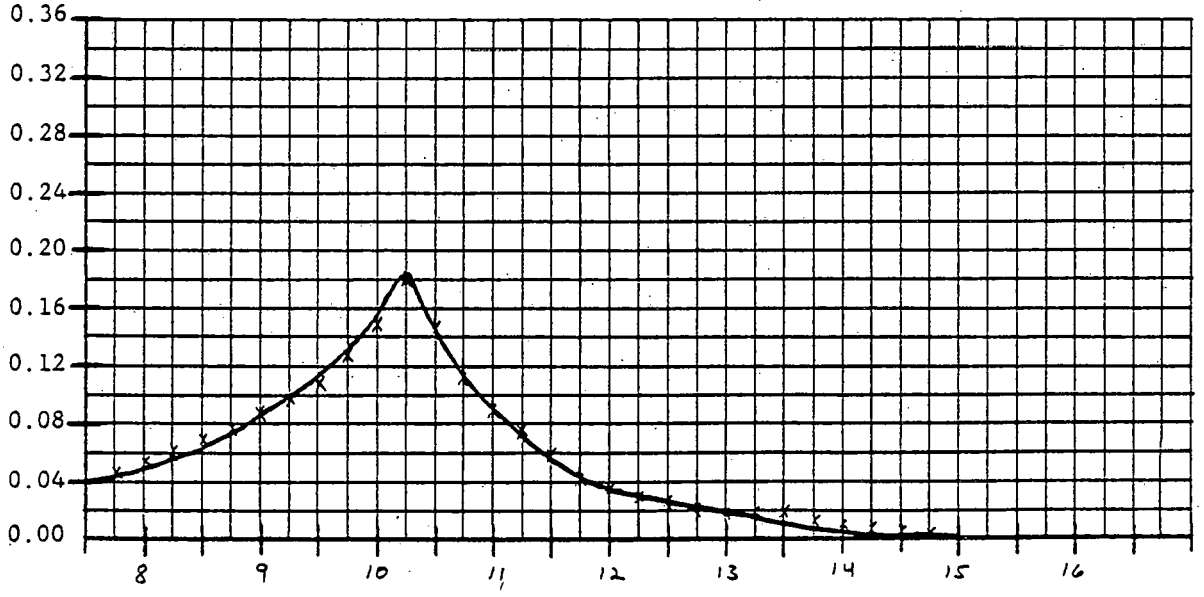



QUANTITY PROJECT DURATION
SUBJECT T

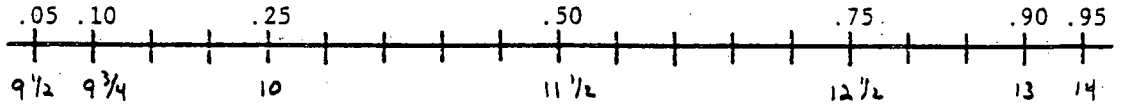
DATE 8/10/79

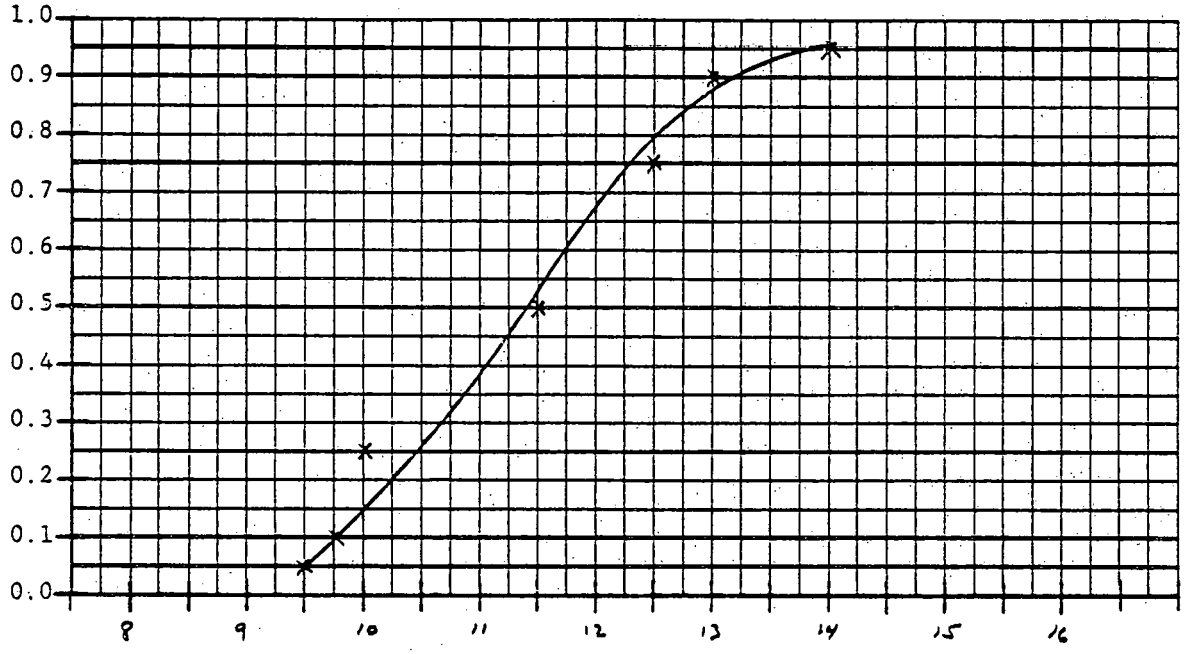


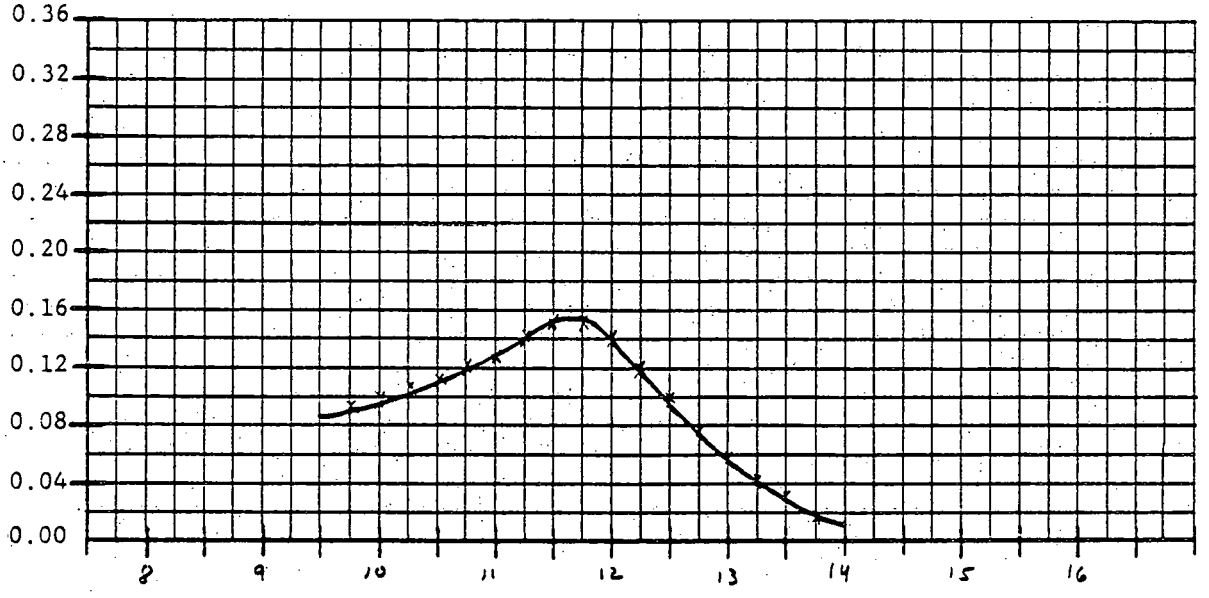



QUANTITY PROJECT DURATION
SUBJECT K
DATE 8/13/79



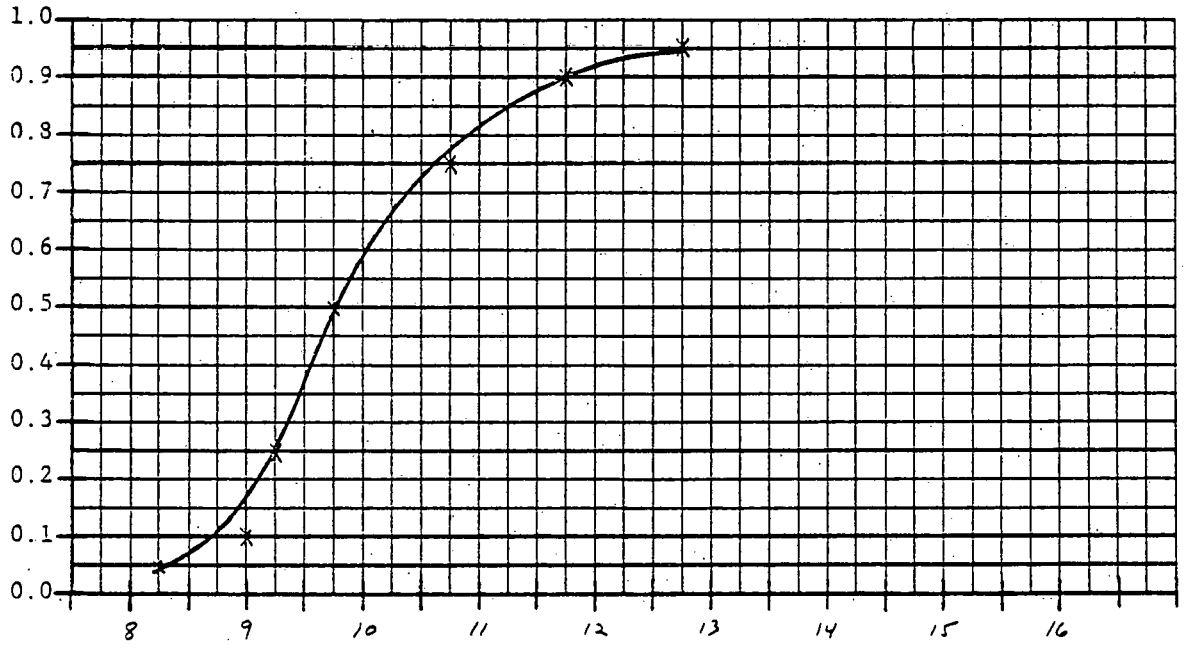



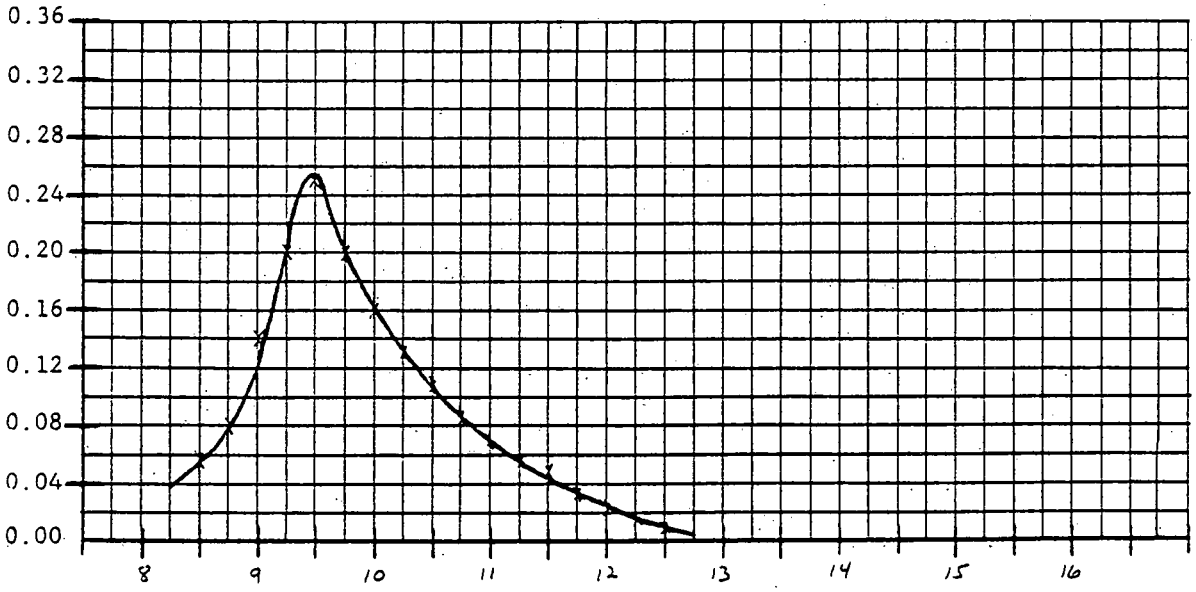



QUANTITY PROJECT DURATION
SUBJECT L

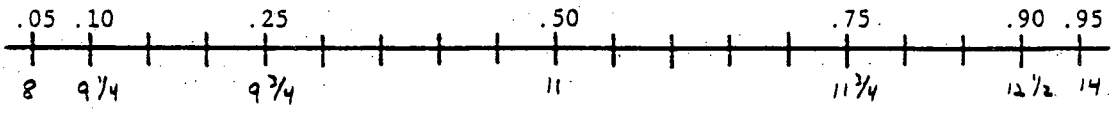
DATE 8/14/79

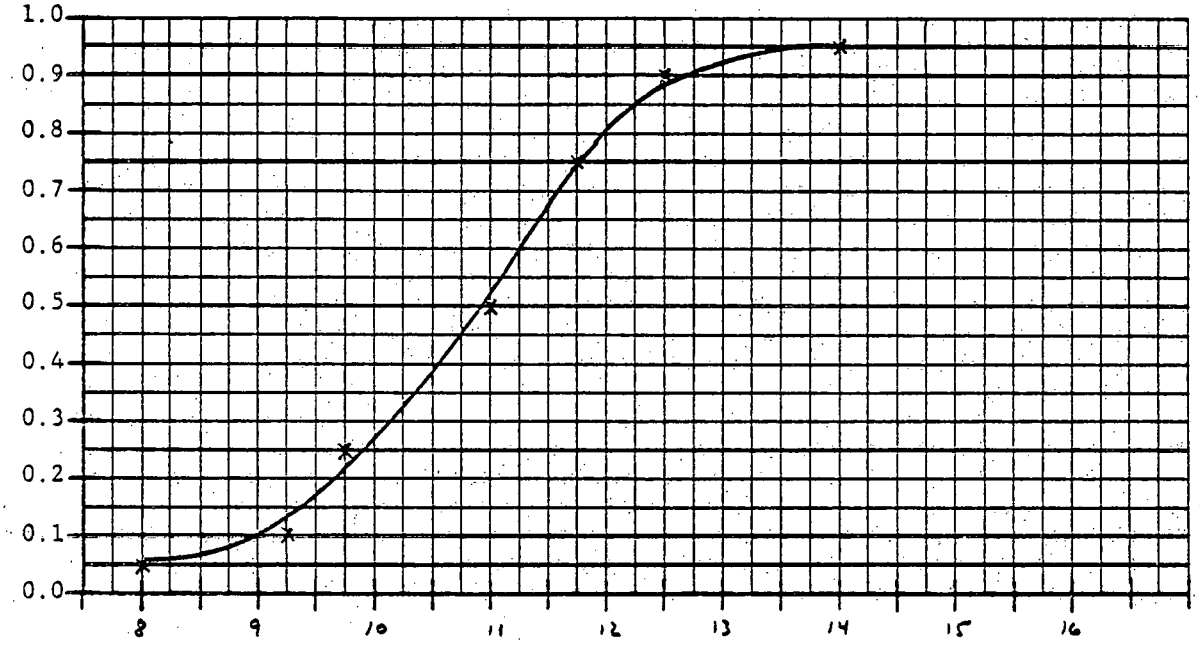
| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 8¼ | 9 | 9¼ | 9¾ | 10¾ | 11¾ | 12¾ |

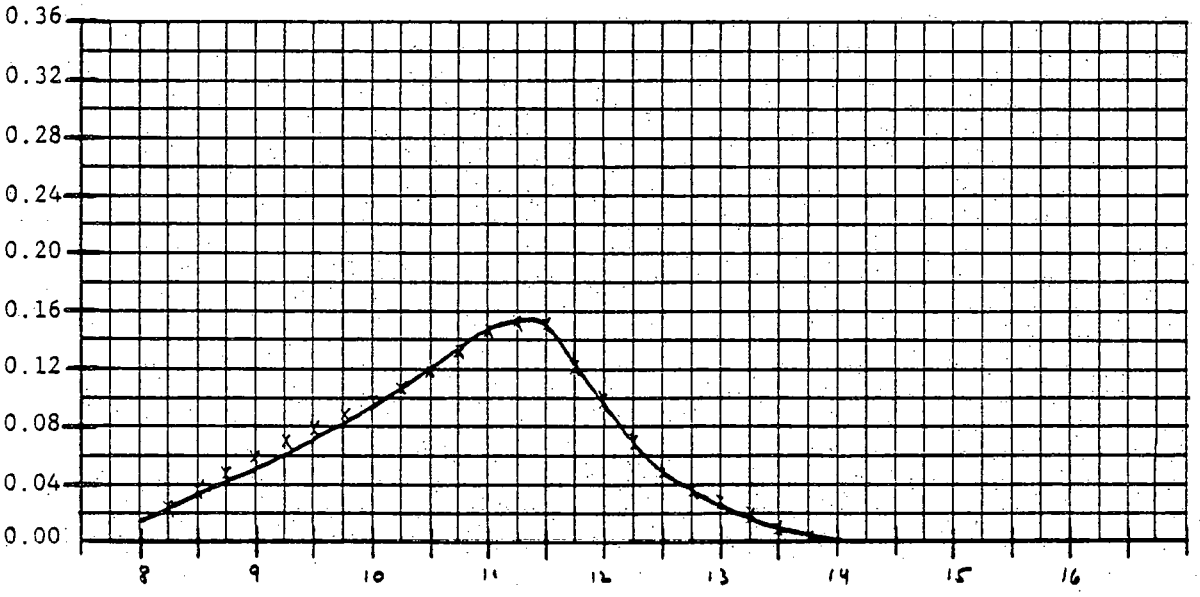


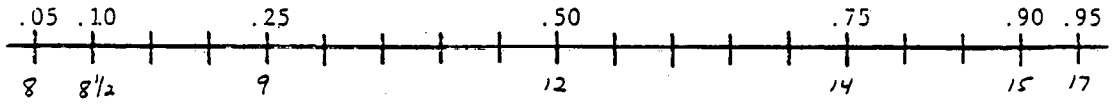
QUANTITY PROJECT DURATION
SUBJECT m
DATE 8/14/79

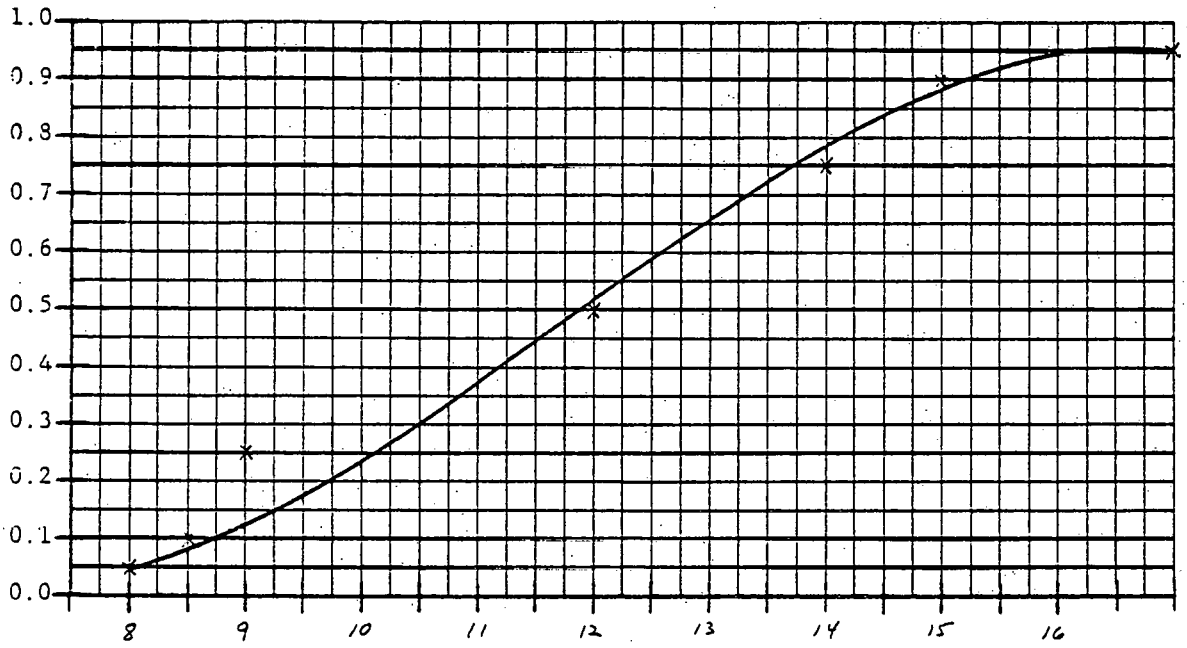


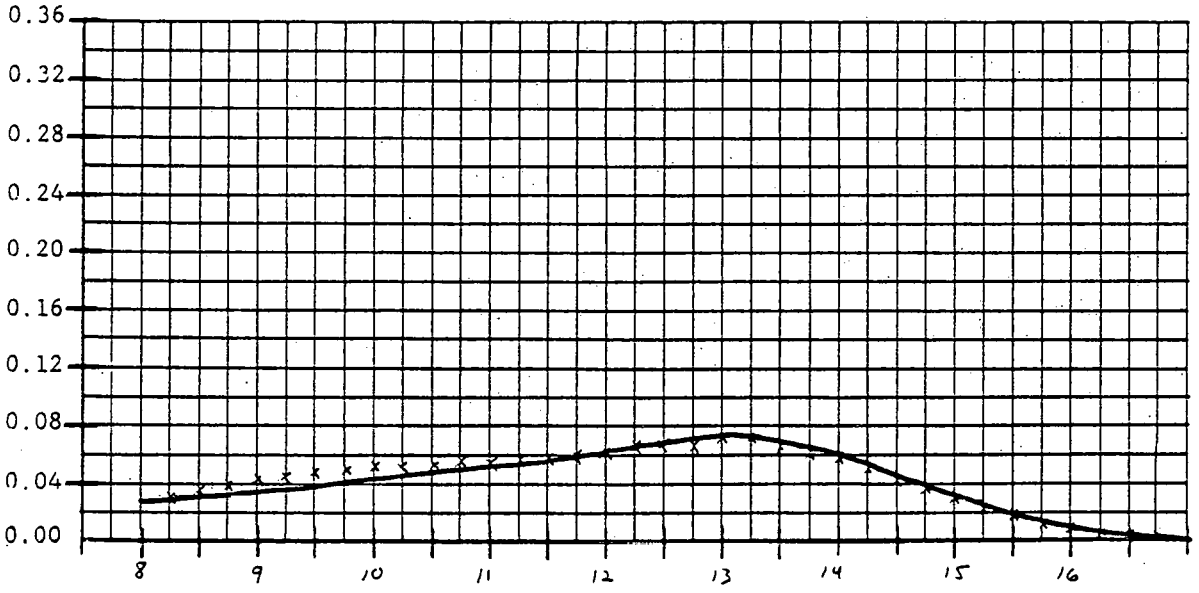



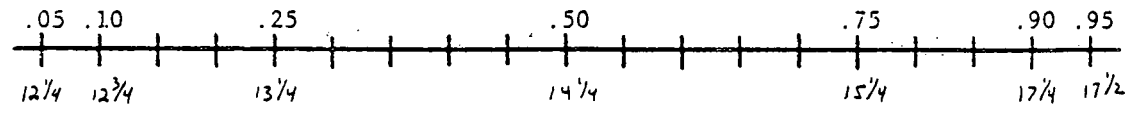
QUANTITY PROJECT DURATION
SUBJECT N
DATE 8/15/79

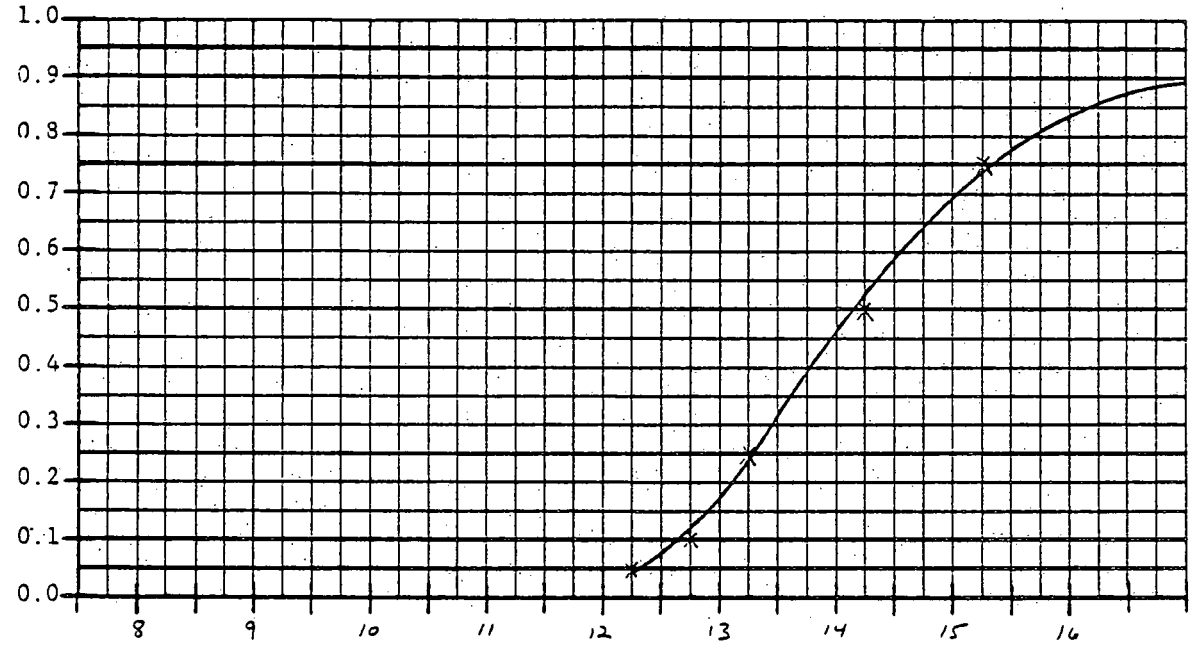


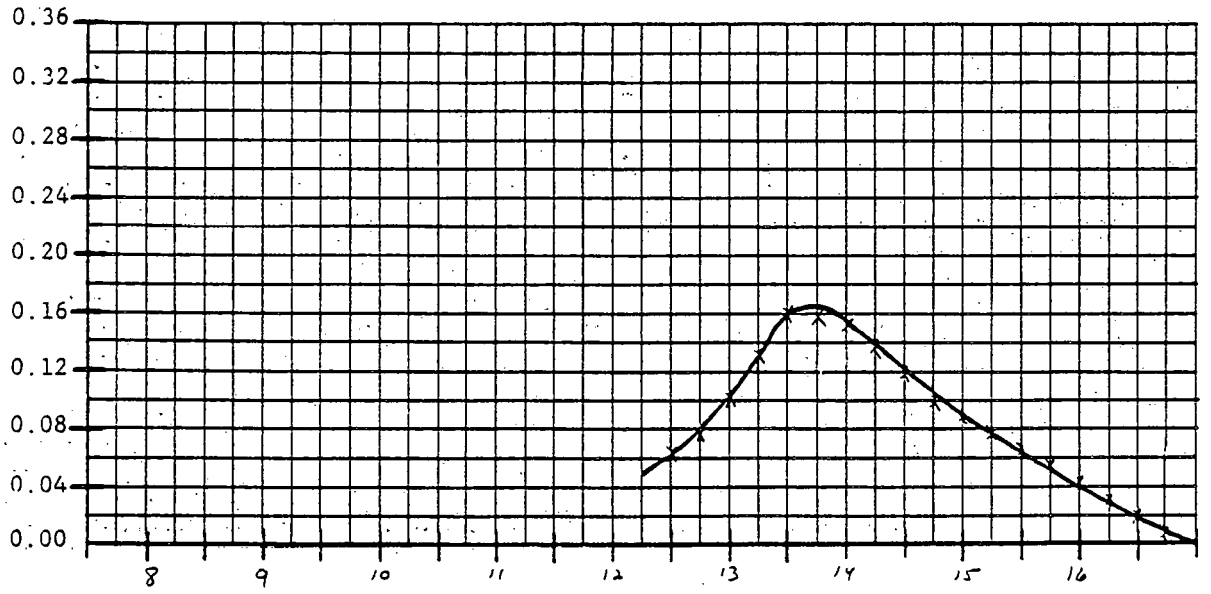



QUANTITY PROJECT DURATION
SUBJECT O
DATE 8/9/79

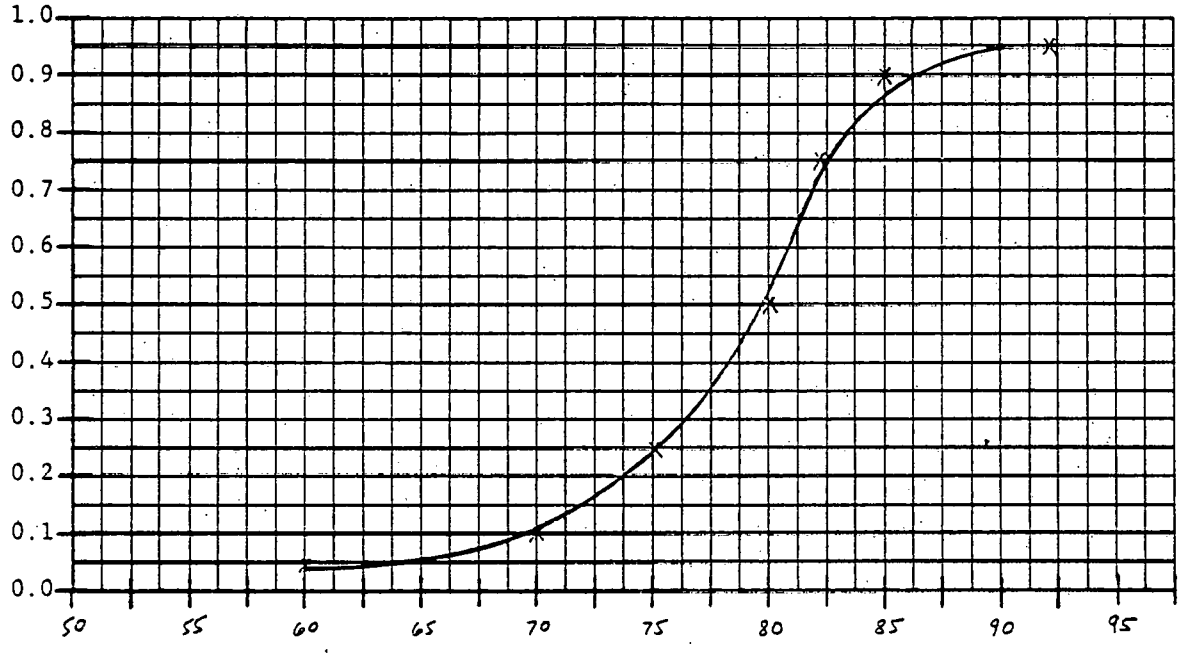


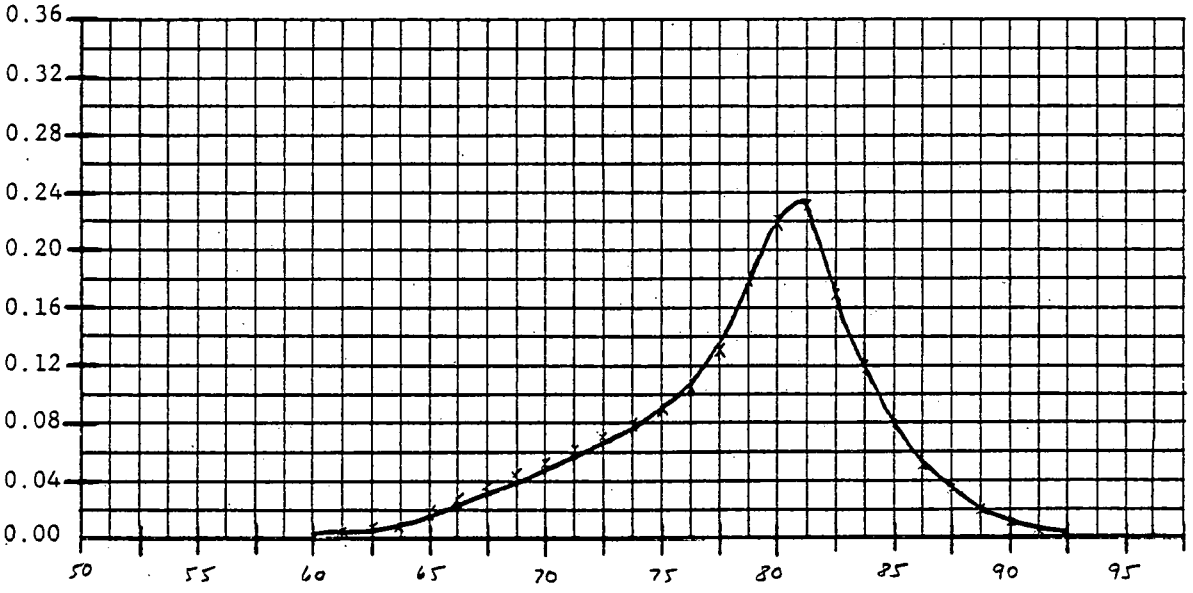



QUANTITY ON STREAM FACTOR
SUBJECT A
DATE 8/2/79

| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 60 | 70 | 75 | 80 | 82 | 85 | 92 |

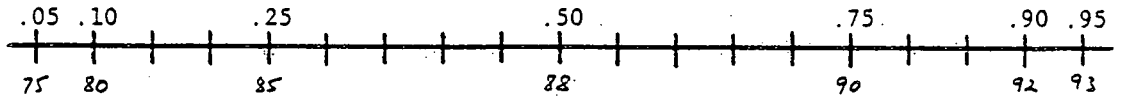


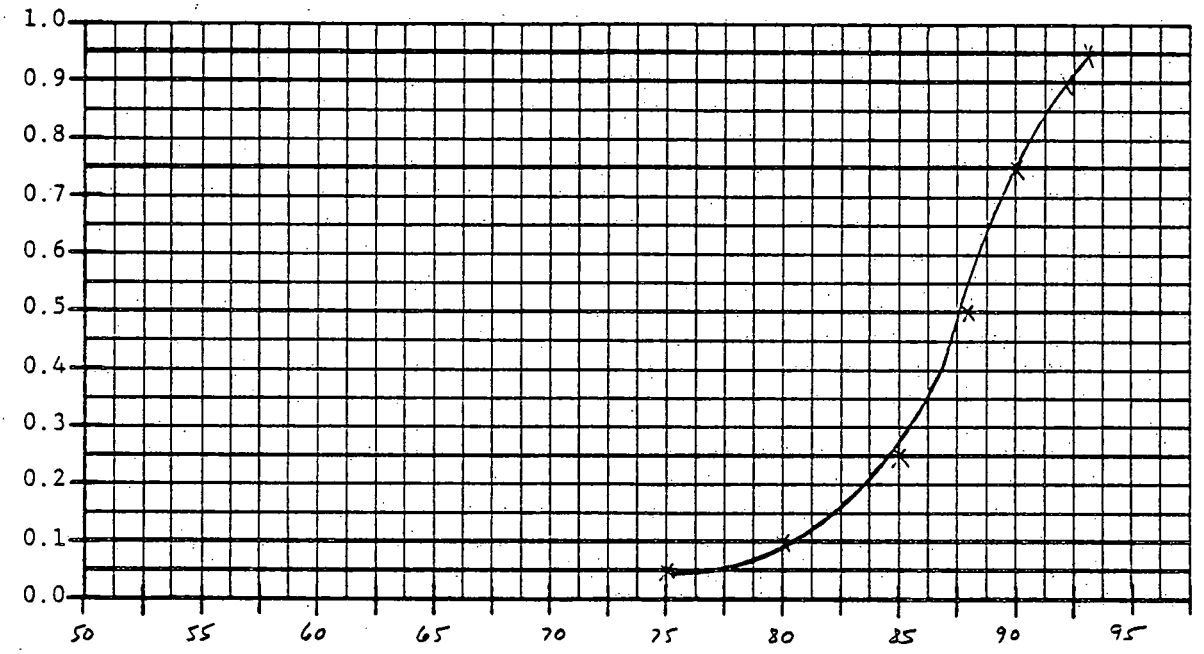



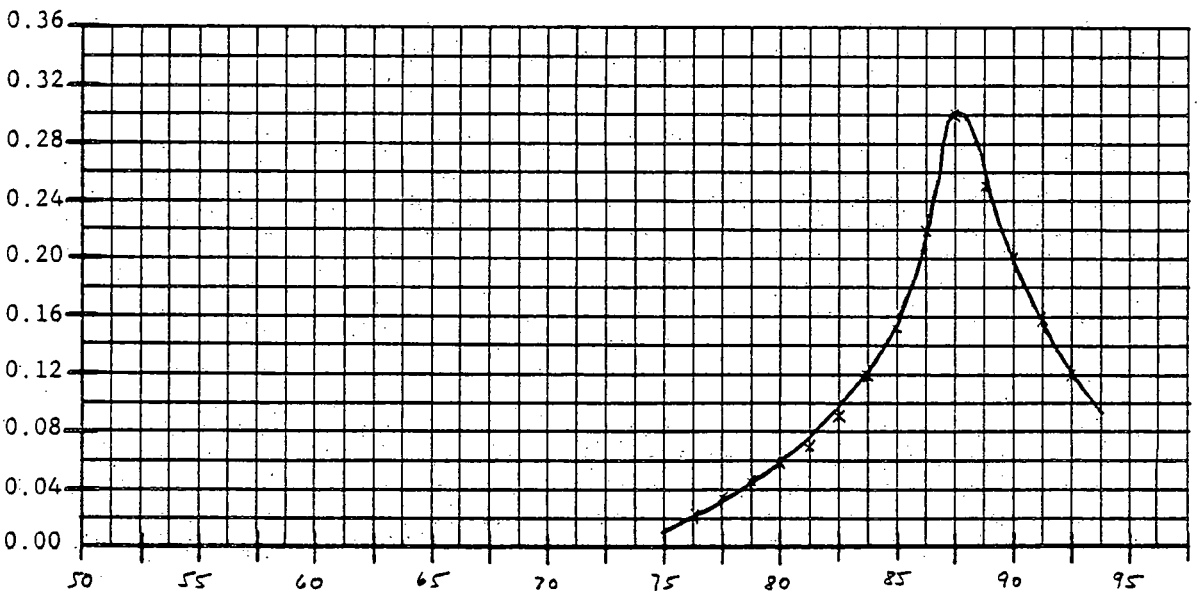
QUANTITY ONSTREAM FACTOR

SUBJECT C

DATE 8/2/79



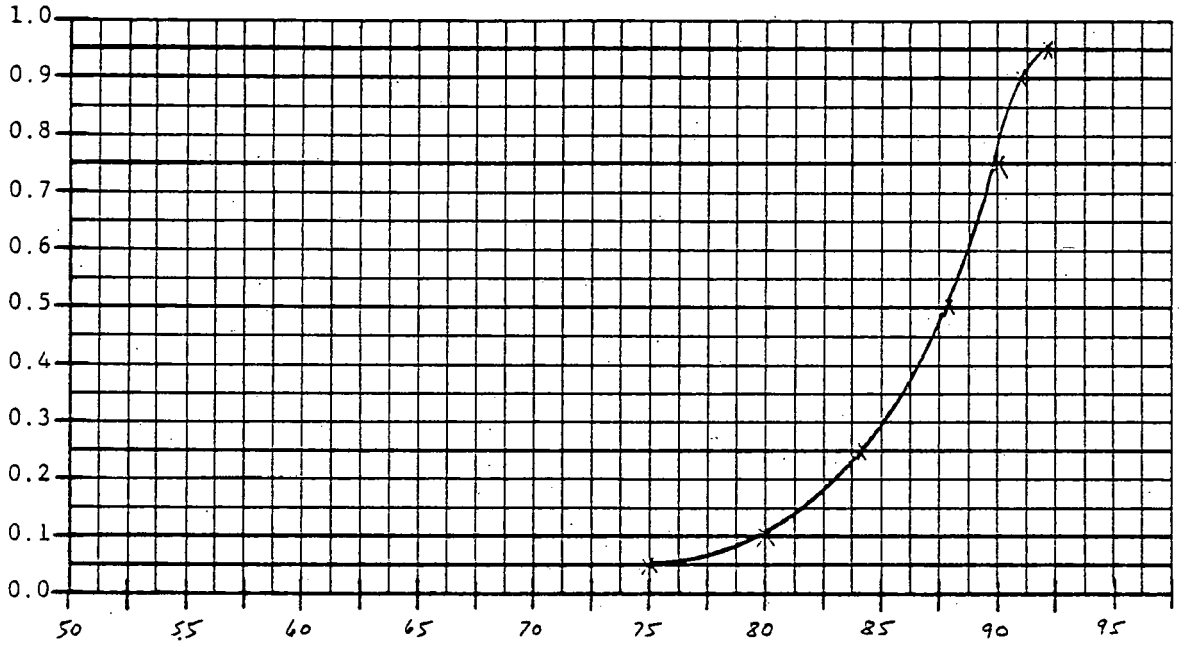



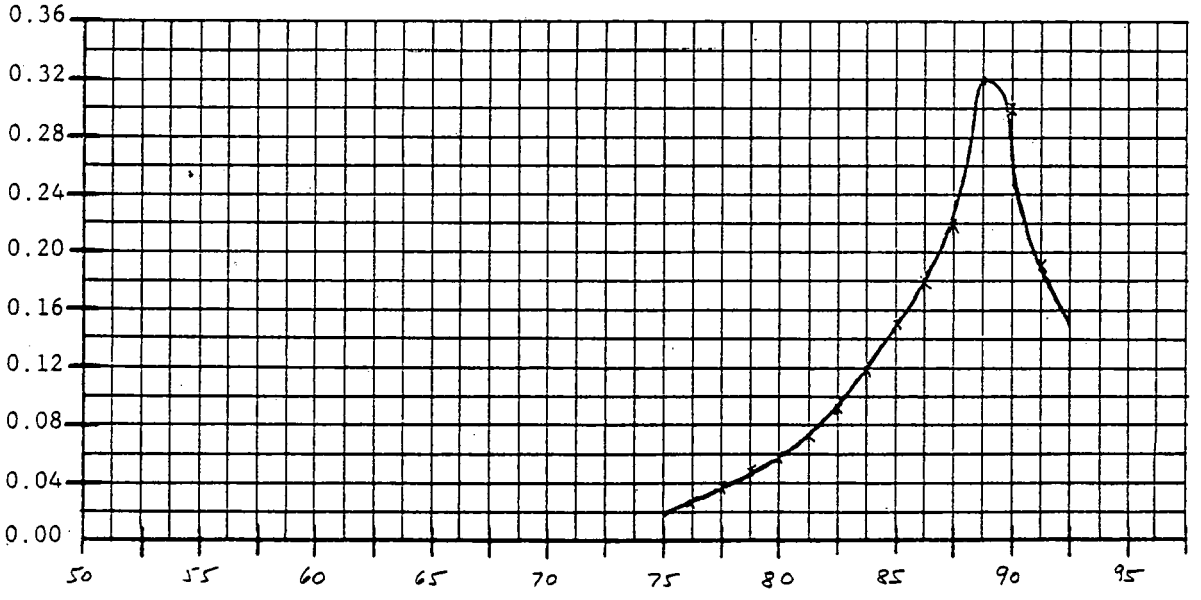



QUANTITY ONSTREAM FACTOR
SUBJECT D

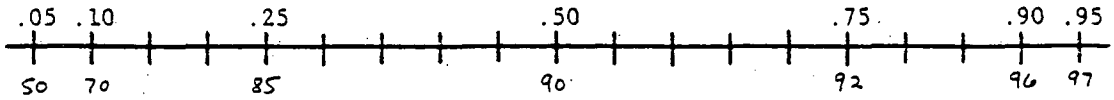
DATE 8/8/79

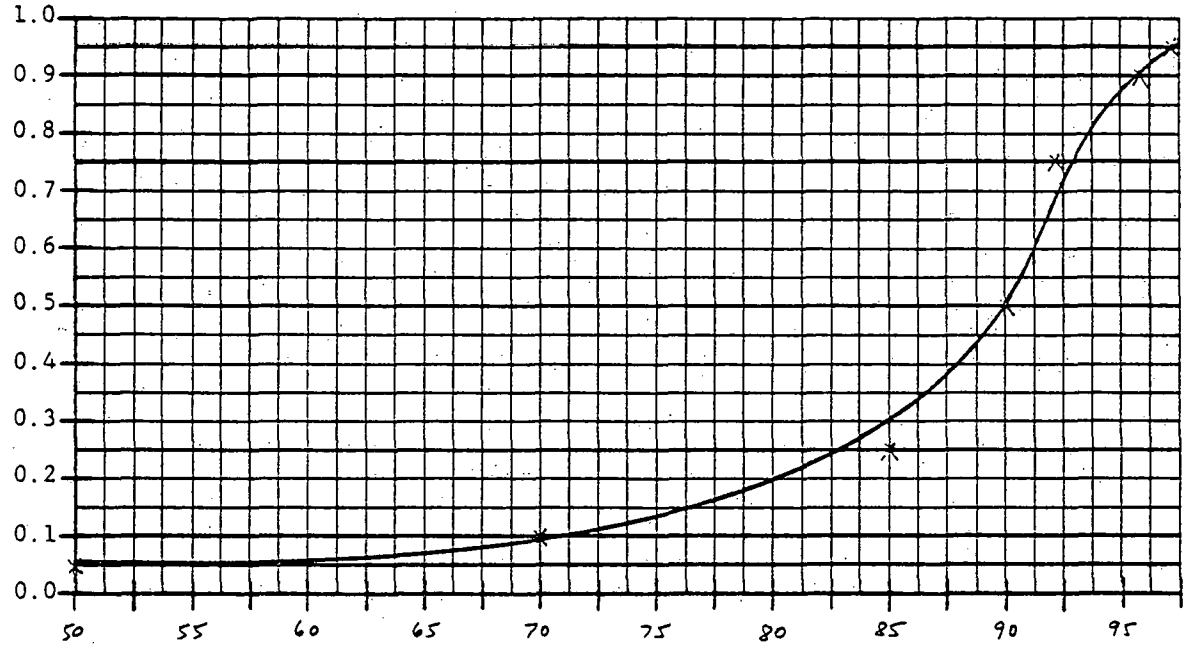
| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 75 | 80 | 84 | 88 | 90 | 91 | 92 |

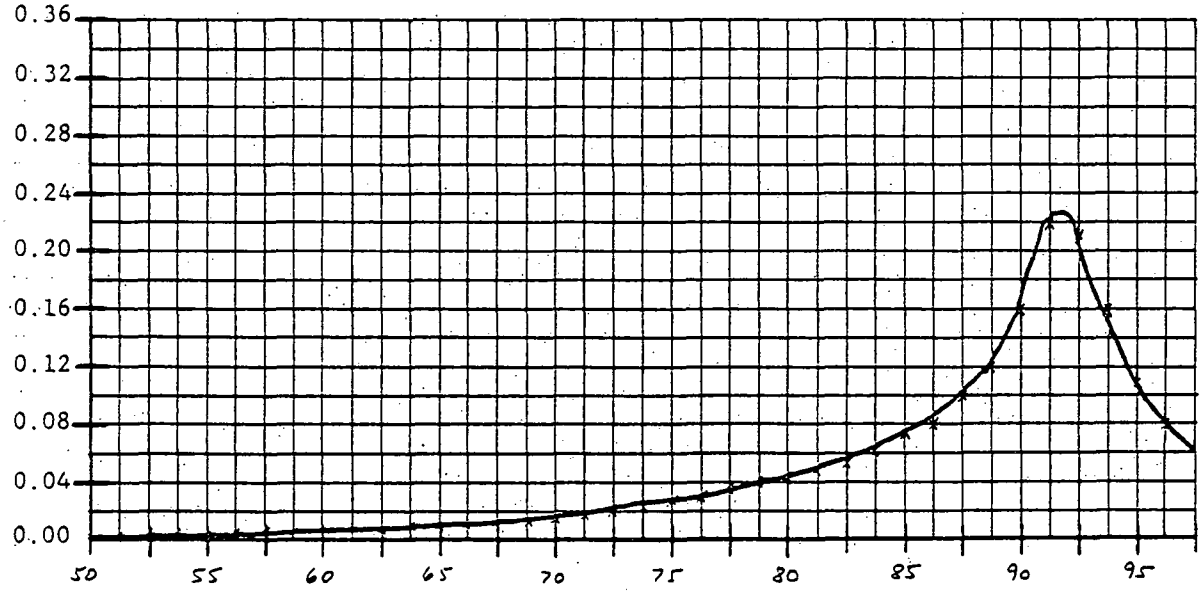


QUANTITY ON STREAM FACTOR
SUBJECT E
DATE 8/8/79

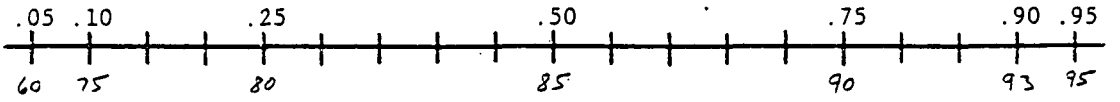


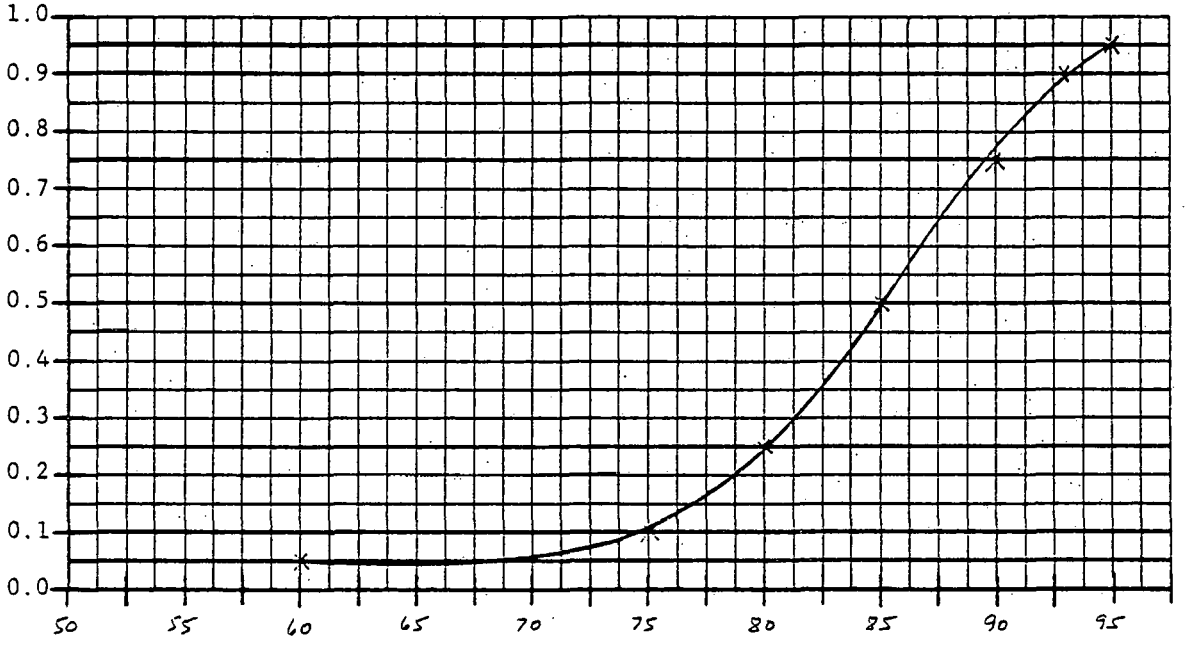



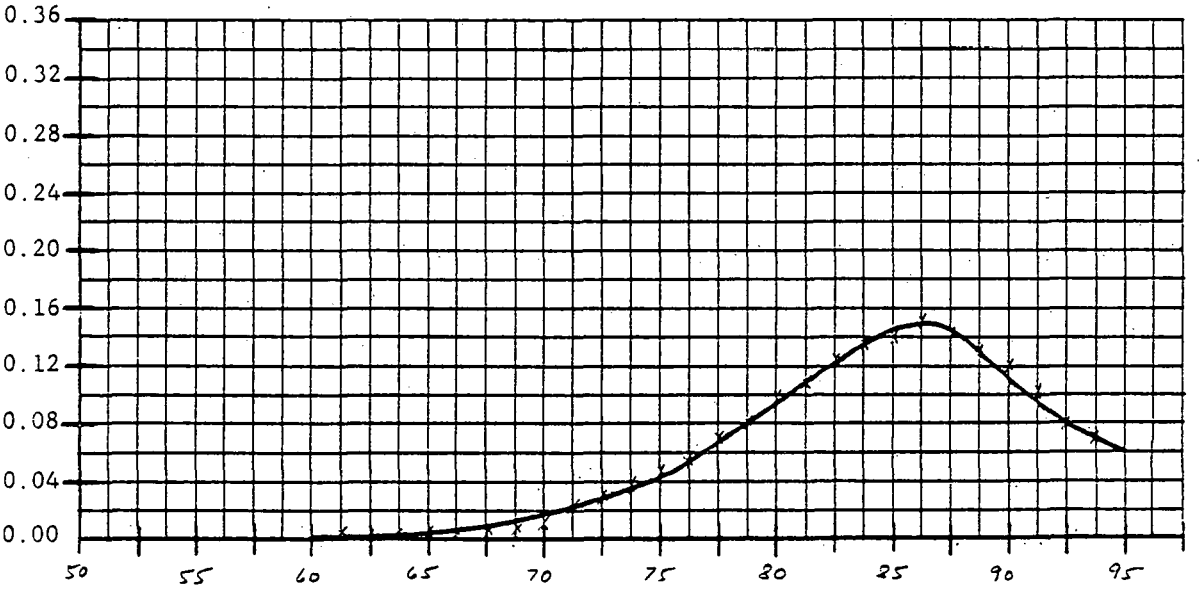



QUANTITY ONSTREAM FACTOR
SUBJECT F

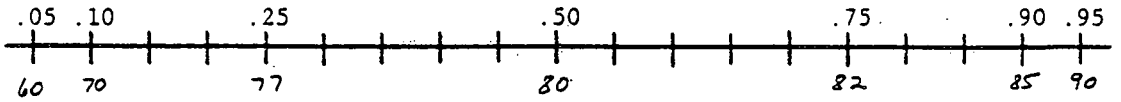
DATE 8/9/79

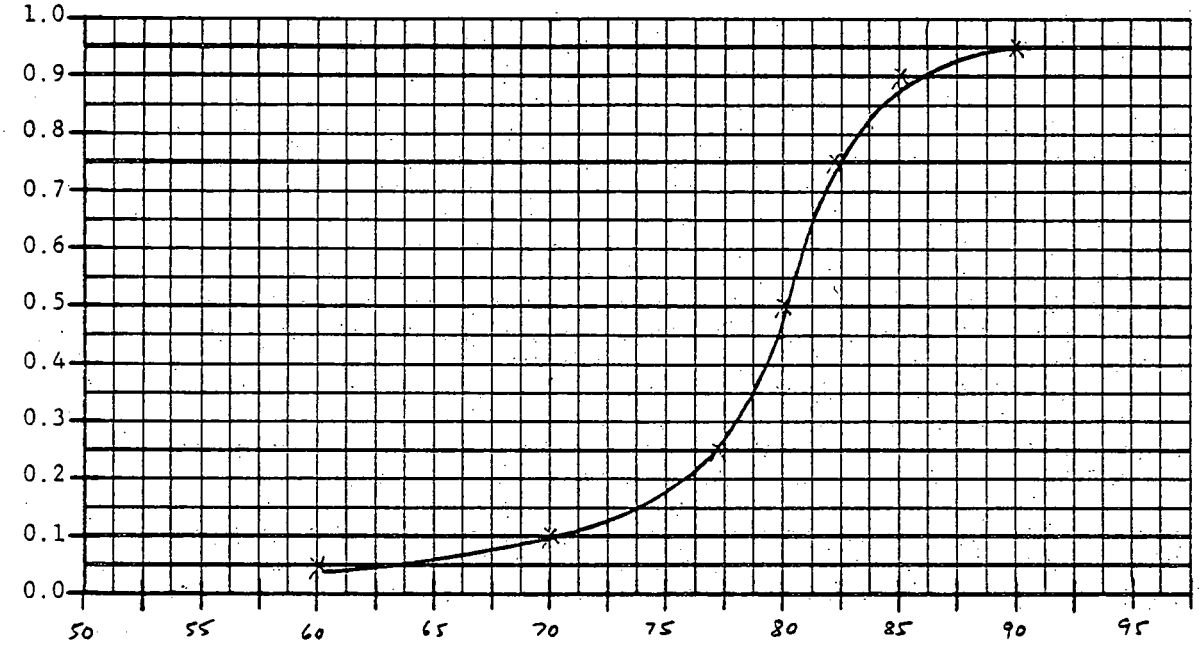


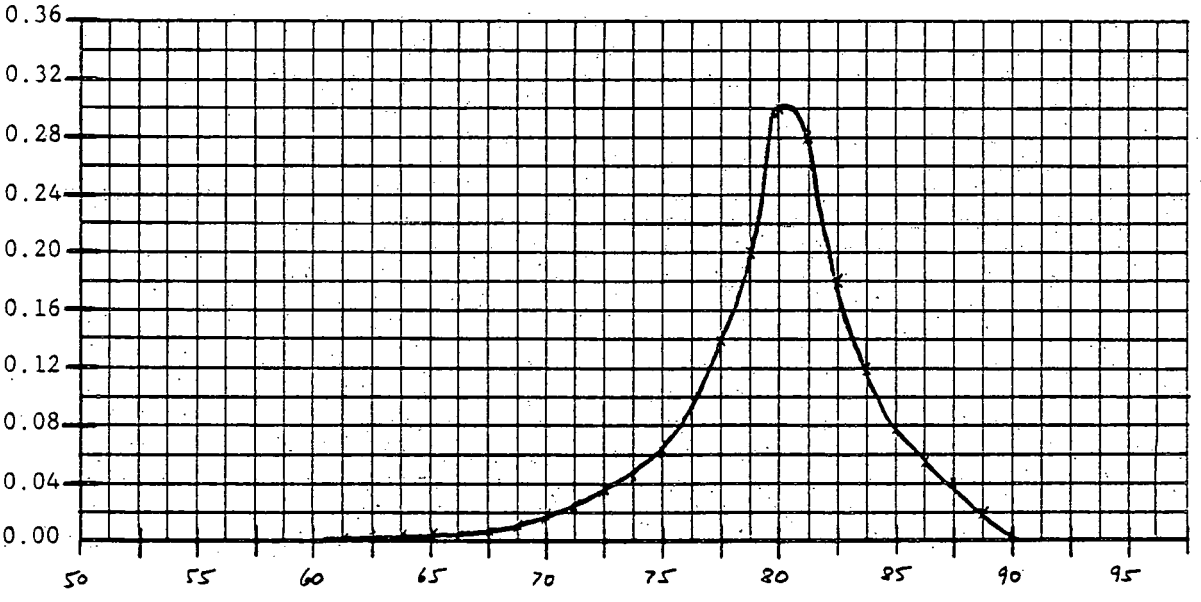



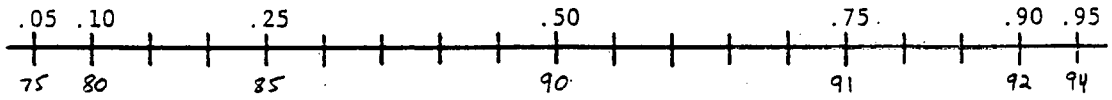
QUANTITY ON STREAM FACTOR
SUBJECT G
DATE 3/10/79

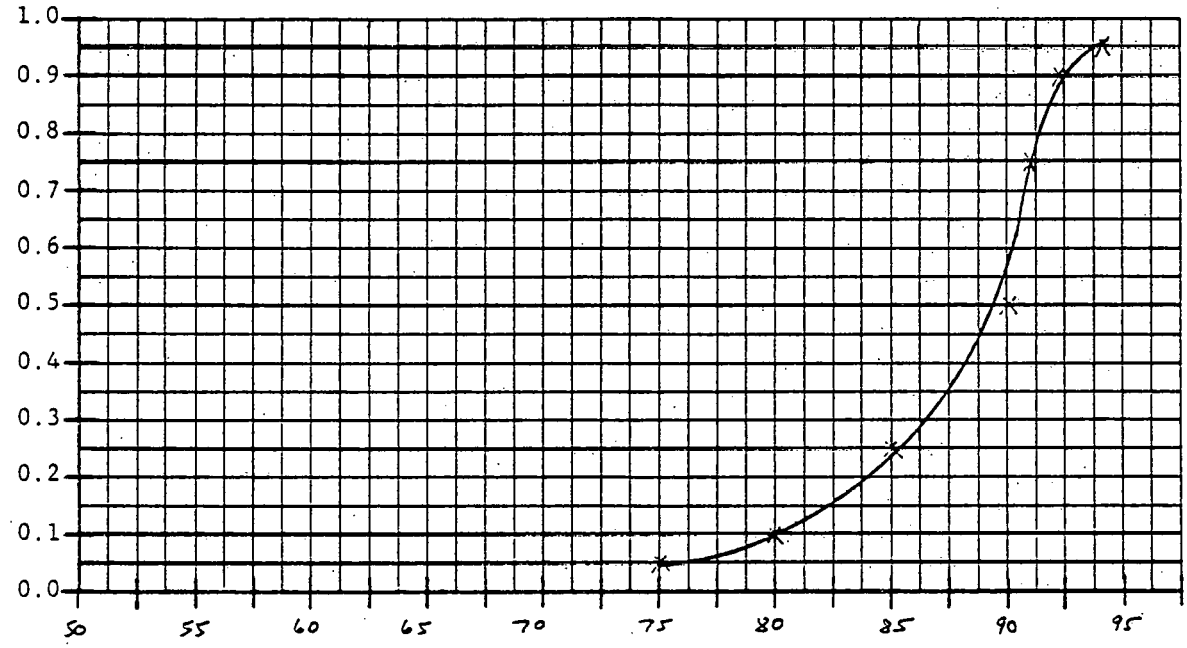


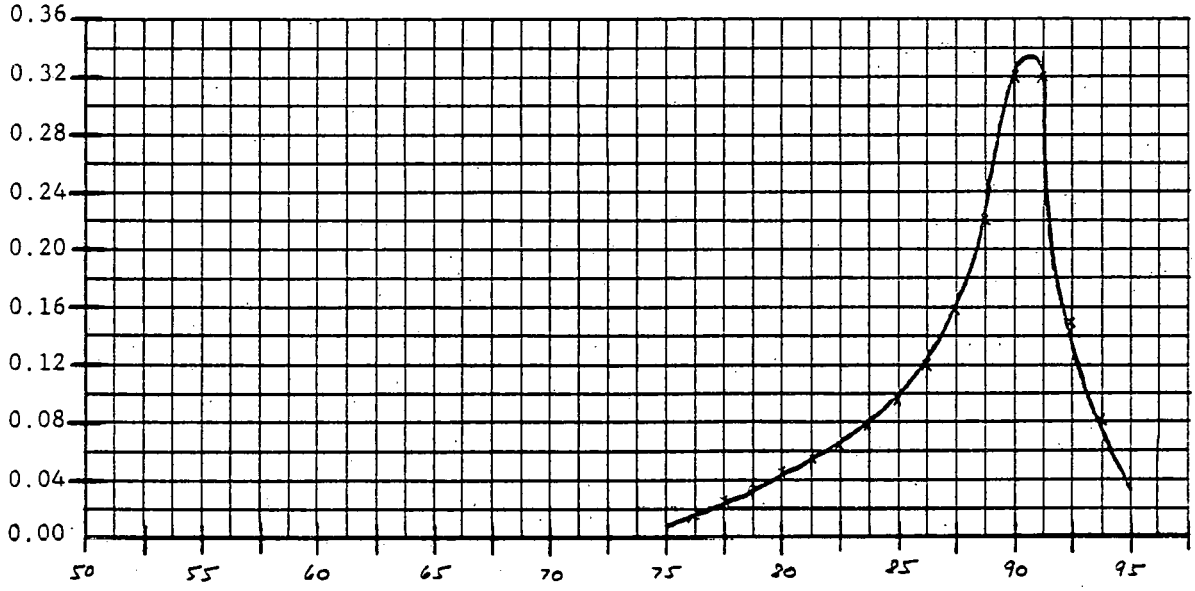



QUANTITY ONSTREAM FACTOR
SUBJECT H
DATE 8/10/79



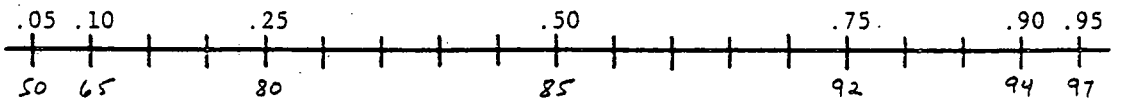



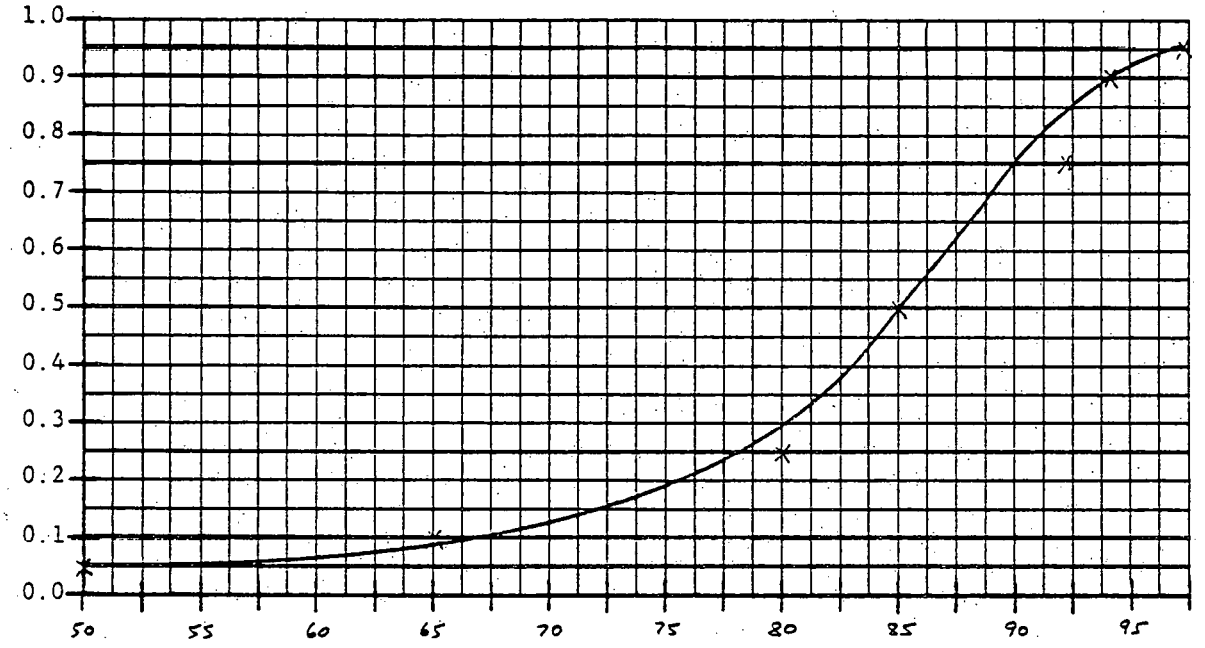



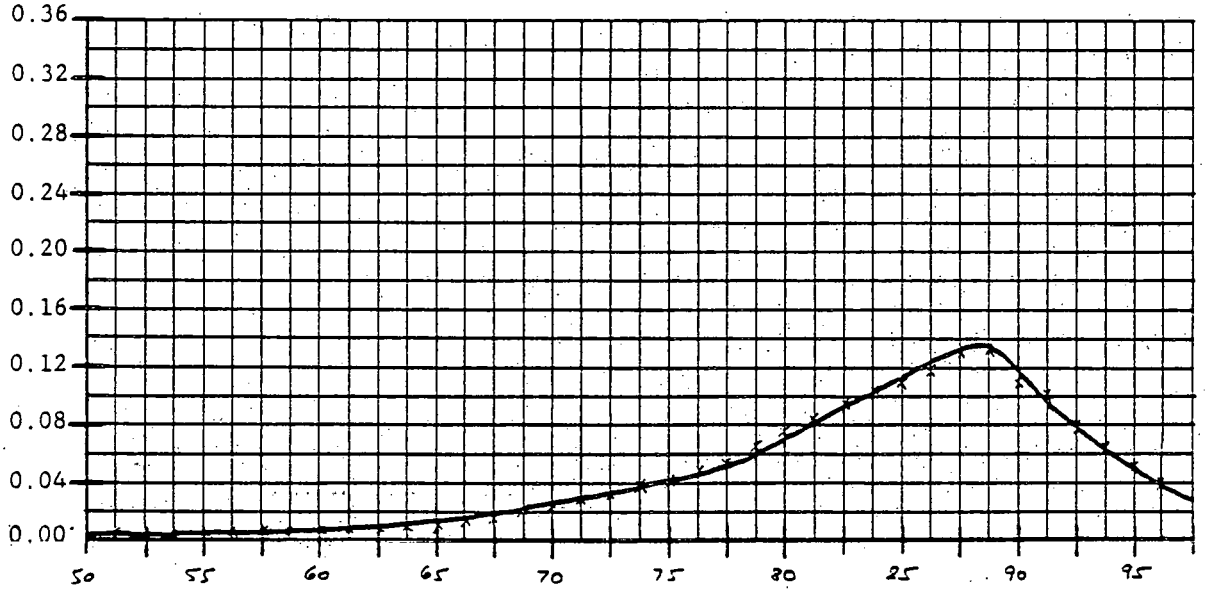
QUANTITY ONSTREAM FACTOR

SUBJECT I

DATE 8/10/79

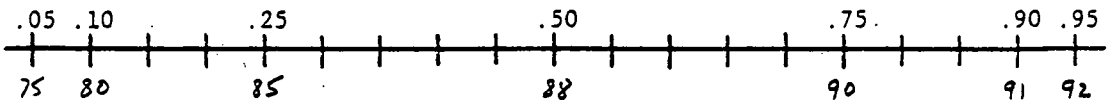


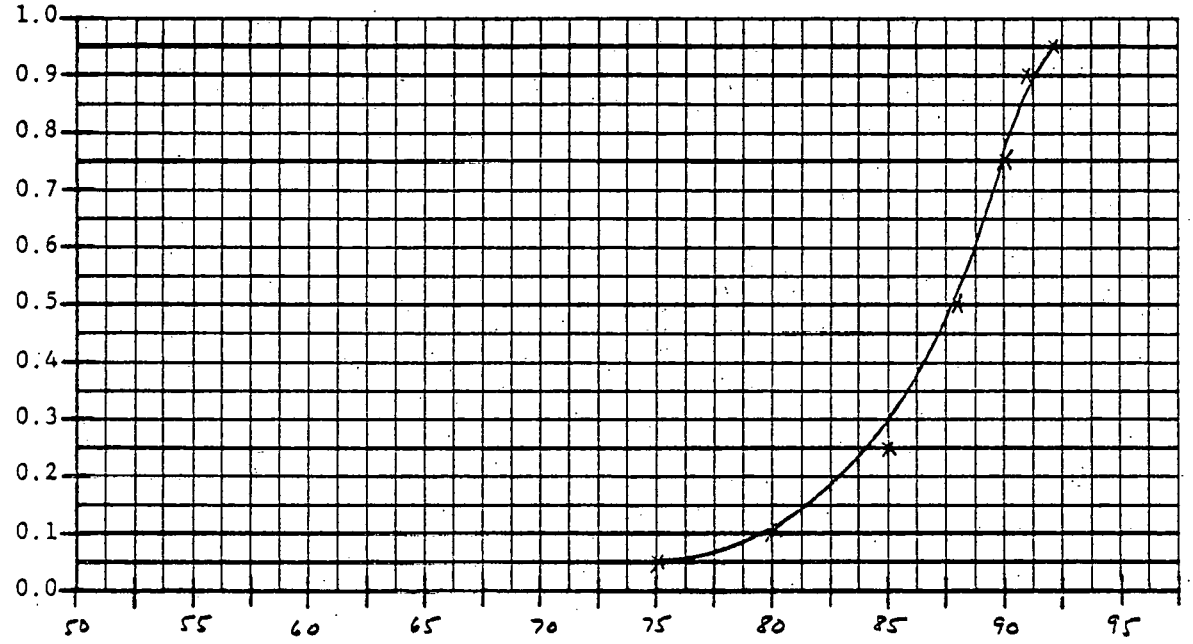



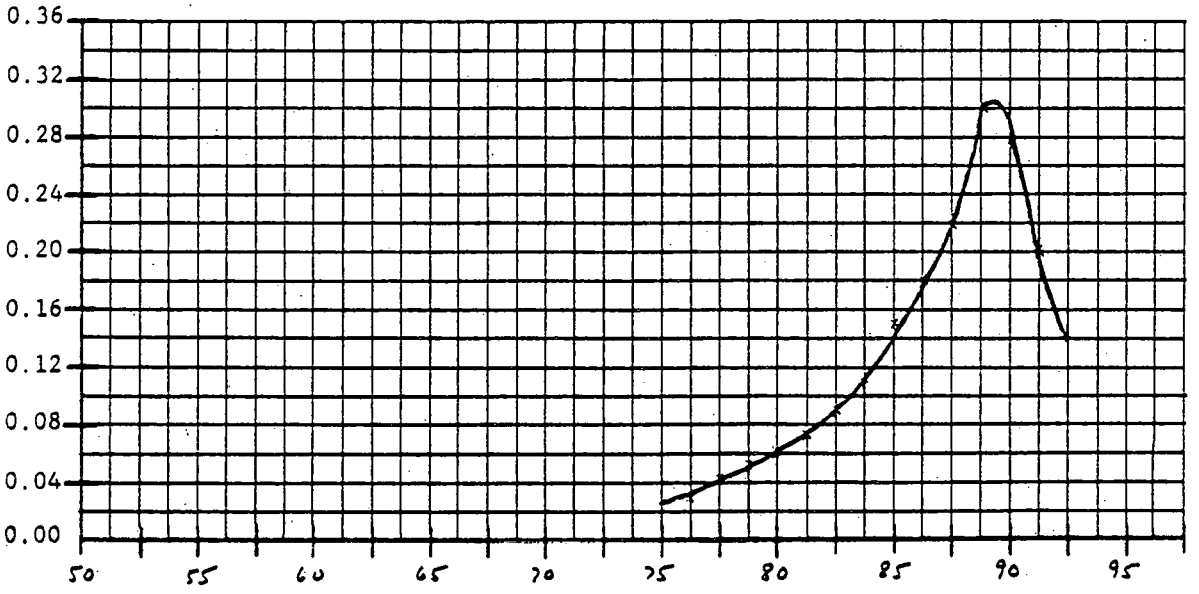



QUANTITY ONSTREAM FACTOR
SUBJECT K

DATE 8/13/79



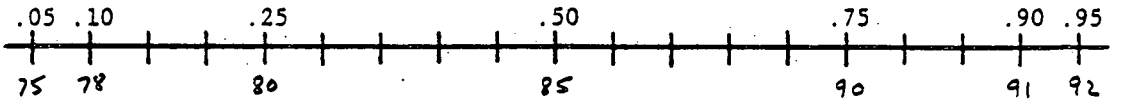



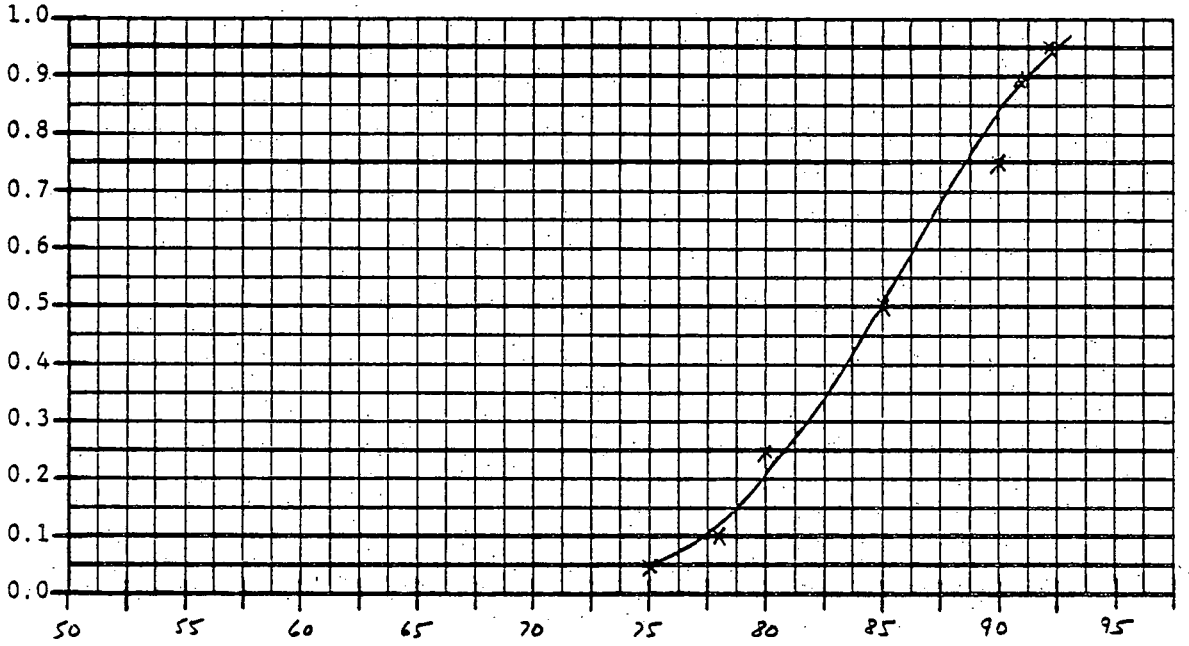



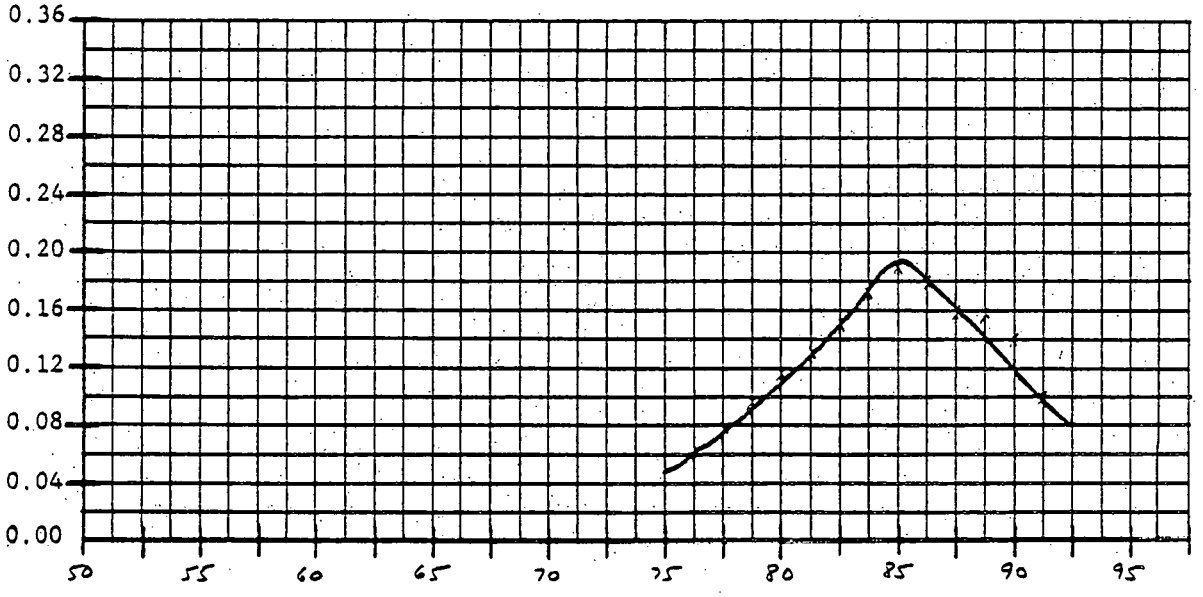
QUANTITY ONSTREAM FACTOR

SUBJECT L

DATE 8/14/79

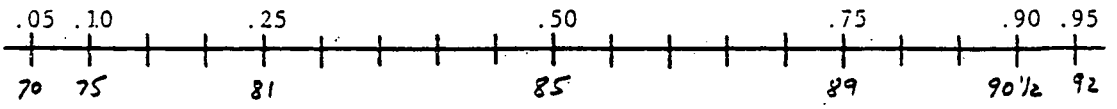


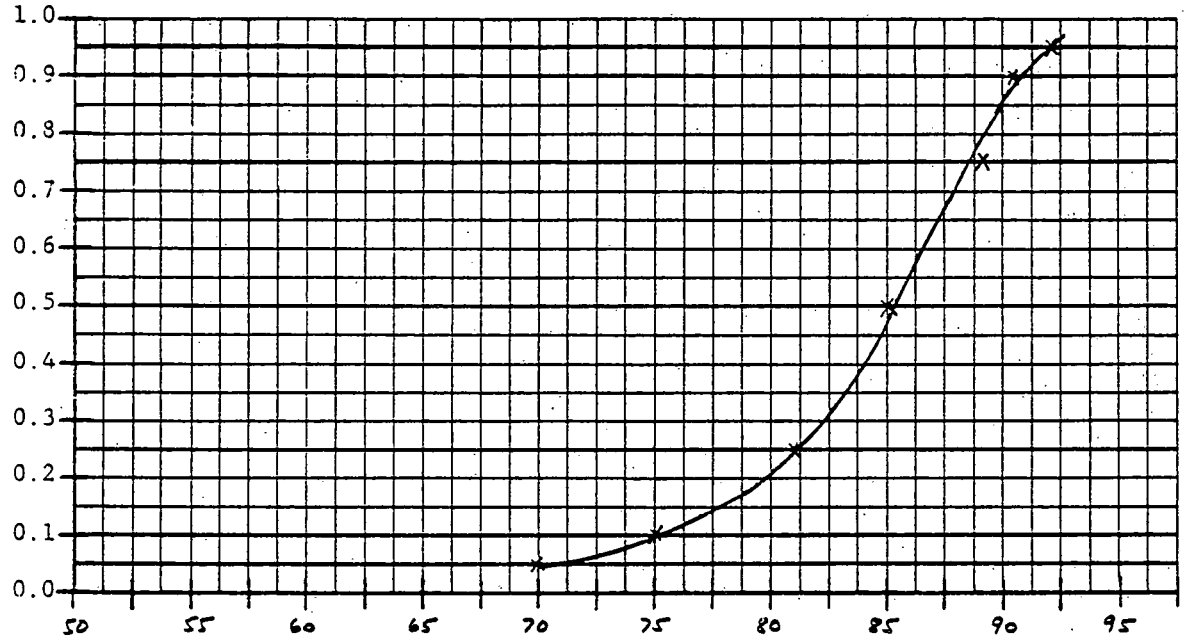



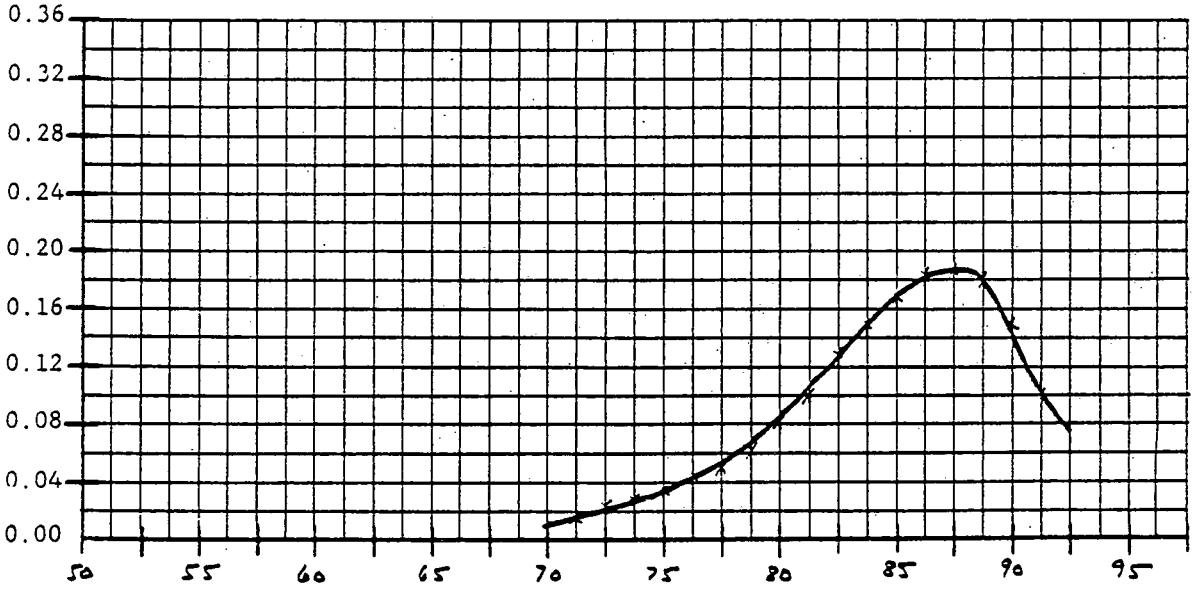



QUANTITY ONSTREAM FACTOR
SUBJECT m

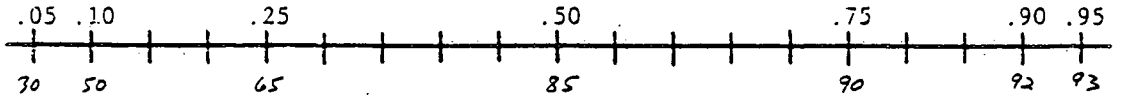
DATE 8/14/79

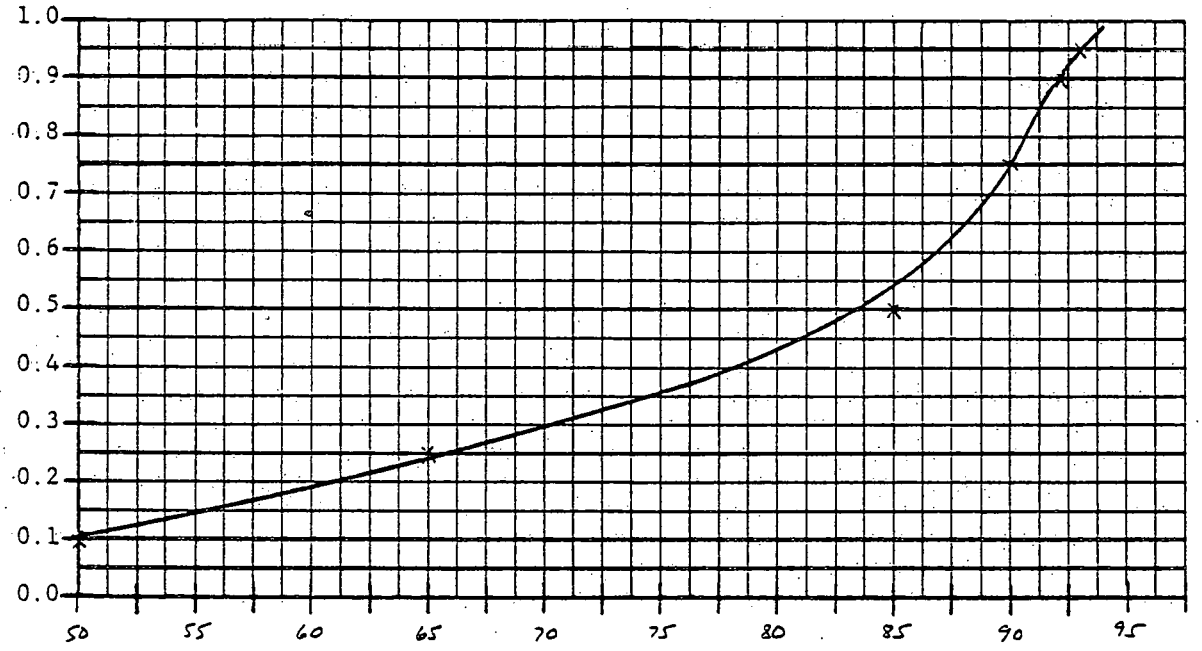


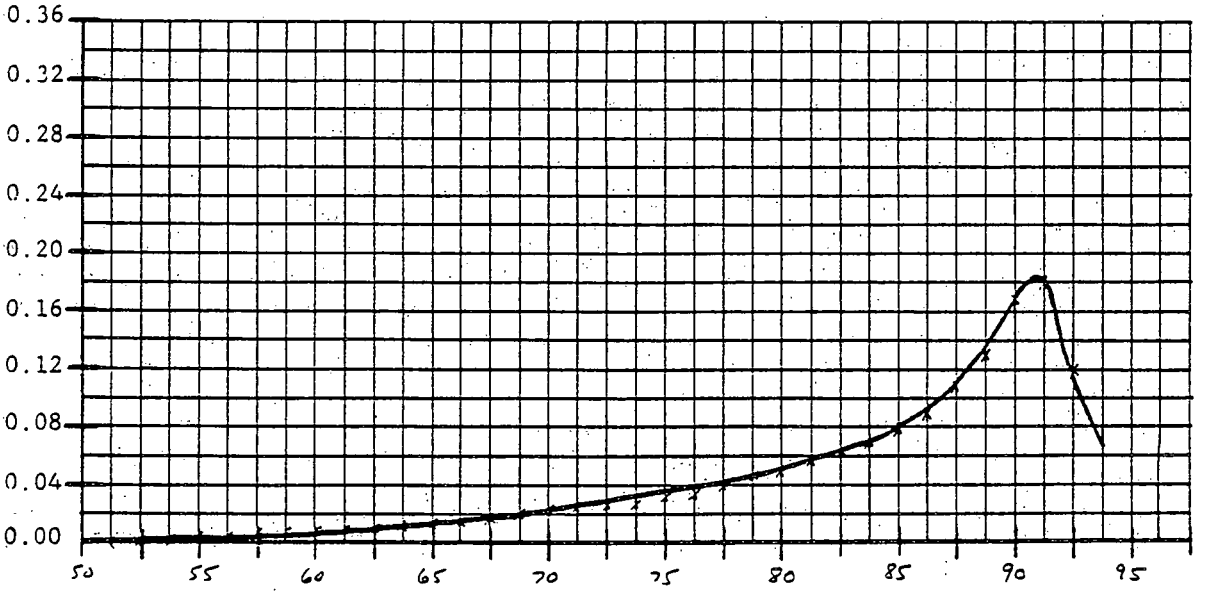



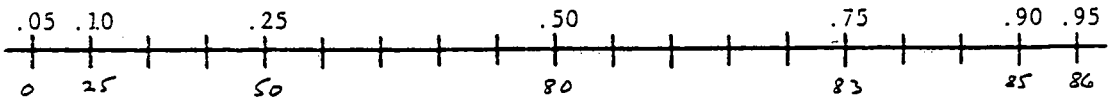
QUANTITY ONSTREAM FACTOR
SUBJECT N
DATE 8/15/79

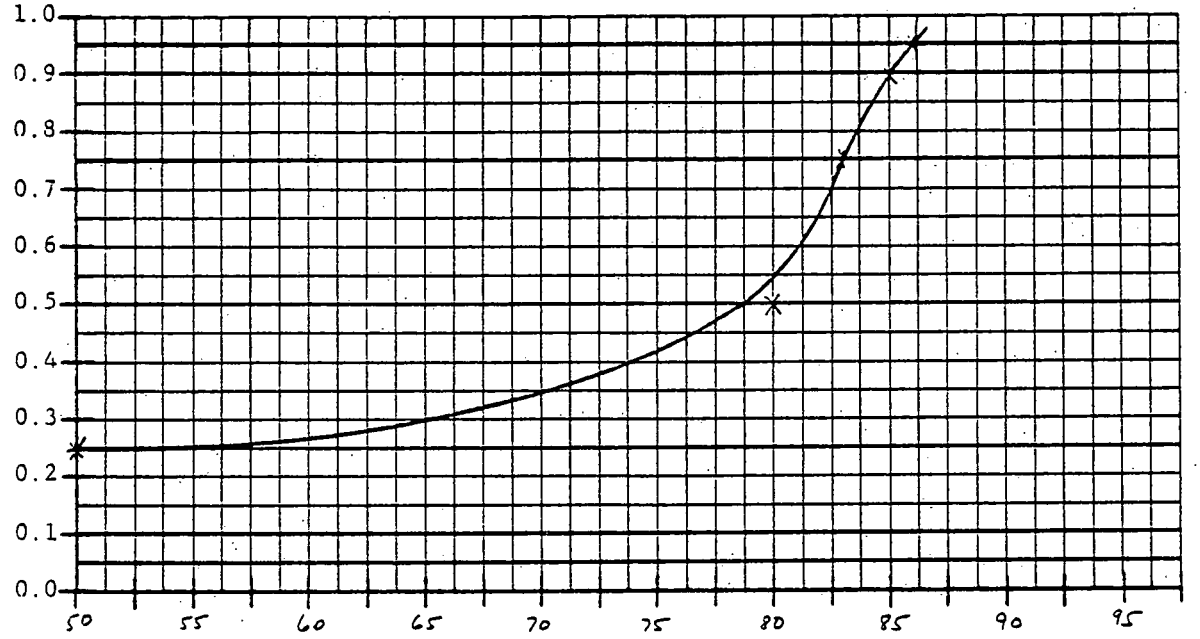


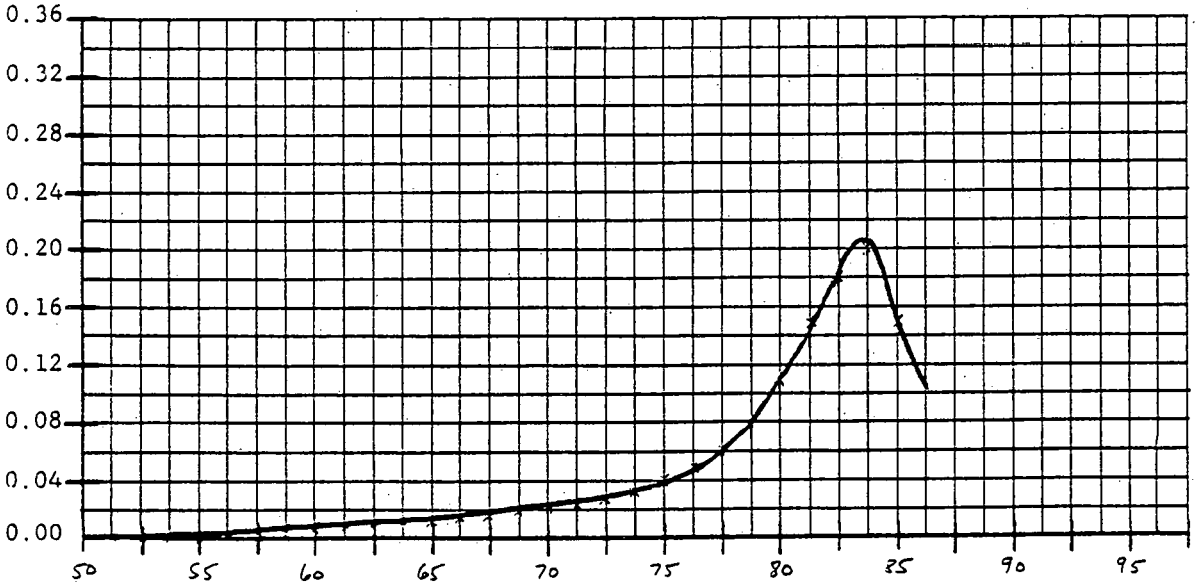



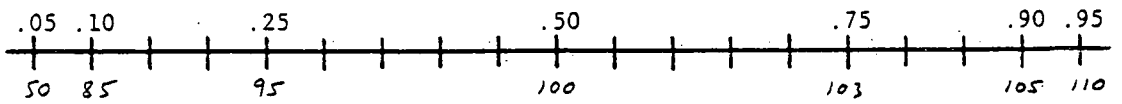
QUANTITY ONSTREAM FACTOR
SUBJECT O
DATE 8/9/79

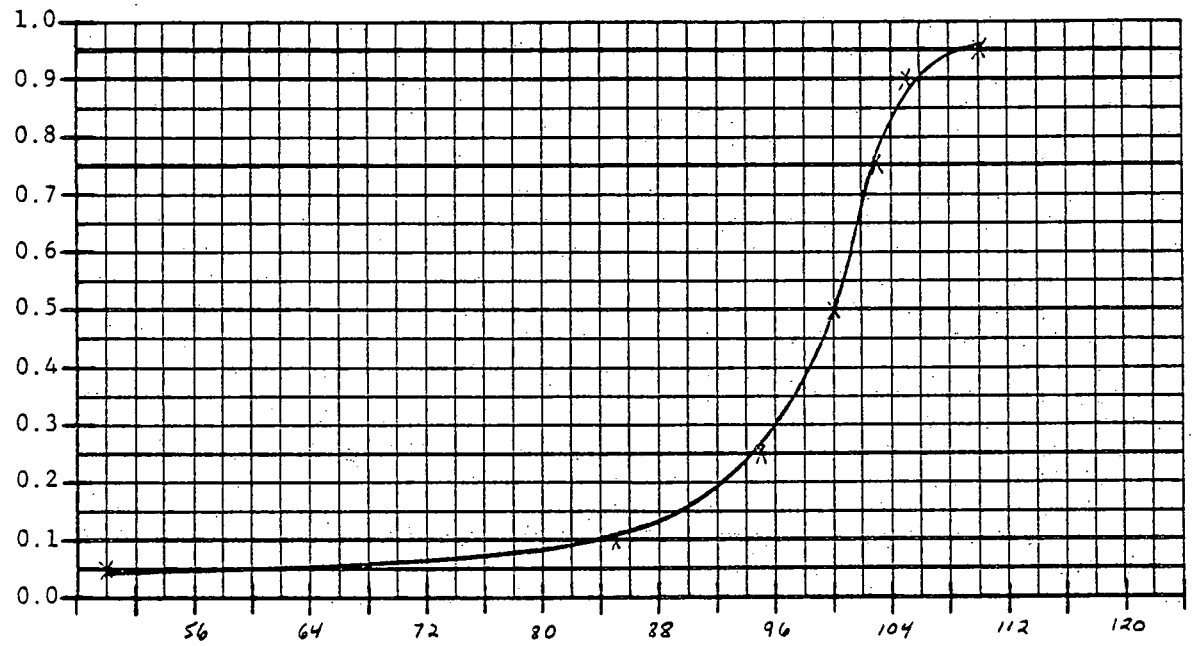


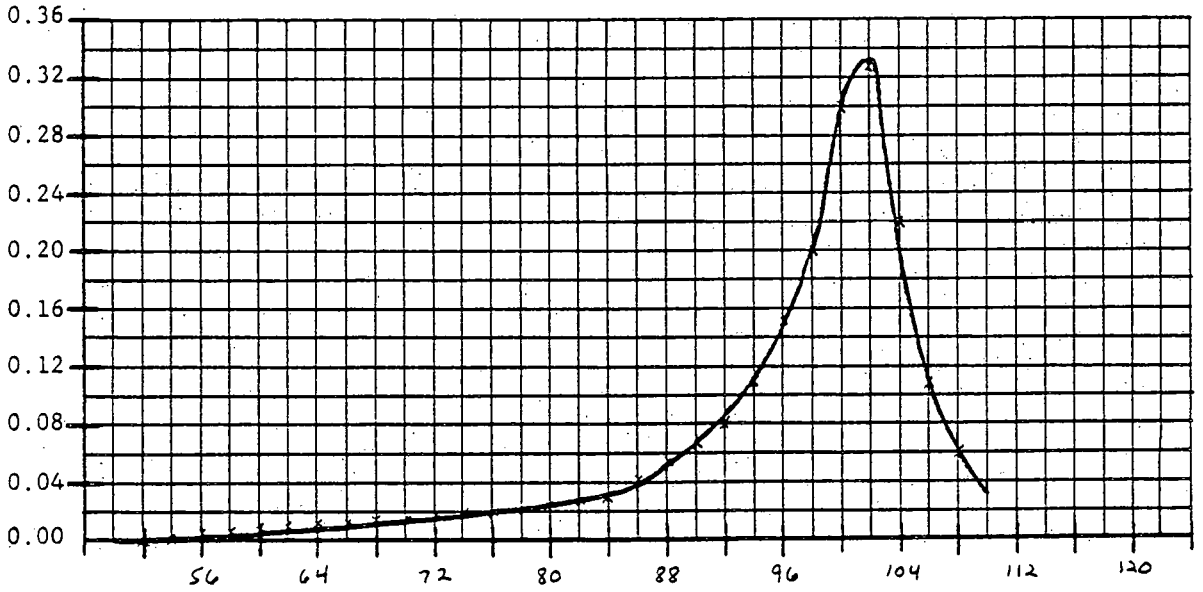



QUANTITY Design Capacity Factor
SUBJECT A
DATE 8/7/79

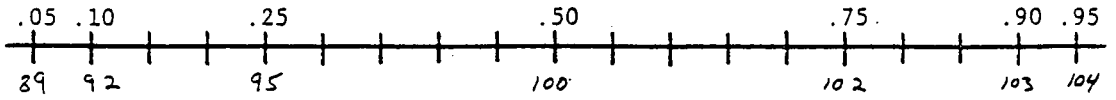


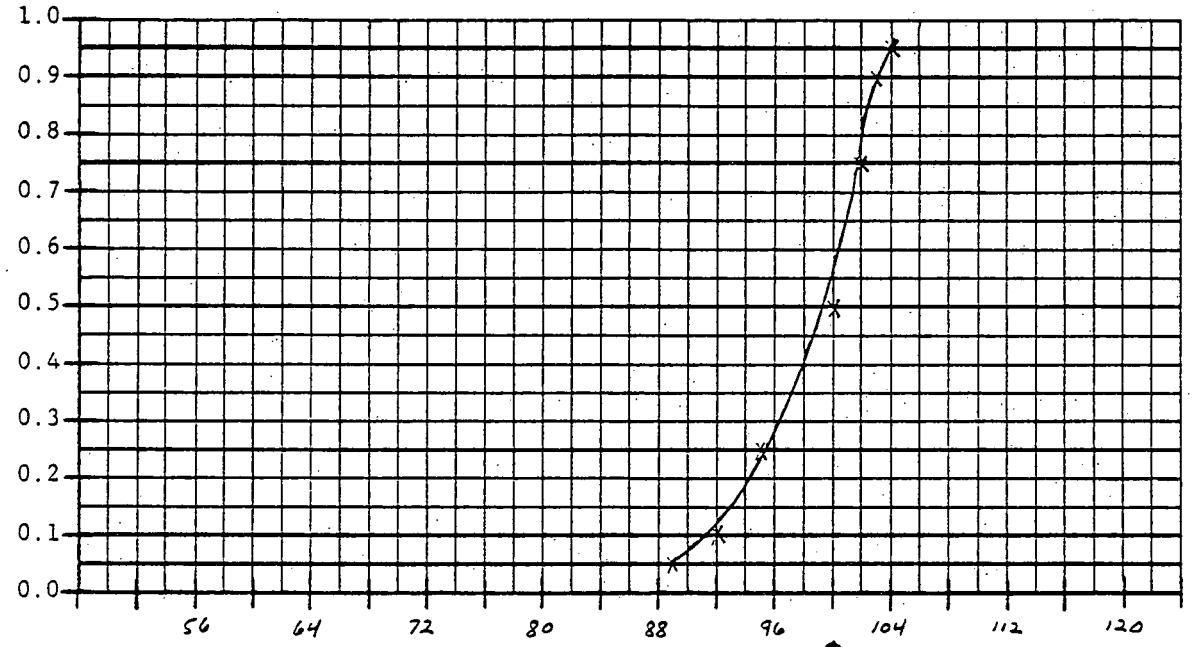



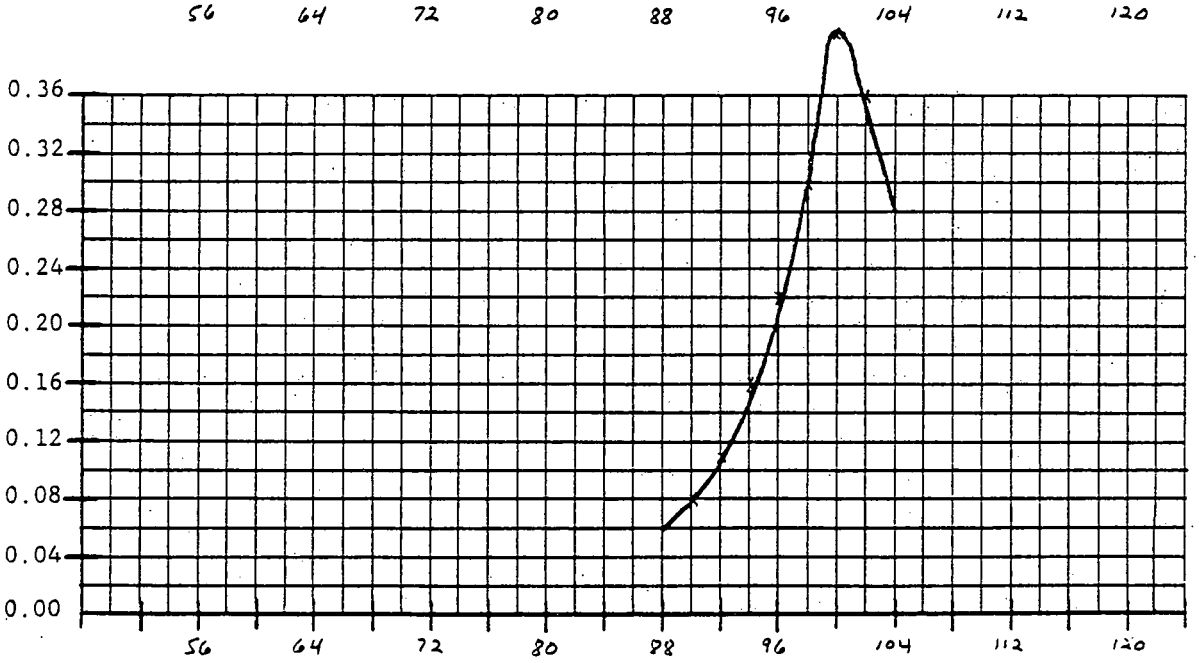



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT C

DATE 8/8/79

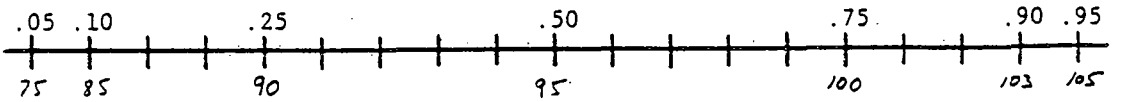


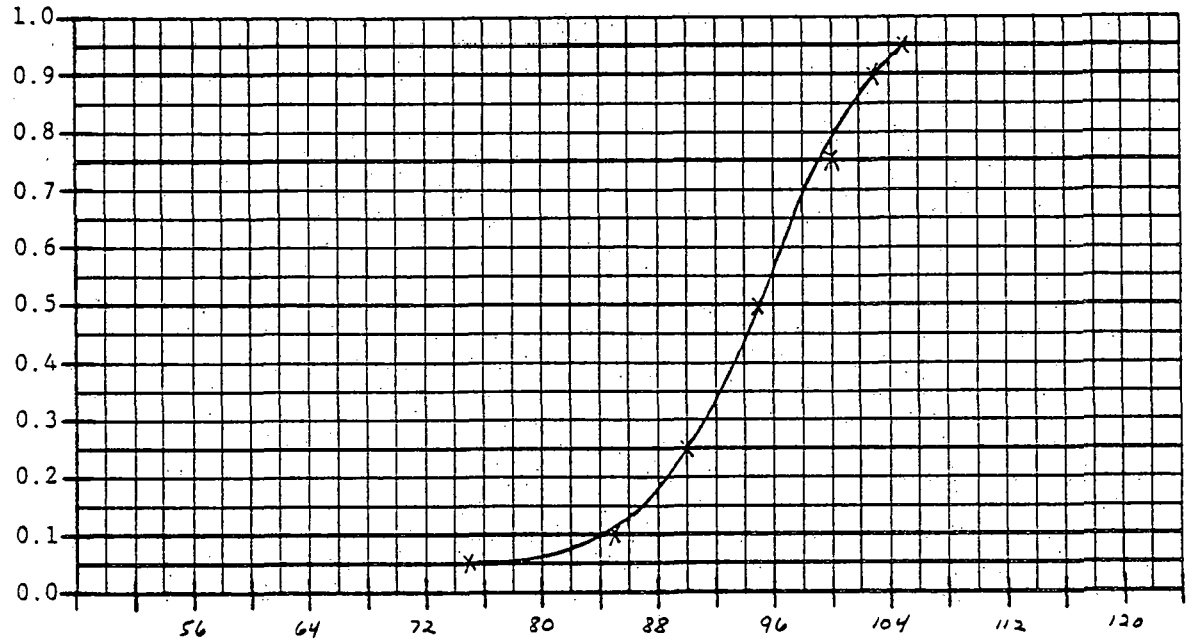



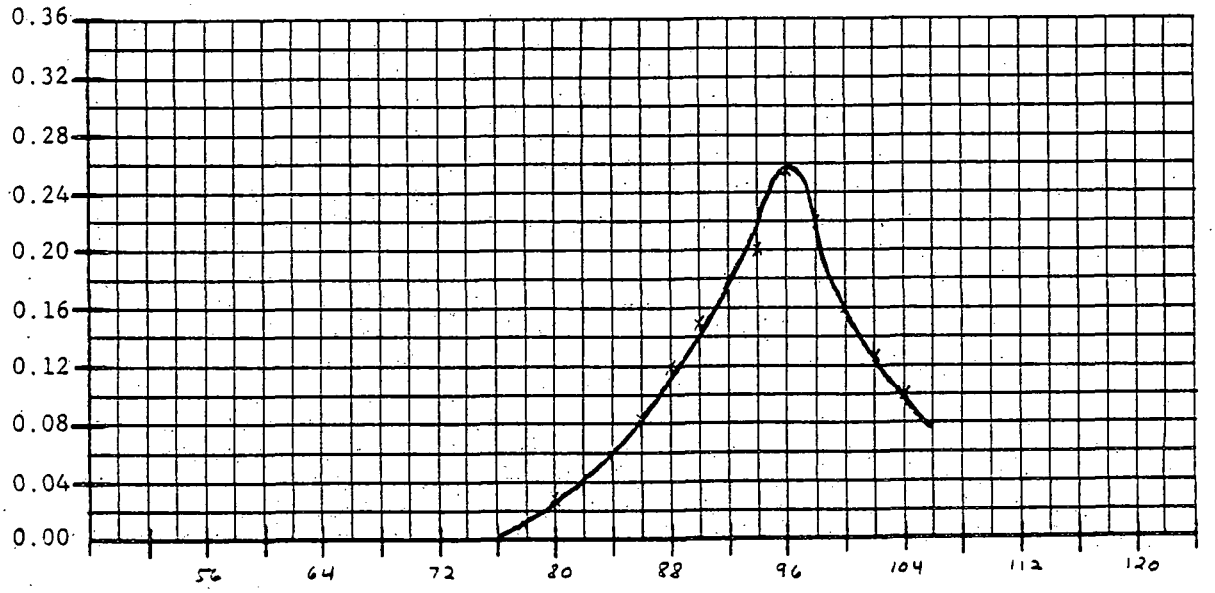



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT D

DATE 8/8/79

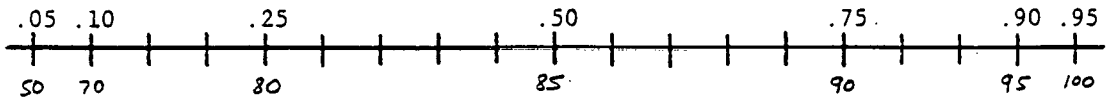


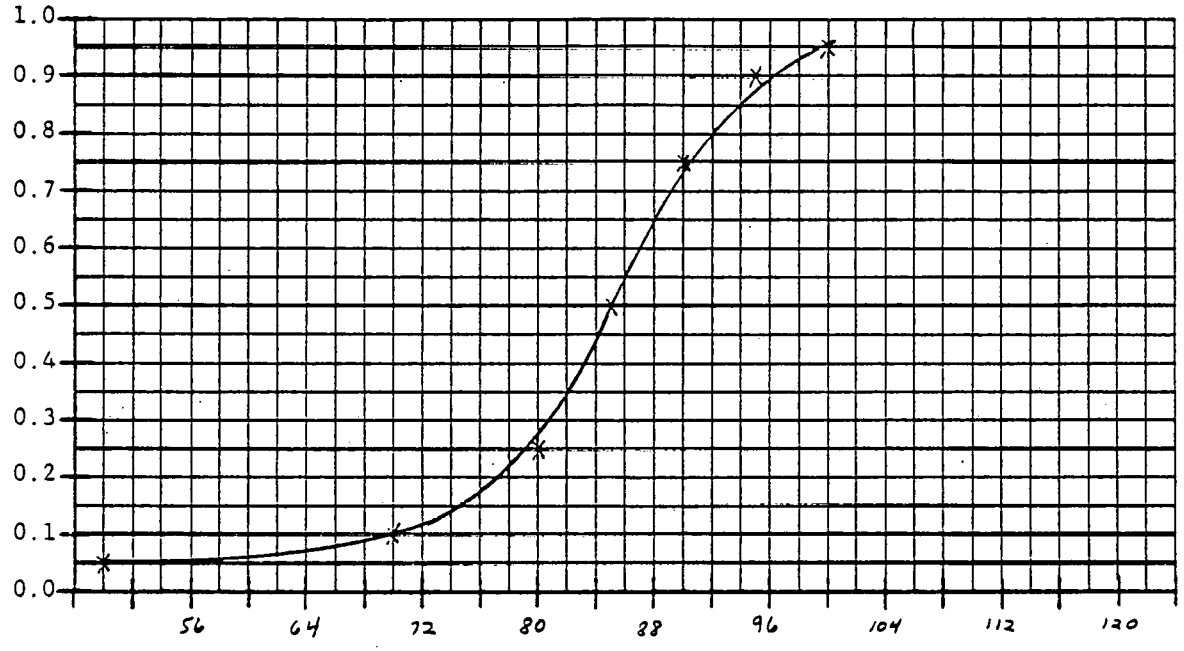



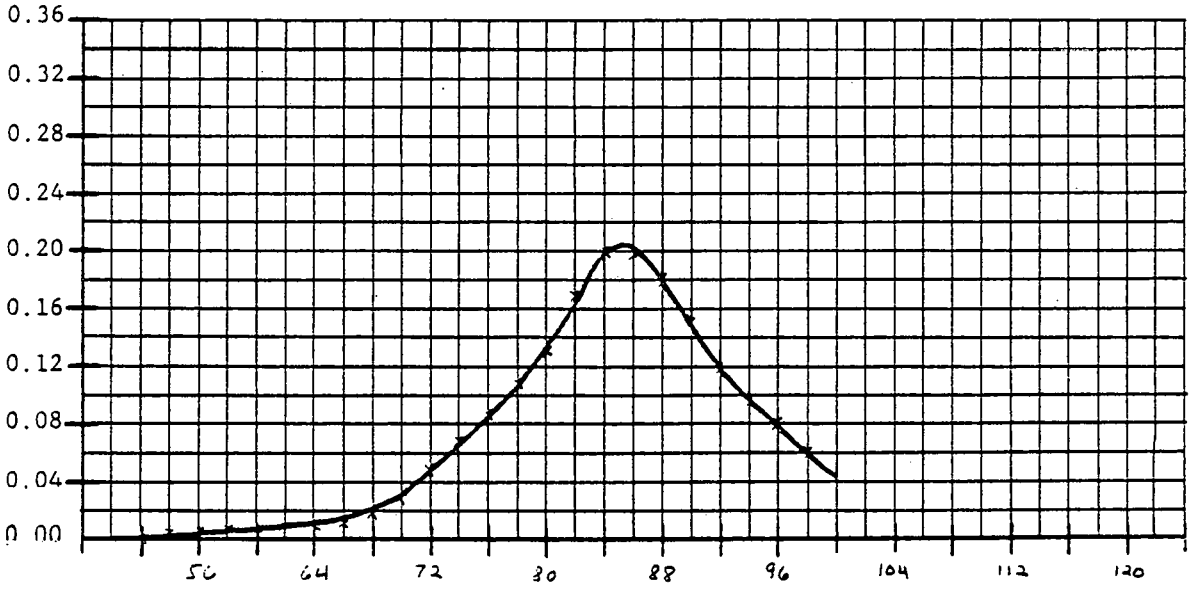



QUANTITY Design Capacity Factor
SUBJECT E

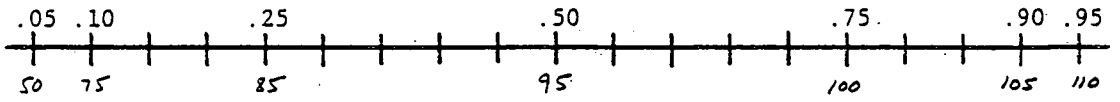
DATE 8/3/79

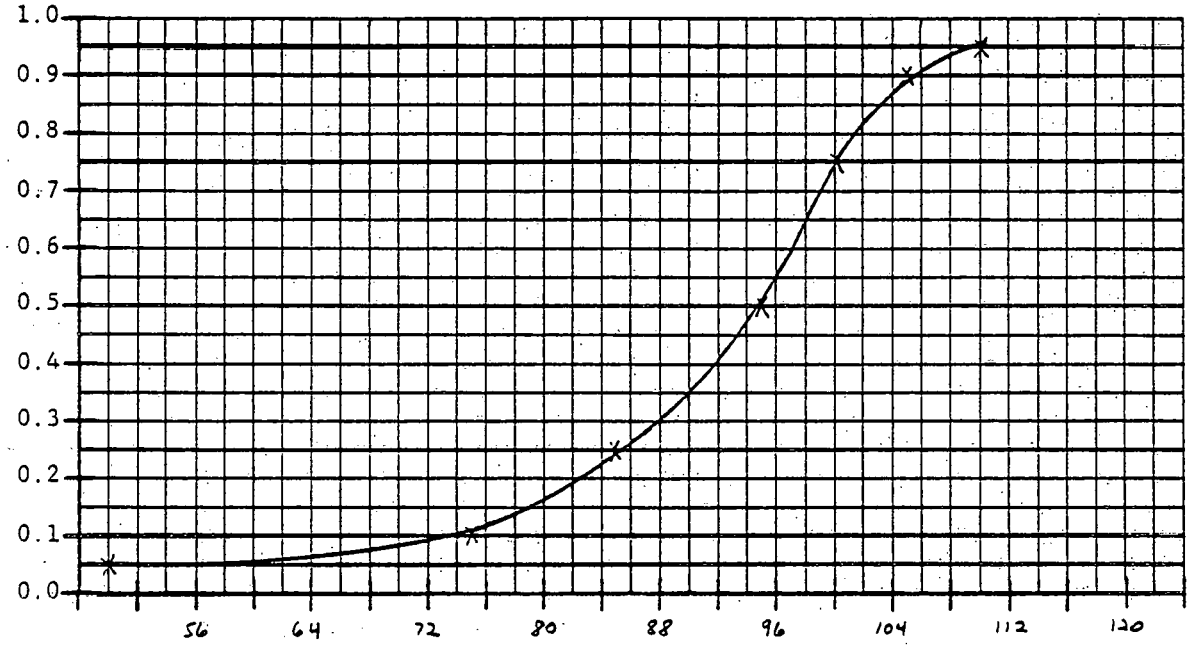


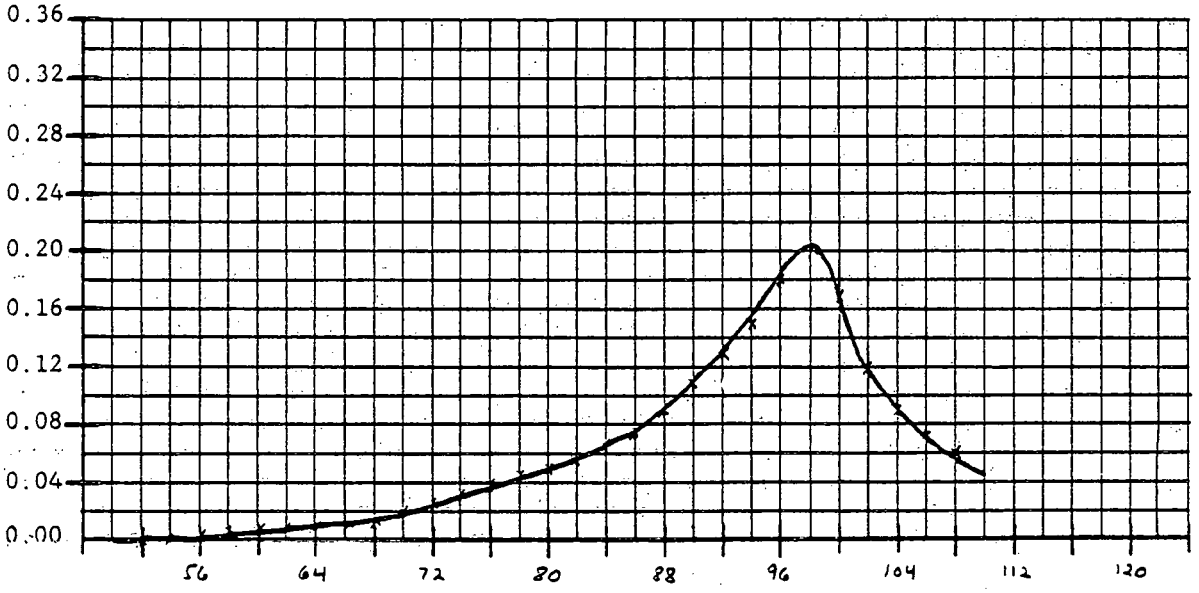



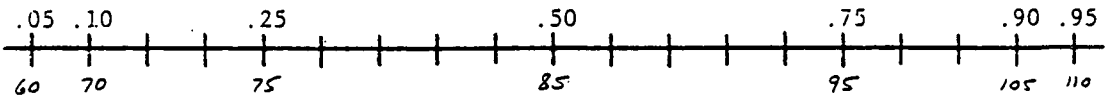
QUANTITY DESIGN CAPACITY FACTOR
SUBJECT F
DATE 8/9/79

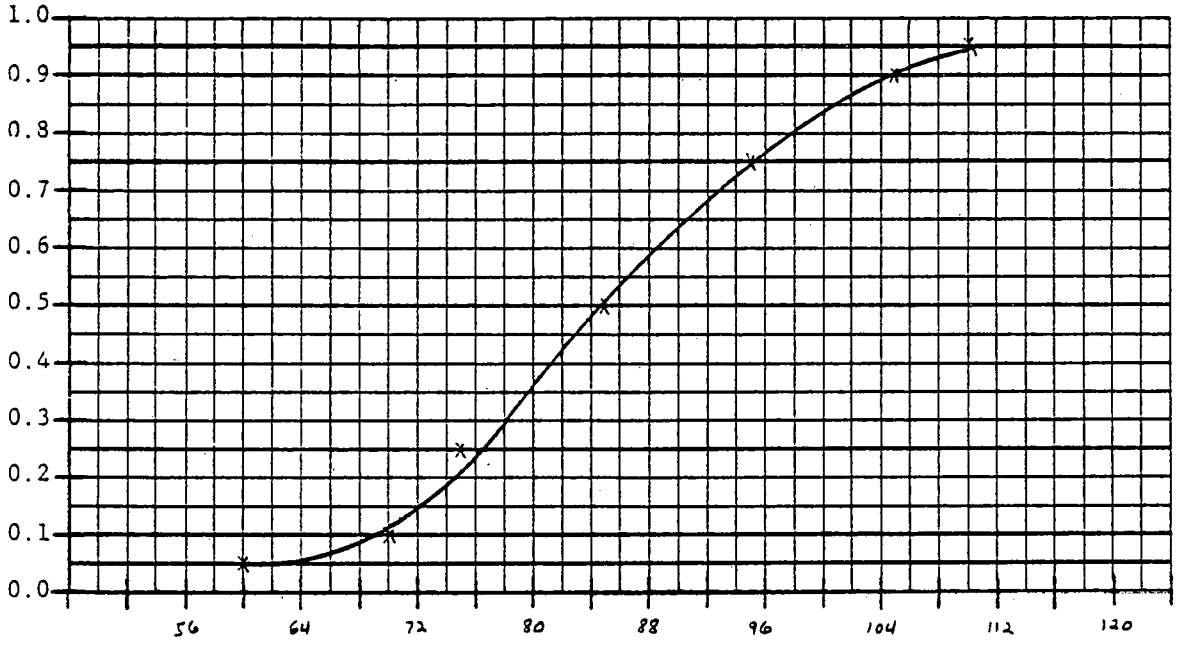


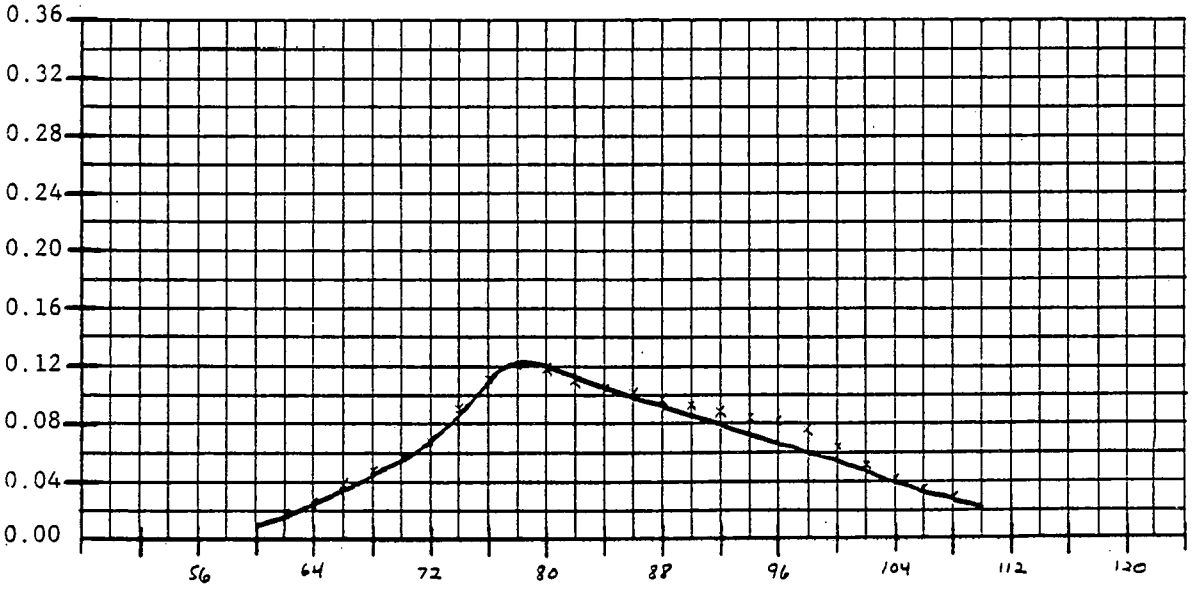



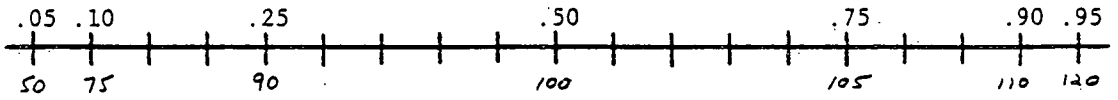
QUANTITY Design Capacity Factor
SUBJECT G
DATE 8/10/79

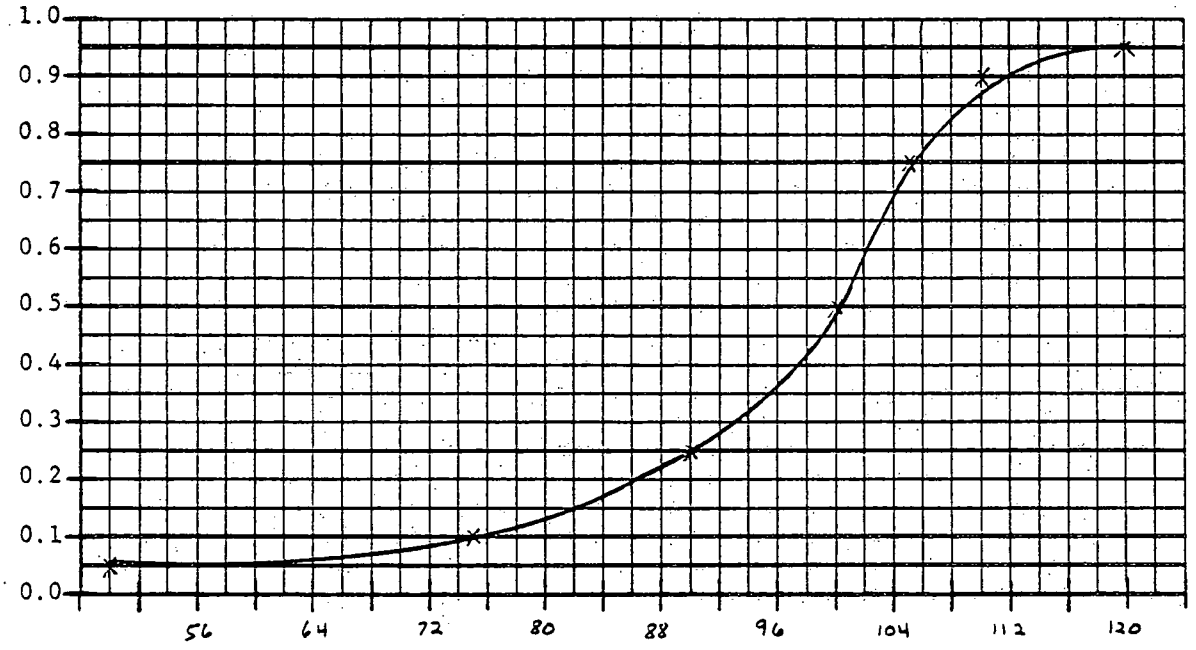


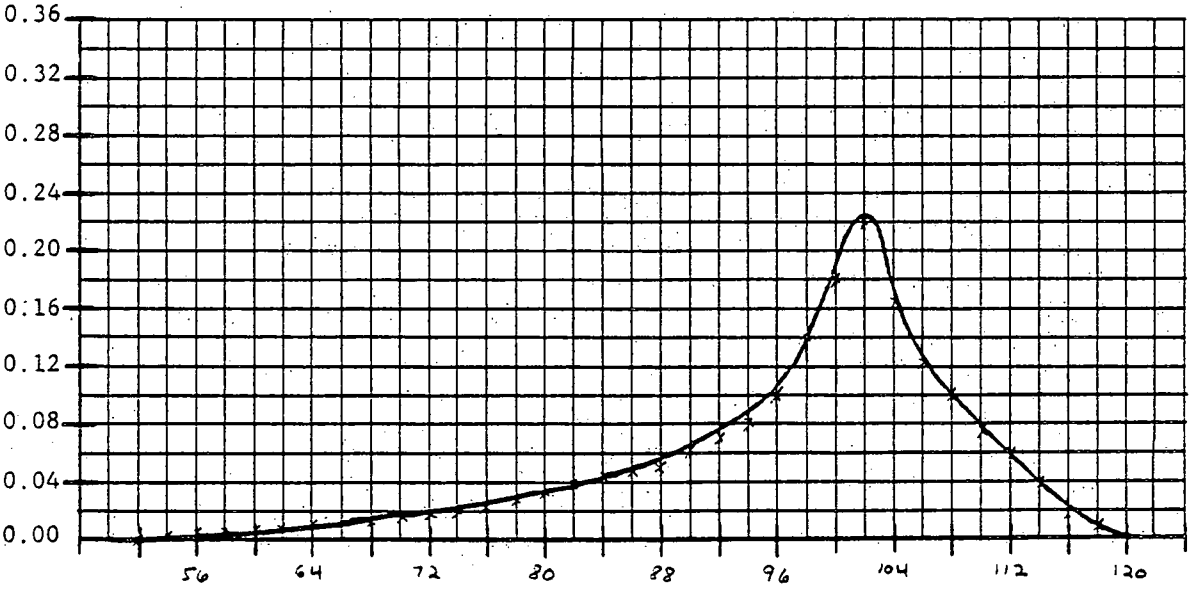



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT H
DATE 8/10/79



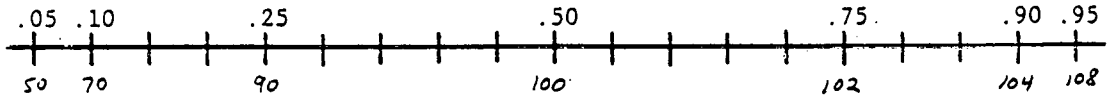



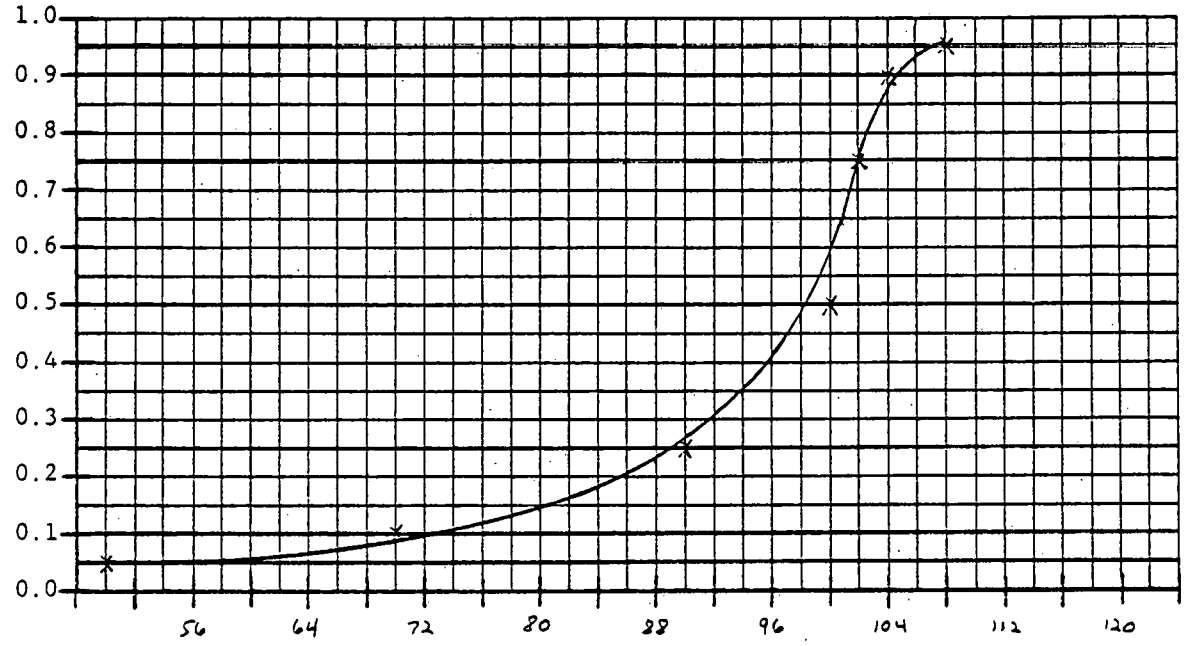



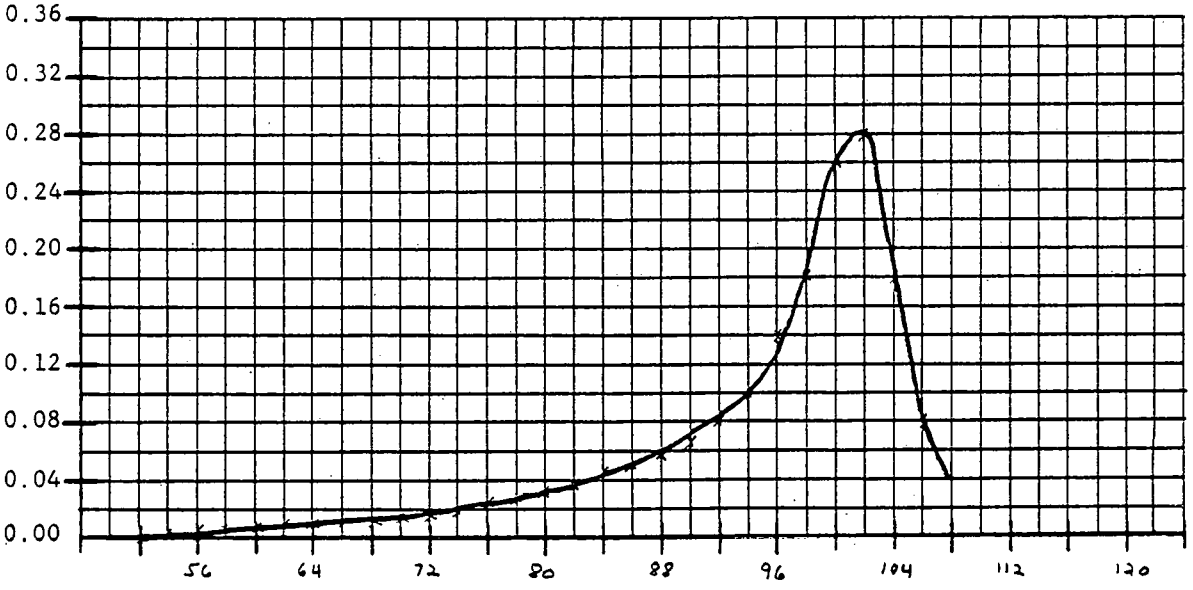
QUANTITY DESIGN CAPACITY FACTOR 71

SUBJECT I

DATE 8/10/79

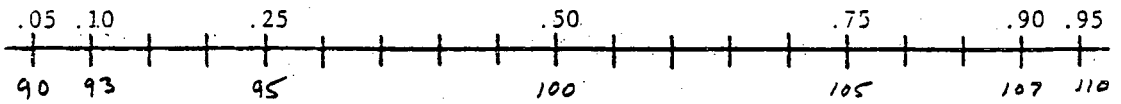


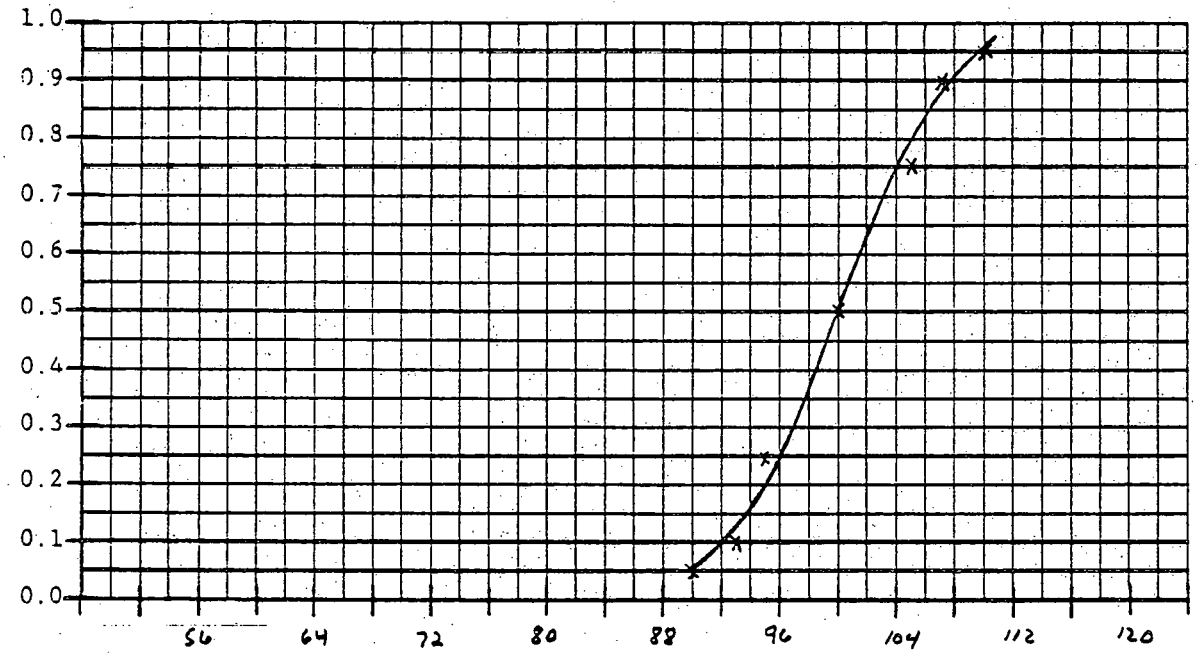



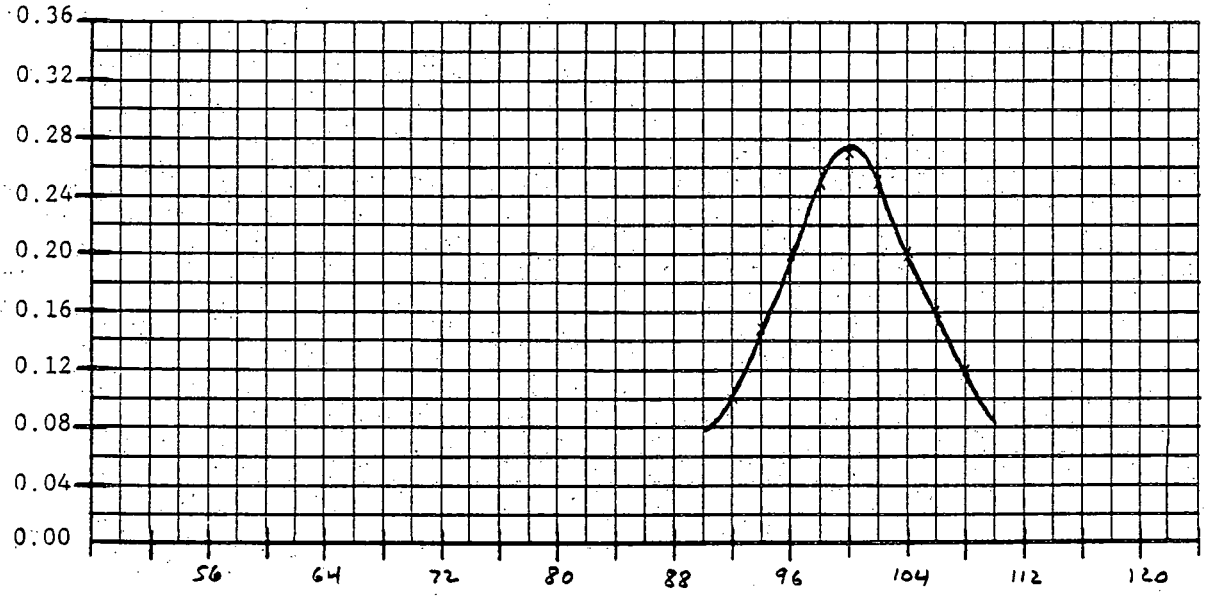



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT K

DATE 8/13/79

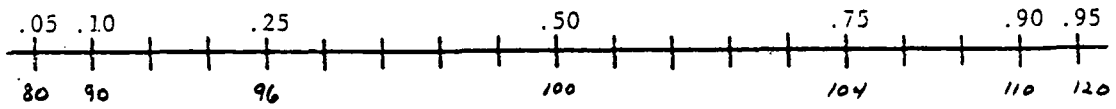


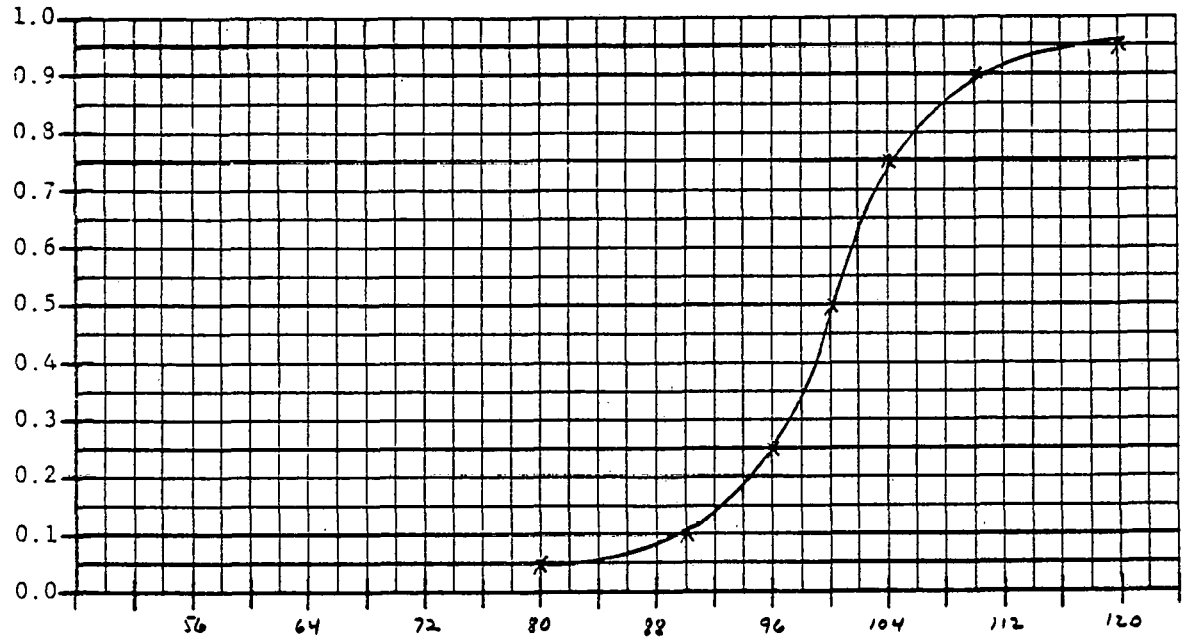



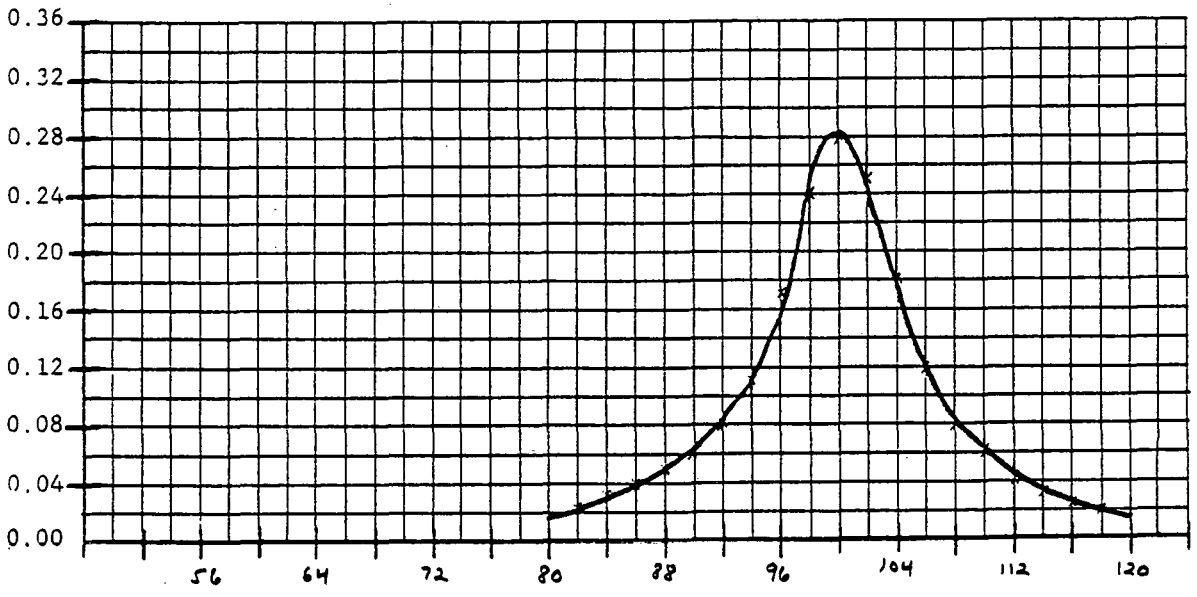



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT L

DATE 8/14/79

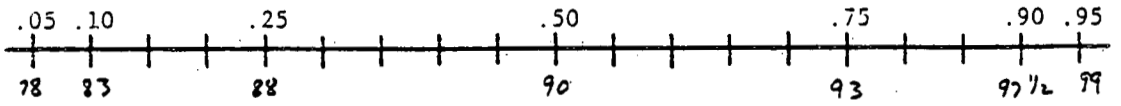


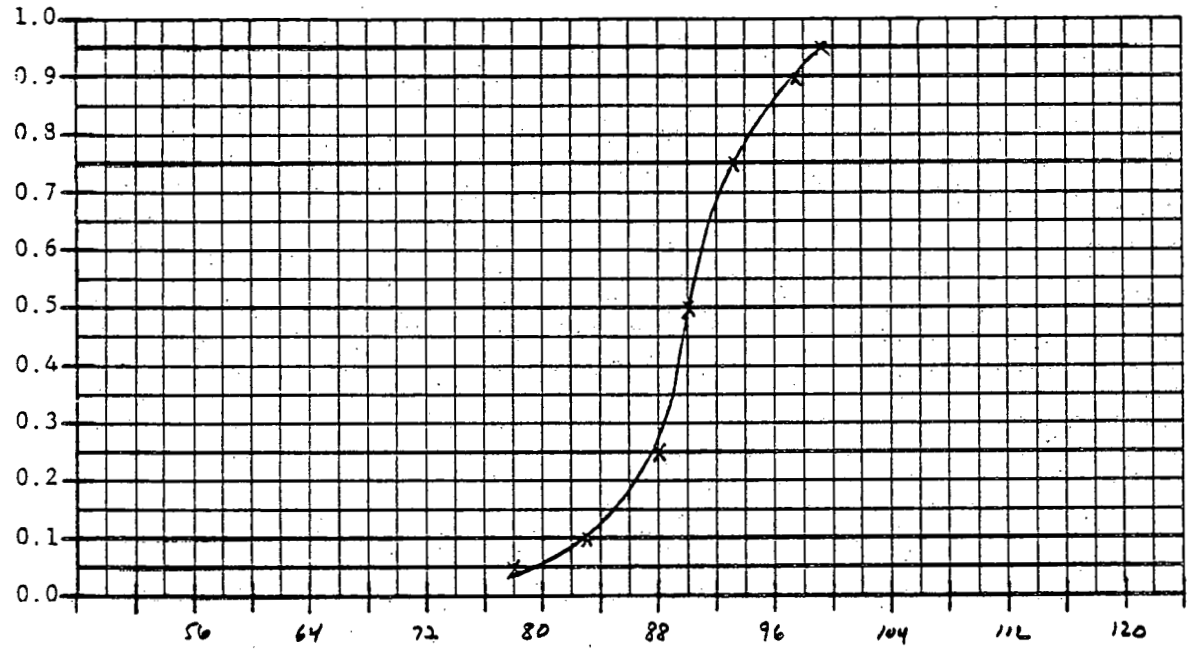



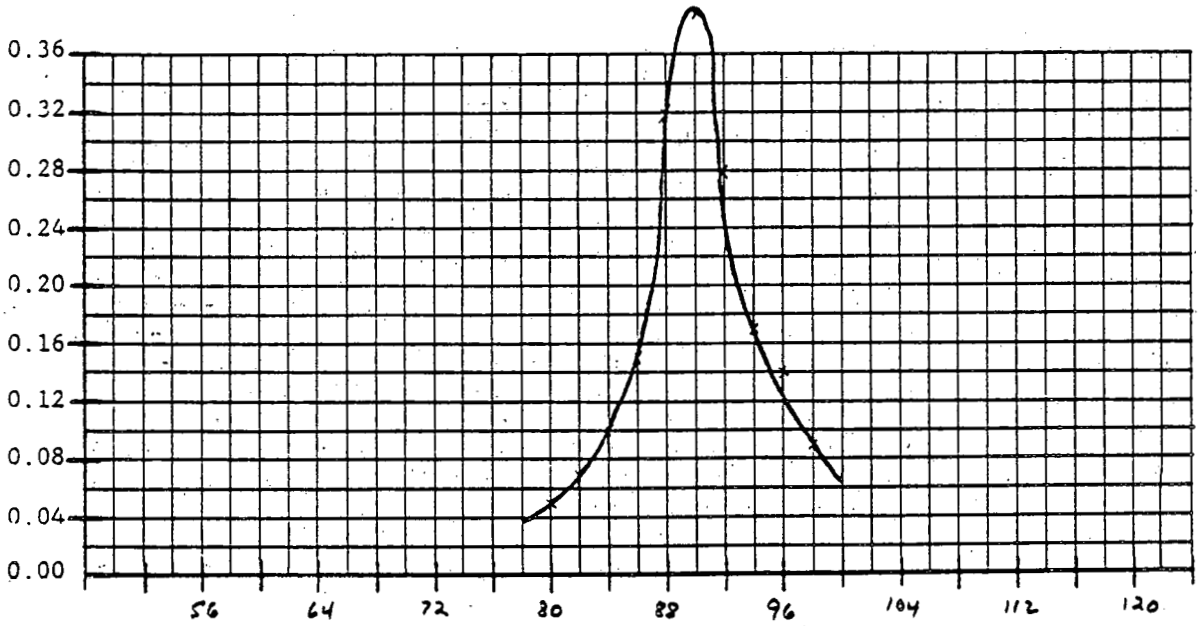



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT M

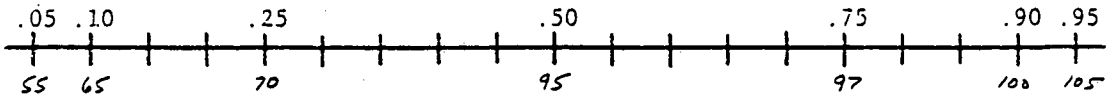
DATE 8/14/79

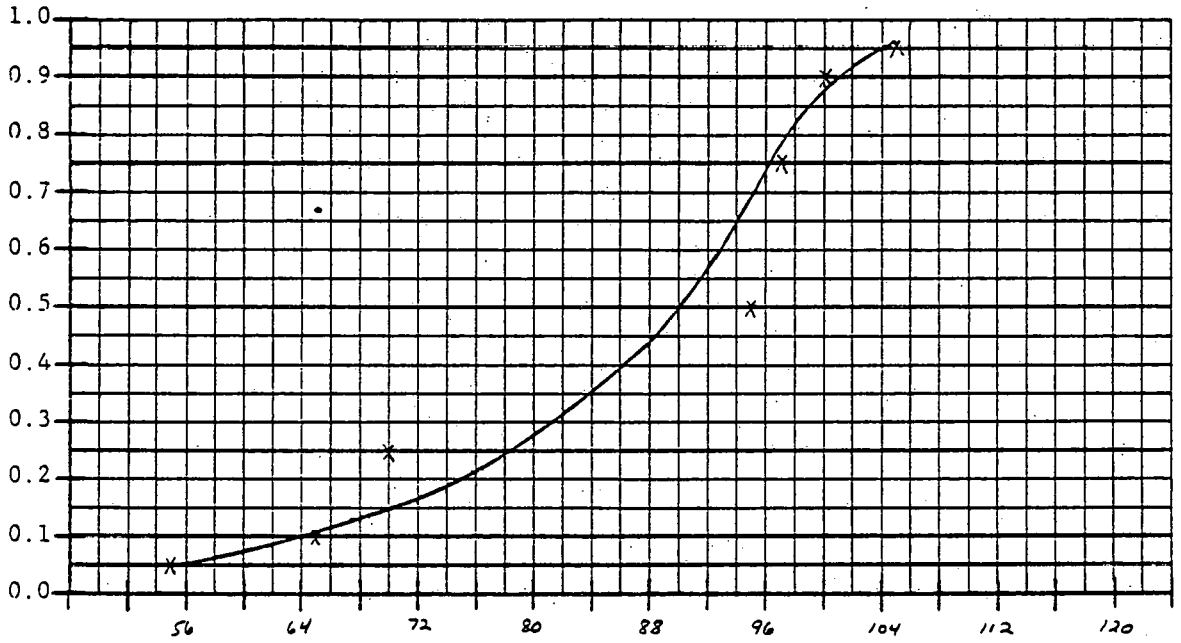


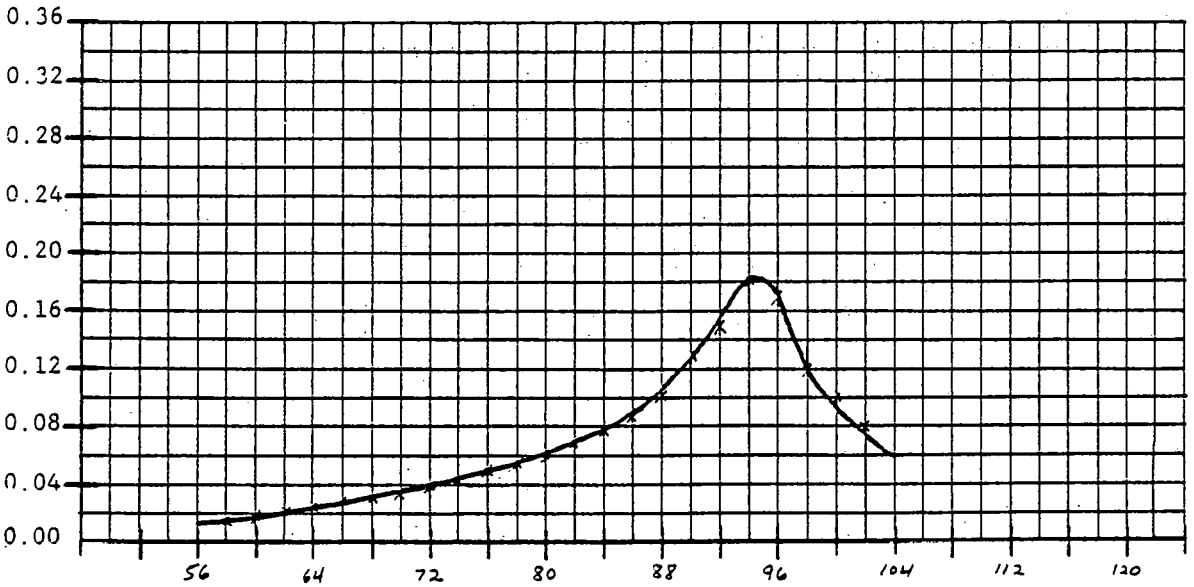



QUANTITY DESIGN CAPACITY FACTOR
SUBJECT N
DATE 8/15/79



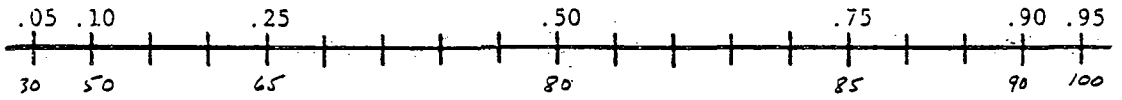



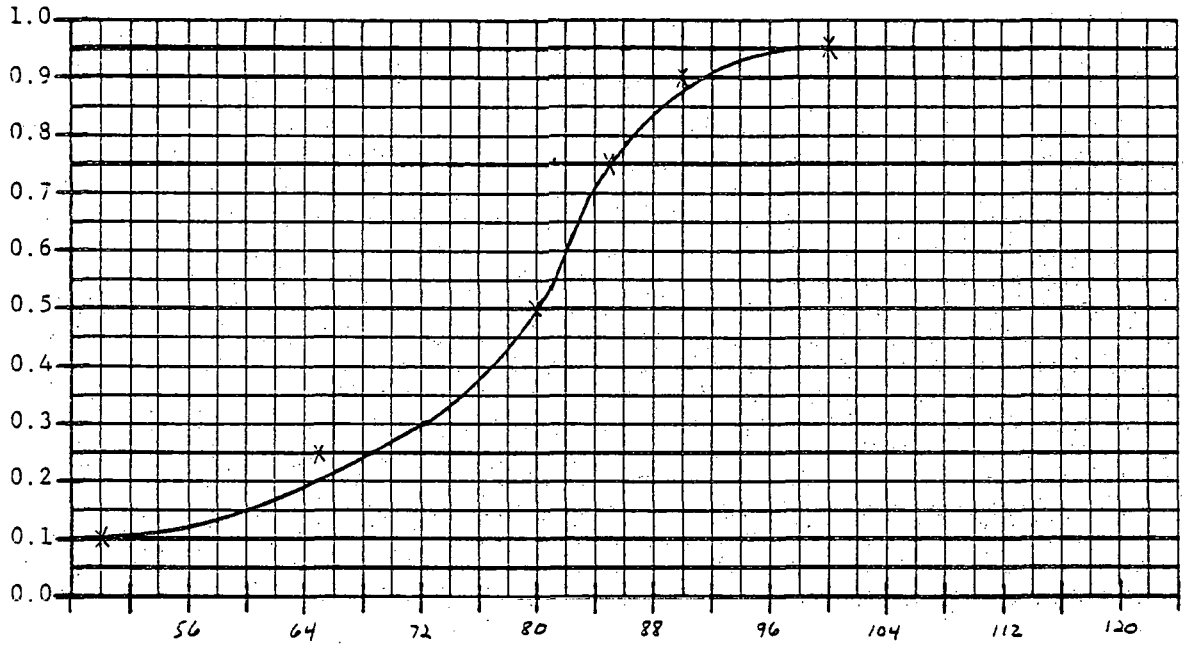



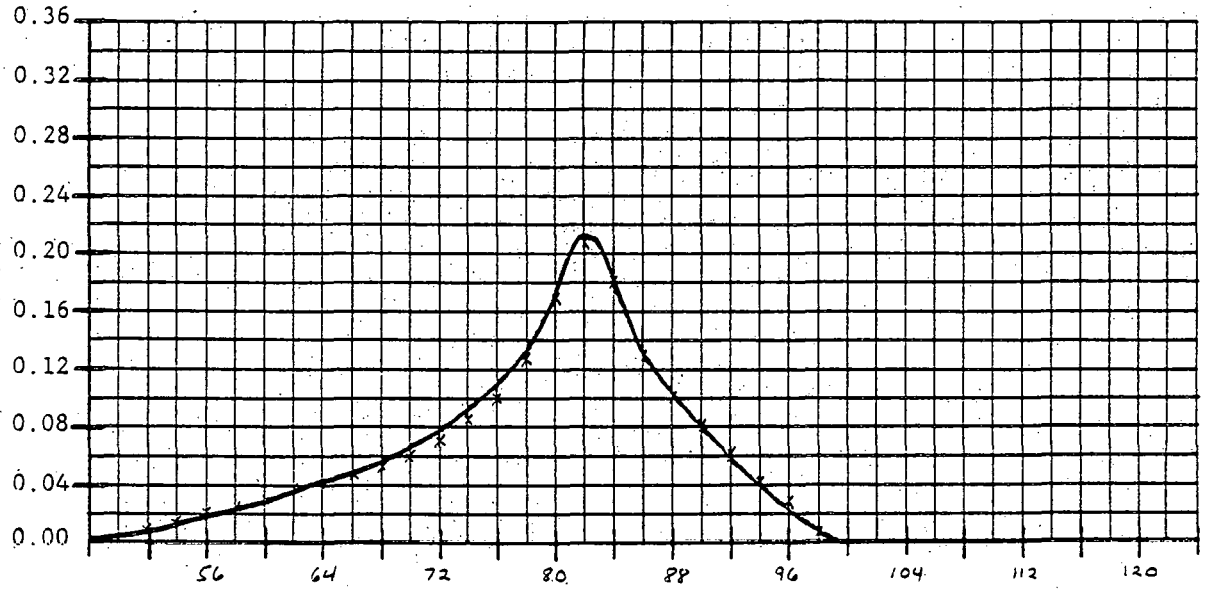
QUANTITY DESIGN CAPACITY FACTOR

SUBJECT O

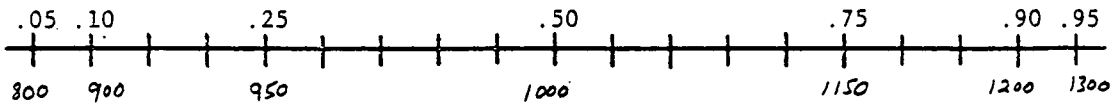
DATE 8/9/79

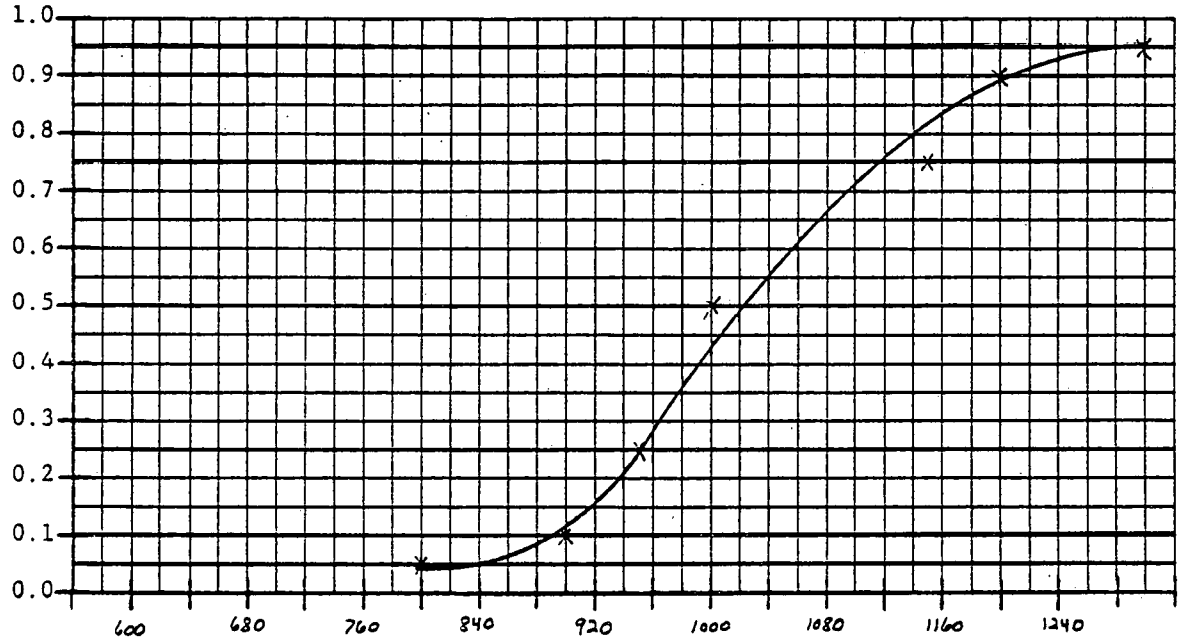


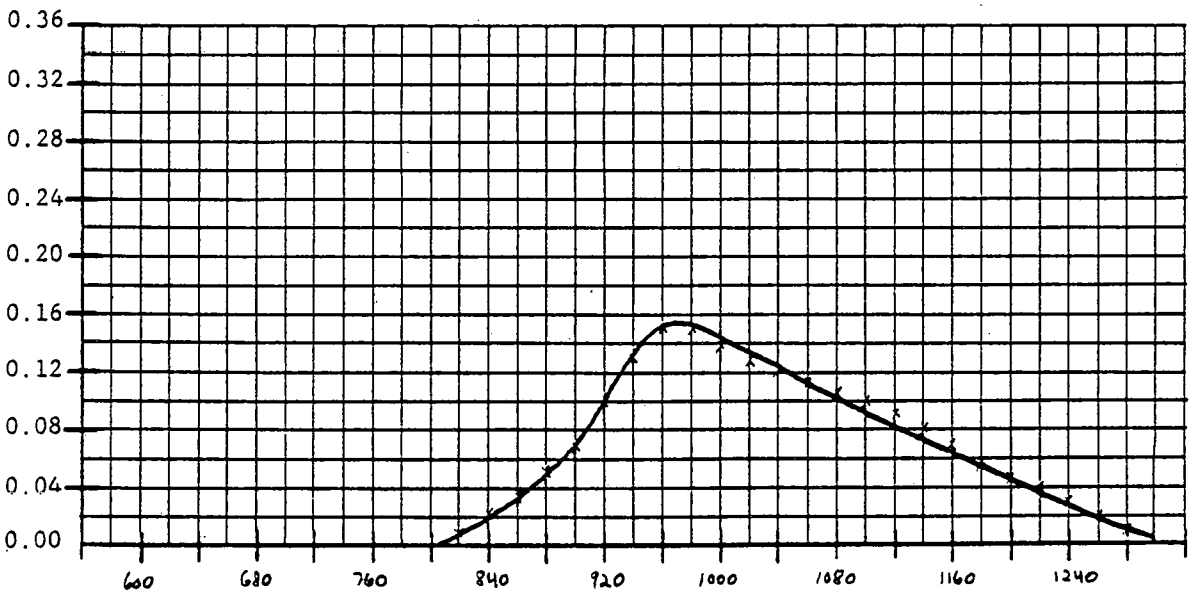



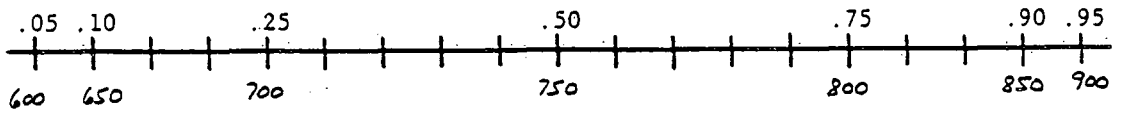
QUANTITY CAPITAL COSTS
SUBJECT B
DATE 8/7/79

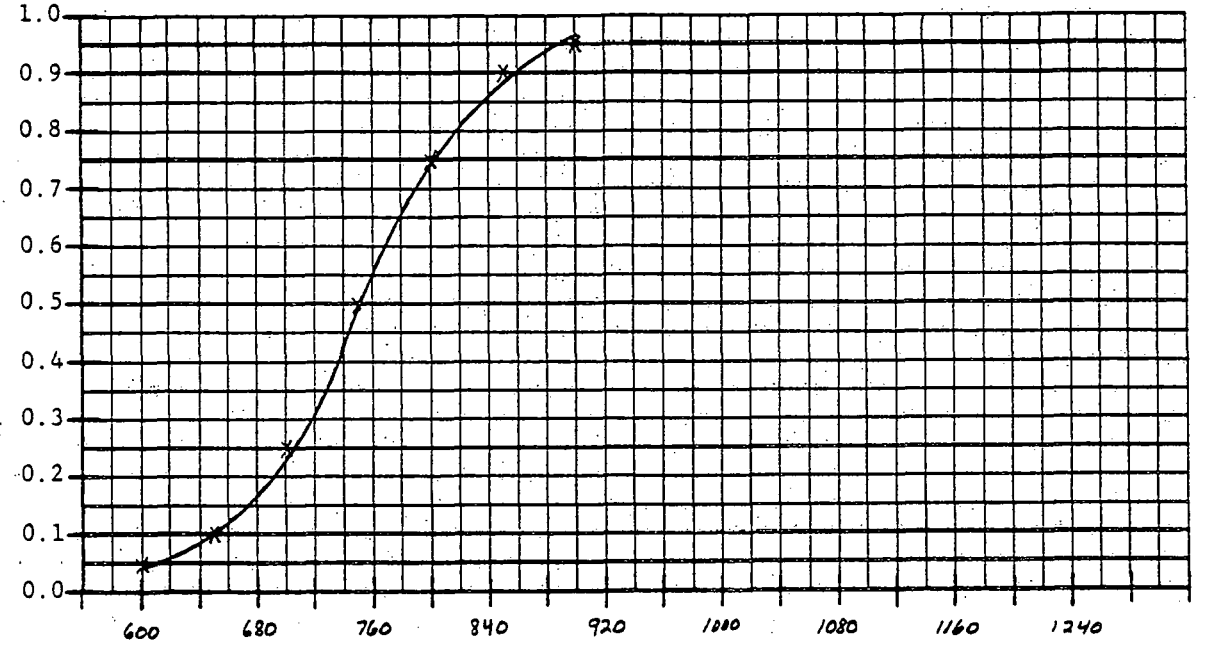


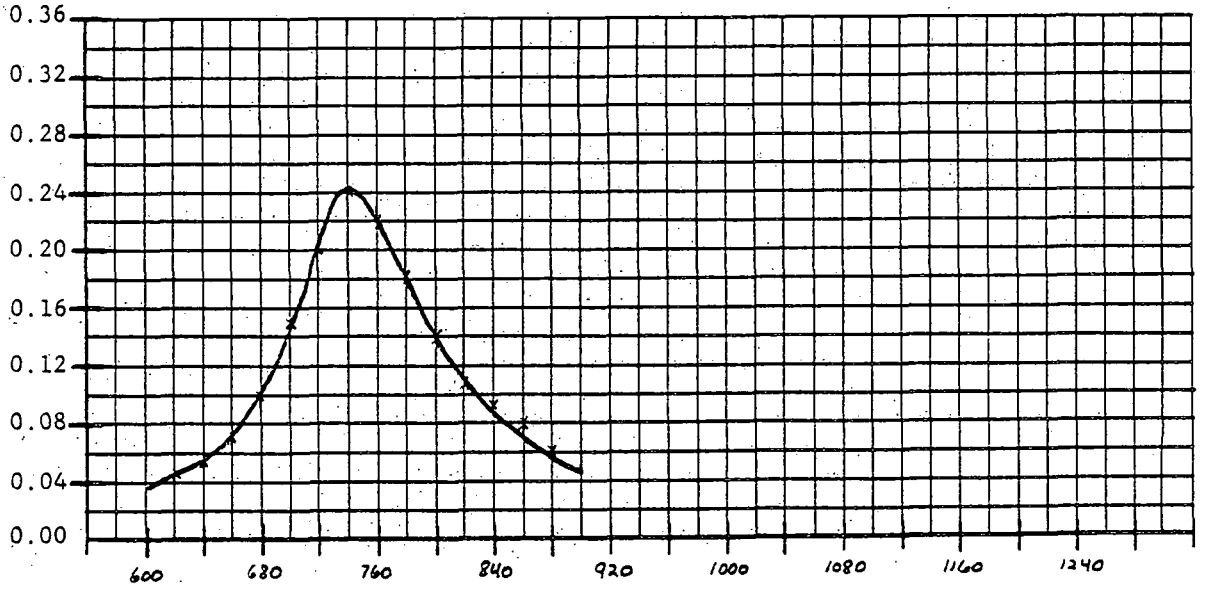



QUANTITY CAPITAL COSTS
SUBJECT C
DATE 8/8/79

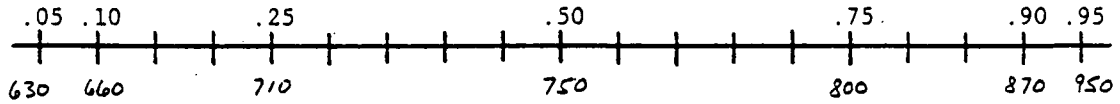


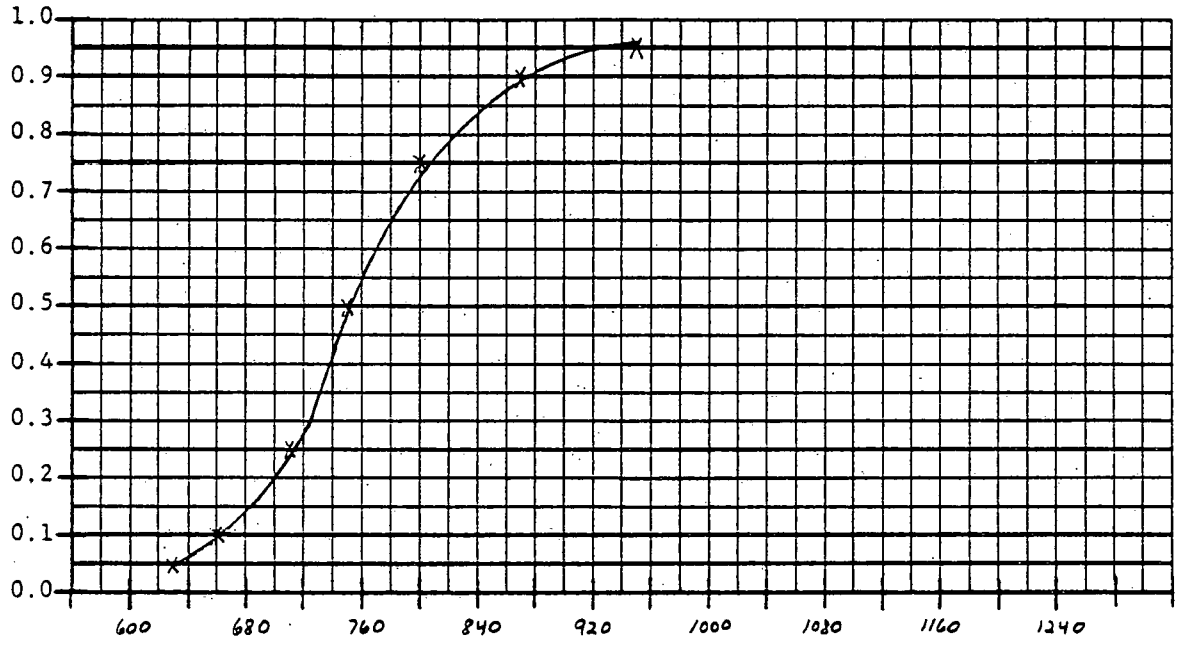



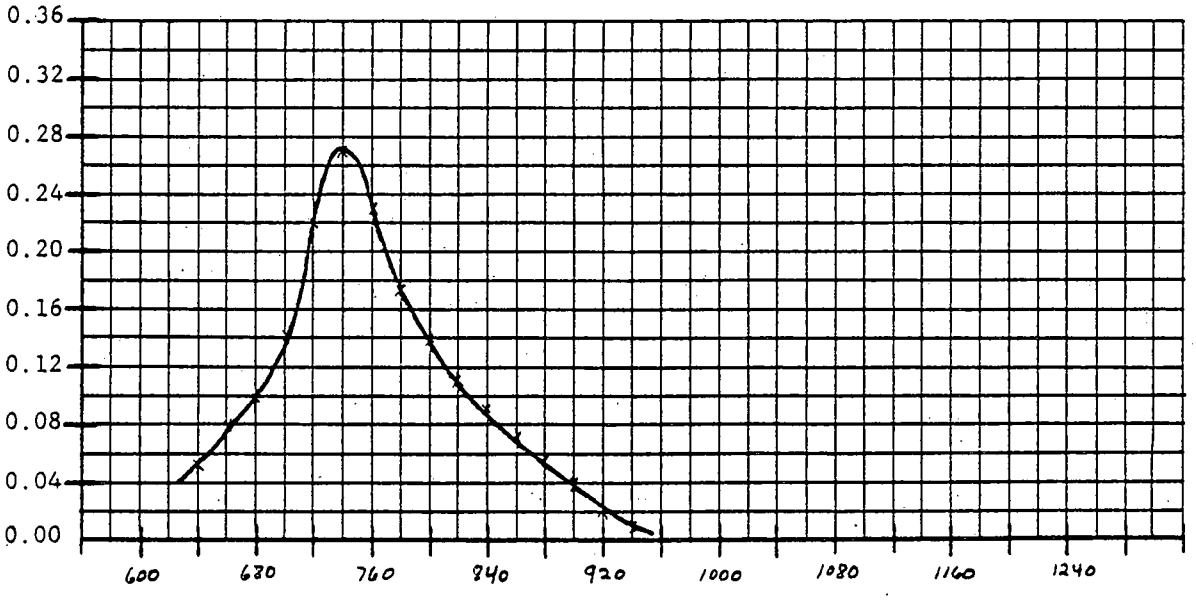



QUANTITY CAPITAL COSTS
SUBJECT Δ

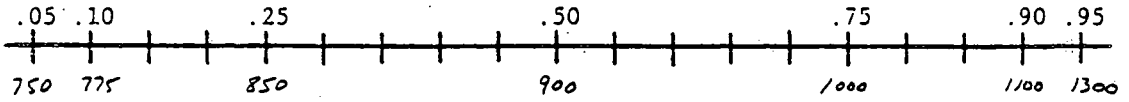
DATE 8/8/79

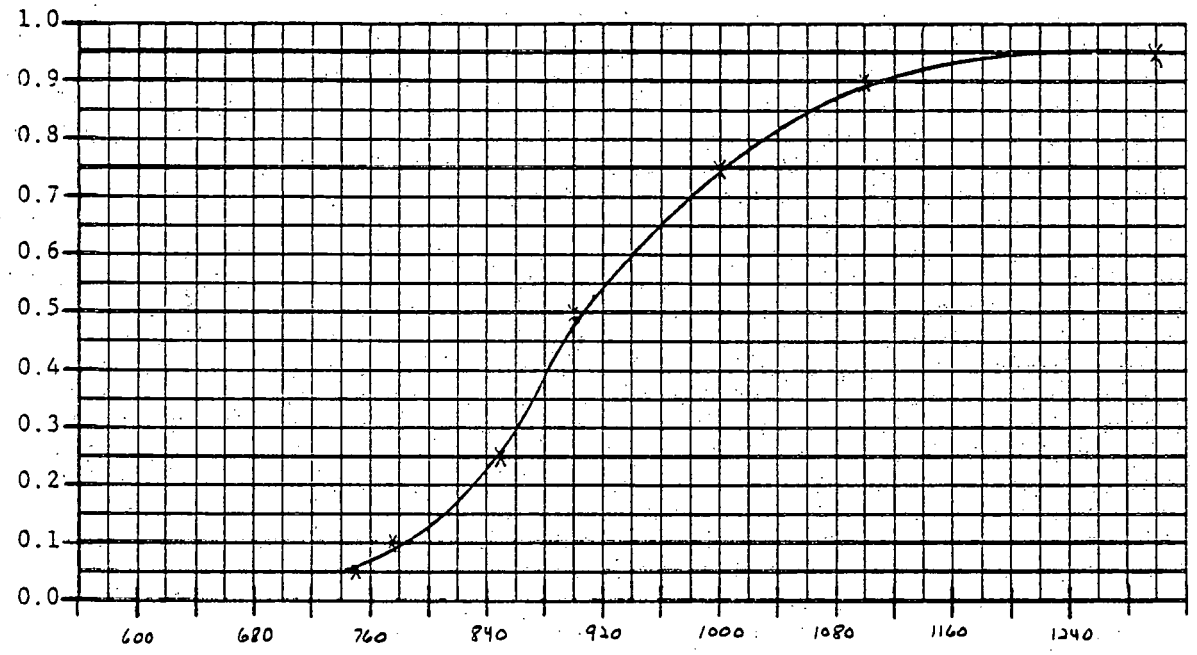


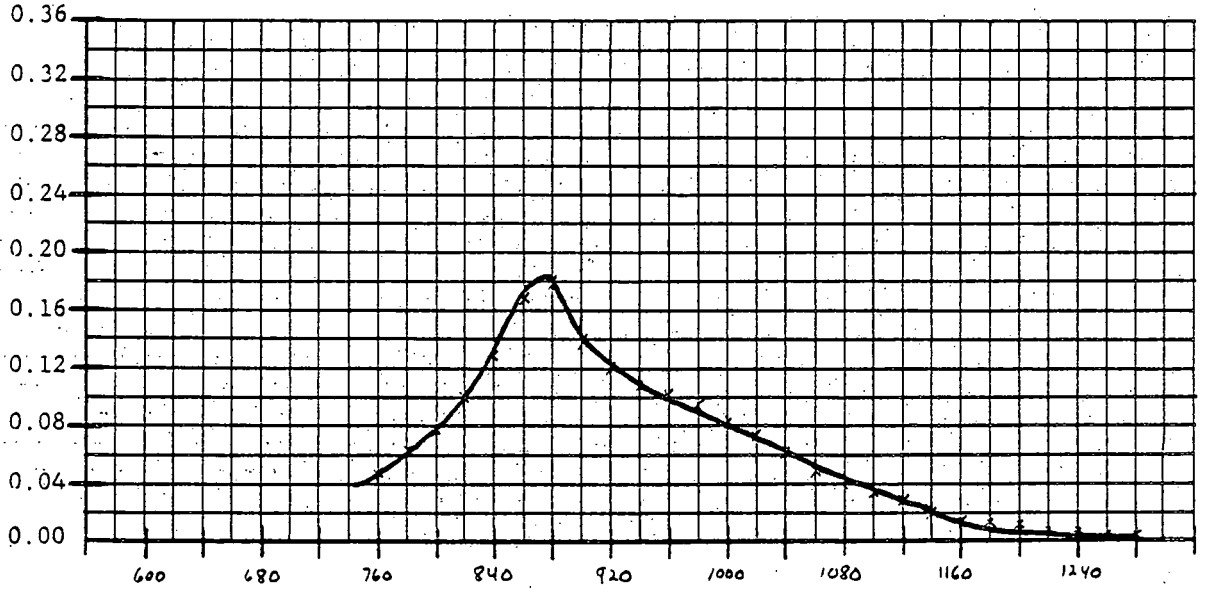



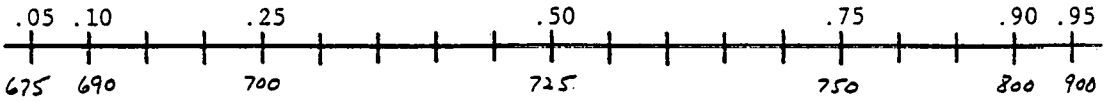
QUANTITY CAPITAL COSTS
SUBJECT E
DATE 8/8/79

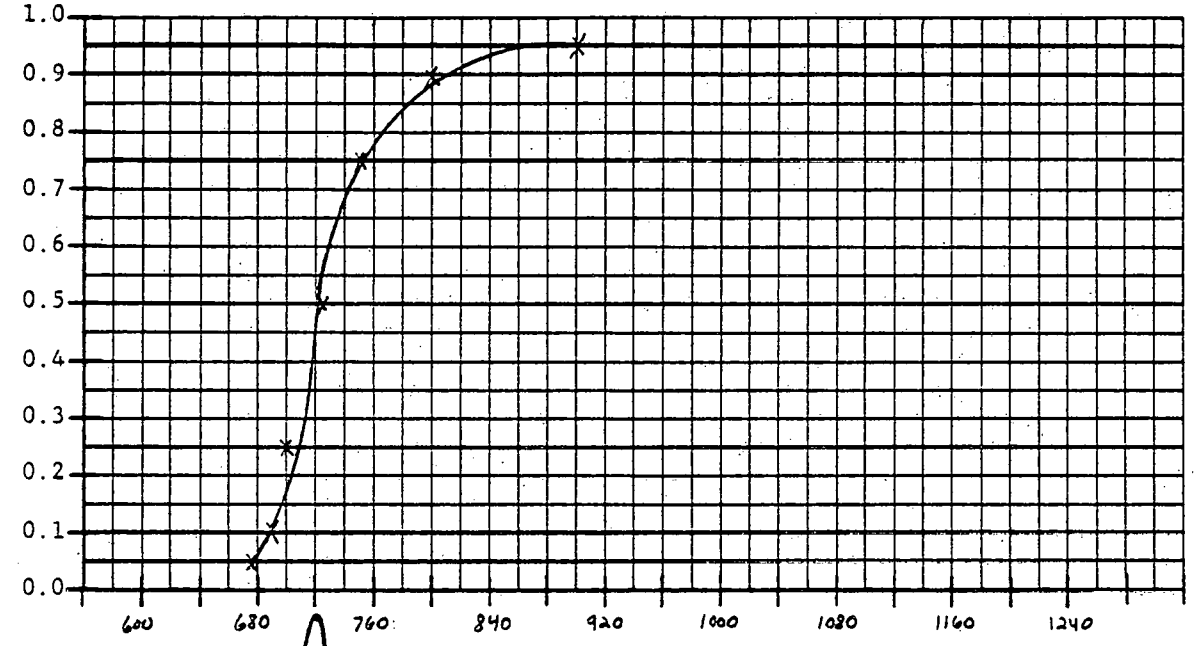


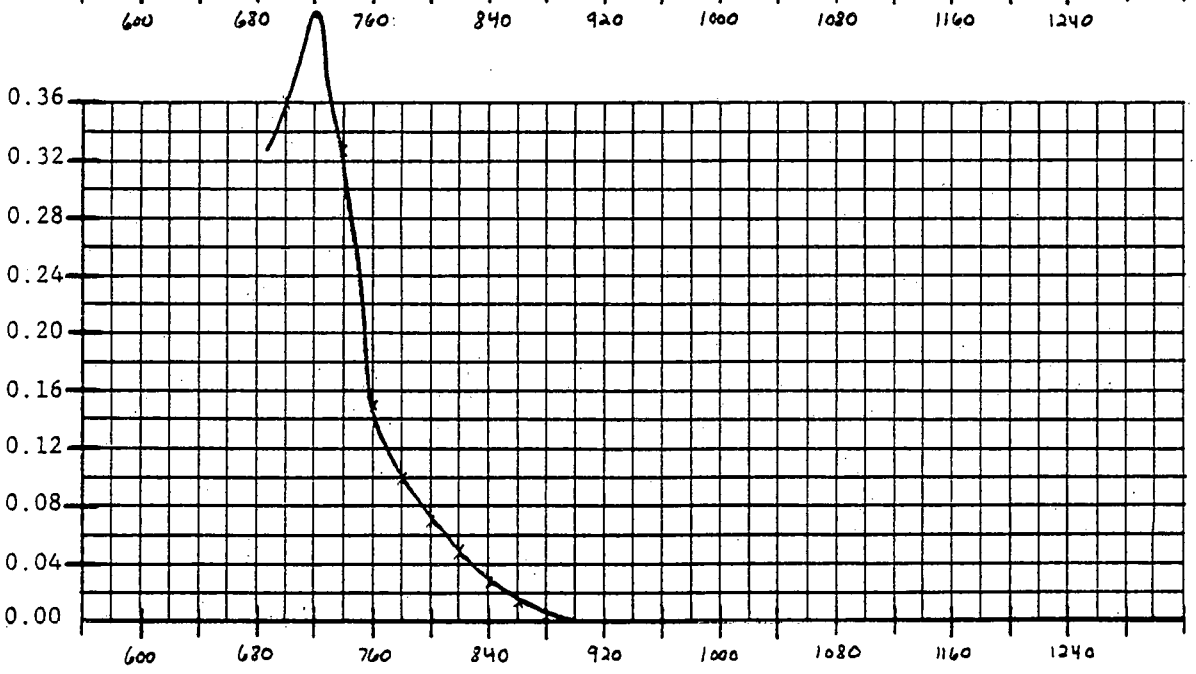



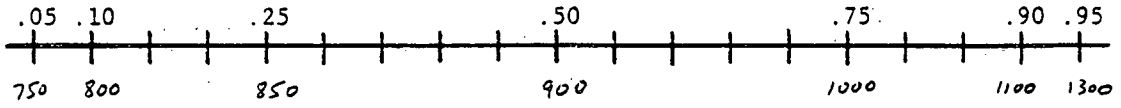
QUANTITY CAPITAL COSTS
SUBJECT F
DATE 8/9/79

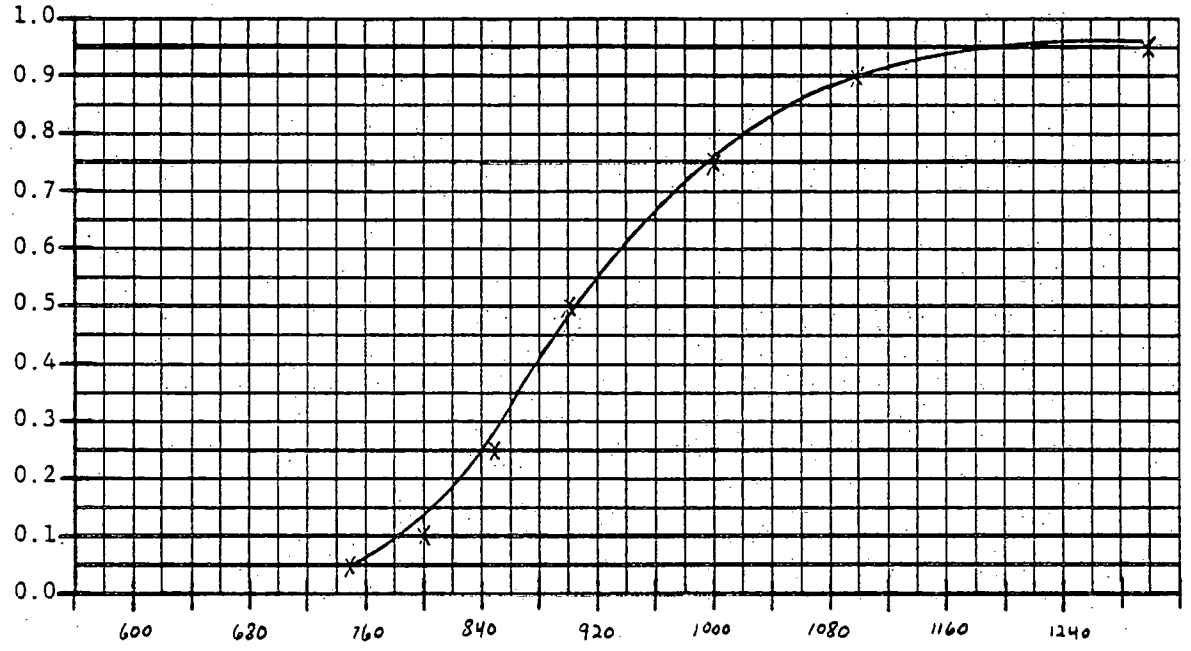


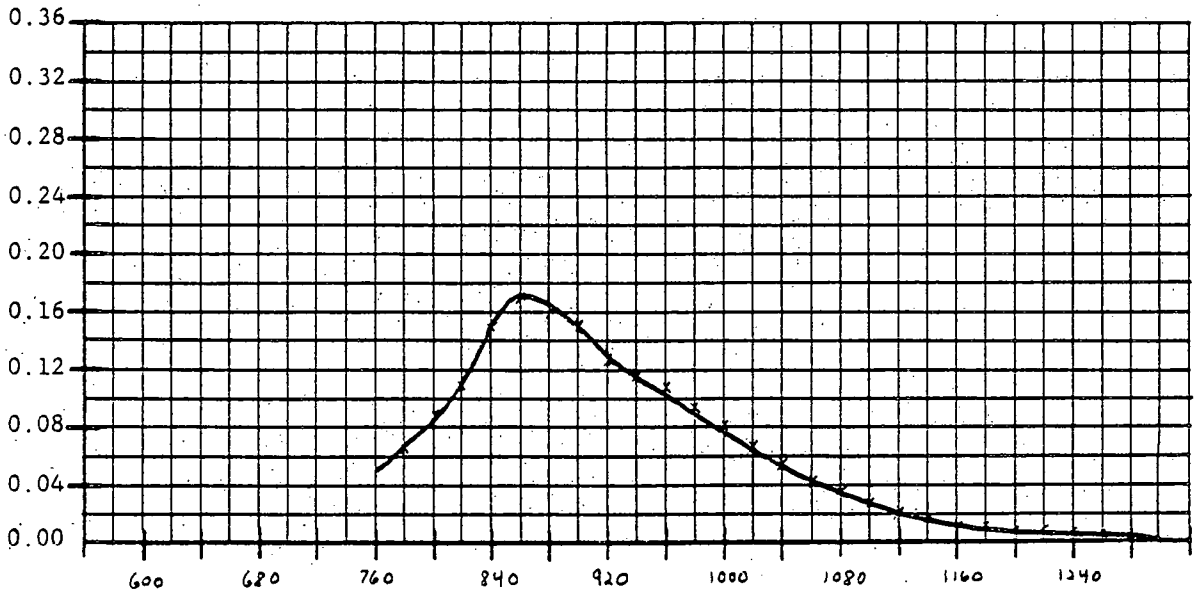



QUANTITY CAPITAL COSTS
SUBJECT G
DATE 8/10/79



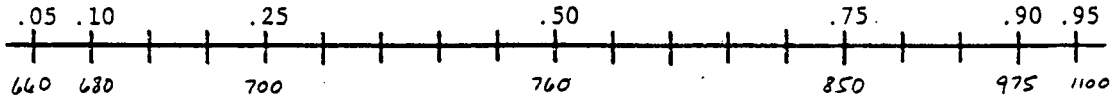



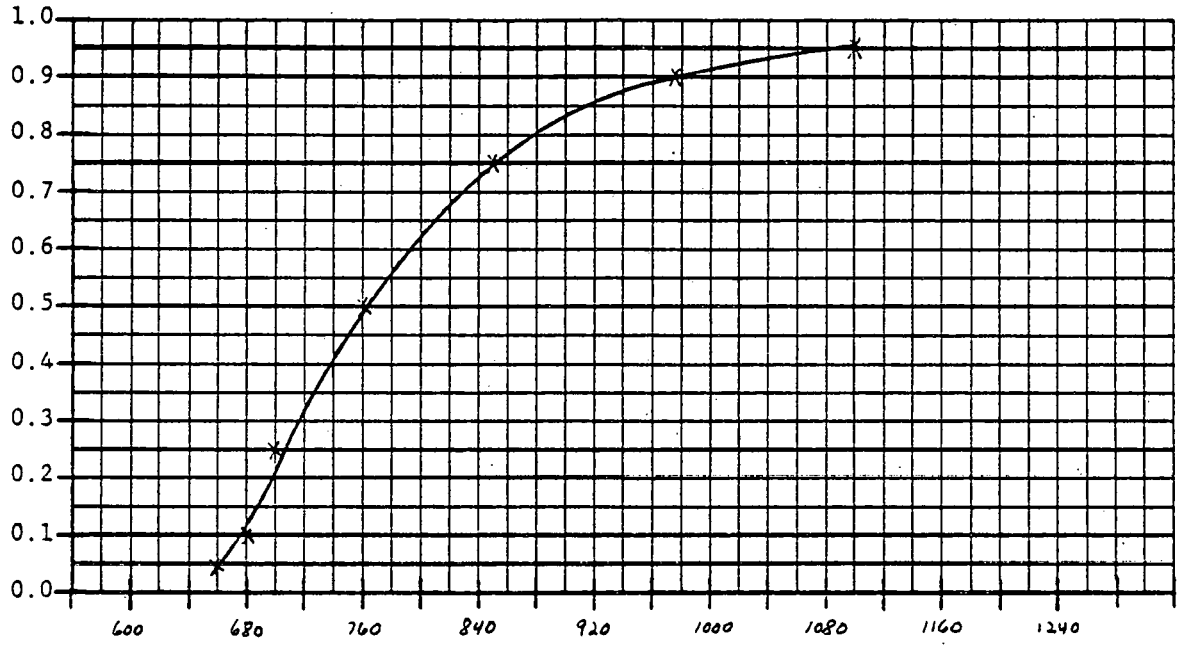



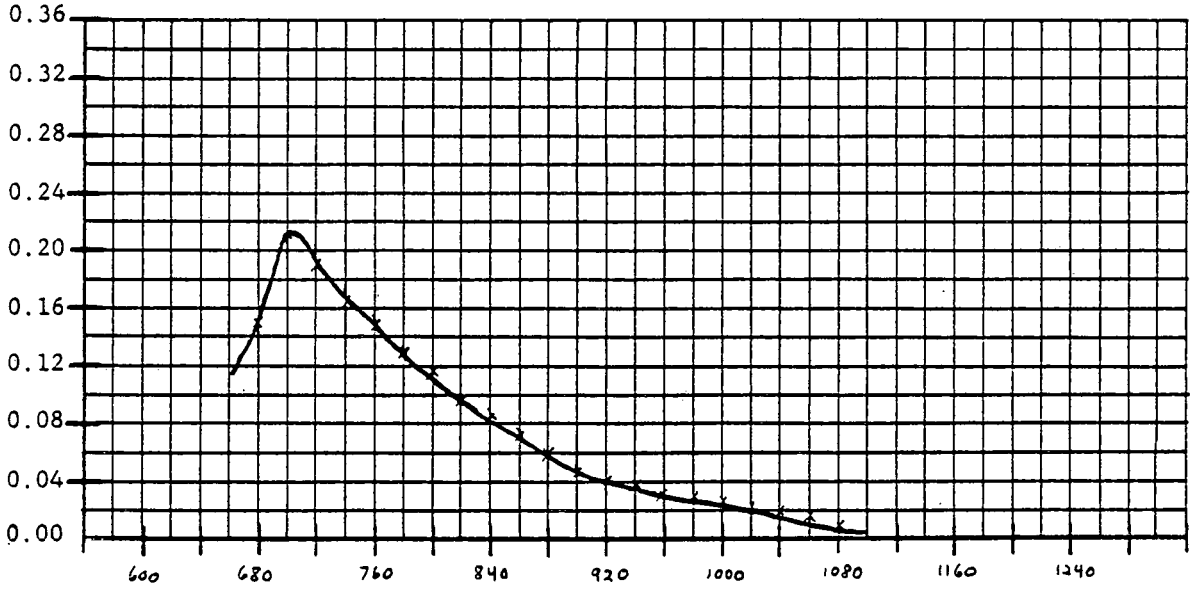
QUANTITY CAPITAL COSTS

SUBJECT H

DATE 8/10/79

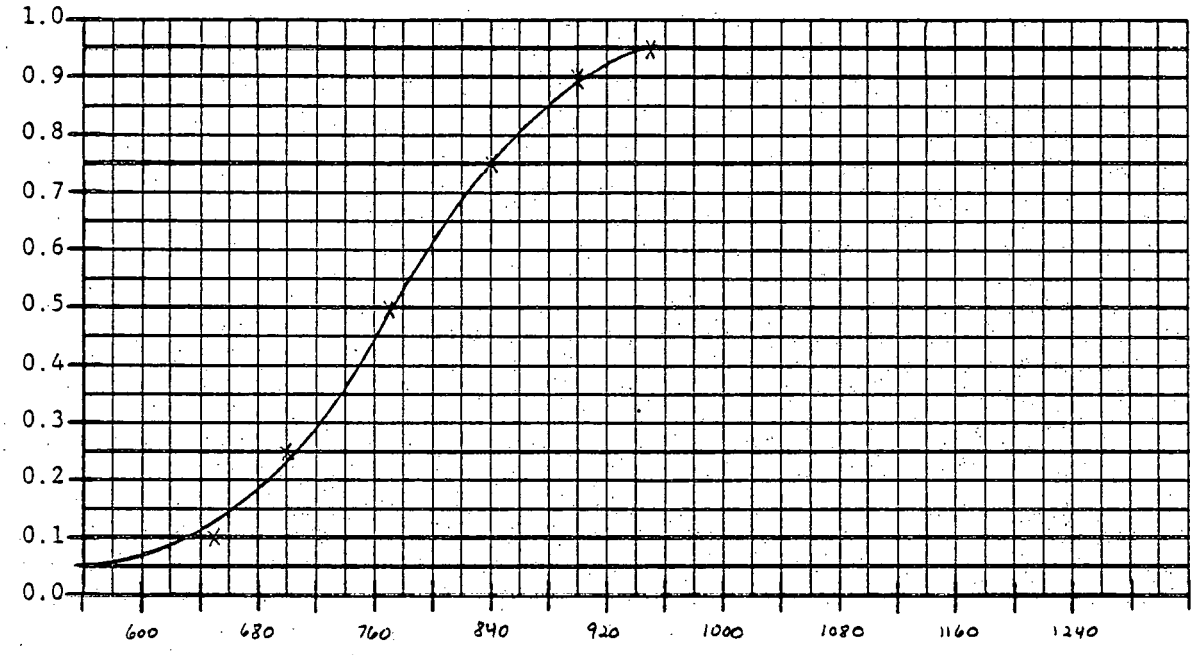


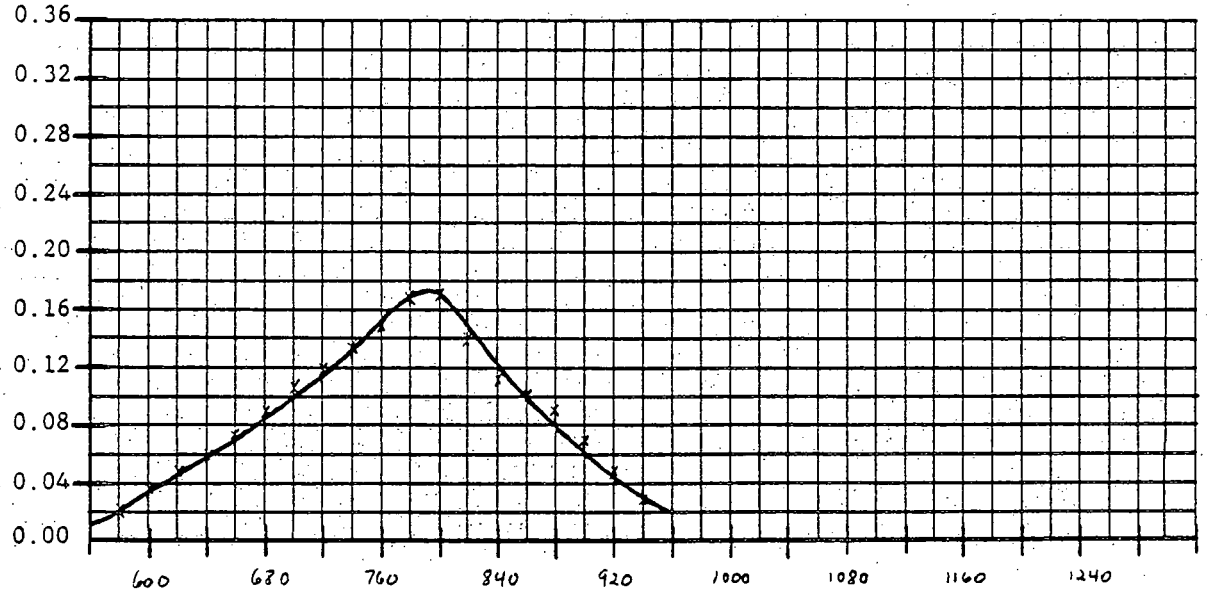



QUANTITY CAPITAL COSTS
SUBJECT I
DATE 8/10/79

| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 550 | 650 | 700 | 770 | 840 | 900 | 950 |

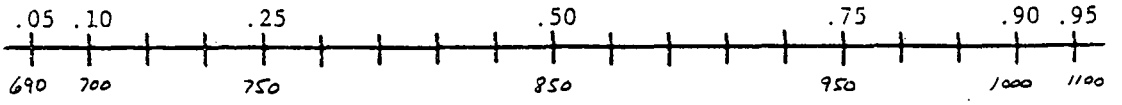


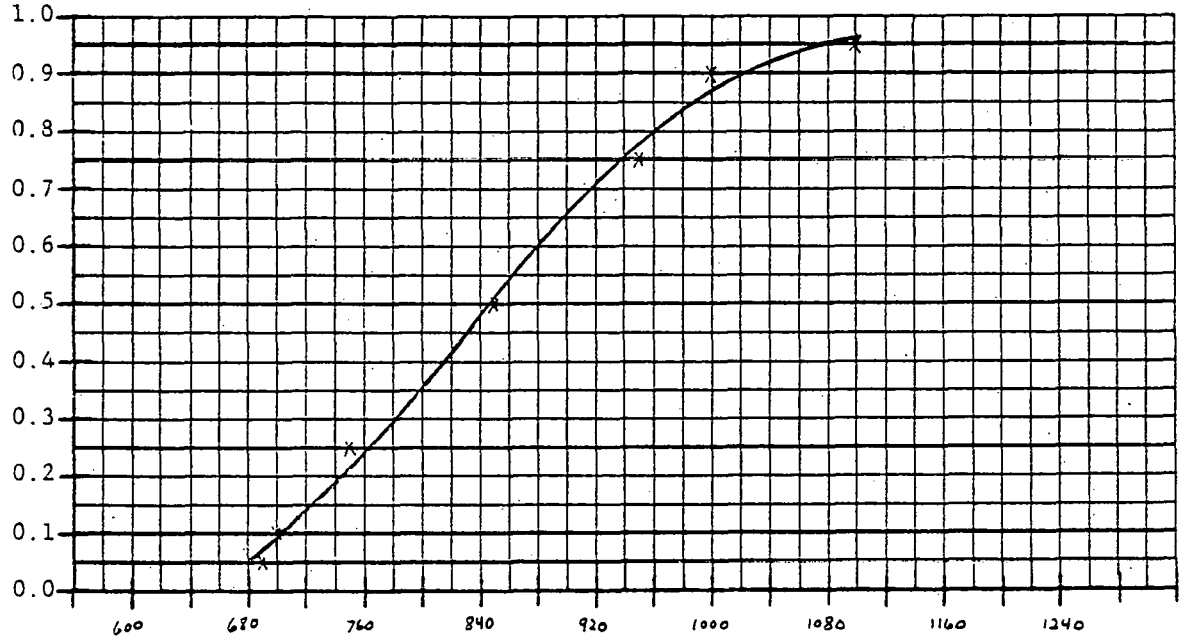



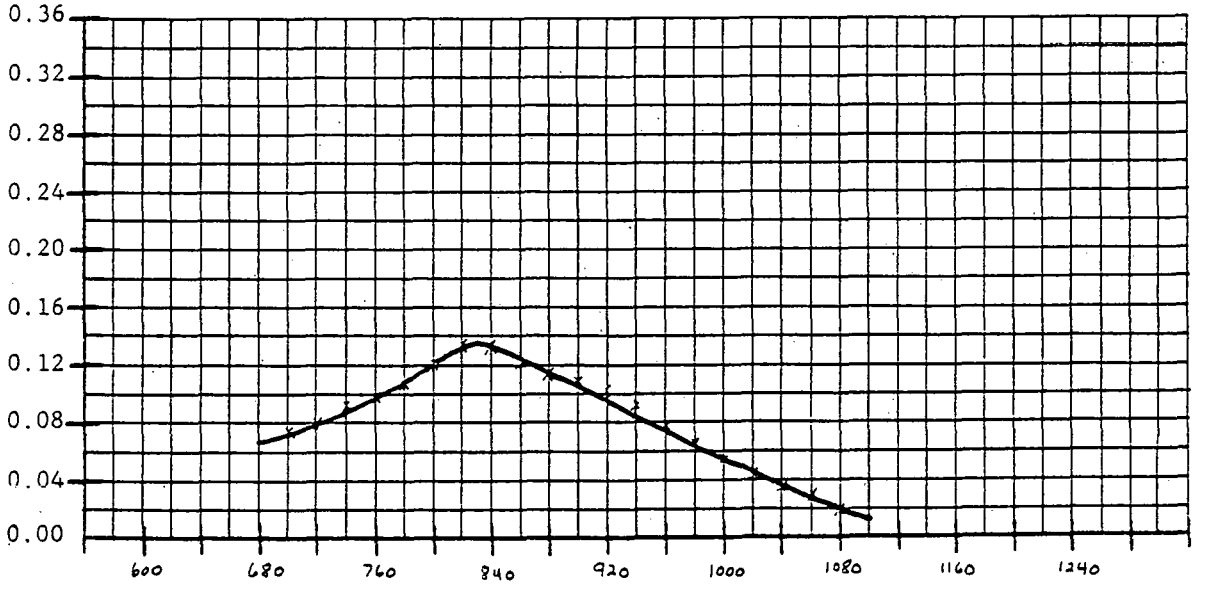
QUANTITY CAPITAL COSTS

SUBJECT J

DATE 8/13/79



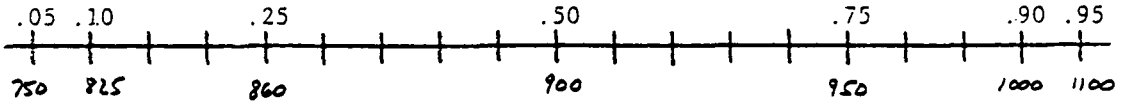



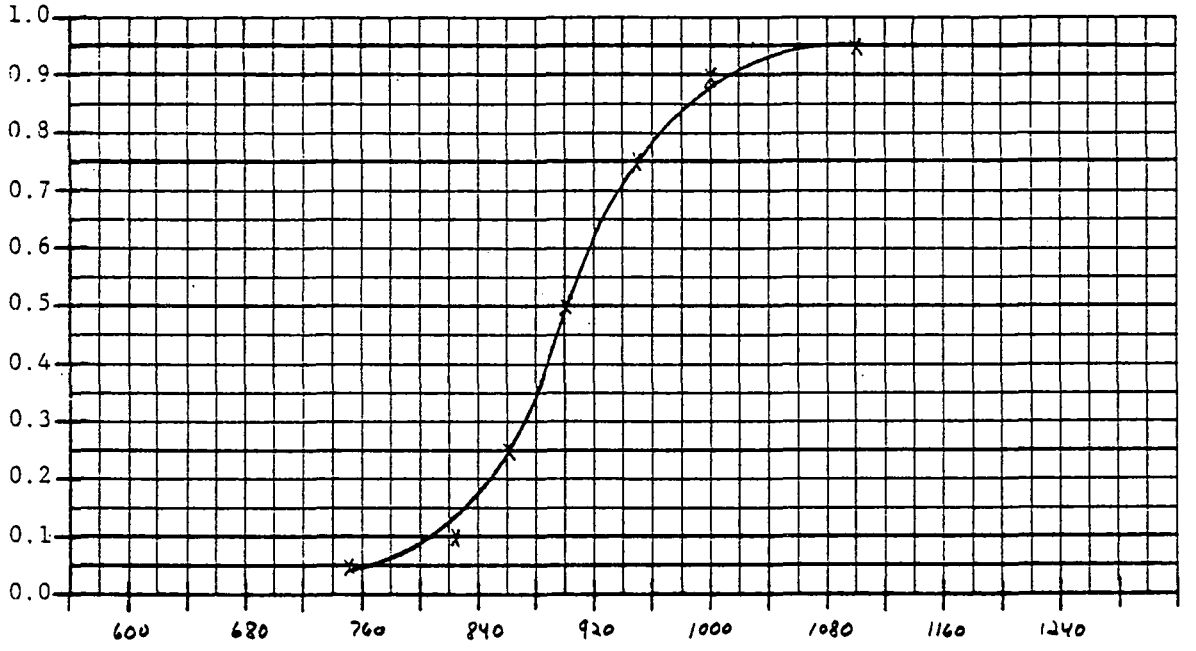



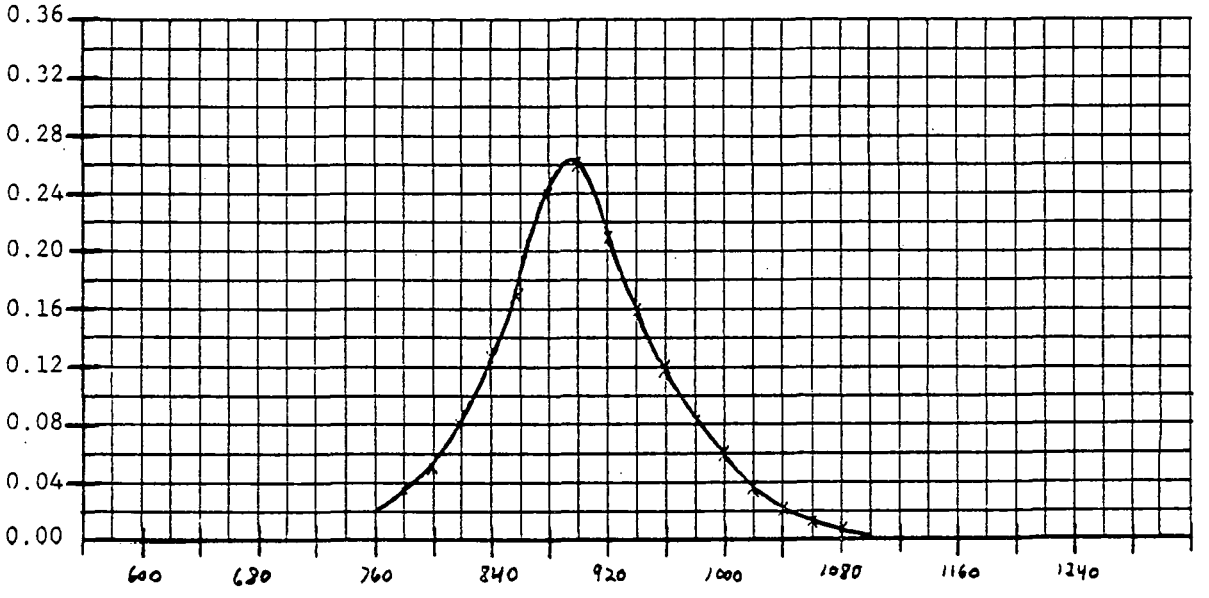
QUANTITY CAPITAL COSTS

SUBJECT L

DATE 8/14/79

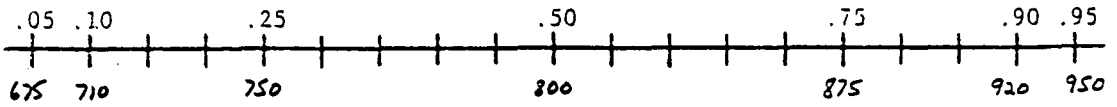


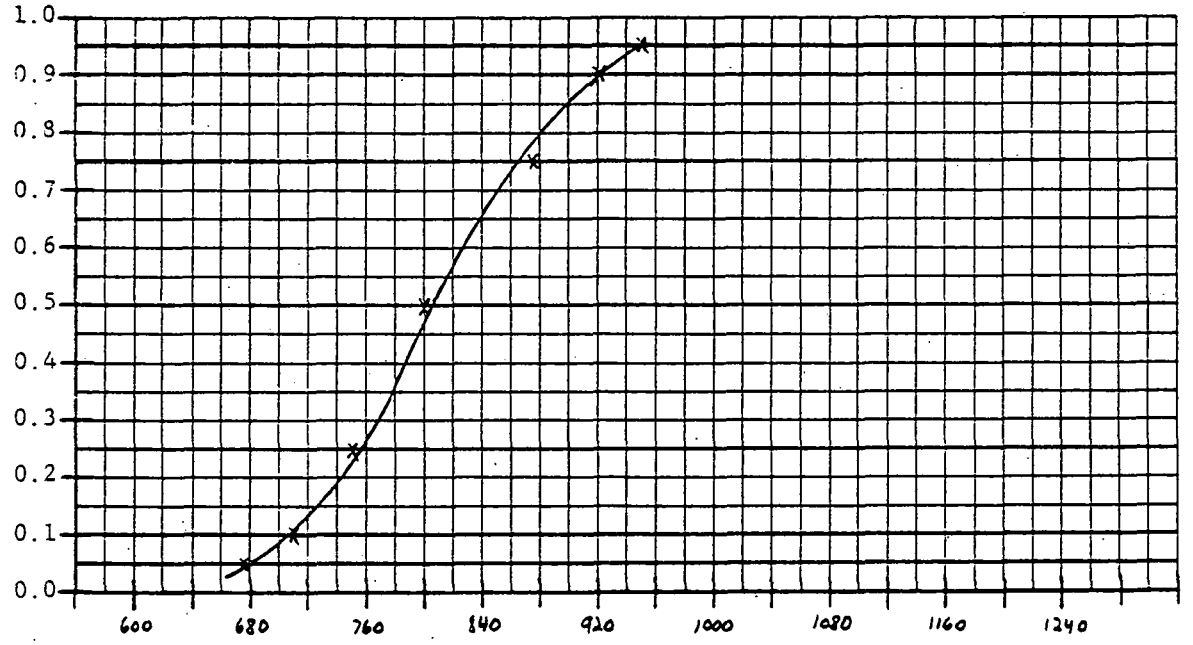



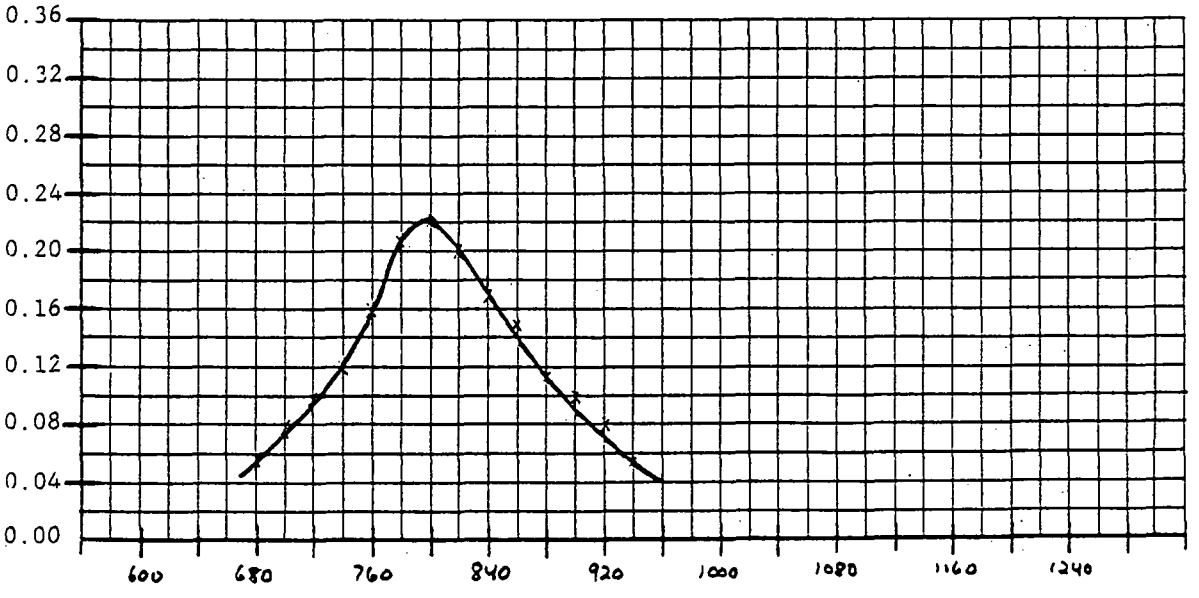



QUANTITY CAPITAL COSTS
SUBJECT M

DATE 8/14/79



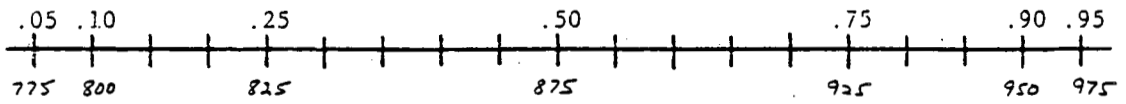



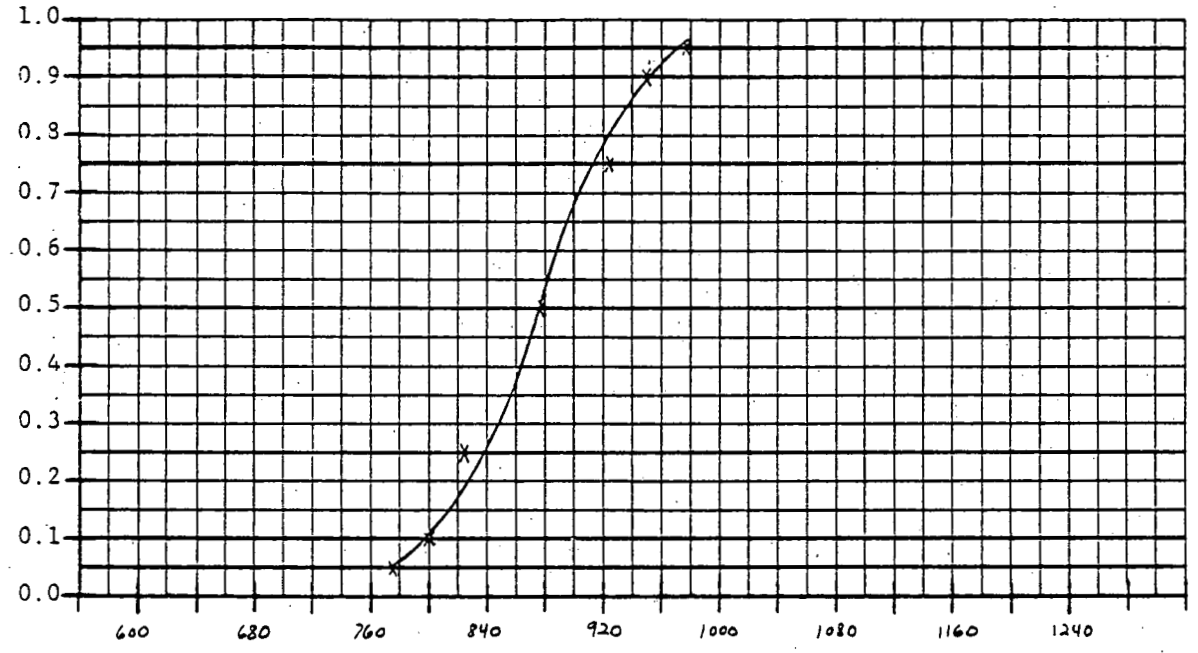



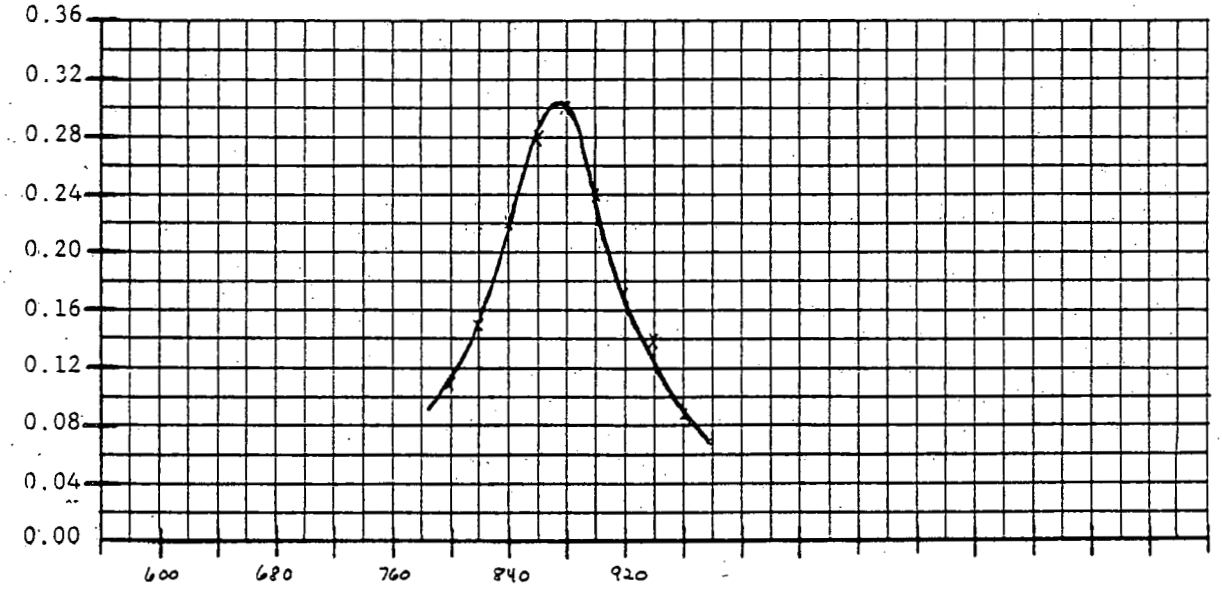
QUANTITY CAPITAL COSTS

SUBJECT N

DATE 8/15/79



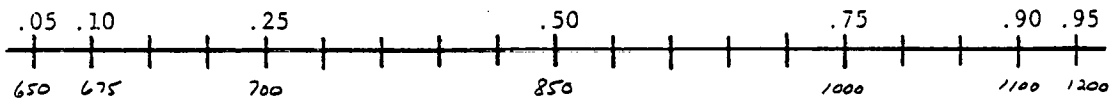



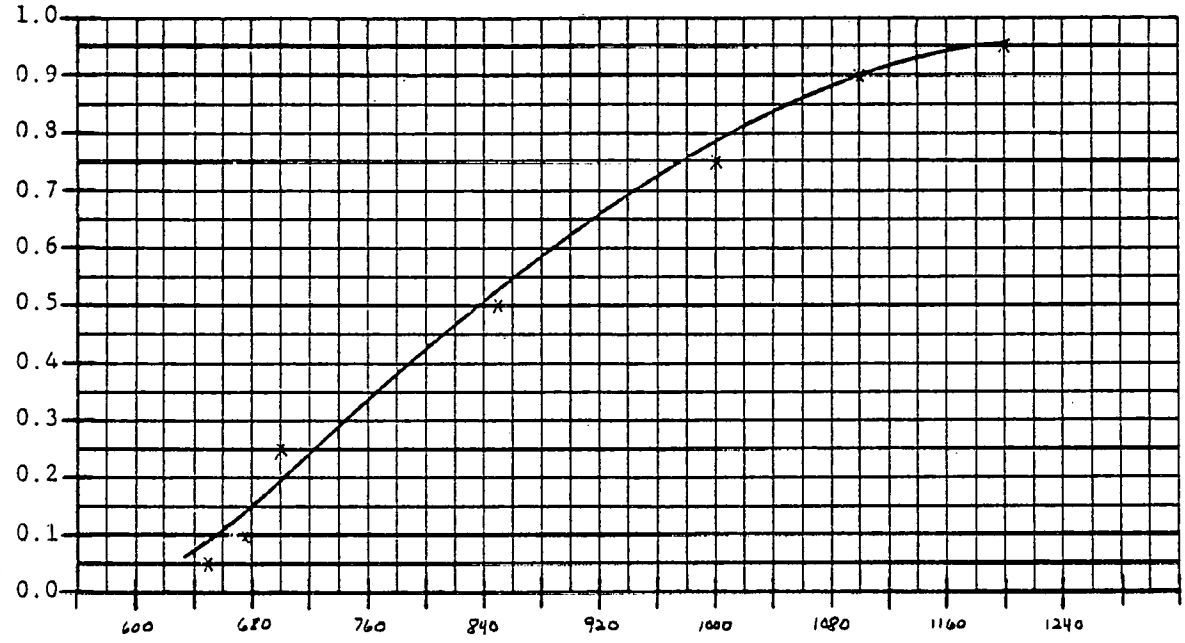



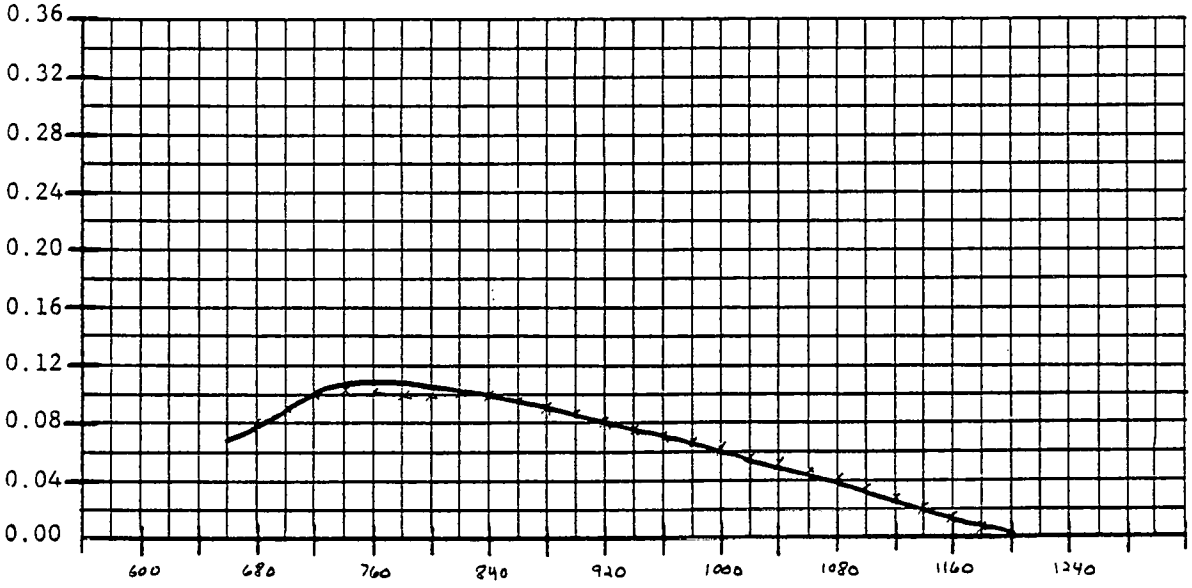
QUANTITY CAPITAL COSTS

SUBJECT O

DATE 8/9/79



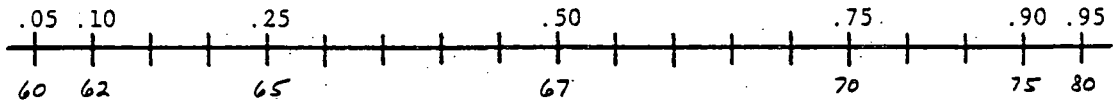



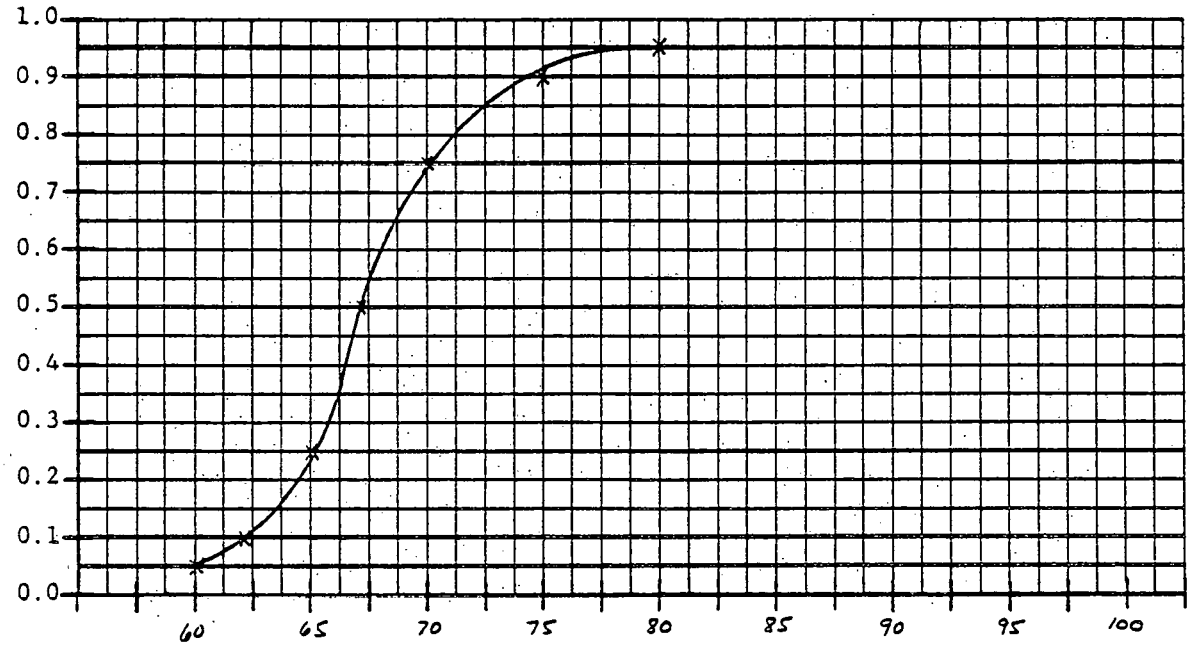



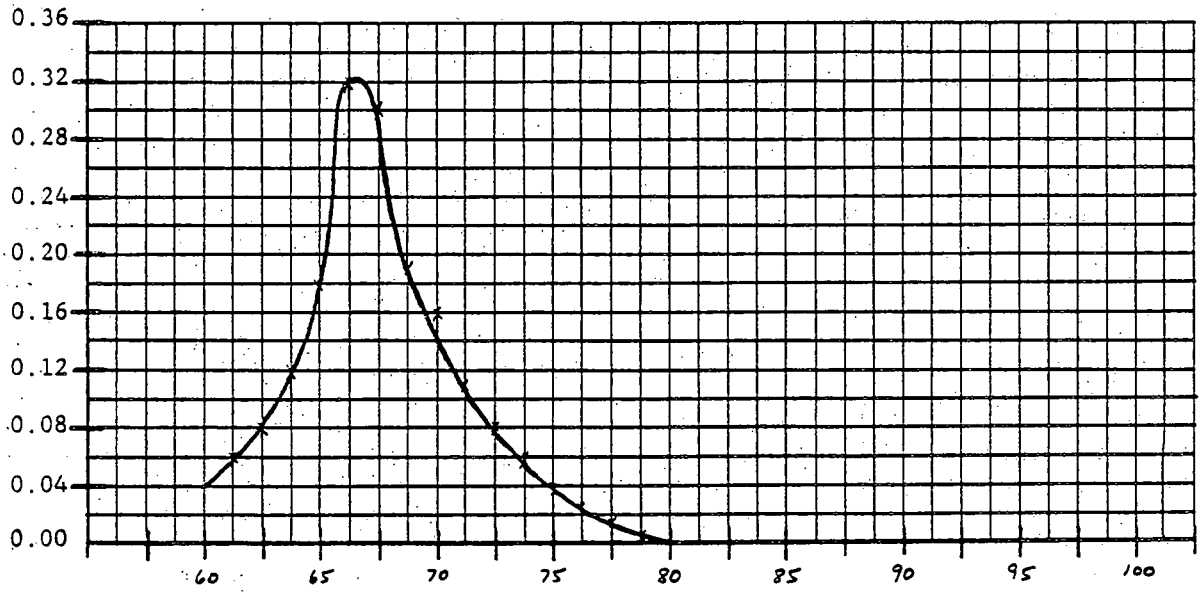
QUANTITY OPERATING COSTS

SUBJECT C

DATE 8/8/79

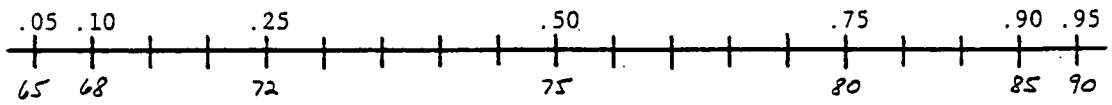


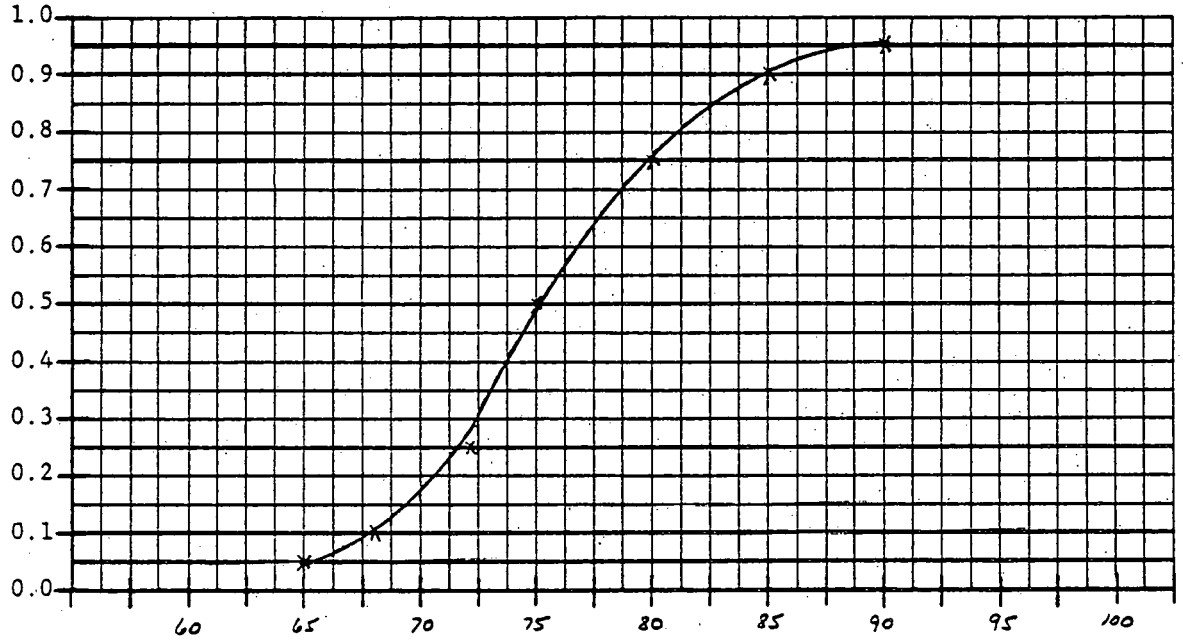



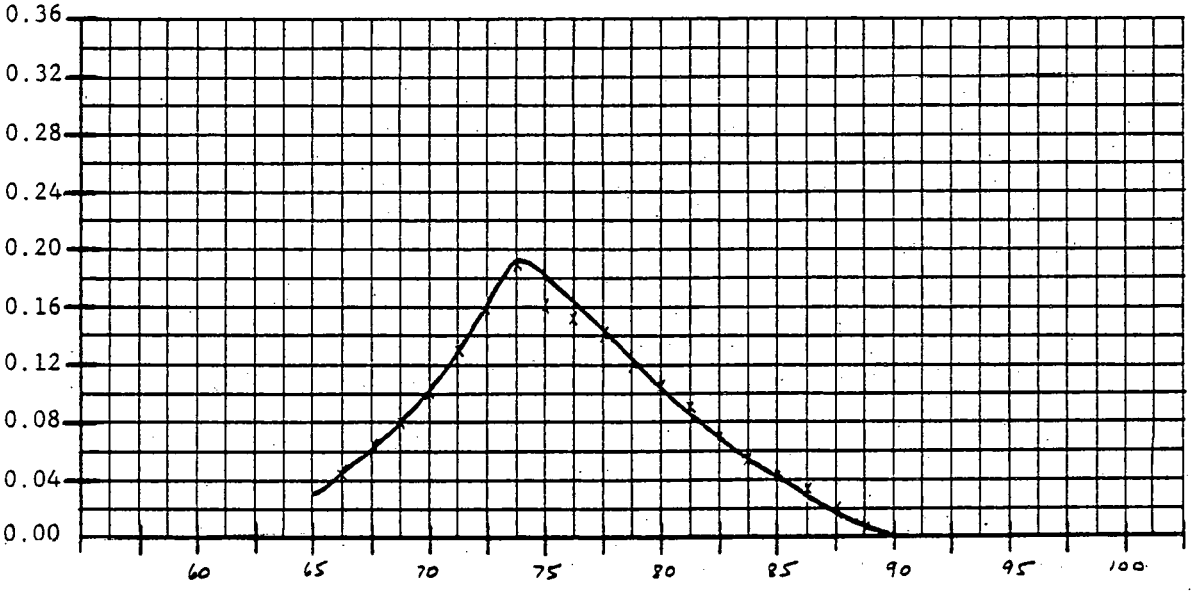



QUANTITY OPERATING COSTS
SUBJECT D

DATE 8/8/79

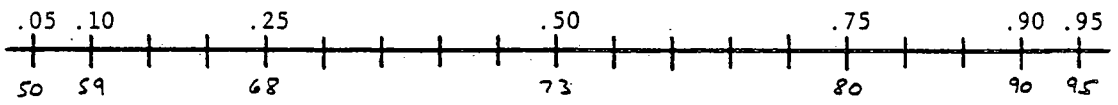


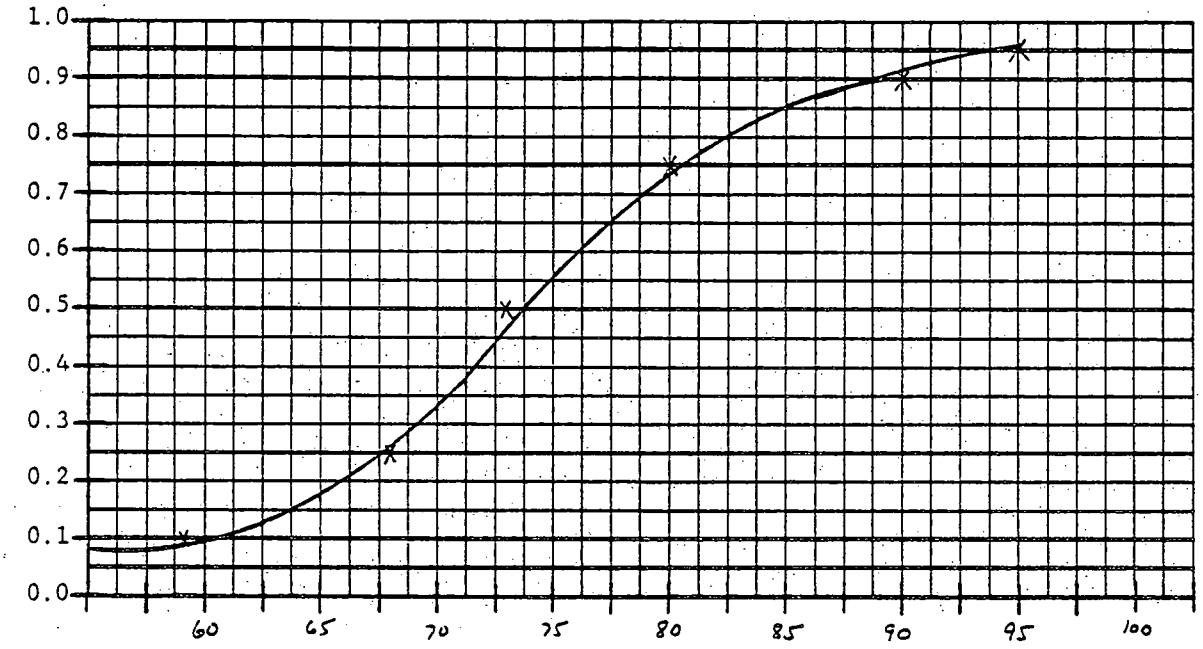



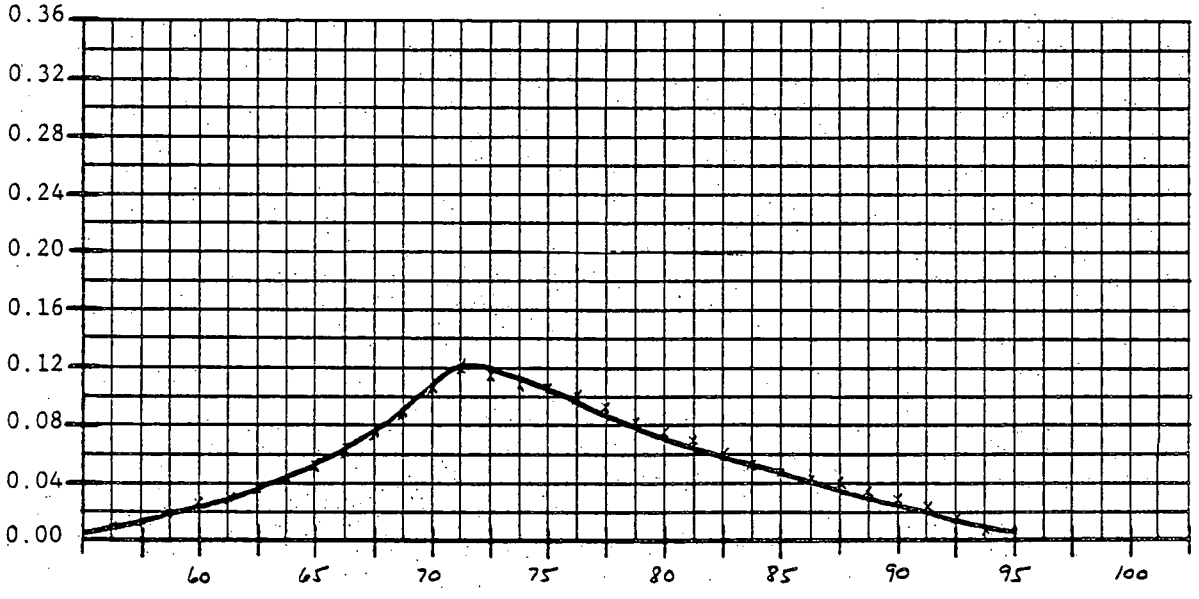



QUANTITY OPERATING COSTS
SUBJECT E

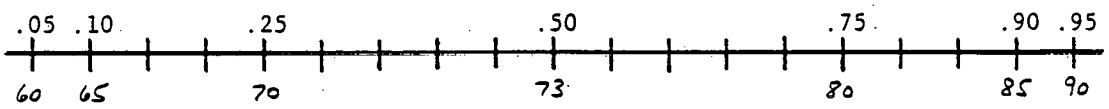
DATE 8/8/79

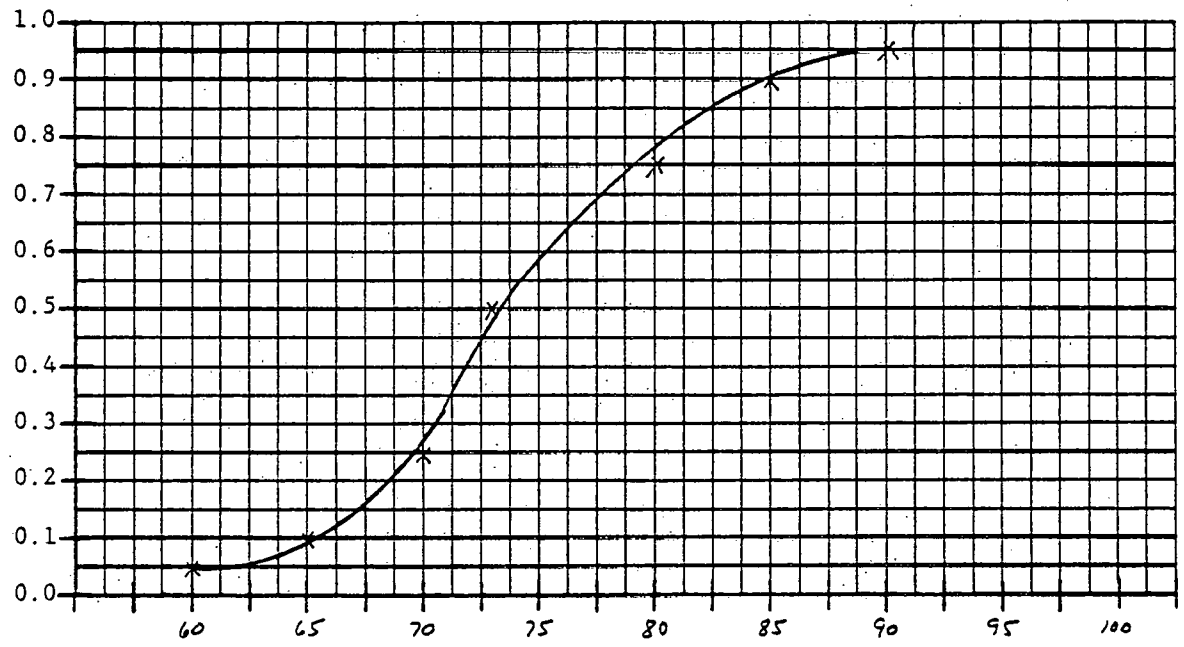


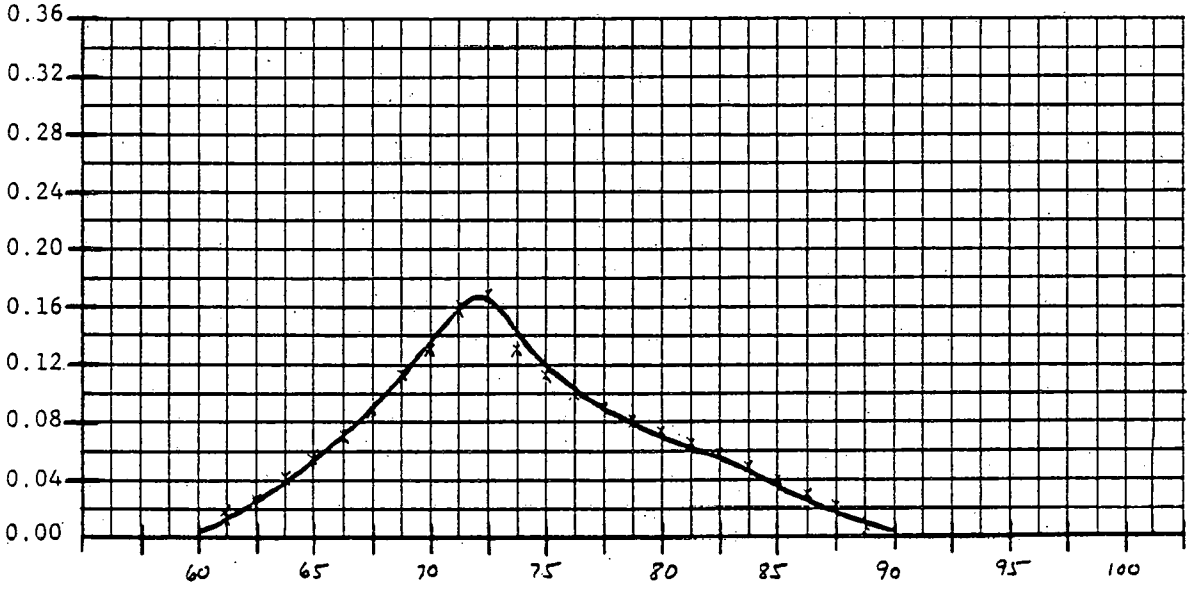



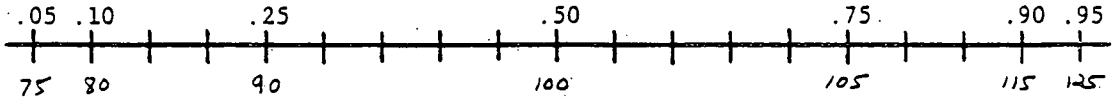
QUANTITY OPERATING COSTS
SUBJECT F
DATE 8/9/79

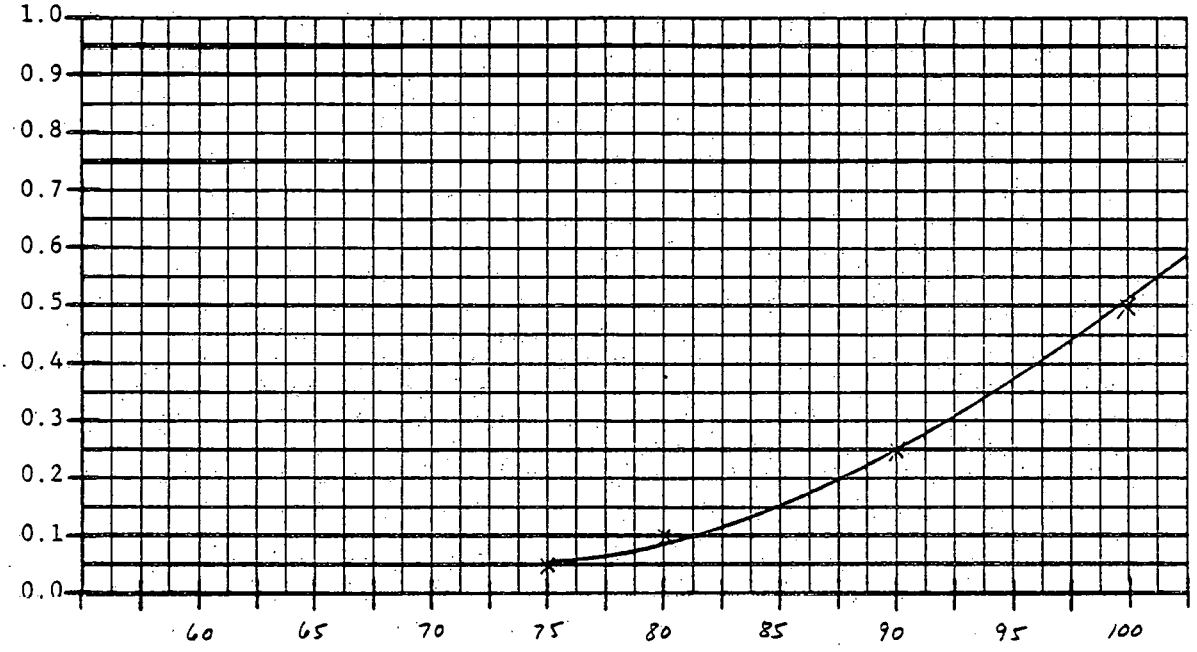


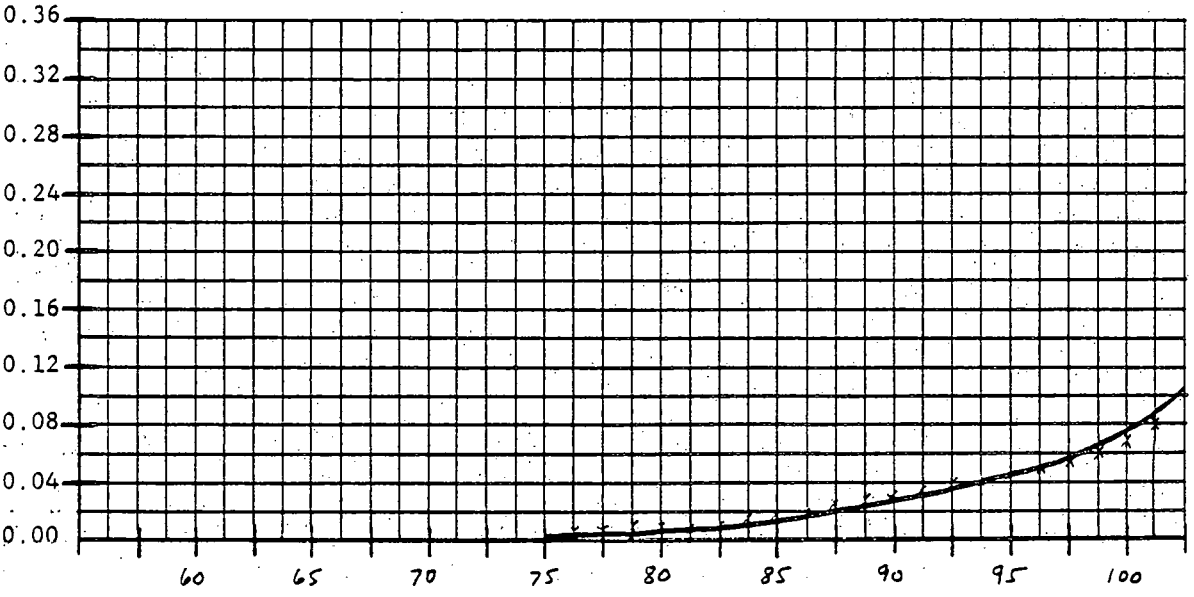



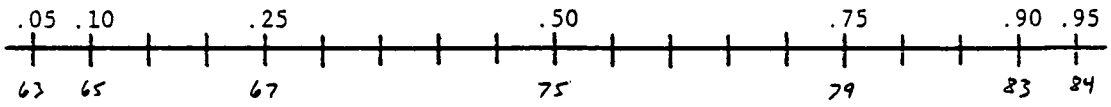
QUANTITY OPERATING COSTS
SUBJECT G
DATE 8/10/79

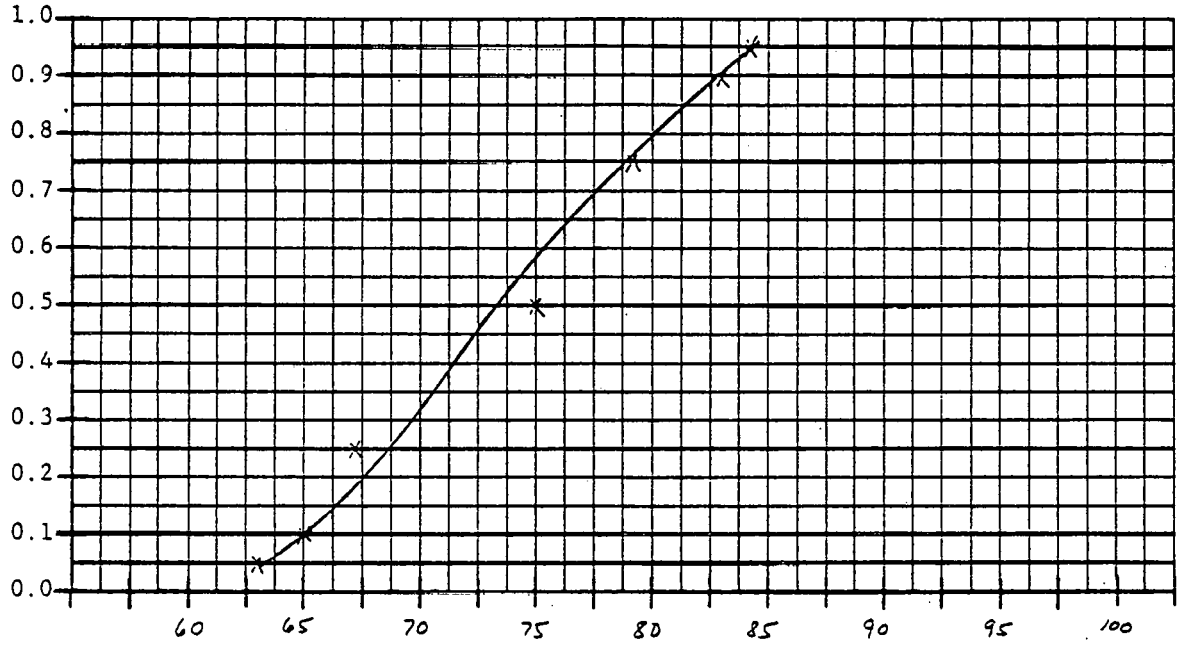


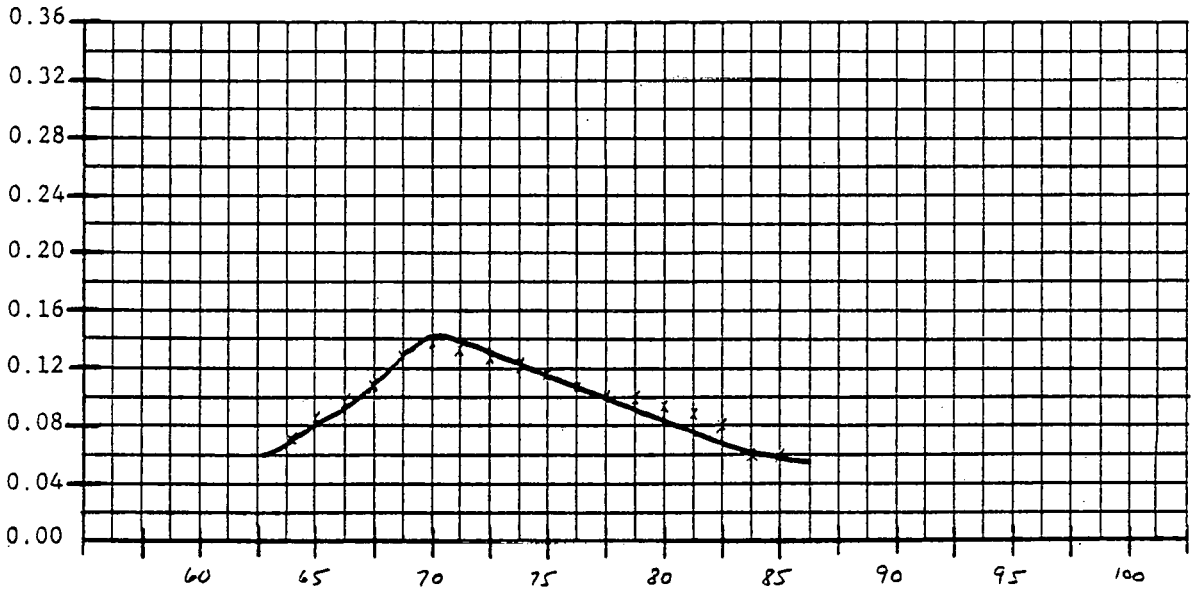



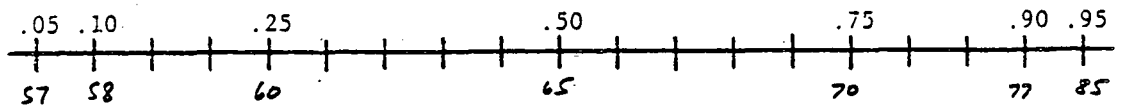
QUANTITY OPERATING COSTS
SUBJECT I
DATE 8/10/79

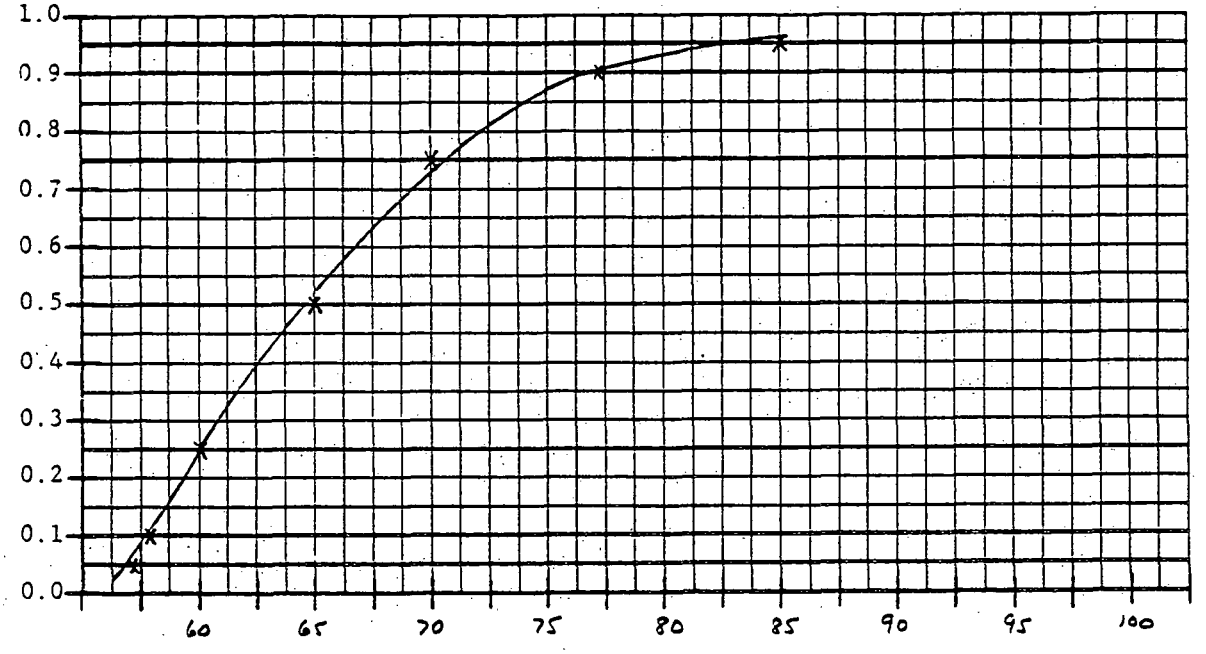


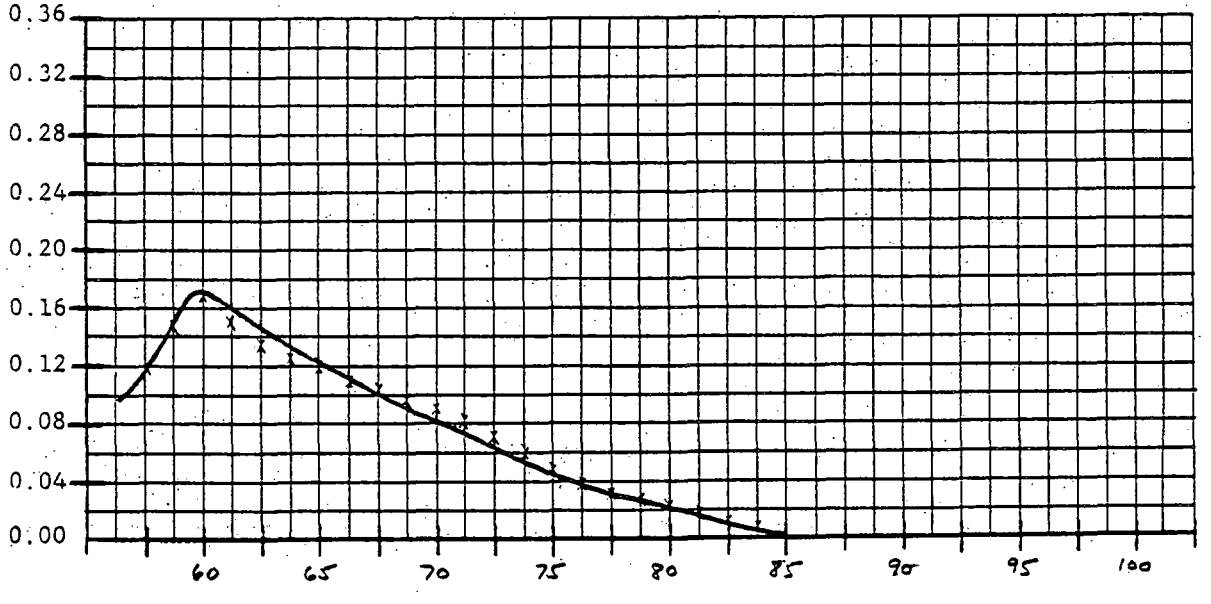



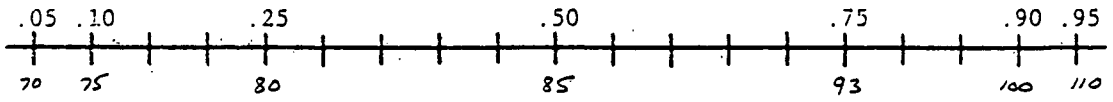
QUANTITY OPERATING COSTS
SUBJECT m
DATE 8/14/79

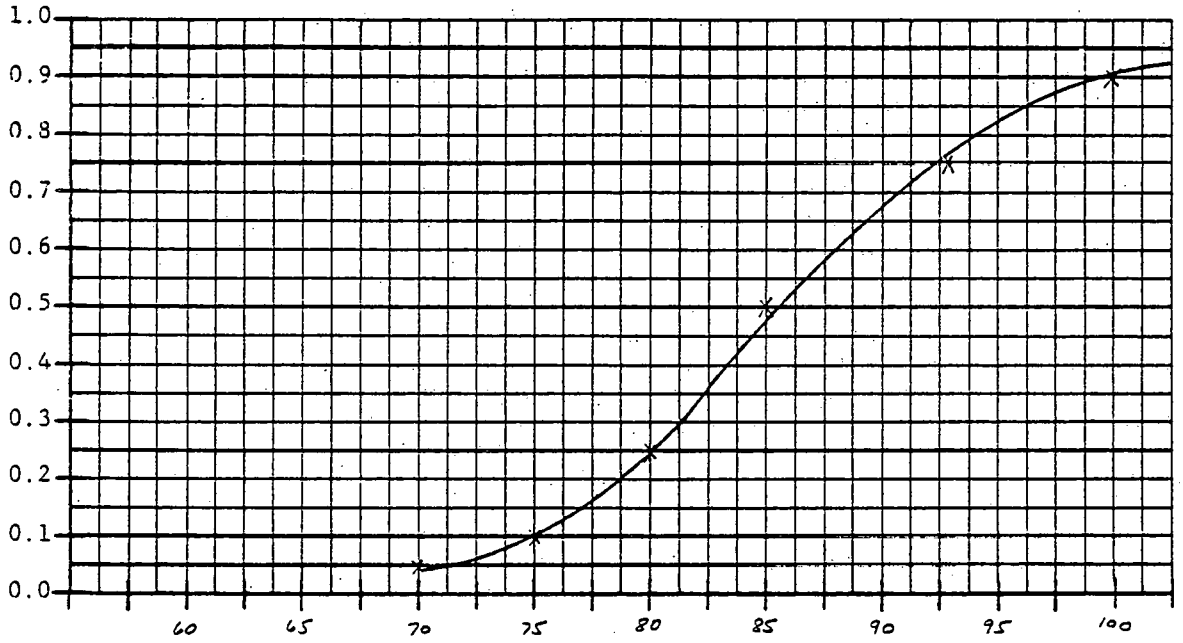


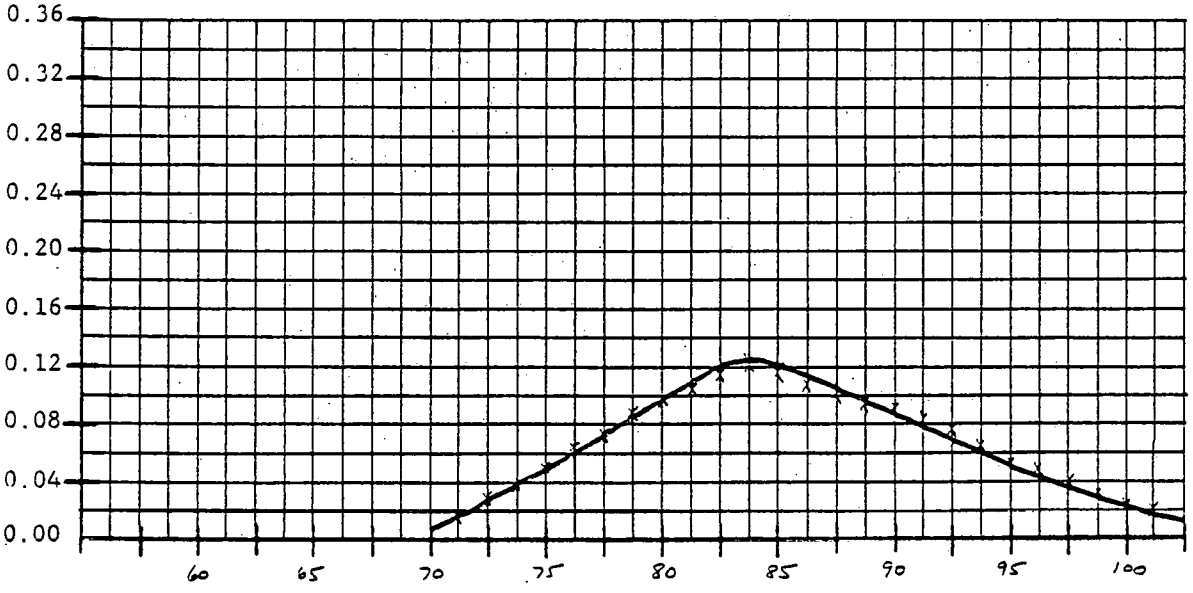



QUANTITY OPERATING COSTS
SUBJECT N
DATE 8/15/79



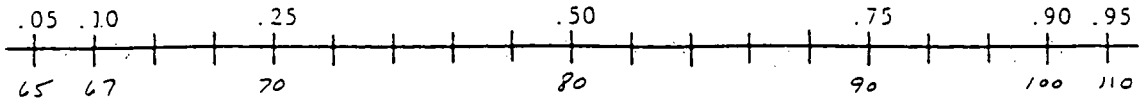



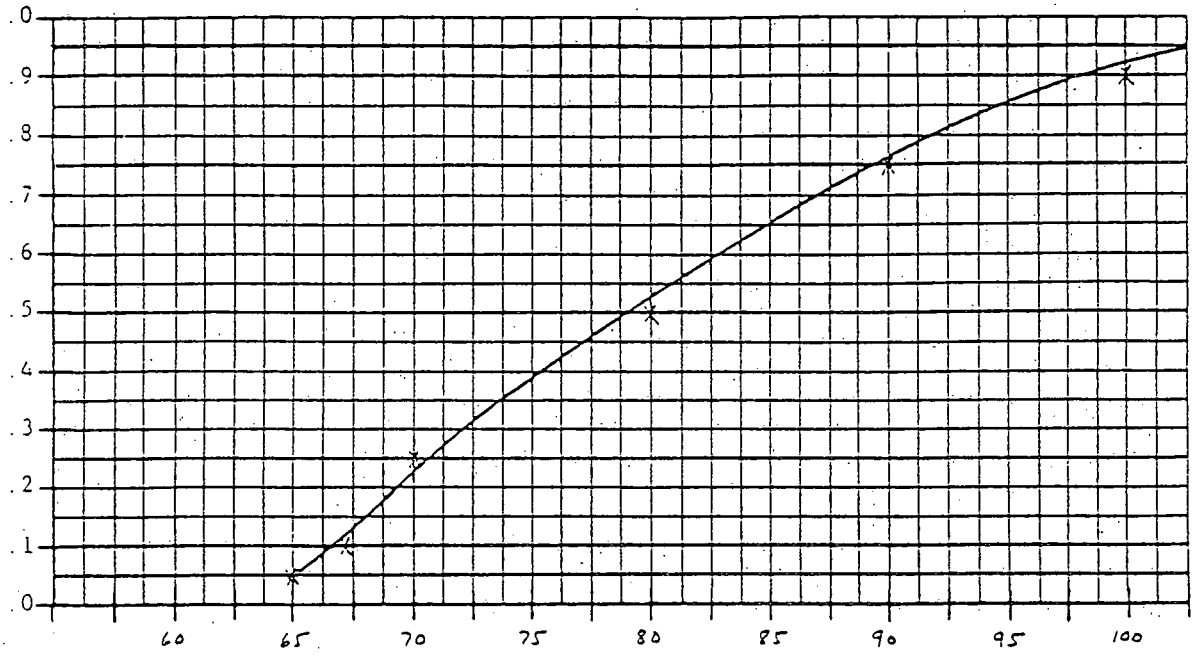



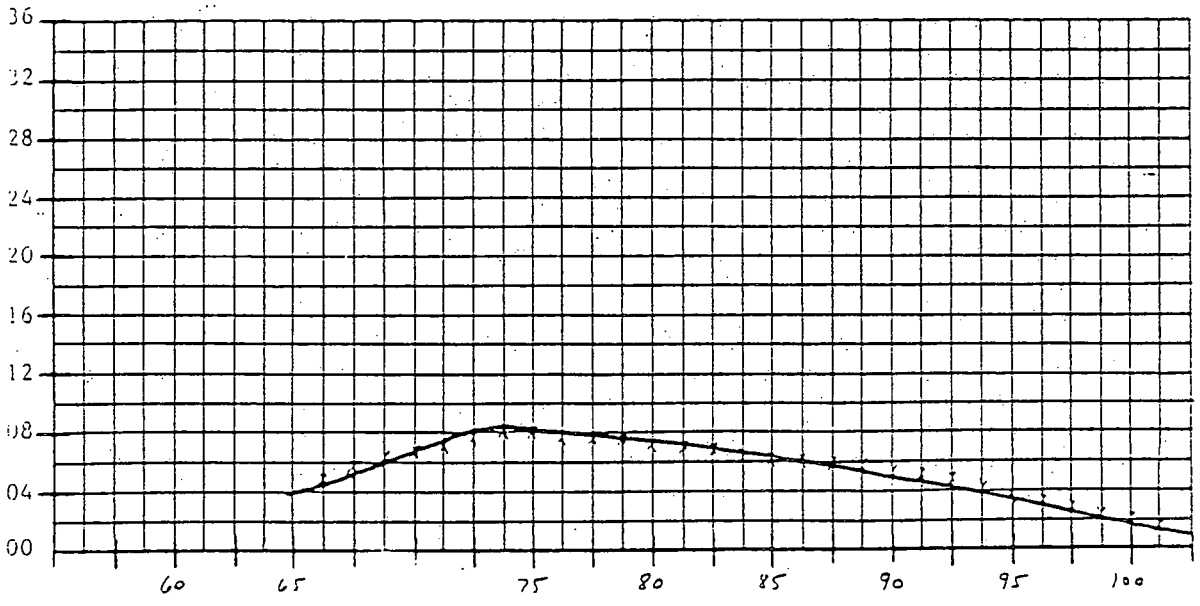
QUANTITY OPERATING COSTS

SUBJECT O

DATE 2/9/79



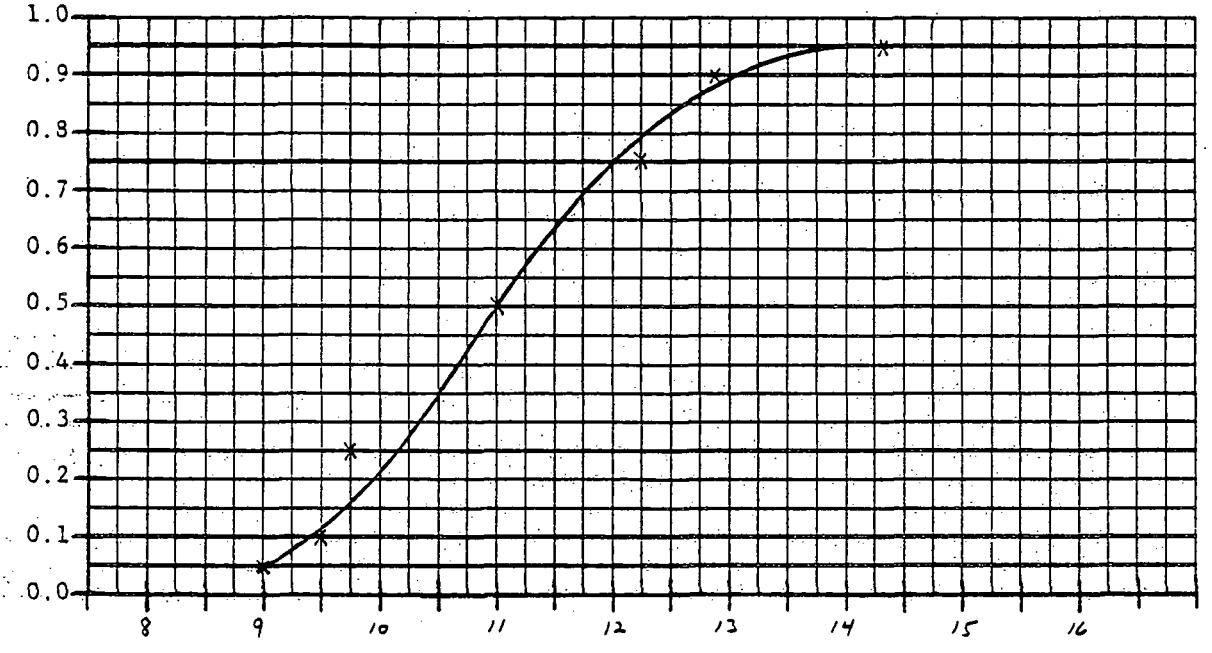
APPENDIX B

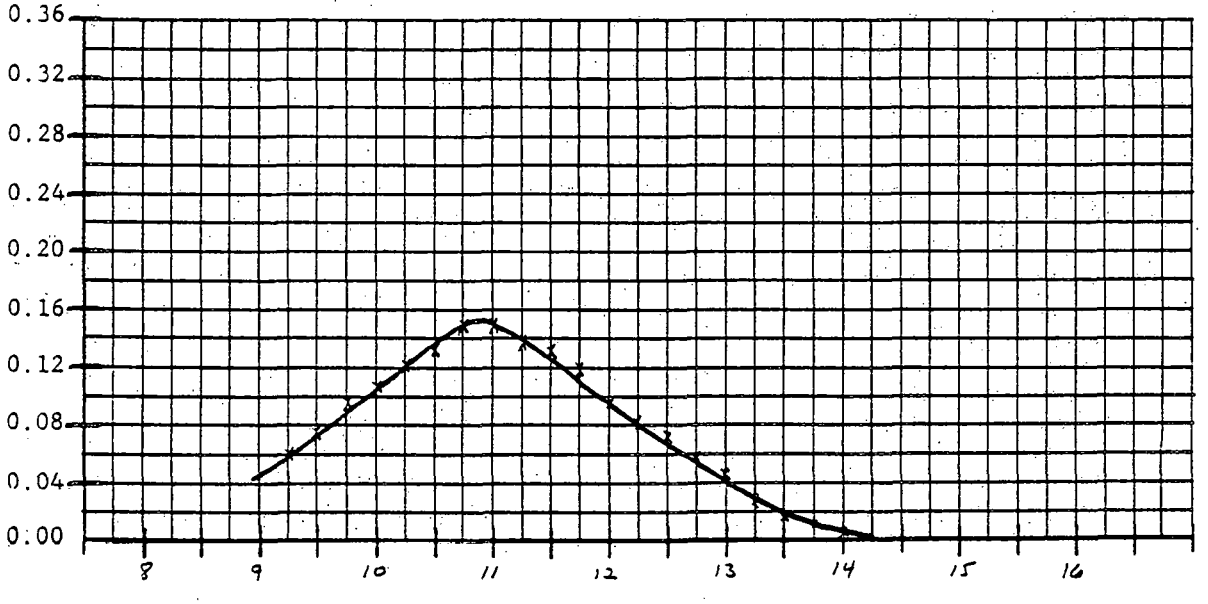
# APPENDIX

# B

QUANTITY PROJECT DURATION
SUBJECT COMBINED DATE

| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 8.98 | 9.44 | 9.73 | 10.98 | 12.22 | 12.83 | 14.31 |

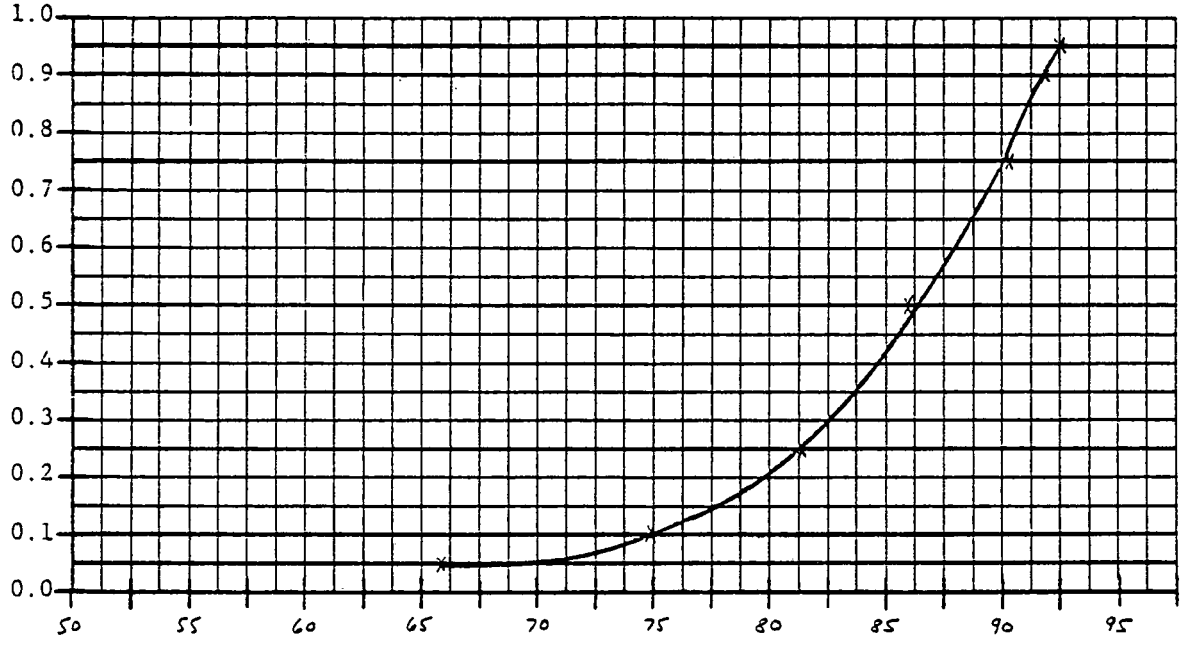


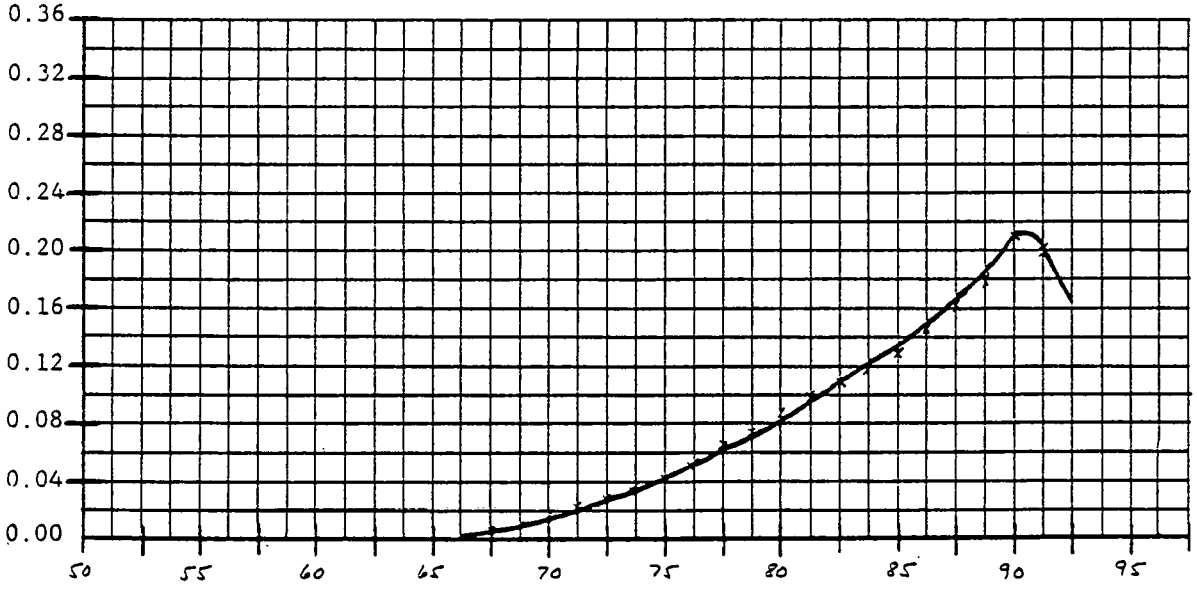



QUANTITY ONSTREAM FACTOR

SUBJECT COMBINED DATE

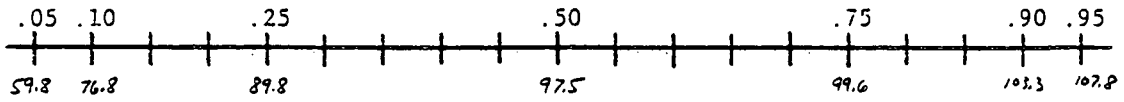
| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 65.9 | 74.8 | 81.5 | 86.1 | 90.4 | 91.8 | 92.5 |

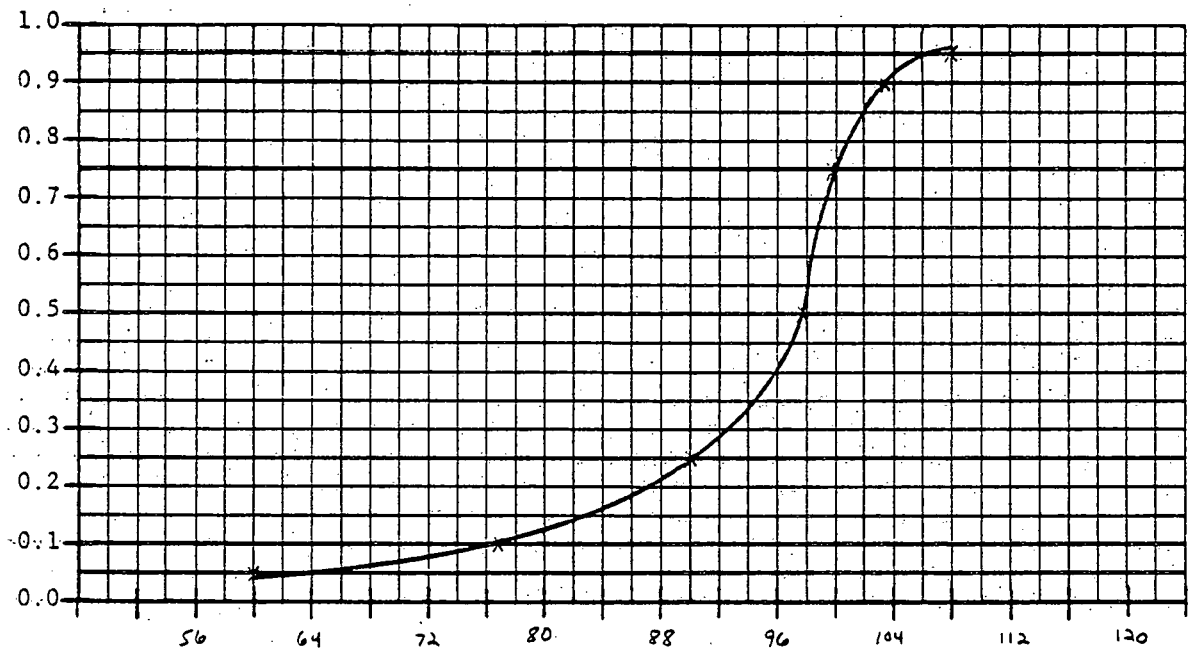


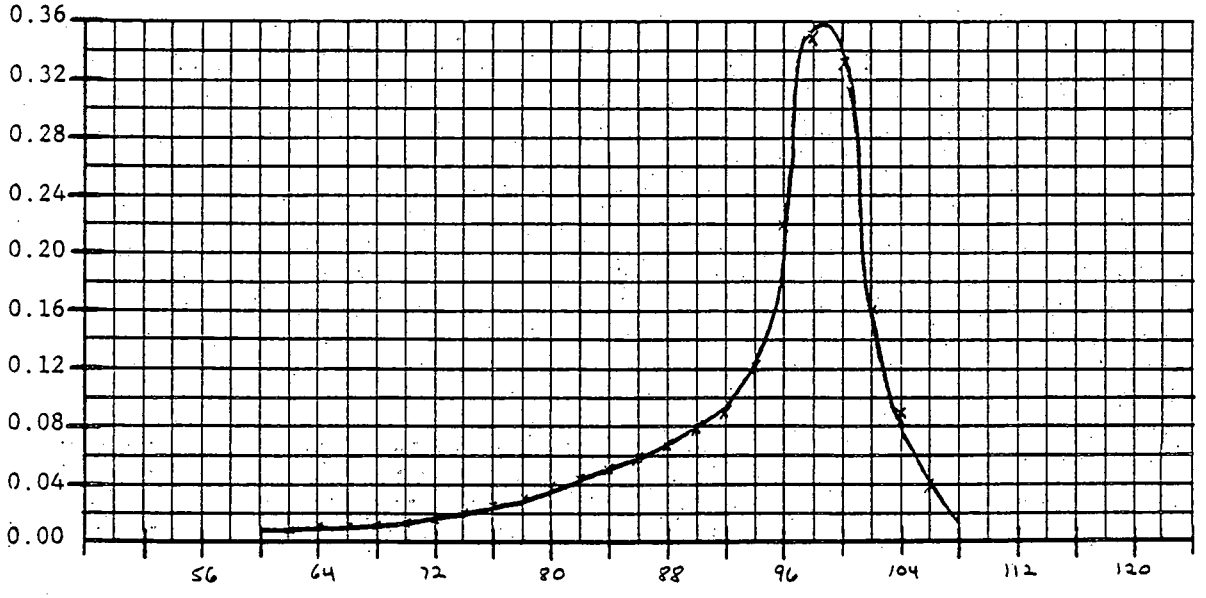



QUANTITY DESIGN CAPACITY FACTOR

SUBJECT COMBINED DATE



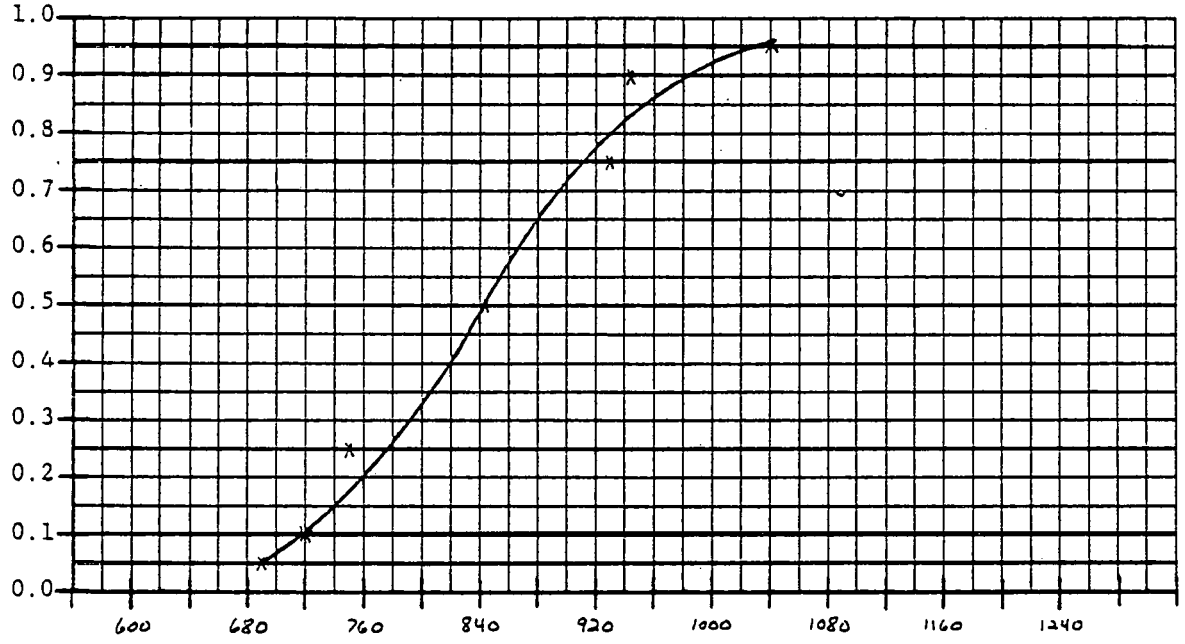



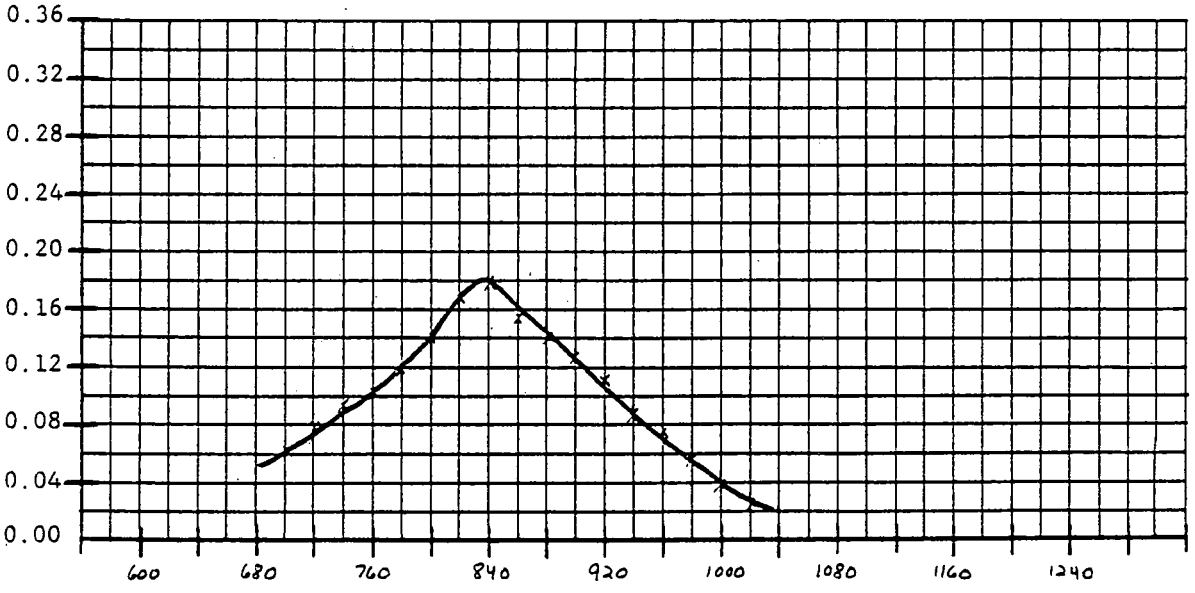



QUANTITY CAPITAL COSTS

SUBJECT COMBINED DATE

| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 692 | 721 | 749 | 845 | 932 | 945 | 1041 |

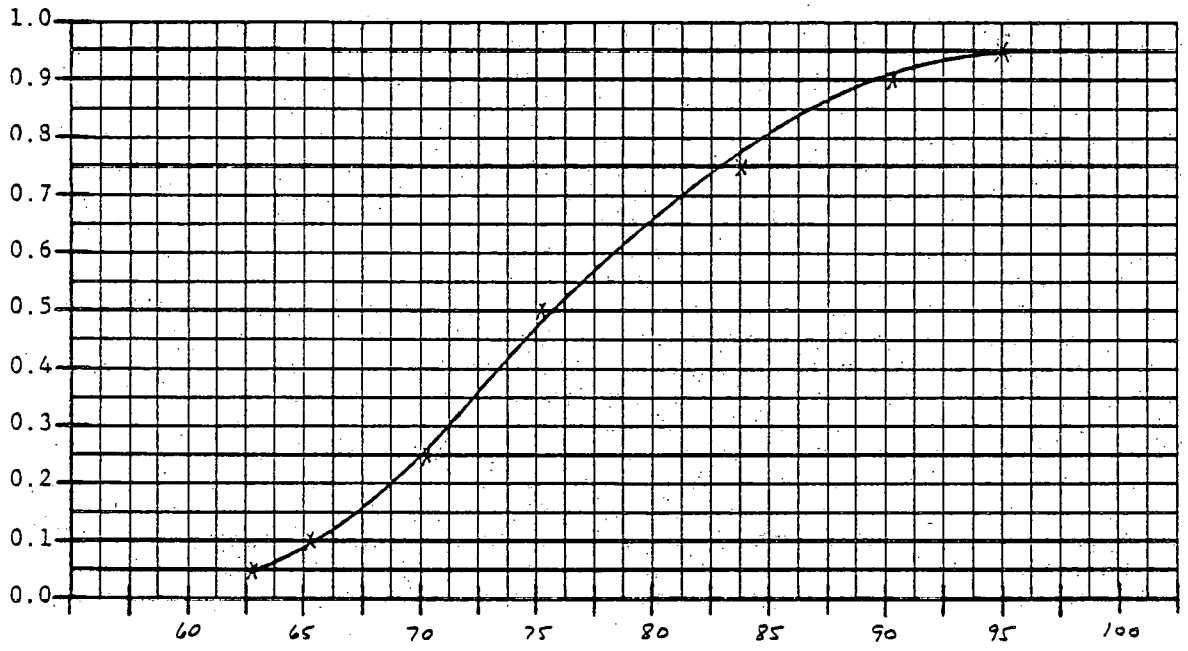


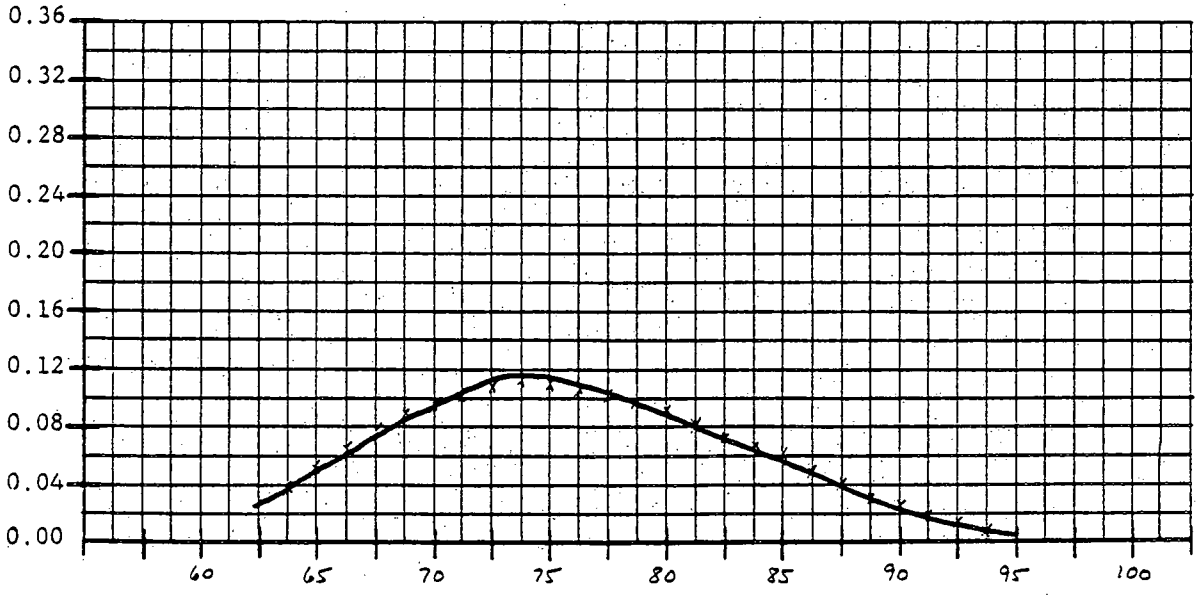



QUANTITY OPERATING COSTS

SUBJECT COMBINED DATE

| .05 | .10 | .25 | .50 | .75 | .90 | .95 |
|---|---|---|---|---|---|---|
| 62.9 | 65.4 | 70.3 | 75.4 | 83.7 | 90.5 | 94.9 |

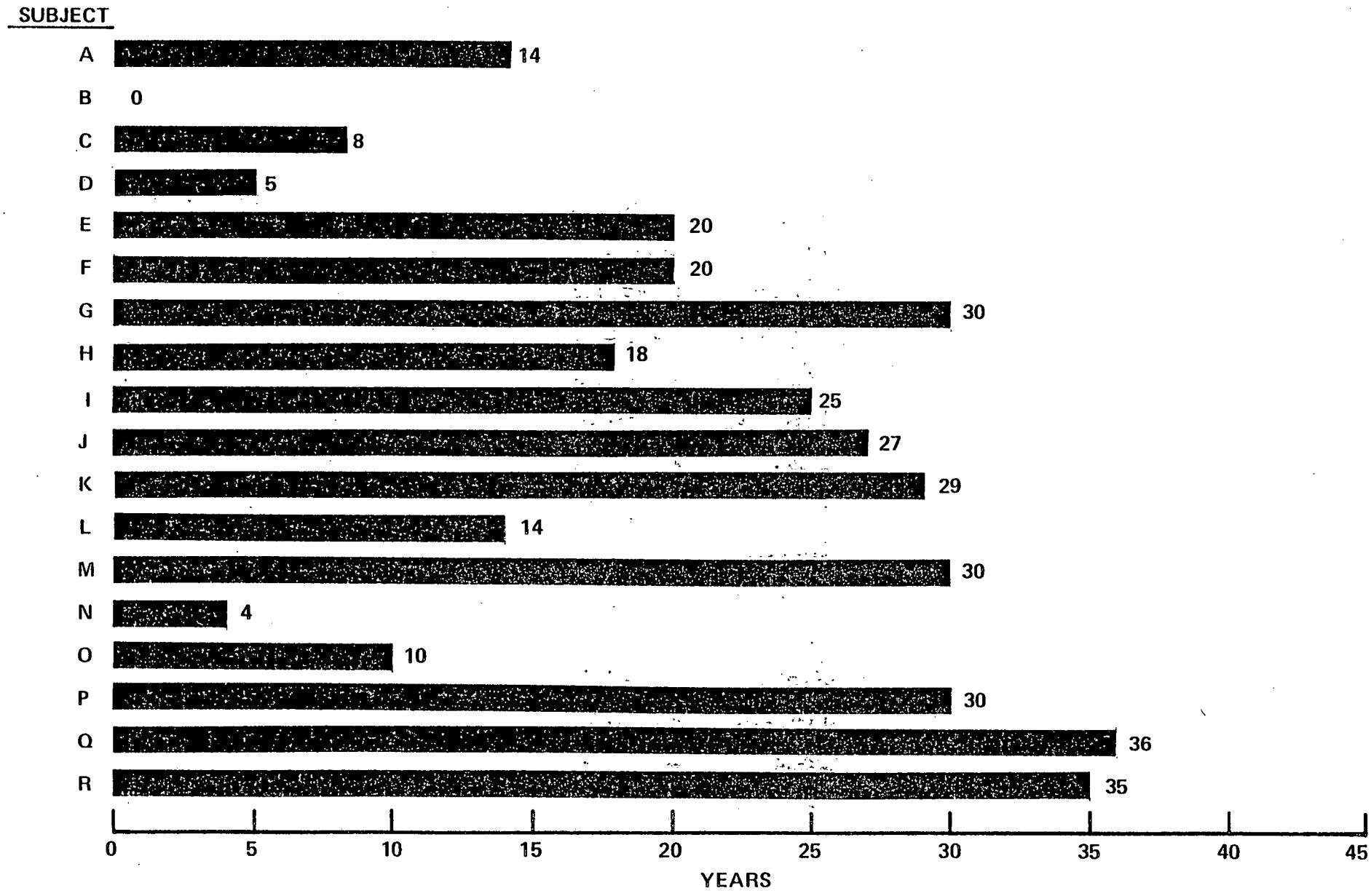


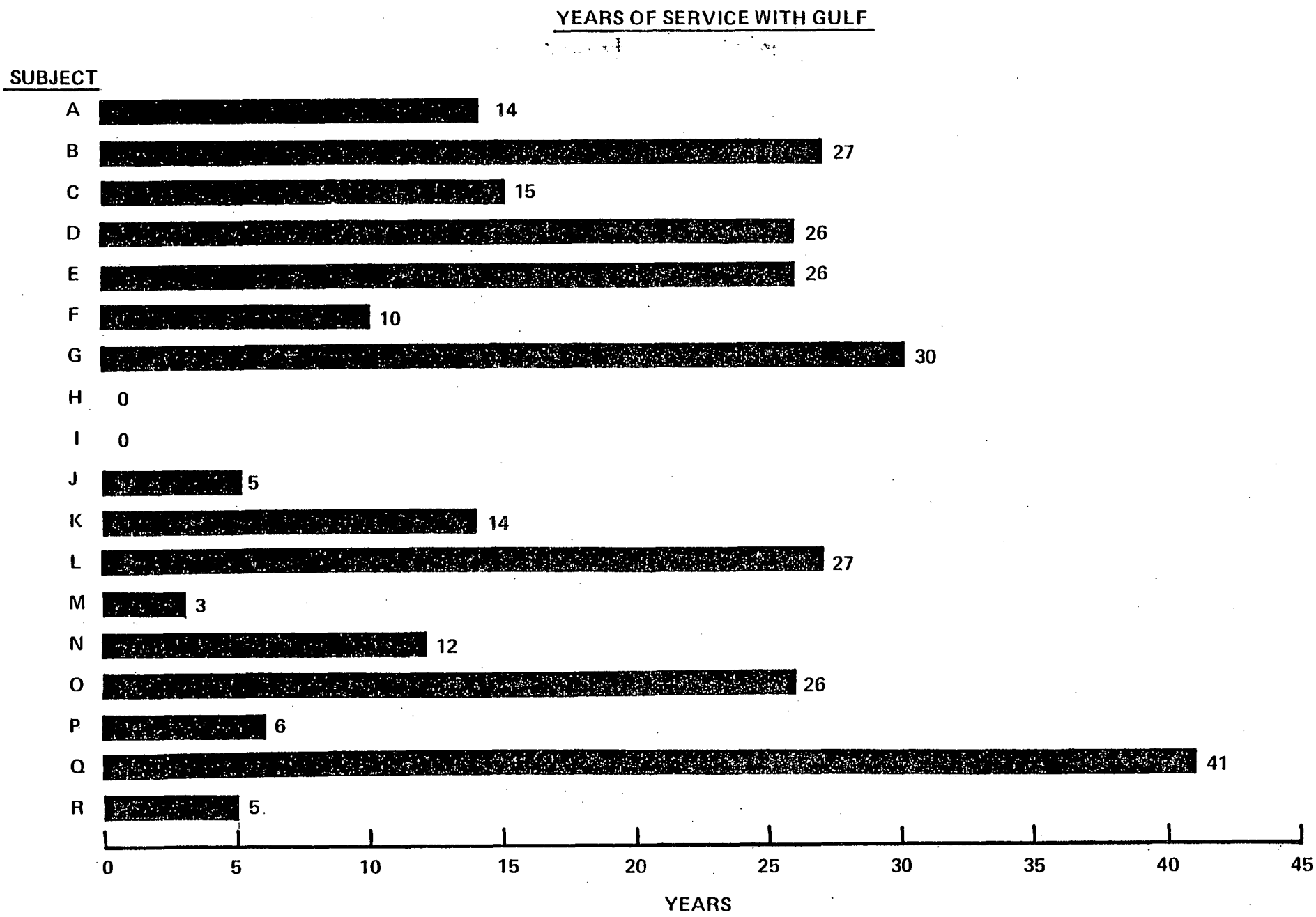



# APPENDIX

# C

## YEARS OF EXPERIENCE IN LARGE-SCALE PETROLEUM, PETROCHEMICAL, OR COAL-TAR PROCESSING




YEARS OF SERVICE WITH GULF
SUBJECT
A 14
B 27
C 15
D 26
E 26
F 10
G 30
H 0
I 0
J 5
K 14
L 27
M 3
N 12
O 26
P 6
Q 41
R 5
0 5 10 15 20 25 30 35 40 45
YEARS

## YEARS OF SERVICE ON THE SOLVENT REFINED COAL PROJECT