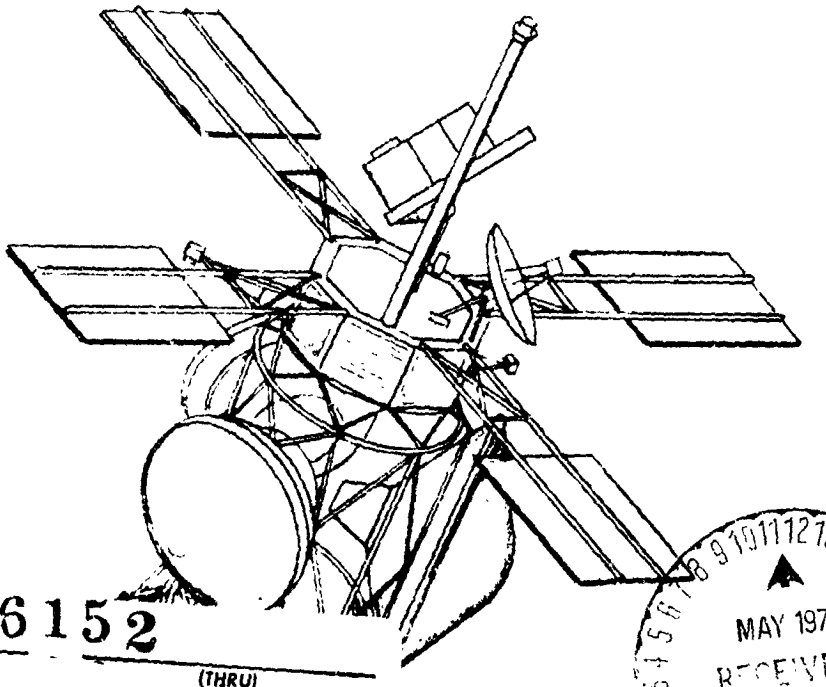
CONTRACT JPL 952534

1975 VENUS MULTIPROBE MISSION STUDY

FINAL STUDY REPORT

VOLUME III
APPENDIXES

APRIL 1970



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1975 VENUS MULTIPROBE MISSION STUDY
FINAL REPORT
March 1970

Volume III
APPENDIXES

Approved

Stephen J. Ducsai,
Study Manager

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Denver Division
Denver, Colorado

FOREWORD

This report has been prepared in accordance with requirements of Contract JPL 952534 to present data and conclusions resulting from a six month study effort performed for the Jet Propulsion Laboratory by the Martin Marietta Corporation. Volume I contains the Introduction, Summary and Conclusions, Volume II contains details of the Technical Studies and Analysis, and Volume III contains the Appendixes.

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SCHEDULE

1.0 STATEMENT OF WORK

(a) The Contractor shall conduct a study of a Venus multi-probe entry mission for a 1975 mission opportunity. The entry probes shall be targeted for significantly different planet locations and environments (e.g., near subsolar, near anti-subsolar and polar sites).

The general areas of effort to accomplish the above objectives are:

(1) Definition of the requirements of an entry mission with multiple probes as a vehicle for extensive exploration of the Venus atmosphere. The entry probes' science capability shall be as specified in study reference specified in paragraphs (b)(5)(A).

(2) Definition of interplanetary transfer and planetary entry trajectories and planetary environment models for development of the baseline mission design. The entry and descent requirements shall be based on the Venus environment models specified in paragraph (b)(5)(B) for a nominal surface pressure range of 70 to 150 Earth atmospheres.

(3) Synthesis of entry probe systems compatible with items specified in paragraphs (a)(1) and (a)(2). The technology and design approache defined in paragraph (b)(5)(C) shall be utilized to the maximum practical degree.

(4) Incorporation of the entry probes specified in paragraph (a)(3) into a planetary vehicle using flyby and direct-impact Mariner-Venus spacecraft alternatives as carriers. The specific science capability of the carrier is not part of the study requirements. The planetary vehicle shall be compatible with the launch constraints of the Titan IIIC vehicle as covered by paragraph (b)(5)(F).

(b) In the performance of this effort the Contractor shall:

(1) Define the interplanetary, planetary flyby, planetary direct-impact, and planetary entry trajectories, consistent with mission scientific requirements, including, but not necessarily limited to, the following considerations:

(A) Definition of baseline impact sites best suited to science criteria specified in paragraph (b)(5)(A).

(B) Definition of approach trajectories for entry probes compatible with a direct telecommunication link to Earth from baseline impact sites.

(C) Definition of entry and descent trajectory parameters (for baseline impact sites) affecting probe system design to determine the most desirable entry conditions for the mission (e.g., aerodynamic heating and deceleration as a function of entry path angle, telecommunication geometry, system weight requirements, and related conditions).

(i) The atmospheric models defined in paragraph (b)(5)(B), applicable to a nominal range of 70-150 Earth atmospheres surface pressure, shall establish the range over which analysis shall be made. The atmospheric parameter range, for which the entry probe systems must be capable of accomplishing mission requirements, shall be determined by tradeoff of subsystem design penalties and the most probable ranges of parameters. Final selection of the baseline range for the probe system design shall be reviewed and approved by JPL.

(ii) Deceleration of the probe to subsonic velocity at an altitude and time before impact shall be insured, compatible with science measurement and data transmission requirements.

(iii) The aerothermodynamic environment shall be compatible with the technology limits and heat shield weights taken from paragraph (b)(5)(D), with exceptions as specified therein.

(D) Definition of interplanetary transfer trajectories consistent with Titan IIIC launch vehicle constraints delineated in paragraph (b)(5)(F) and mission requirements outlined in paragraphs (b)(1)(A) through (b)(1)(C).

(2) Define entry probe systems consistent with the science requirements specified in paragraph (b)(5)(A) and the mission constraints specified in paragraph (b)(1). The systems are not required to survive impact and need not be identical if the study indicates this is not favorable. Results and conclusions shall be documented by system and subsystem functional descriptions and block diagrams, operational sequences, configuration drawings and weight and power summaries. Definition of the systems shall include, but not necessarily be limited to, the following:

(A) Definition of the data system design based on mission requirements, specifically, compatibility with the baseline impact sites.

(B) Design mechanization of science instrument sampling and/or data gathering, including physical arrangement of instruments, ducting and/or sensor exposure required to obtain meaningful measurements of the Venus environment.

(C) Definition of design and technological implications of probe decontamination to the criteria established in paragraph (b)(4)(D).

(D) Definition of probe system propulsion size and accuracy requirements to achieve the baseline impact sites within reasonable dispersions from flyby and direct-impact spacecraft alternatives.

(E) Definition of engineering subsystems requirements and system configuration (e.g., attitude control, aeroshell) to achieve the entry and descent conditions consistent with scientific objectives, based on analyses specified in paragraph (b)(1).

(F) Evaluation of major technology developments necessary for the entry system.

(3) Define flyby and direct-impact planetary vehicle systems which incorporate the entry probes defined in paragraph (b)(2) required to accomplish the probe science mission objectives specified in paragraph (b)(5)(A). The spacecraft shall be based on Mariner project concepts as defined by configuration 20a, page 5-10, in the documentation covered by paragraph (b)(5)(C) with minimum modifications required to reflect the 1975 mission trajectory parameters, the direct-impact alternative, and the interfaces of the entry probes with the spacecraft. Results and conclusions shall be documented by configuration interface drawings, weight and power summaries, interface block diagrams and operational sequences. Analytical estimates of carrier structural suitability or required changes to accommodate the entry probes shall also be made.

(4) Observe the following constraints:

(A) Mission accomplishment shall be during the 1975 launch opportunity. System state-of-the-art will be as of July 1972.

(B) Mission requirements shall be compatible with the Deep Space Net (DSN) capability as described in paragraph (b)(5)(E).

(C) Launch energy requirements shall be based upon use of a Titan IIIC vehicle, in accordance with paragraph (b)(5)(F).

(D) The mission shall be consistent with the NASA planetary quarantine policy specified in NASA Management Manual 4-4-1, "NASA Unmanned Spacecraft Decontamination Policy," September 1963, which for this mission is interpreted to mean that the region of the atmosphere which might be conducive to forms of life shall not be contaminated.

For purposes of this study:

(i) The system shall be assembled in "clean rooms" at specified levels of assembly.

(ii) All hardware entering the planet's atmosphere must be capable of withstanding ethylene oxide (ETO) exposure in accordance with paragraph (b)(5)(G).

(iii) Selected probe equipment (e.g., heat shield and other elements that might outgas or vent to the atmosphere) must be capable of withstanding heat sterilization as defined in paragraph (b)(5)(G).

(iv) The planetary entry systems shall be enclosed in a bacteriological barrier to maintain cleanliness and sterility. After decontamination, the enclosure shall not be opened within any portion of the Earth's atmosphere which might recontaminate the entry system.

(v) Adherence to items covered in paragraphs (a)(4)(D)(i) through (iv) shall apply only to the entry probes. (Note: Exclusion of the spacecraft at this time is for purposes of this study only.)

(E) Trajectory-related constants shall be as defined in paragraph (b)(5)(H).

(5) Utilize the following information:

(A) JPL Section Document 131-03, "Science Criteria for Venus Entry Missions," dated March 3, 1969.

(B) NASA Space Vehicle Design Criteria, "Models of Venus Atmosphere (1968)," NASA SP-8011, dated December 1968.

(C) Avco Report AVSSO-080-68-RR, "1972 Venus Flyby/Entry Probe Mission Study," Final Technical Report, Books I and II, April 1968.

(D) JPL Section Document 131-05, "Venus Entry Heat Shield Design Requirements and Technology Limits." (undated)

(E) JPL Document 611-1, "Tracking and Data System Estimated Capabilities for the Mars 1973 Mission," December 1, 1968.

(F) Titan IIIC launch vehicle performance information contained in JPL Section Document 131-04, dated March 3, 1969.

(G) JPL Specification No. VOL-50503-[illegible]S, "Environmental Specification, Voyager Capsule Flight Equipment Type Approval and Flight Acceptance Test Procedures for the Heat Sterilization and ETO Decontamination Environments," dated January 12, 1966.

(H) JPL TR-32-1306, "Constants and Related Information for Astrodynamic Calculations 1968," dated July 15, 1968.

(I) JPL-generated trajectory data (tabulated) for the 1975 launch opportunities for Venus missions. This does not include Venus entry trajectory information.

(6) Provide the following reports and documentation:

(A) One (1) reproducible and twenty-five (25) print copies of a Monthly Technical Progress Letter Report to JPL and five (5) print copies to Goddard Space Flight Center (GSFC), which shall include, but not necessarily be limited to, the following:

(i) The detailed technical progress made during the reporting period.

(ii) A brief discussion of technical problems encountered and their solution.

(iii) A brief review of the detailed program for the ensuing month.

(iv) An evaluation of conditions which may affect completion of the study Contract.

(v) JPL Form 3177 entitled "Monthly Progress Repor. shall be utilized in complying with this requirement.

(B) One (1) reproducible and six (6) print copies of JPL Form 3174 entitled "Milestone Progress Report."

(C) An Effort Report for the Key Personnel listed in Article 4. The report shall include the name, classification, inclusive dates and hours worked for each individual.

(D) One (1) reproducible and six (6) print copies of a Monthly Financial Report which shall include, but not necessarily be limited to, the following:

(i) Contractor Financial Management Report, NASA Form 533b (Feb. 67).

(ii) A Graphic Presentation indicating rate of actual expenditure and projected expenditures to completion of Contract.

(E) A Midterm Oral Technical Presentation at JPL to include, but not necessarily be limited to, the progress of the work performed during the reporting period. The Contractor's Key Personnel on this study shall be present at this Midterm presentation. Twenty-five (25) copies of the slide material (annotated) shall be available to JPL and five (5) copies to GSFC three (3) working days prior to the time of the presentation.

(F) Five (5) copies to JPL and one (1) copy to GSFC of a Preliminary Draft of the Final Engineering Report for JPL approval.

(G) One (1) reproducible and seventy-five (75) print copies of a Final Engineering Report covering all effort accomplished in the performance of the Contract to JPL and five (5) copies to GSFC. The report shall be presented in the following general format:

(i) Definition of task.

(ii) Definition of terms.

(iii) Assumptions and constraints.

(iv) Presentation of Supporting Analysis and Rationale.

(v) Results and conclusions.

(H) A Final Oral Presentation at JPL to include, but not necessarily be limited to, the results of all work performed under this Contract. Twenty-five (25) copies of the slide material shall be delivered to JPL and five (5) copies to GSFC three (3) working days prior to presentation.

(I) A technical meeting between the Contractor and JPL shall be held at the Contractor's facility two (2) weeks after date of Contract, at which time the Contractor shall present a Detailed Study Plan. This study plan shall basically reflect the approach described in Martin Marietta Corporation Technical Proposal P-69-45, Volume 1, dated April 1969.

(J) At the request of either JPL or the Contractor, informal discussions shall be held at Contractor's facility to review the progress of the study, or any other matter pertinent thereto.

(c) JPL will:

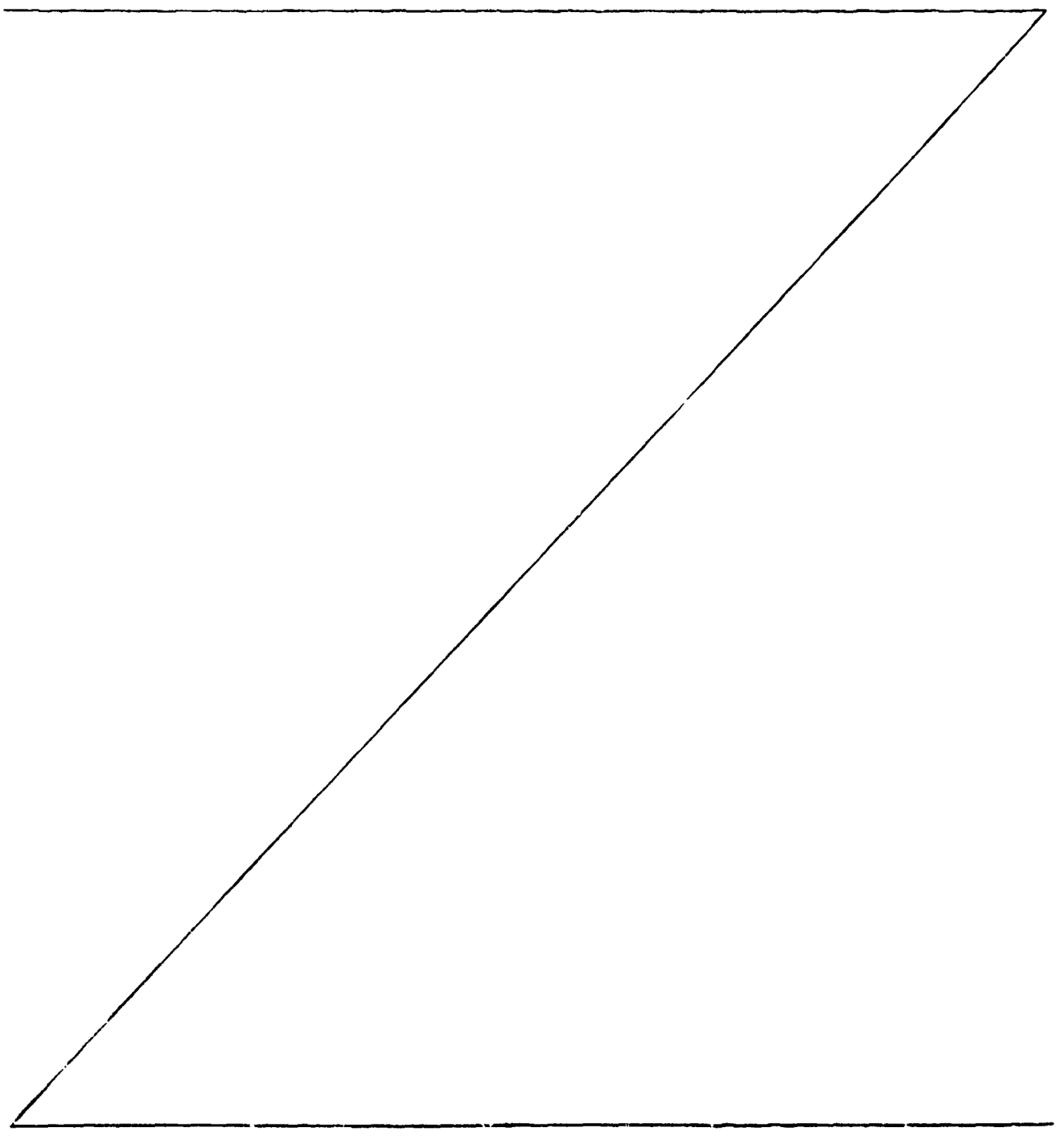
(1) Furnish to the Contractor, within five (5) calendar days after date of Contract, the data shown under paragraph (b)(5)

(2) Approve, disapprove, provide comments or suggestions on Detailed Study Plan as specified in paragraph (b)(6)(I) on or before five (5) working days after presentation by the Contractor.

(3) Approve, disapprove, provide comments or suggestions with regard to the Preliminary Draft of the Final Engineering Report as specified in paragraph (b)(6)(F) on or before ten (10) working days after receipt from the Contractor.

(4) Approve, disapprove, provide comments or suggestions with regard to the Final Engineering Report as specified in paragraph (b)(6)(G) on or before five (5) working days after receipt from the Contractor.

(5) Approve, disapprove, provide comments or suggestions with regard to the selection of the baseline range for the probe system as specified in paragraph (b)(1)(C)(i) on or before five (5) working days after receipt from the Contractor.



Science Criteria for Venus Entry Missions

Introduction:

The purpose of this document is to specify representative science objectives and instrumentation for study of a 1975 Venus entry mission. These objectives and instruments are the science constraints to be used for defining entry system characteristics, entry sites and supporting subsystem requirements. These objectives are derived from a cooperative agreement per GSFC and JPL based documents (1) and (2).

Venus Exploration Questions:

Venus exploration objectives are defined, in this document, in terms of the questions below for which answers are sought by the entry missions to be studied.

1) What is the composition of the atmosphere?
   a) Are the minor constituents uniformly mixed throughout the atmosphere?
   b) Can any constituents condense to form liquids on the surface of the planet?
   c) Are argon, neon, or nitrogen present in the atmosphere, and what is their origin?
   d) How is the abundance of these gases related to that of the major constituent CO_2?
   e) What ionic species are present in the upper atmosphere?
   f) What is the photochemistry of the upper atmosphere?
2) What is the distribution and chemical composition of the clouds?
   a) Are the clouds composed of condensed vapors or of solid particles?
   b) If the cloud particles are solids, are they ice crystals (or other condensables) or dust?
   c) If the clouds are dust, is the dust the result of volcanic eruption or of surface disintegration?
   d) What size are the particles?
   e) Are the clouds uniformly distributed vertically in the atmosphere, or are there several cloud layers?
3) What is the general circulation pattern of the atmosphere?
   a) Is there any variation of the vertical temperature or compositional profiles with latitude?

b) Are the polar regions cooler than the equatorial region?
c) What is the physics of interaction between the clouds and atmospheric heat sources?
d) Is the high surface temperature due to a greenhouse effect, to convective heating, or to what effect?
e) To what extent is the atmosphere responsible for a redistribution of surface or internal material?
f) What is the variation in temperature between the dayside and the nightside?
g) Are there high-speed winds on Venus:

Venus Entry Probes Instrumentation:

The following is a listing of instrumentation for the Venus entry mission study, with brief descriptions of the exploration objective to which it applies and some of the important considerations in the proposed use of the instrument. Table I provides quantitative information for each instrument. The number and capability of entry systems required to integrate the proposed instrumentation to accomplish the major mission objectives is the fundamental task of the mission study.

Accelerometers:

It is proposed to determine the structure of the Venus atmosphere (i.e., pressure, temperature, and density, as functions of altitude) by measurement of vehicle acceleration during high speed entry into the atmosphere. Acceleration measurements provide one of the simplest and most direct means to determine atmosphere structure during the portion of the entry when the vehicle is enveloped by a shock layer in which the gas properties have been significantly changed from ambient conditions. The principle underlying this experiment is a simple and straightforward one - that aerodynamic resistance to motion is proportional to the density of the atmosphere and the square of the velocity. The atmospheric density is thus proportional to the deceleration with the factor of proportionality $2(m/C_DA)/V^2$, where m is the vehicle mass, A its frontal area, C_D the drag coefficient, and V the instantaneous velocity. The drag coefficient is known from laboratory measurements. (Post-experiment laboratory work will be devoted, if necessary, to obtaining a drag coefficient at atmospheric conditions closely duplicating those encountered, both with respect to composition and Mach number

and Reynolds number.) The measured accelerations are integrated to define the instantaneous velocity.

Other data obtained from the accelerometer measurements include altitude differences, given by integration of the vertical component of velocity; static pressure, given by integration of the barometric equation using measured densities; and the T/M ratio, defined by the ratio of pressure to density. The temperature profile can then be calculated using this ratio and the mean molecular weight of the atmospheric gas mixture obtained from mass spectrometer measurements or from low speed measurements of pressure, temperature, and acceleration.

The measurement accuracy required for this experiment has been studied at some length. As a result of these studies, a pendulous force balance accelerometer with a reading accuracy of 0.1 percent of full scale or better will be used. The Bell Aerosystems Model VII has capabilities considerably in excess of this requirement.

The experiment requires that a three-axis grouping of accelerometers be mounted at the probe center of gravity with a fourth unit providing a redundant measurement of axial acceleration. In order to realize the required accuracy of 0.1 percent of full scale, 10-bit digitization of each accelerometer measurement will be required.

Pressure Gauges

The range of atmospheric pressure, 0.05 atmos (1 psi) to 150 atmos (2200 psi), is such that accurate and reliable capsule-potentiometer and torsion-tube potentiometer gauges can be used.

Temperature Gauge

Temperature measurements must be made over the range 200 to 900°K. In order to achieve the accuracy needed for the identification of condensing atmospheric materials, platinum temperature-sensing elements must be used and they must be well ventilated.

It is proposed to use a single platinum resistance element operated over temperature intervals of 200-300, 300-400, 400-600, and 600-900°K by means of

temperature actuated range switching. Measurement error before telemetry will be ± 0.5% of the temperature intervals or ± 0.5°K for the two low temperature intervals and ± 0.5° for the high temperature interval. Further reduction in error can be obtained by reduction of the temperature interval size.

Neutral Particle Mass Spectrometer:

The instrument will measure atmospheric composition from the beginning of probe operation down to the surface of Venus. Since the probe will be moving subsonically the composition measurements will be directly interpretable in terms of the ambient composition.

Instrument mass range will be from 1-90 AMU. During mass range sweep, signal sensing will be employed and thus vacant mass-numbers positions will not be sampled. Sample mass-number identification and amplitude measurement requires 15 bits and is set for 10 bps output or 1.5 sec sampling time per mass signal. Since the telemetry rate is constant the sweep rate is determined by the total number of detectable mass signals. More detectable mass signals will result in longer range sweep time, fewer detectable mass signals will shorten the range sweep time.

Thermal Radiometer:

It is proposed to use a downward looking radiometer in the 6.5 to 8.5μ and 9.2 to 10.8μ regions. In the first spectral range CO_2 is relatively transparent but in the second spectral range it is absorbing or opaque. The main source of atmospheric opacity in the window spectral region is therefore caused by the particles composing the clouds. The second channel yields essentially the ambient atmospheric temperature. The first or window channel yields a mean atmosphere corresponding to a lower altitude.

In a near adiabatic atmosphere the difference in the brightness temperature between the two channels is thus proportional to the transmission characteristics of the clouds. Small differences correspond to opaque clouds, large differences to thin or absent clouds.

The radiometer experiment provides therefore a vertical profile or the effective cloud density. Water clouds or clouds of other condensation products must be confined to layers while dust clouds must be relatively uniformly distributed through the whole atmosphere. The measurement of the particle stratification is

therefore suited to distinguish between condensation and noncondensation clouds.

Near the surface, just before impact the experiment also provides a remote surface temperature measurement.

The radiometer will be of a rugged construction using thermocouples as detectors and broad band interference filters to isolate the desired spectral regions.

Solar radiometer

The divergence of the flux of solar radiation represents the fundamental dynamical drive of the atmosphere. The object of this experiment is to measure this quantity at all levels in the Venus atmosphere.

Where the upward and downward fluxes differ significantly, the net flux can be derived from the upward and downward components, measured separately. If the atmosphere is very deep, however, these two components (F^+ and F^- will be essentially the same and a measure of the flux divergence can be derived from the relationship

$$F^+ - F^- = \frac{4}{3} \frac{d}{d\tau} (F^+ + F^-)$$

where τ is the optical depth.

To apply this relationship, measurements have to be made in spectral ranges over which optical properties are approximately constant. Our wavelength bands would be $\lambda < 0.5\ \mu$, $0.5\ \mu < \lambda < 1.5\ \mu$, $1.5\ \mu < \lambda < 2.5\ \mu$ and $\lambda > 2.5\ \mu$, chosen to separate regions with differing particle albedos.

The field of view of the instrument comprises five 30° apex angle cones. The five cones are contiguous and are arranged in a fan shape with the first field of view starting at 20° from the zenith and the fifth field of view ending 10° from the nadir. Since the probe is rotating, the effective field of view of the instrument is approximately spherical. In order to achieve wavelength selection, the radiation from each conical field of view is separated by a dichroic beam splitter into the four required wavelength ranges. In summary, the spherical field of view about the probe is divided by the radiometer into five contiguous 30° bands and each band is observed in four wavelength regions. The first band is near the zenith, the third band covers the region of the horizon and the fifth band is near the nadir.

If we take a detector area of 10 mm^2 and a solid angle of 0.2 steradians, then, from experience with terrestrial measurements, we may expect power on the order of 1 μ-watt in each field of view and in each wavelength band. The contribution of direct sunlight would be of the order of 1 m-watt. These power levels are easy to measure, for instance with PbS detectors, using choppers and phase sensitive detectors to provide stability.

The signal from each of the 20 detectors which comprise the array should be sampled and integrated on board the vehicle for times corresponding to around 1 km change in attitude. The sampling should be synchronized with the spin rate of the vehicle (which can be derived by timing the intervals between successive passage of the sun by the detectors), so that for each 1 km interval we present 20 signals sampled at perhaps 6 different azimuth positions, for a total of 120 readings. If we ask for 7 bits of accuracy in each number, plus an additional 3 bits to define attenuator settings, we have a total of 1200 bits to be read out for each 1 km interval. In addition, we should take occasional dark readings and calibration readings from a standard light source. If this data rate proves to be too high, the azimuth resolution can be reduced.

This radiometer should have a field of view from the vehicle in which as little solid angle as possible is obscured in the vertical (say, no more than a cone of 30° diameter). Its environment should be at a constant temperature ($\pm 1^\circ$ K) not above 300°K. If the temperature is not maintained constant it must at least be measured (again $\pm 1^\circ$ K).

Nephelometer

The preliminary configuration is a short range low power unit with an arc light source. Because of the low angle of the sun and the downward view of the receiver optics solar background interference is considerably reduced.

Further investigation will be made to determine if a ranging unit is feasible within the given allotment of weight, size, power and data output. A ranging unit would be used to give an indication as to the horizontal homogeneity of the cloud structure. The spacecraft TV can obtain this homogeneity information for the top of the clouds but no instrument other than the ranging nephelometer has been found to be suitable for obtaining this information from within the clouds.

Cloud particle number-density and size

Individual particles will be detected, measured, and counted by optical means. Two possibilities are under consideration; in both cases, the atmosphere must stream through a tube attached to the probe. The first method is to illuminate a small volume, and count flashes due to 90° scattering by the particles traversing the volume. The second, now under development, observes the shadows of the particles against a fiber-optic detecting mosaic. This method is much more tolerant of background light, but the instrumentation is more complicated.

Cloud particle composition

A fundamental problem to be solved in a Venus atmosphere mission is that of the chemical composition of the clouds. The method of choice for providing such information is mass spectrometry. The mass spectrometer can accept and analyze samples within a very broad range of chemical compositions and provide precise results with microgram quantities of sample. No other single instrument having this capability can reasonably be packaged in small probes along with several other experimental systems. In addition to a gas-source mass spectrometer, which can be used to analyze evaporated condensate from the cloud particles, there must be on board a solid-source mass spectrometer to analyze solid particles of the clouds (or the solid portion remaining after evaporation) which may consist of salts or mineral materials from the surface. It would be desirable to measure masses in the range of 3 to 100 atomic mass units. Preliminary studies, though they should not overlook other analytical techniques such as α-ray backscattering, should be concerned with developing techniques for evaporating the sample at the source. Presently untreated rock minerals are analyzed using spark source mass spectrometry. Perhaps bulky spark generating equipment can be modified to be suitable size and power rating, or perhaps a laser beam can be used to evaporate samples in the source region. The presence of sample material in the beam could be determined by measuring light scattered from the sample.

In order to obtain a sample of cloud particulate material in a form suitable for instrumental analysis of the sort contemplated in the previous paragraph it is usually desirable to have the particles on or in a substrate or surface which will not interfere with, skew, or decrease the sensitivity of the analysis. The sampling technique which best seems to meet those requirements is inertial deposition. A two or three stage cascade impactor seems most attractive at present. Thus, some information concerning particle size ($\rho^{\frac{1}{2}}d$) could be obtained. Each stage or a portion thereof could be eventually transferred

directly into the source of the mass spectrometer. Different portions of each stage could be treated with different substrate material for particle retention. Prior to introduction to the mass spectrometer the sample could (and should) be introduced to an evaporation chamber in which condensate material can be evaporated and the gases from this can be analyzed in the gas mass spectrometer. The air stream between stages could be monitored with a photo-optical single particle counter. This could give valuable information on the variations of particle concentrations in the sampled air.

Since the efficiency of each stage of the impactor will vary with air density, proper operation will require a regulating device for the sampling pump. Studies of the sampling system should consider the possibilities of using ultraclean filters and possibly electrostatic precipitators for sample collection. The material to be used for a back-up filter for the impactor will be of great concern, as will be the choice of substrate materials. Design parameters such as pumping rates, size of stages and jets will have to be decided based on expected properties of the Venusian atmosphere.

In summary, it is recognized that the principal problems to be faced in the sampling and analysis of Venusian cloud particles are those pertaining to collecting them in a proper manner for their subsequent analysis and the method of introduction of the material into the analyzing regions of the instrument chosen.

Evaporimeter - condensimeter

A typical instrument comprises a light source illuminating a reflector and the reflected image of the source being observed by a phototube. The reflector is cycled over a wide temperature range while it is continuously bathed with the gas which carries the condensible. At a pressure and temperature characteristic of the particular condensible the condensible condenses on, or evaporates from the reflector, depending upon whether the reflector temperature is decreasing or increasing, and a change in light intensity is observed by the phototube. The gas inlet to the reflector and all optical windows in contact with the condensible must be heated well above the ambient temperature in order to prevent unwanted condensation which would clog the inlet tube and cloud the illumination and observation optical units. The optical output should be sampled at time intervals corresponding to small temperature changes of the reflector in order to accurately identify the condensible. The gas sprayed on the reflector must be dust free. Reflector temperature measurement and gas pressure measurements should be made concurrently, if possible, with the optical measurements. Gas flow

must be sufficiently large to allow rapid sample change, but not so large as to cause a reduction of the range of the temperature cycle by convective heat transfer.

Altitude and Drift Radar:

The purpose of this experiment is to measure horizontal and vertical winds by radar techniques.

The altitude radar will comprise an FM, S-band unit with a maximum range of 6 km. Altitude measurement error before telemetering will be 100 meters or less. Descent rate error will be 10 cm/s or less. Counting techniques can be employed should smaller error in range and speed be desired.

The drift radar will comprise an X-band FM unit with maximum range of 6 km and will look 30° down from the horizon. Without probe spin, or with spin periods of 100 seconds or more, measurement of probe drift requires two radar units with orthogonally directed look angles. With probe spin periods of less than 100 seconds a single radar unit is sufficient, but the probe must not spin too fast if low drift speeds are to be measured. Drift speeds of 2 cm/s to 2 m/s yield X-band doppler frequency shifts of from 0.3 to 30 Hz.

Measurement of the smaller frequency requires counting of cycles for a minimum time of 4 seconds, during which time the look direction of the radar should not change by more than about 60°. Thus a spin rate of 15°/s is satisfactory for measuring drift speeds as low as 2 cm/s.

The drift radar will be designed to detect drift speeds of 2 cm/s to 2 m/s with an error of ± 1 cm/s after transmission. Range measurement by the drift radar will assist in identifying surface physical features; range measurement error before transmission will be less than 100 meters.

Optimization of the altitude and drift radar systems is closely related to optimization of the entire large probe system and its instruments and is proceeding in step with them.

Transponder:

The probe data transmission system will include a carrier transponder for the purpose of measuring probe range and drift speed during descent. Probe departure speeds will be measured to within ± 2 cm/s from Earth and a range uncertainty of ± 2.5 km.

References:

1. "A Venus Multiple-Entry-Probe Direct-Impact Mission -- Scientific Objectives and Technical Description," Goddard Space Flight Center, Greenbelt, Maryland, January 1969.

2. "Scientific Questions for the Exploration of the Terrestrial Planets and Jupiter," Mackin, R. J., Jr., et al. JPL TM 33-410, October 1, 1968.

TABLE 1. INSTRUMENT SPECIFICATIONS

Instrument	Vol., $in.^3$	Wt., lbs.	Power, Watts	Sampling Interval, Meters	Word Size, Bits	Words Per Sample	Bits Per Sample
Accelerometers (4)	24	1.9	4.0	(Δt = 0.2 sec)	10	4	40
Pressure Gauges (5) (Switched)	10	0.8	0.1	300	8	1	8
Temperature Gauge (Range-Switched)	15	0.8	0.2	300	8	1	8
Neutral Particle Mass Spectrometer (1-90 AMU)	280	10	10-20	1000	15	40	600
Thermal Radiometer	18	3	3	100	7	2	14
Solar Radiometer	100	4	3	1000	10	120	1200
Nephelometer	100	4	3	100	8	2	16
Cloud Particle (No., Density, Size)	500*	8	10	100	10	8	80
Cloud Particle Composition (3-100 AMU)	500	20	50-60	7000	16	100	1600
Evaporimeter-Condensimeter	70	2	10	1500	8	57	456
Alt. Radar	50	3	18	400	7	1	7
Drift Radar	50	3	18	150	8	6	48

*including a tube, 1" dia., 15" long

B. Section Document 131-04

Titan IIIC Launch Vehicle Performance

For Venus Entry Mission Study

I. General

Titan IIIC vehicles will be equipped with a standard aerodynamic fairing of modular design, now being developed by McDonnell Douglas. The fairing is a ten foot diameter cylinder with a cone and hemisphere nose cap. Total length varies between 15 and 50 feet in 5-foot increments. See attached Figure 1 for a sketch of the nose fairing and payload envelope. From a consideration of the payload envelope volumes shown on sheet 2 of Figure 1, it appears that the two smaller fairings are probably adequate for JPL missions.

II. Launch Operations Concept

The fairing as designed does not lend itself to encapsulating the payload. The launch operations concept is as follows:

1. The payload (spacecraft) is made ready, placed on its adapter, mounted on a truck and covered with a protective shroud (or dummy fairing).
2. The payload is moved to the launch pad and hoisted into the Universal Environmental Shelter (UES), which is an enclosed space of the mobile service tower.
3. The payload/adapter is mated to the Transtage at Station 77, the protective shroud is removed, and the flight fairing is installed.

The UES has platforms to allow work on the payload, and although not a true clean room, is airconditioned to 75 ±2 deg. F, 50% relative humidity maximum, and maintains a positive pressure differential of 1/4 ±1/8 in. water. Conditioned air is available for the payload through an umbilical to the fairing after fairing installation.

III. In-Flight Separation

The fairing splits longitudinally into three 120 deg. sections. Separation may occur at anytime from 210 seconds after launch (payload option), within the following vehicle flight constraints:

1. Dynamic pressure: less than 1 psf
2. $q \propto$ product: less than 15 lb-deg/ft^2
3. Axial load factor: less than 4 g's

The most probable discrete separation times are 240, 280 and 300 seconds after launch. The following data is abstracted from an aerodynamic heating reference trajectory.

Time (sec)	Altitude (feet)	Velocity (fps)	$\propto$ (Degrees)	Mach No.
210	270,200	8,500	10.70	10.790
240	318,776	10,952	6.17	13.360
280	382,986	13,794	9.92	- - -
300	409,281	14,421	11.45	- - -

In the payload capability information which follows, the separation time utilized is 280 seconds after launch.

IV. Payload Capability

A curve of gross payload vs C_3 is shown on Figure 2. This payload curve is to be corrected by the user as follows:

1. Subtract 9% of the fairing weight from the gross payload.
2. For launch azimuth of 114°, subtract the payload equivalent to one additional unit of C_3.
3. For launch azimuth of 45°, subtract the payload equivalent to 2.3 additional units of C_3.
4. For each additional 10 seconds of fairing separation time past 280, subtract 17 lbs. payload.

NOTE that the "net payload" which results from the above corrections must include any mission-peculiar or payload-peculiar items such as the spacecraft adapter.

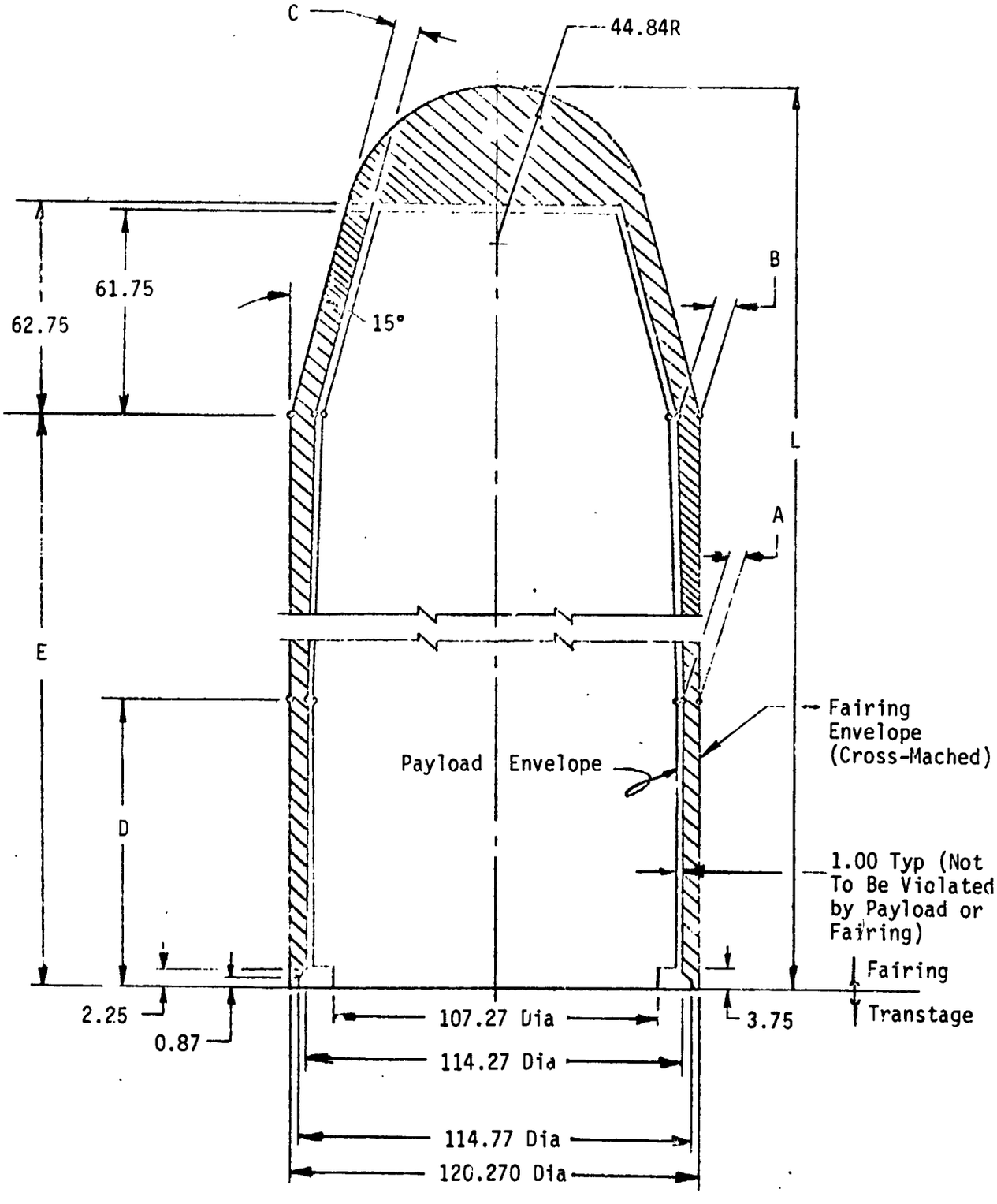


Figure 1. Titan III Payload and Fairing Envelopes
(Sheet 1 of 2)

Configuration Number	L (in)	A (in)	B (in)	C (in)	D (in)	E (in)	Wt. (lbs)	Payload Envelope Volume (ft^3)
XX15	180	3	3	3	84	84	1213	741
XX20	240	3	3	3	144	144	1440	1085
XX25	300	3	3	3	144	204	1668	1428
XX30	360	3	3.1	3.6	144	264	1896	-
XX35	420	3	3.7	4.2	144	324	2143	-
XX40	480	3	4.3	4.8	144	384	2370	-
XX45	540	3	4.9	5.4	144	444	2617	-
XX50	600	3	5.5	6.0	144	504	2845	-

Figure 1. Titan III Payload and Fairing Envelopes
(Sheet 2 of 2)

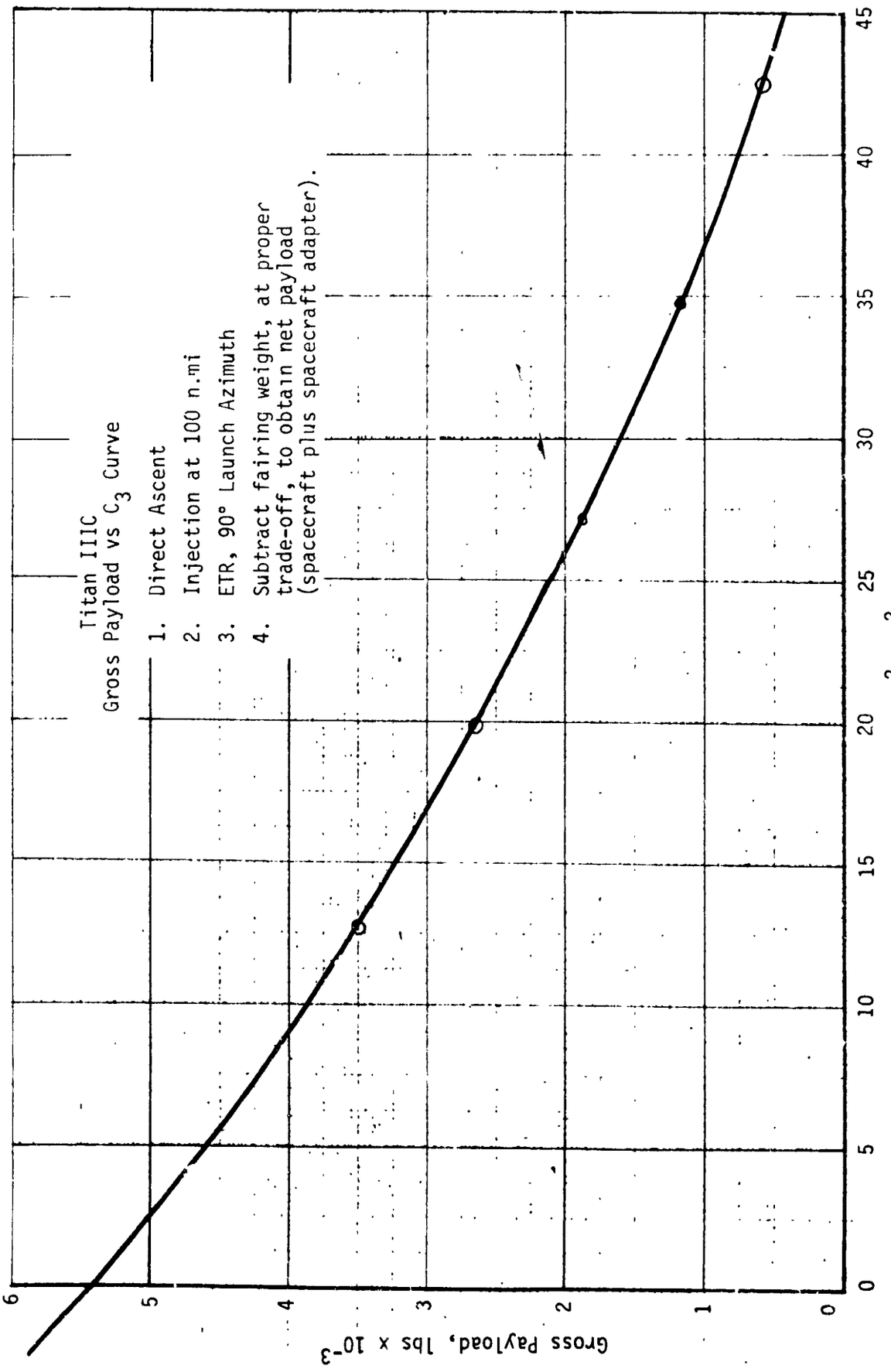


Figure 2. Titan IIIC Gross Payload vs C_3

C. JPL Section Document 131-05

VENUS ENTRY HEAT SHIELD DESIGN REQUIREMENTS AND TECHNOLOGY LIMITS*

INTRODUCTION

For purposes of system study, the aerothermodynamic and heat shield technology base is considered to be sufficiently established from previous efforts. Therefore, it is intended that the contractor expend only minimal time on hypersonic capsule aerodynamics, heat transfer and heat shield weight calculations. This is not to say that problems do not exist in these areas, but rather to indicate that the technology is sufficiently well understood, below an entry velocity of 35,000 ft per sec, such that the resources of this study can be better applied to the system aspects of the multi-probe mission. This document supercedes any information given in the Description of this document attached to JPL RFP No. GR-2-3971, 13 March 1969.

To provide a basis for selecting heat shield weights for a range of entry and vehicle conditions, JPL has calculated heat transfer and heat shield response. A summary of the methods used, results obtained, and the relationship of the environment to the simulation available in ground test facilities is presented. Conditions for possible exceptions to the heat shield weights contained herein are also given.

If, after contract initiation, the contractor requests additional conditions to be calculated that are acceptable to JPL, such information will be provided within a mutually agreed upon time span.

METHODS

The prediction of entry heat transfer utilized the procedures discussed in Ref. 1. The only change consisted of the addition of an approximate radiation cooling correction based on Ref. 2.

Heat shield meterial response was calculated by use of the AVCO 1600 computer program (Ref. 3). The thickness of material required as heat shield was defined as that depth (of a much thicker layer) which was predicted to have a peak in the temperature-time history equal to 600°F. This type of curve thus represents an equivalent bondline temperature-time history.

Factors of safety were obtained by allocating uncertainty limits to both heat transfer and heat shield related parameters, and subsequently performing an error analysis (Ref. 3). This analysis indicated that the resultant

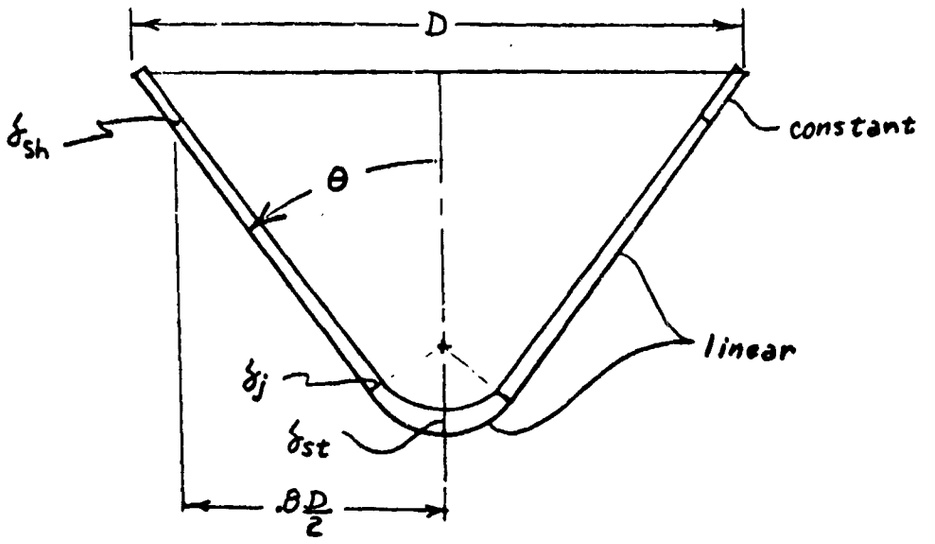
*For use with JPL Contract No. 952534, Martin Marietta Corp.
**Revised in accordance with terms of this document and Technical Direction Memorandum No. 3 dated 10/3/69.

safety factor for both AVCOAT 5026-39/HC-G and X6300 Carbon Phenolic is about 1.5, so that for these materials this value was used for all results of this document. In addition, a manufacturing tolerance of 0.02 inches was added arithmetically at all body locations, after application of the above safety factors. For the X6300 Carbon Phenolic a heat of pyrolysis as low as 300 BTU/lb was utilized.

NOTATION

A	maximum cross-sectional area of entry vehicle
A_S	forebody surface area of entry vehicle
C_D	drag coefficient
D	diameter of entry vehicle
M	mass of entry vehicle
q_R	radiative heating rate
R_N	nose radius
V_E	entry velocity at 815,000 ft altitude (V-3 Venus atmosphere, NASA SP-8011)
W	total forebody heat shield weight
W_E	total entry vehicle weight
γ_E	entry path angle at 815,000 ft altitude
ρ_v	density of virgin ablative material
δ	thickness of heat shield prior to ablation
τ	aerodynamic shear in absence of ablation

Subscripts st, j, and sh as shown



RESULTS

A tabulation of conditions investigated and a summary of results are given in Table 1 for a 60° half-angle blunted cone of various nose radii. In addition, half-cone angles of 45° and 30° with one-foot nose radii were investigated for the nominal cases indicated in Table 1. All of these results have the safety factors and manufacturing tolerance included.

To assess the effect of different materials than considered in Table 1, three additional ones presented in Table 2 were investigated for the entry conditions shown. Although AVCOAT 5026-39/HC-G yields the lowest weight per unit area for the stagnation point, shear strength might be a controlling factor in material selection.

Typical cold-wall heat transfer time histories are shown in Fig. 1. Velocities of 40,000 and 44,000 ft/sec are shown for comparison purposes only.

Typical dynamic pressure and heat shield temperature time histories are shown in Fig. 2. It is seen that the maximum imposed load occurs well before peak bondline temperature, indicating that the critical stress for the aeroshell structure may occur after peak dynamic pressure in some cases.

Figures 3 through 12 represent two families of heat shield graphs corresponding to Table 1: figures 3 through 7 giving total heat shield weight per unit forebody surface area (W/A_s) as a function of entry angle, ballistic

coefficient and base diameter as independent parameters; and figures 8 through 12 giving heat shield weight per unit entry vehicle weight as a function of the same three parameters. Curves for 44,000 ft/sec entry velocity are shown for comparison purposes only.

Figures 13 and 14 show the effect of half-cone angle on weight fraction and unit weight for fixed conditions except for entry mass, M. The latter is indicated on figure 13 to drop with decreasing half-cone angle as a result of decreasing drag coefficient. A drop in entry weight could be unacceptable on an absolute payload basis so that either an increase in size or M/C_DA (requiring a decrease in γ_E) would be needed with decreasing cone angle.

Maximum aerodynamic shear tabulated in table 1 is plotted in figures 15 and 16 as a function of entry angle and base diameter, respectively. This should enable the contractor to select a material on a shear level basis.

Figure 17 shows the relationship of the stagnation point environment for a one-foot nose radius, spherically-blunted cone entering at 36,000 ft/sec, to capabilities of NASA ground-test facilities assuming flat-faced models. Convective heating rate is shown as a function of stagnation pressure, with radiative heating rate in effect normal to the page. It is apparent from this plot that full simulation even for an $M/C_DA = 0.6$ and $\gamma_E = -45^0$ is difficult to achieve because of the radiative heating level. This circumstance could be alleviated by reducing nose radius and/or entry velocity of the probe.

EXCEPTIONS

During the study the contractor may adjust the heat shield weight figures if the contractor provides justification, acceptable to JPL, on the basis of:

1. Demonstrable uncertainties in heat transfer or heat shield prediction techniques.

2. The need for scaling to body sizes or shapes for which data is not provided.

3. Use of other materials.

REFERENCES

1. Spiegel, J. M., Wolf, F., and Zeh, D. W.; "Simulation of Venus Atmospheric Entry at Earth Re-Entry," AIAA Paper No. 68-1146, Williamsburg, Va., December 3-5, 1968.

2. Page, W. A., et al; "Radiative Transport in Inviscid Non-Adiabatic Stagnation Region Shock Layers," AIAA Paper No. 68-784, Los Angeles, Calif., June 1968.

3. Prospective JPL publication by Jaworski, W., and Nagler, R. G.; "A Parametric Analysis of Venus Entry Heat Shield Requirements."

TABLE I. TABULATION OF HEAT SHIELD DIMENSIONAL AND WEIGHT RESULTS (θ=60°; P_E=1 ; α_E=-50°; C_D=1.528)

TRAJECTORY DATA								AVCOAT 5026-39/HC-G					X6300 CARBON PHENOLIC				
Run No	V_E ft/sec	M/SA slugs/ft²	γ_E degrees	D ft	R_N inch	M slugs	$\bar{\tau}$ lbs/ft²	δ_{st} inch	δ_s inch	δ_{sh} inch	W/As lbs/ft²	W/A'E	δ_{st} inch	δ_s inch	δ_{sh} inch	W/As lbs/ft²	W/A'E
1	32,000	0.3	-20	4	12	5.76	4.48	0.335	0.326	0.330	0.86	0.069	0.316	0.306	0.309	2.25	0.176
2			-45				6.41	0.262	0.253	0.268	0.71	0.056	0.248	0.238	0.252	1.82	0.143
3			-90				7.92	0.230	0.219	0.242	0.63	0.050	0.216	0.205	0.227	1.62	0.127
4		0.6	-20			11.52	6.34	0.380	0.367	0.386	1.01	0.040	0.357	0.344	0.361	2.59	0.101
5*			-45				9.90	0.280	0.278	0.290	0.77	0.030	0.263	0.262	0.272	1.97	0.077
6			-90				13.30	0.253	0.246	0.282	0.73	0.029	0.238	0.232	0.264	1.87	0.073
7		1.2	-20			23.04	9.10	0.428	0.394	0.465	1.18	0.023	0.402	0.371	0.435	3.01	0.059
8			-45				17.25	0.341	0.320	.446	1.08	0.021	0.320	0.301	0.418	2.78	0.054
9			-90				22.50	0.321	0.307	0.324	0.86	0.017	0.300	0.284	0.351	2.41	0.047
10	"	0.6	-45		4	11.52	20.20	0.330	0.309	0.304	0.82	0.032	0.311	0.290	0.284	2.09	0.082
11				2	12	2.88	9.12	0.287	0.278	0.308	0.77	0.030	0.270	0.262	0.287	1.95	0.077
12					4		16.90	0.330	0.309	0.311	0.81	0.032	0.311	0.290	0.291	2.09	0.082
13				8	24	46.08	8.94	0.274	0.267	0.312	0.81	0.032	0.258	0.251	0.295	2.09	0.082
14					12		10.90	0.288	0.278	0.303	0.82	0.032	0.271	0.262	0.292	2.11	0.083
15					4		20.42	0.333	0.309	0.312	0.84	0.033	0.314	0.290	0.291	2.15	0.085
16	36,000	0.3	-20	4	12	5.76	5.38	0.351	0.342	0.358	0.94	0.074	0.322	0.314	0.326	2.36	0.185
17			-45				8.45	0.268	0.264	0.293	0.76	0.060	0.246	0.243	0.267	1.91	0.149
18			-90				10.10	0.236	0.225	0.253	0.66	0.052	0.217	0.208	0.230	1.64	0.129
19		0.6	-20			11.52	7.84	0.391	0.377	0.409	1.06	0.042	0.357	0.346	0.372	2.65	0.104
20*			-45			"	12.75	0.312	0.296	0.321	0.84	0.033	0.286	0.270	0.292	2.09	0.082
21			-90			"	16.30	0.294	0.281	0.327	0.84	0.033	0.270	0.259	0.280	2.01	0.079
22		1.2	-20			23.04	11.60	0.504	0.426	0.561	1.37	0.027	0.461	0.389	0.510	3.42	0.067
23			-45				22.20	0.445	0.422	0.524	1.30	0.026	0.406	0.386	0.473	3.23	0.063
24			-90				29.30	0.428	0.401	0.465	1.18	0.023	0.391	0.367	0.422	2.94	0.058
25		0.6	-45		4	11.52	25.60	0.377	0.342	0.339	0.91	0.036	0.346	0.313	0.311	2.28	0.090
26				2	12	2.88	11.52	0.309	0.290	0.325	0.81	0.032	0.282	0.267	0.296	2.03	0.079
27					4		21.40	0.375	0.343	0.327	0.86	0.034	0.344	0.314	0.299	2.16	0.085
28				8	24	46.08	11.22	0.301	0.291	0.358	0.92	0.036	0.276	0.267	0.330	2.30	0.09
29					12		13.95	0.317	0.300	0.360	0.93	0.037	0.290	0.273	0.328	2.32	0.091
30					4		25.80	0.378	0.345	0.366	0.98	0.039	0.346	0.314	0.331	2.42	0.095

* NOMINAL CASES

TABLE 2. COMPARISON OF PERFORMANCE OF TYPICAL HEAT SHIELD MATERIALS $(M/C_DA = 0.6)$

MATERIAL	V_E ft/sec	γ_E degrees	ρ_v lbs/ft^3	δ_{st} inch	$(W/A)_{st}$ lbs/ft^2
AVCOAT 5026-39/HC-G	36,000	-45	33	0.201	0.554
HIGH DENSITY PHENOLIC NYLON			75	0.122	0.776
LOW DENSITY PHENOLIC NYLON			35	0.209	0.610
X6300 CARBON PHENOLIC			90	0.177	1.330
FOAMED SILICONE ELASTOMER			35	0.217	0.632
AVCOAT 5026-39/HC-G		-20	33	0.256	0.703
HIGH DENSITY PHENOLIC NYLON			75	0.177	1.100
LOW DENSITY PHENOLIC NYLON			35	0.261	0.760
AVCOAT 5026-39/HC-G	32,000	-45	33	0.179	0.492
HIGH DENSITY PHENOLIC NYLON			75	0.102	0.637
LOW DENSITY PHENOLIC NYLON			35	0.177	0.516
X6300 CARBON PHENOLIC			90	0.162	1.22
FOAMED SILICONE ELASTOMER			35	0.198	0.578
AVCOAT 5026-39/HC-G		-20	33	0.248	0.680
HIGH DENSITY PHENOLIC NYLON			75	0.165	1.030
LOW DENSITY PHENOLIC NYLON			35	0.222	0.645

* NO SAFETY FACTOR OR MANUFACTURING TOLERANCE APPLIED

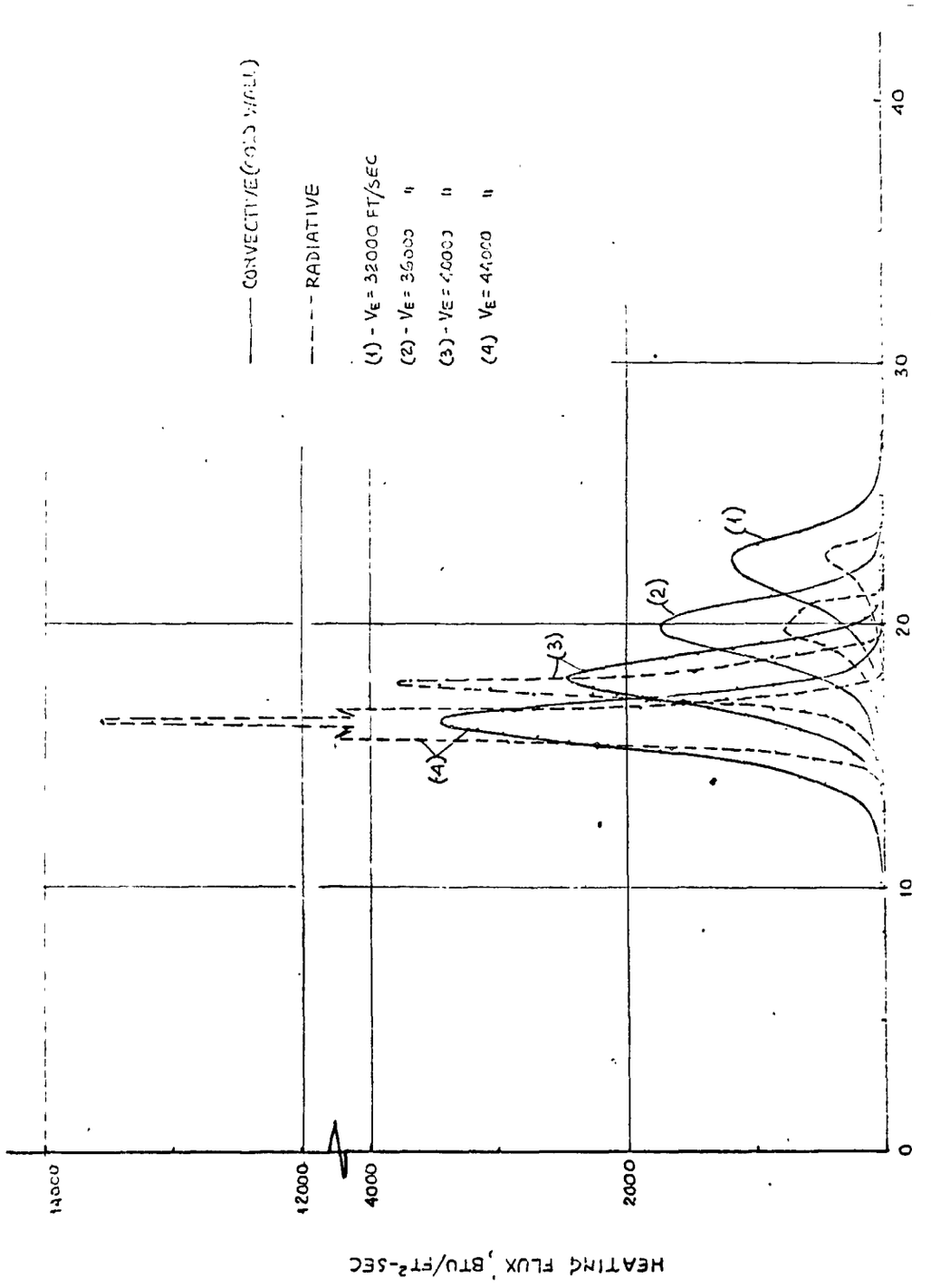


FIG. 1 CONVECTIVE AND RADIATIVE HEATING FLUXES FOR NOMINAL ENTRY TRAJECTORIES (SEE TABLE 1)

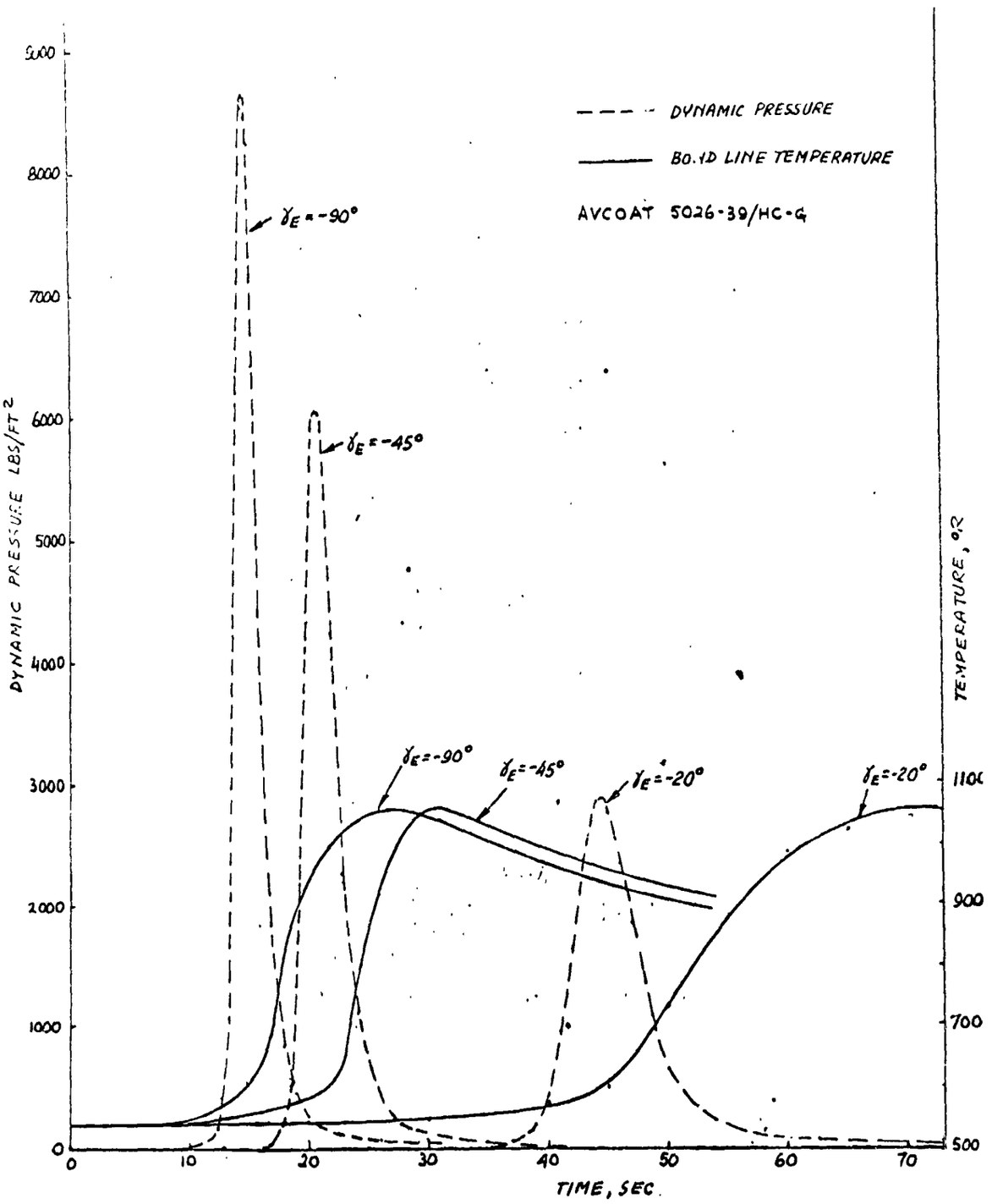


FIG. 2 DYNAMIC PRESSURE AND BOND LINE TEMPERATURE V_E = 36000 FT/SEC; M/C_DA = 0.6 $\frac{\text{slugs}}{\text{FT}^2}$

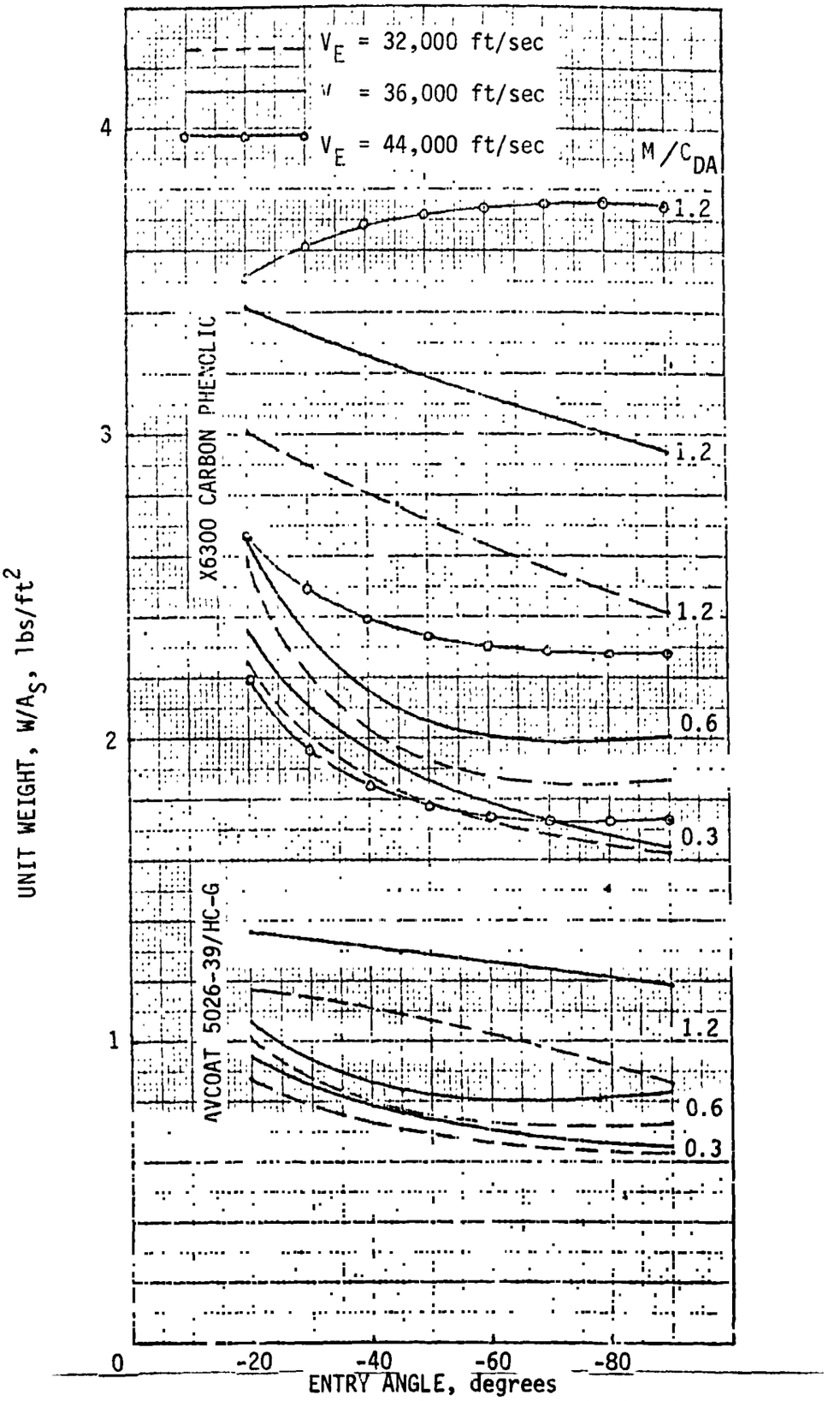


Fig. 3 Effect of entry angle on heat shield unit weight (θ = 60°; D = 4 ft; R_N = 12 inch.)

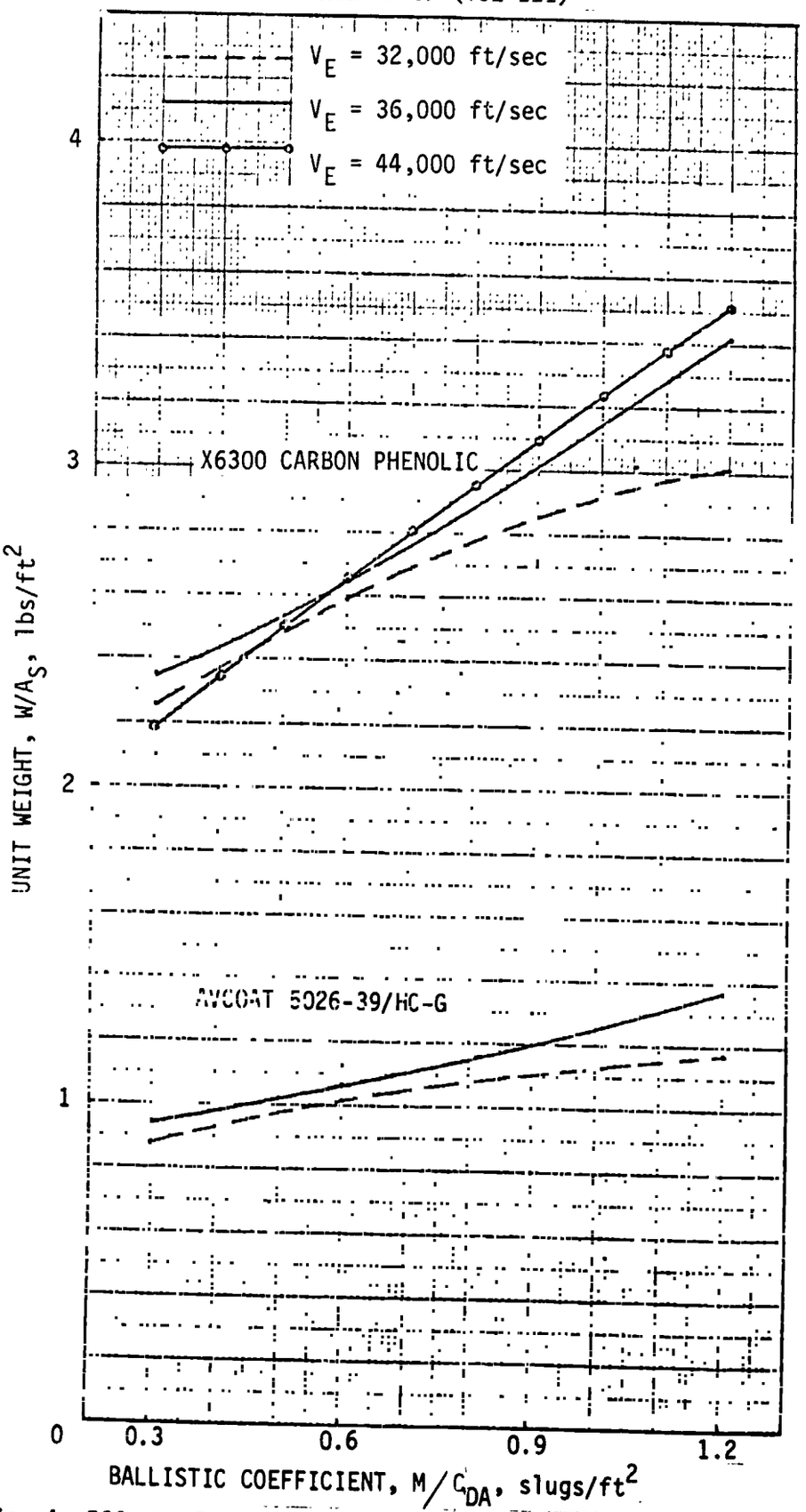


Fig. 4 Effect of ballistic coefficient on heat shield unit weight (γ_E = -20°, θ = 60°; D = 4 ft; R_N = 12 inch)

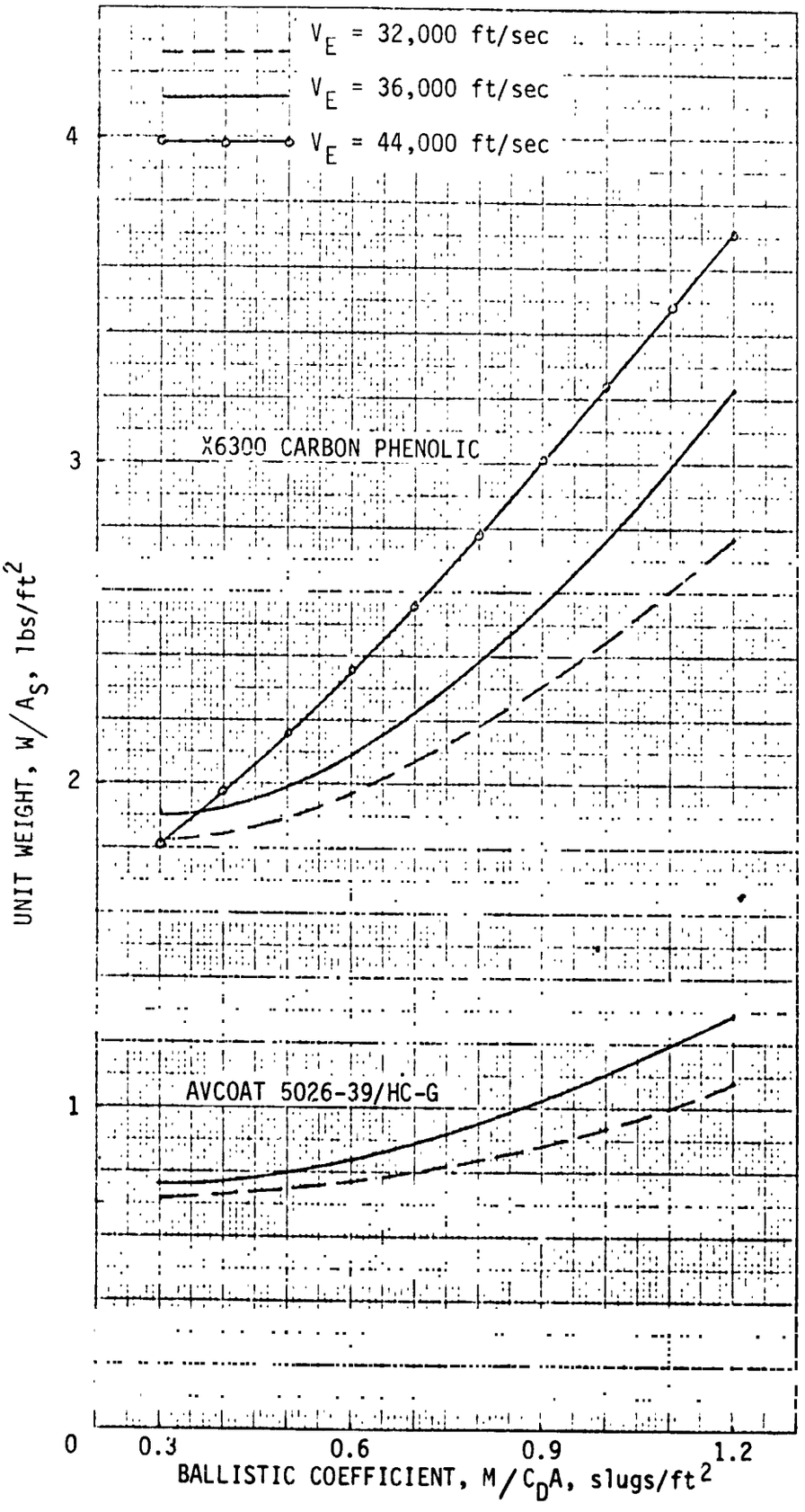


Fig. 5 Effect of ballistic coefficient on heat shield unit weight (γ_E = -45°; θ = 60°; D = 4 ft; R_N = 12 inch)

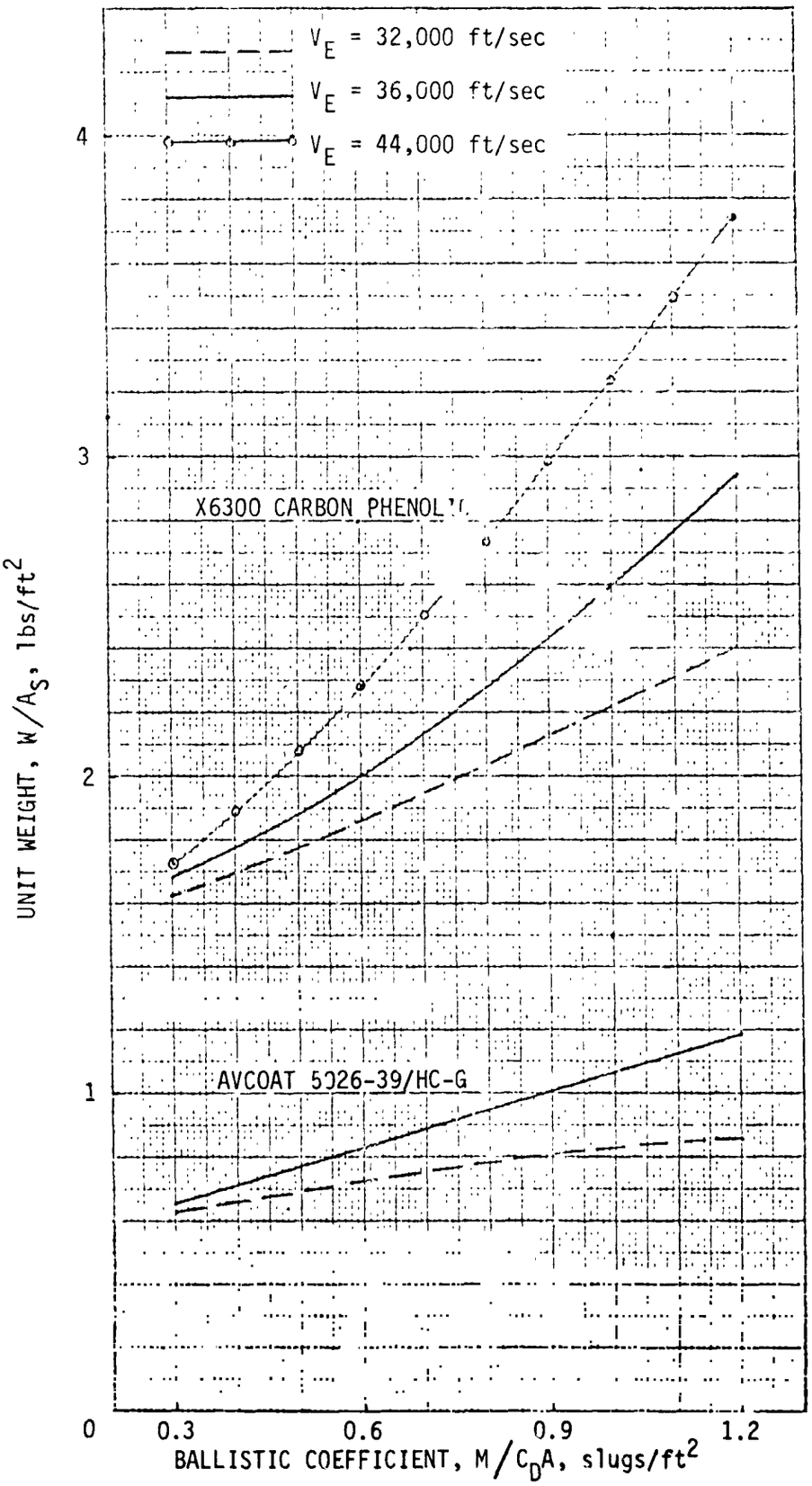


Fig. 6 Effect of ballistic coefficient on heat shield unit weight (γ_E = -90°; θ = 60°; D = 4 ft; R_N = 12 inch)

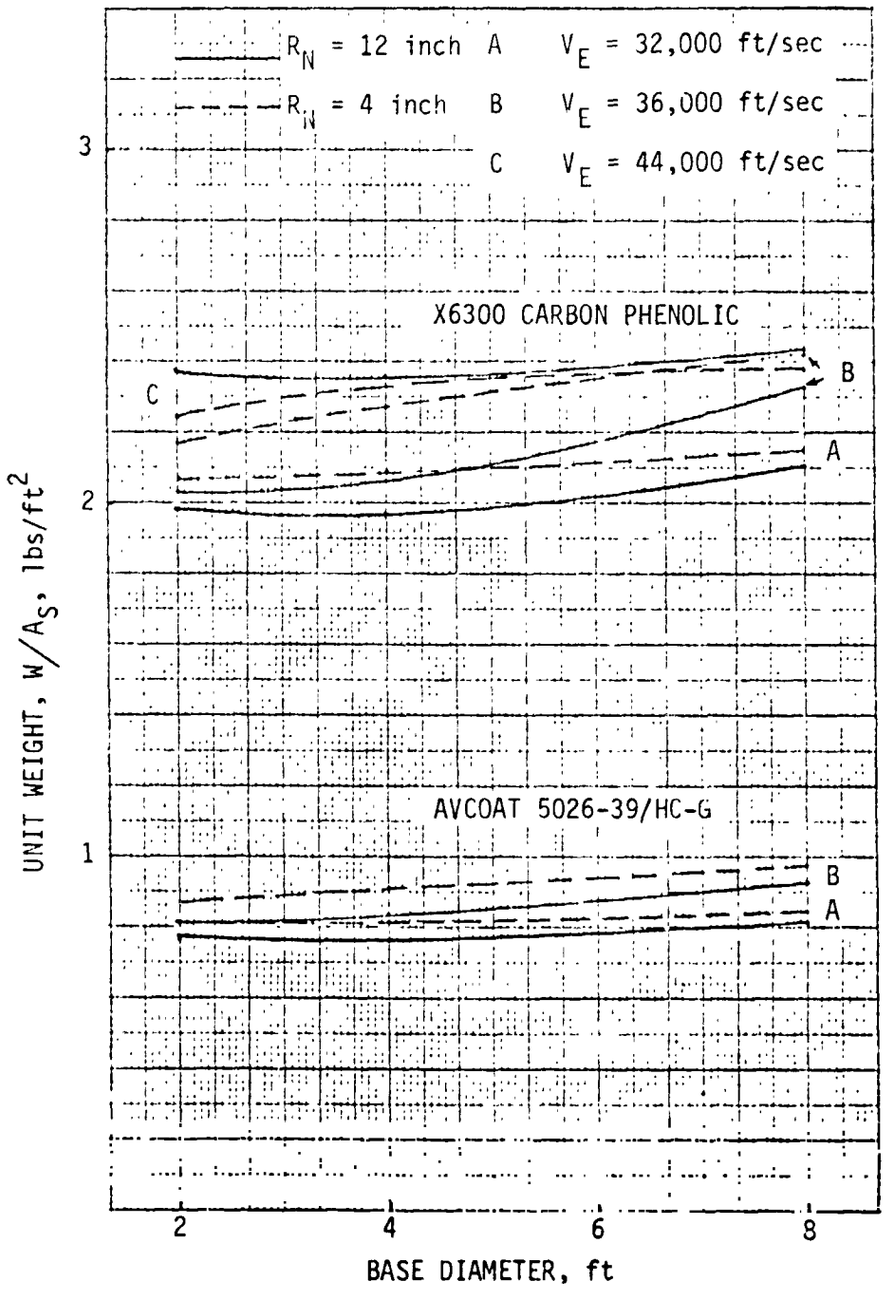


Fig. 7 Effect of body base diameter on heat shield unit weight
(γ_E = -45°; M/C_DA = 0.6 slugs/ft^2; θ = 60°)

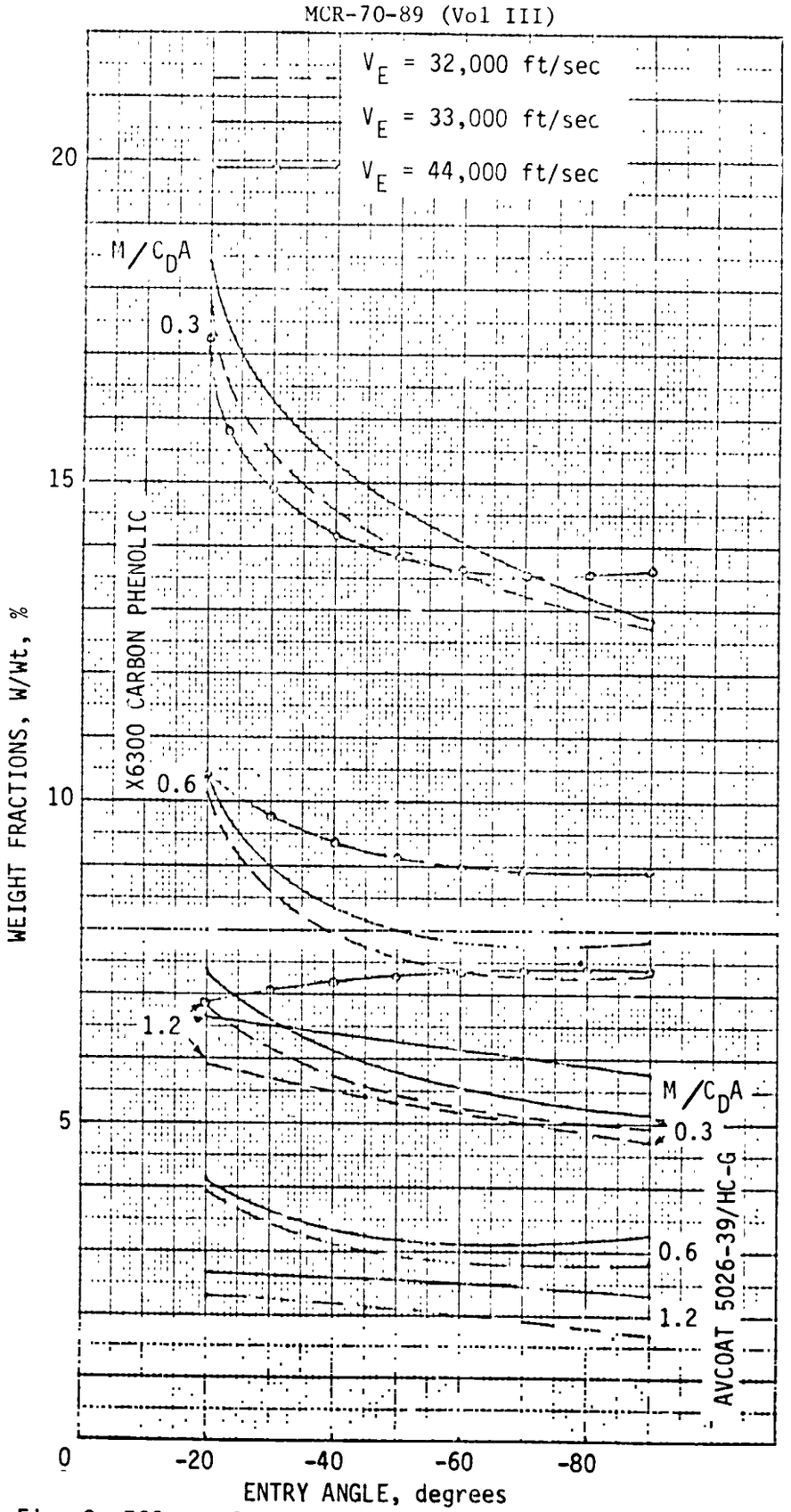


Fig. 8 Effect of entry angle on heat shield weight factors (θ = 60°; D = 4 ft; R_N = 12 inch)

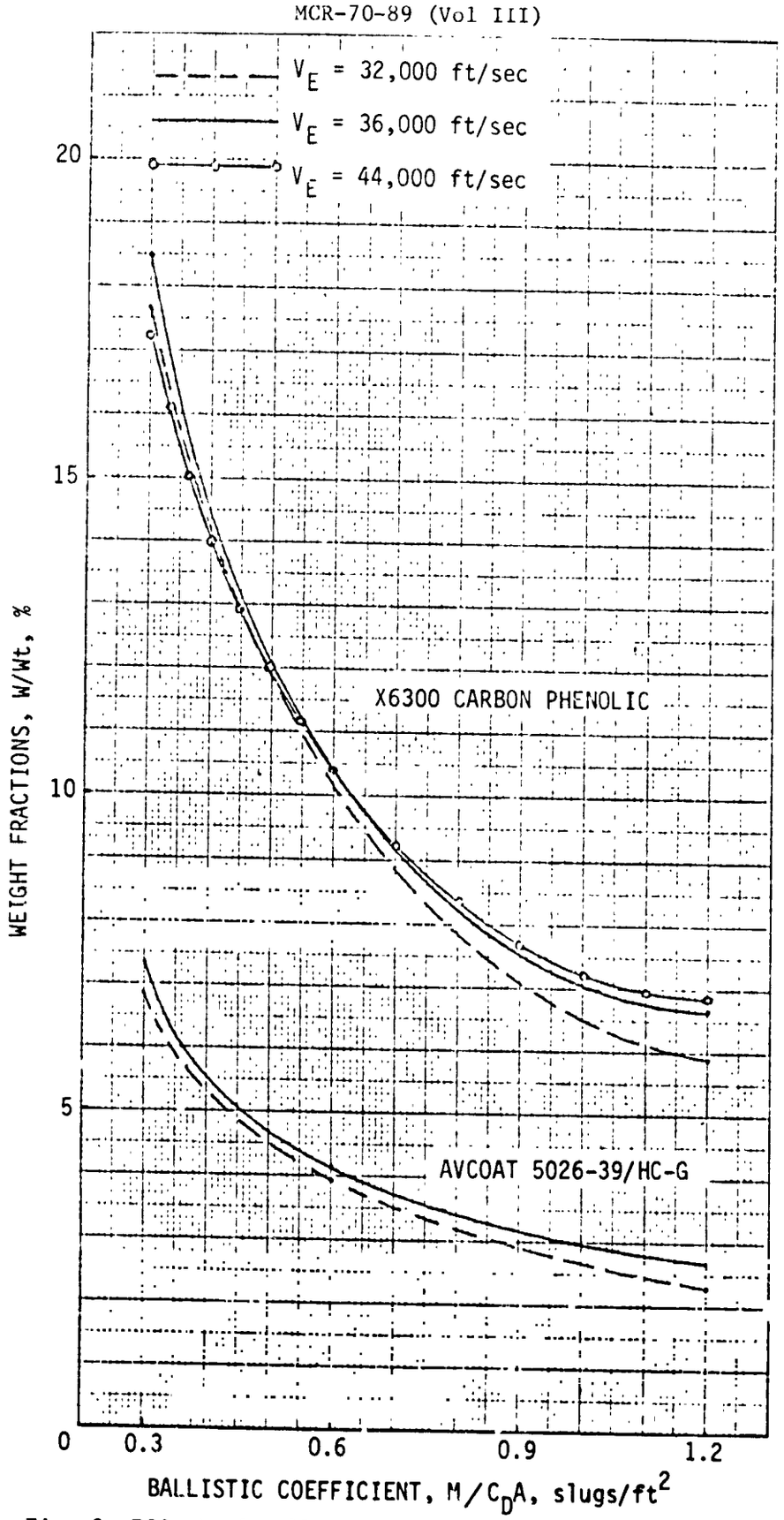


Fig. 9 Effect of ballistic coefficient on heat shield weight fractions (γ_E = -20°; θ = 60°; D = 4 ft; R_N = 12 inch)

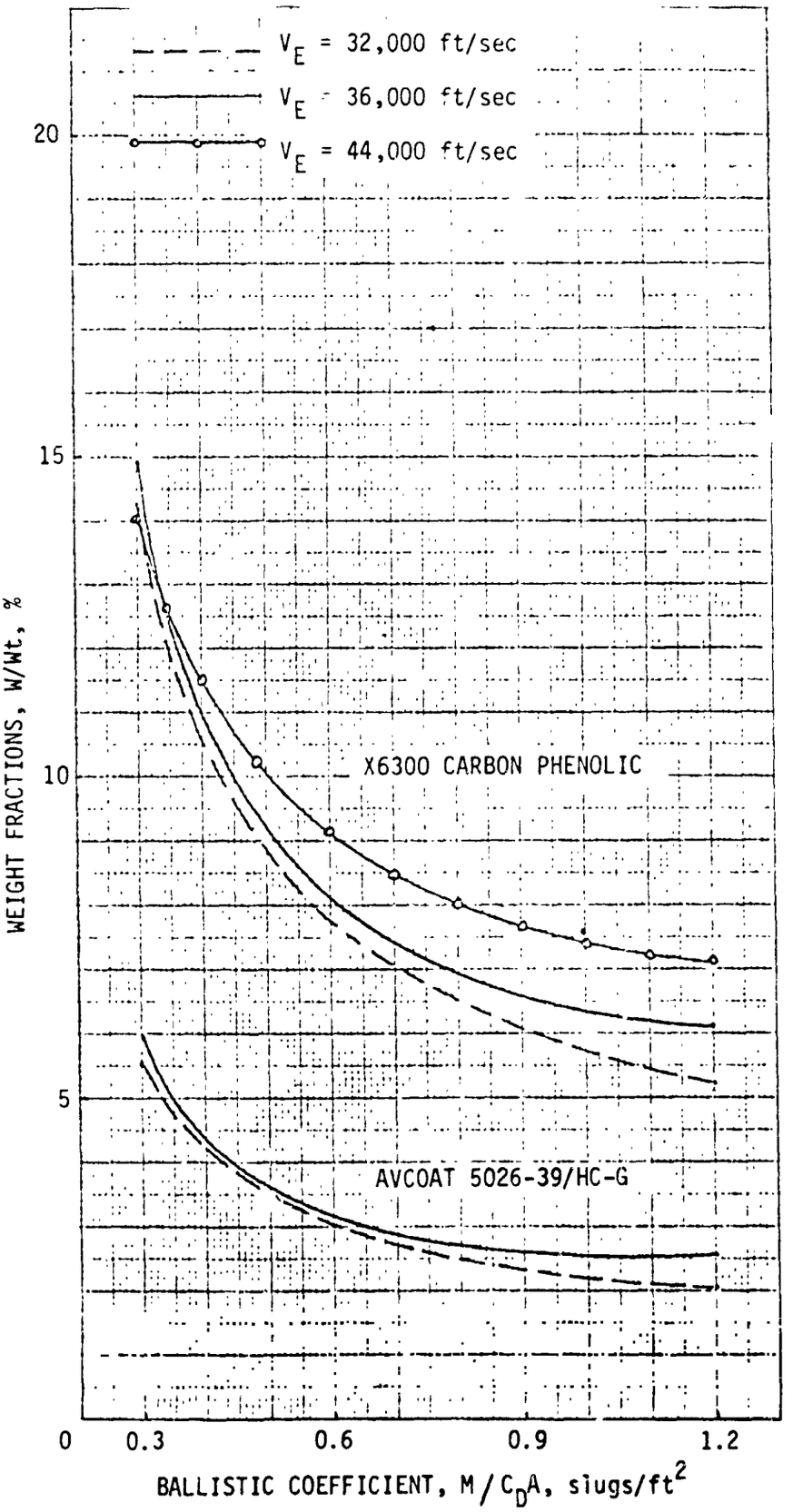


Fig. 10 Effect of ballistic coefficient on heat shield weight fractions (γ_E = -45°; θ = 60°; D = 4 ft; R_N = 12 inch)

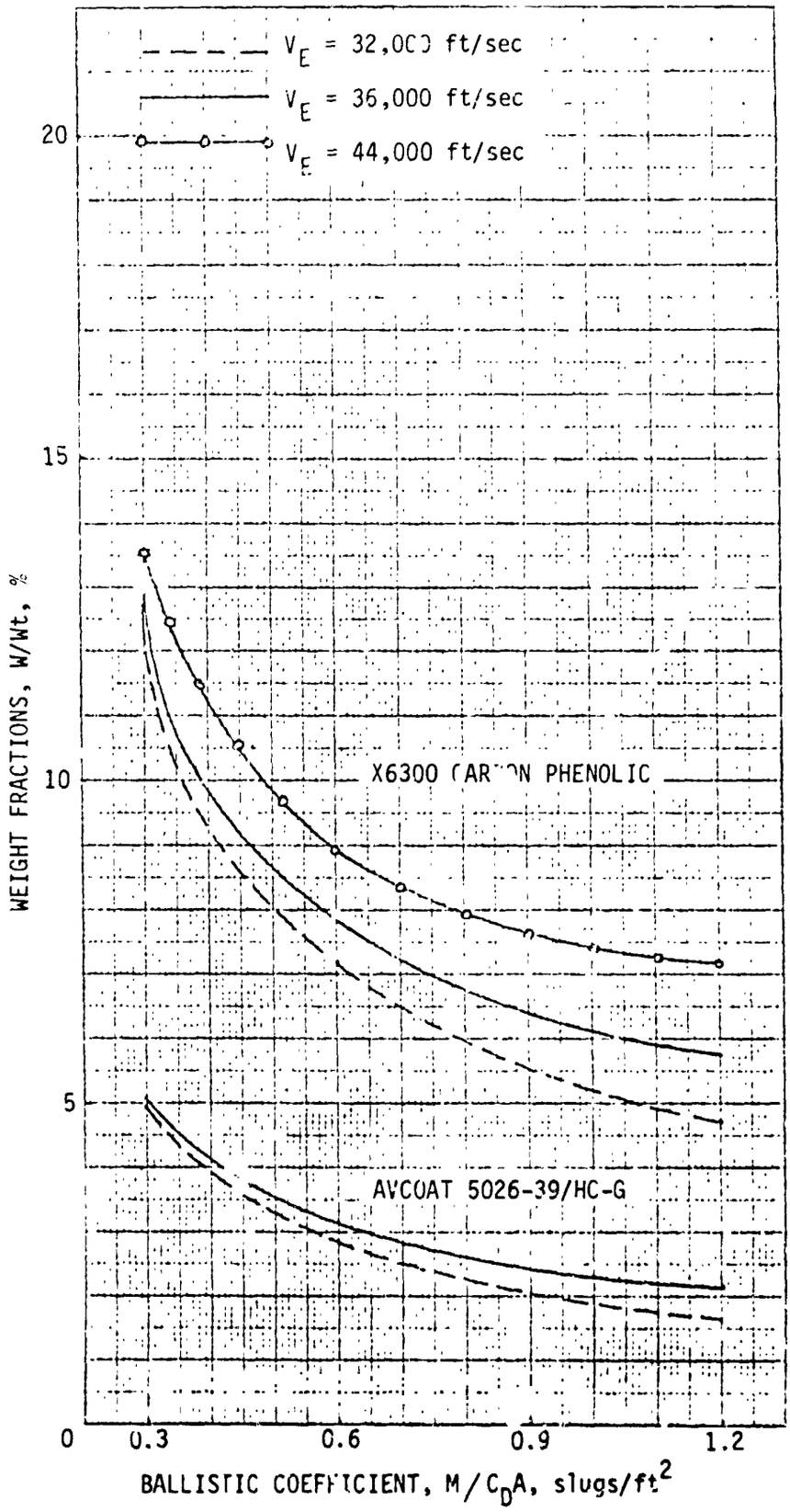


Fig. 11 Effect of ballistic coefficient on heat shield weight fractions (γ_E = -90°; θ = 60°; D = 4 ft; R_N = 12 inch)

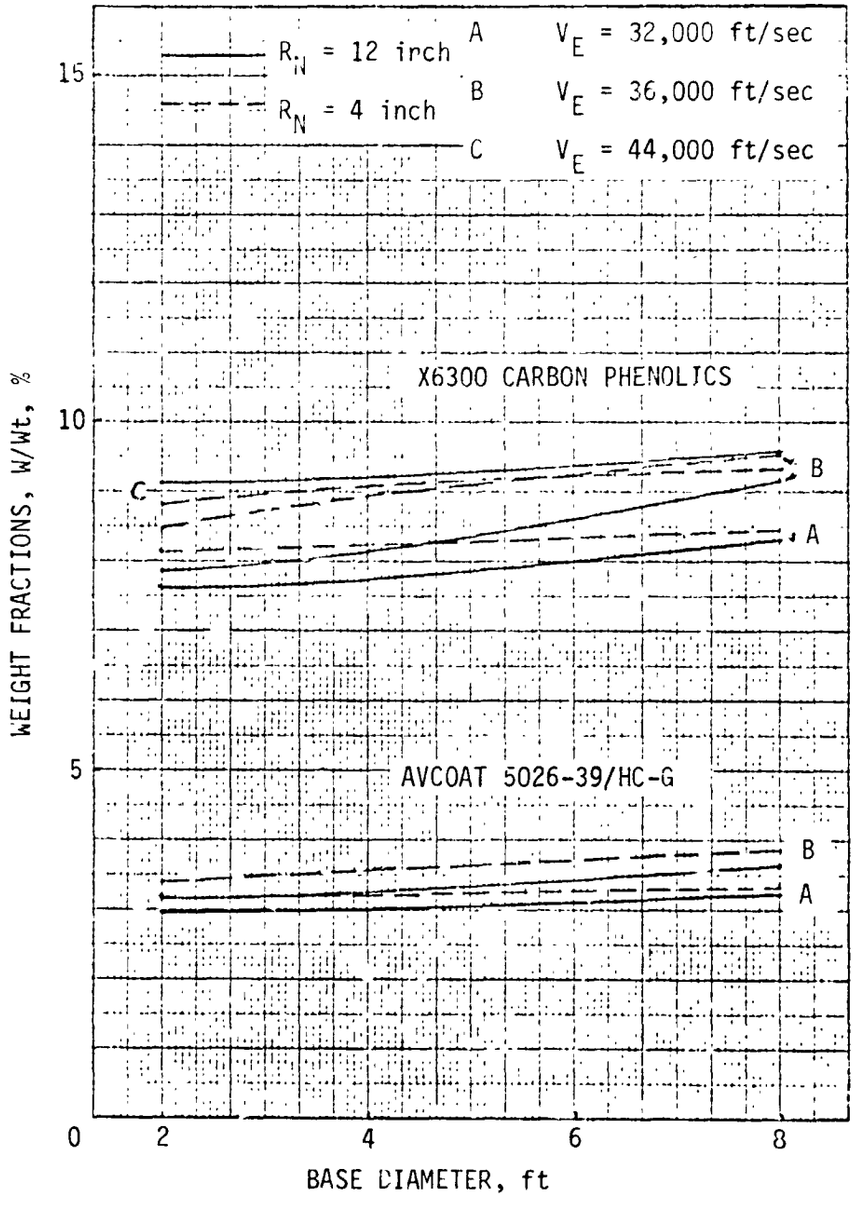


Fig. 12 Effect of body diamcter on heat shield weight fractions
(γ_E = -45°; M/C_DA = 0.6 slubs/ft^2; θ = 60°)

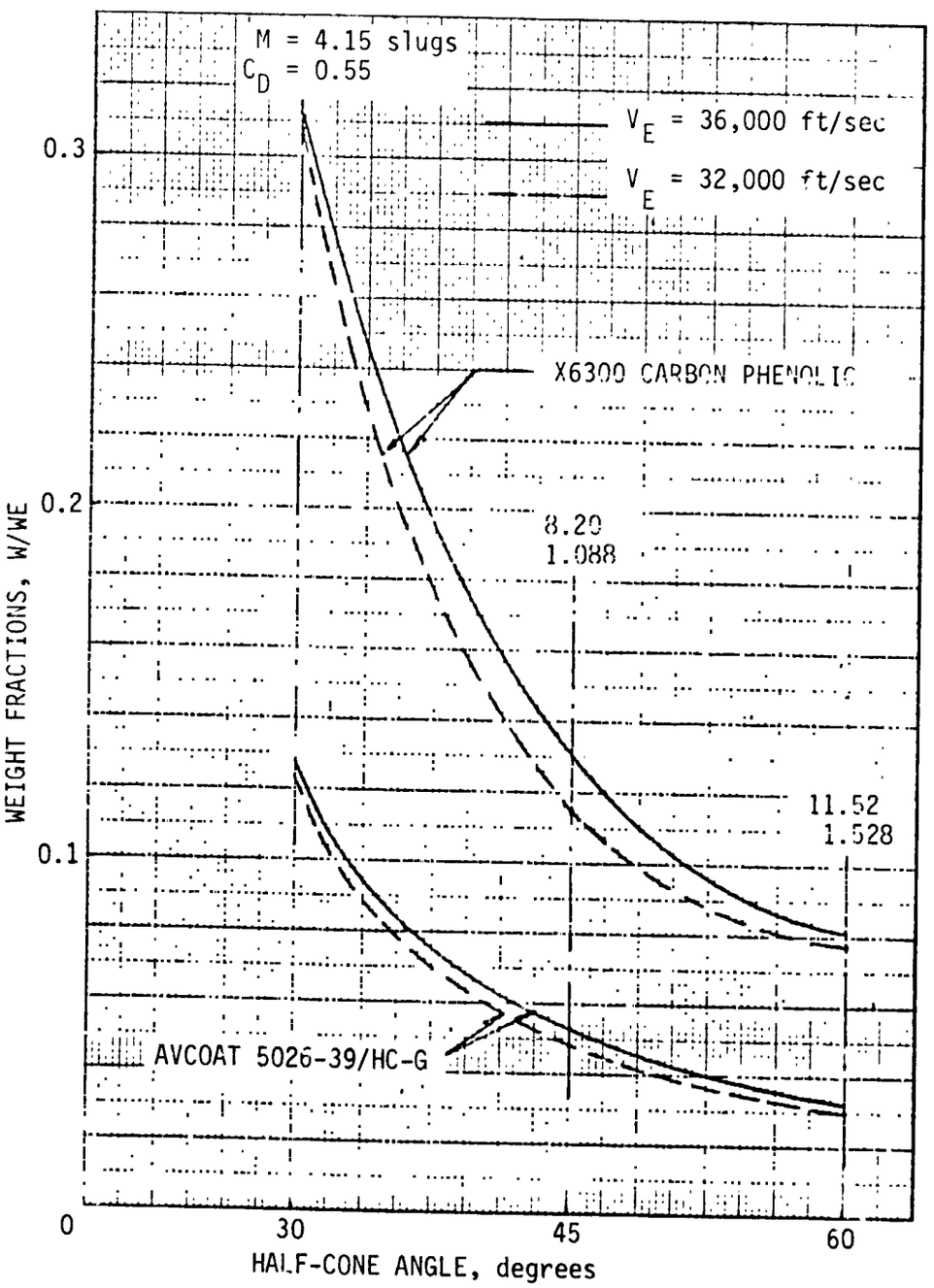


Fig. 13 Effect of half-cone angle on heat shield weight fractions
(γ_E = -45°; M/C_DA = 0.6 slugs/ft^2; D = 4 ft; R_N = 12 inch)

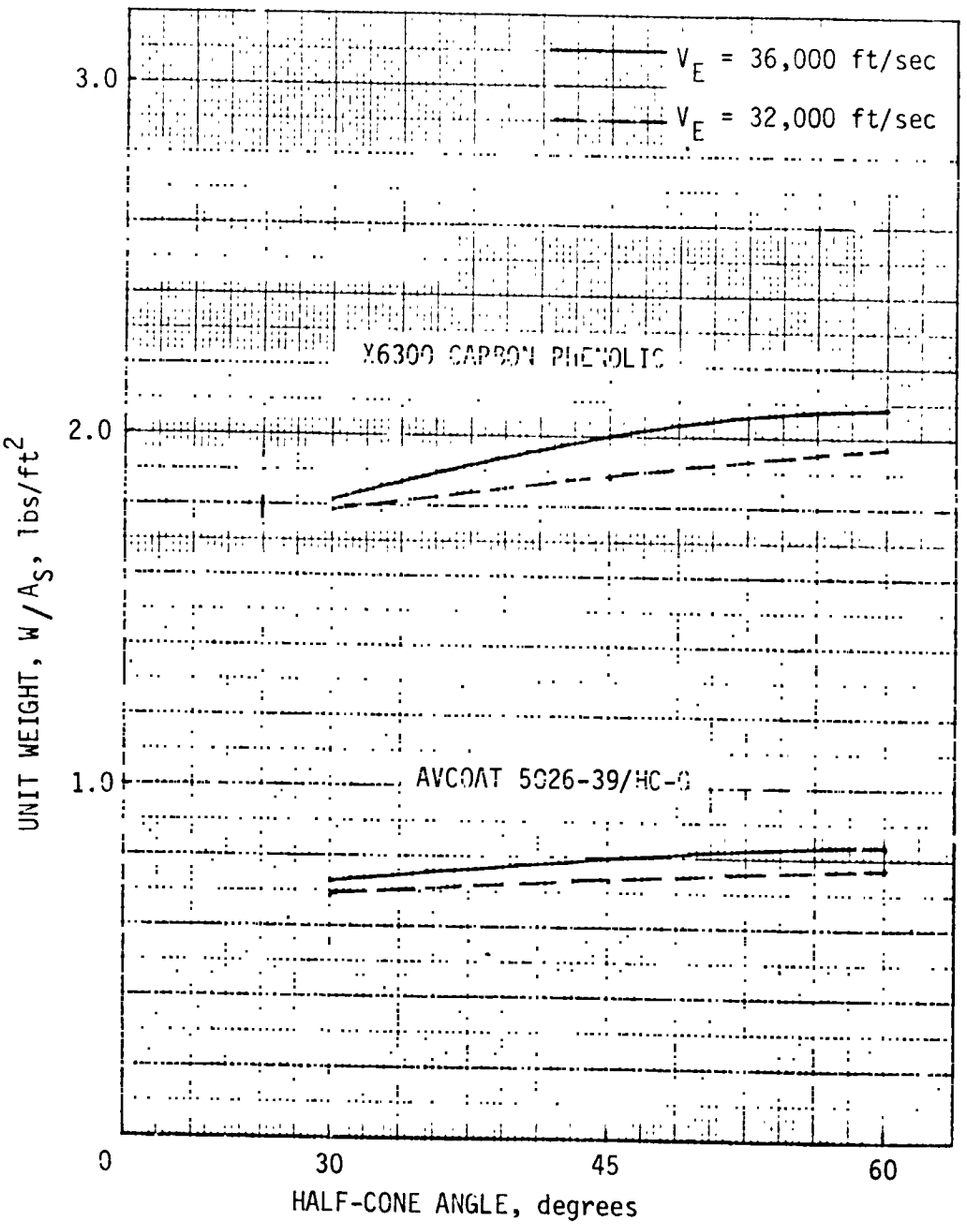


Fig. 14 Effect of half-cone angle on heat shield unit weight (γ_E = -45 ; M/C_DA = 0.6 slugs/ft^2; D = 4 ft; R_N = 12 R_N = 12 inch)

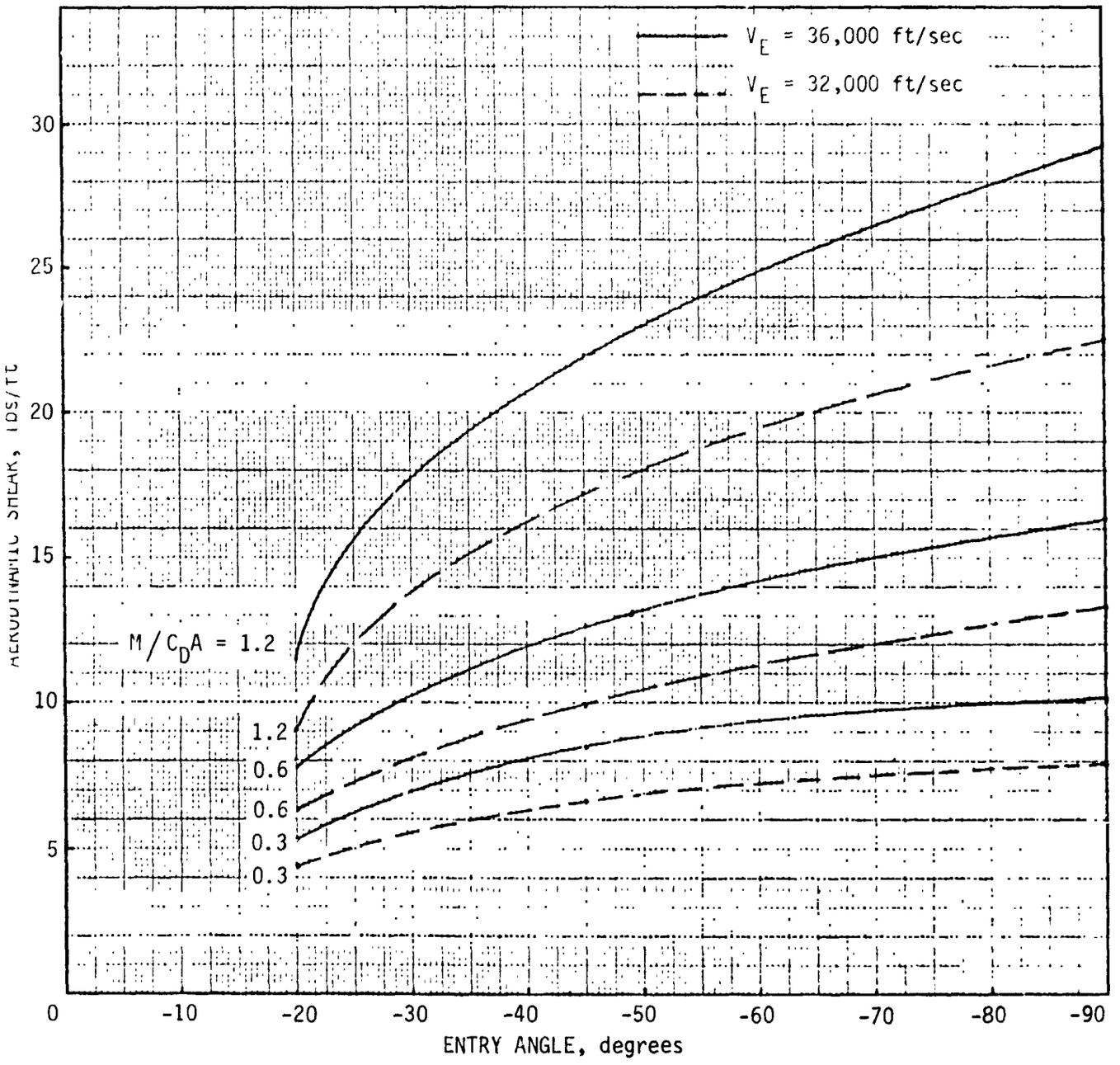


Fig. 15 Effect of entry angle on aerodynamic shear
(θ = 60°; D = 4 ft; R_N = 12 inch)

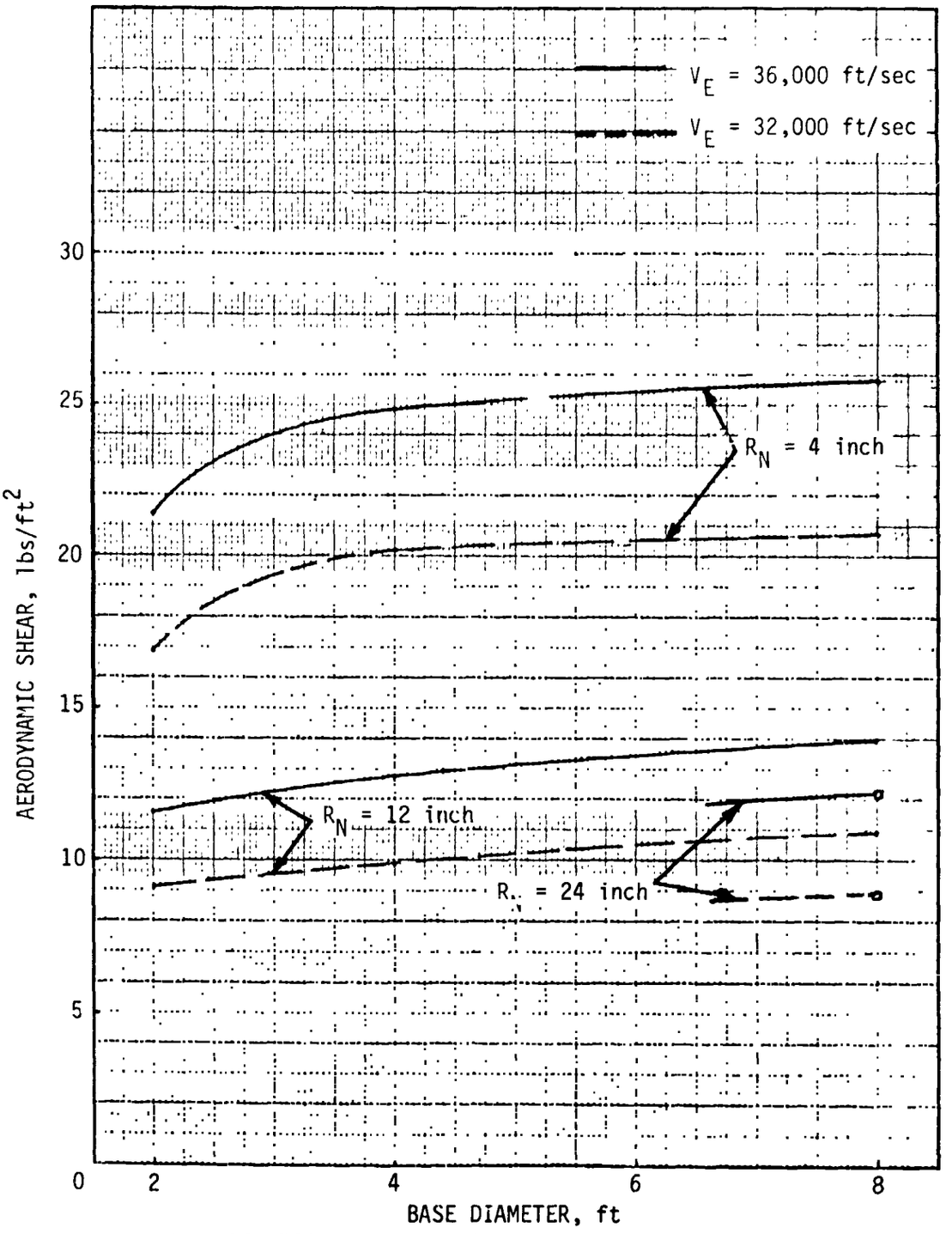


Fig. 16 Effect of base diameter on aerodynamic shear
(γ_E = -45°; M/C_DA = 0.6 slugs/ft^2; θ = 60°)

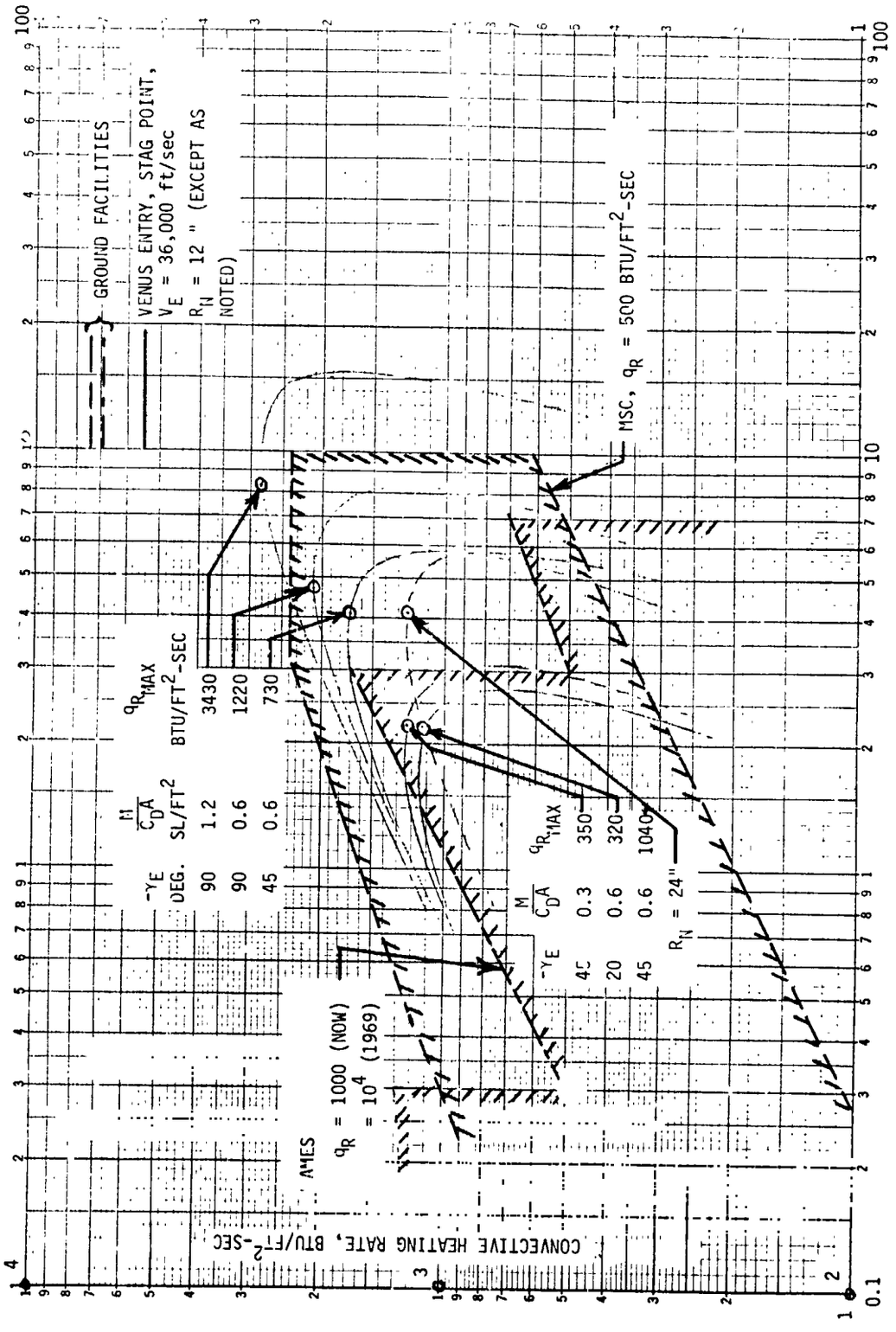


Fig. 17 NASA GROUND-TEST SIMULATION CAPABILITY

A. TECHNICAL DIRECTIVE MEMORANDUM 1, DATED 9/17/69

The Study Plan presented by the Contractor to JPL on Sept. 10-11 is hereby approved provided the plan is modified on conform to the following:

1. Because of a concern by JPL that problem identification resulting from task 8 (Entry Probe synthesis) may occur too late in the schedule to permit corrective actions, it is recommended that a trial probe synthesis be initiated in the fourth week of the study. This trial case is defined as one combination of instrumented probes and selected target sites. The particular combination will be recommended by the Contractor not later than Sept. 19 and approved by JPL not later than Sept. 23.

   A meeting will be held to obtain a report on the trial case; said meeting to be called by JPL with time and place by mutual agreement with the Contractor, except that it shall occur about one half way to the mid term oral report date.

2. The breadth of the tasks need to be narrowed somewhat earlier than shown in the study plan in terms of the number of possible science/probe combinations. To aid in this regard, JPL is providing the Contractor with science priorities as follows:

   Priority 1 - Composition and distribution of the clouds.

   Priority 2 - Atmospheric circulation from just above the cloud layer and below.

   Priority 3 - Vertical structure of atmosphere, particularly in regions not covered by Venera's 4, 5, and 6.

   Priority 4 - Upper Atmosphere.

   These priorities are not intended to be used as a basis for excluding any of the science objectives or instruments specified in the Work Statement.

3. Considerations of buoyant stations (i.e., balloons) in this study are to be limited to utilizing existing preliminary designs and other existing related information such as tracking techniques. For use in determining atmospheric circulation, the buoyant station must be applicable to the region from just

above the cloud layer and below. In terms of pressure, the region of strongest interest corresponds to about 200 mb and above.

4. Landing site limitations resulting from communications, power, and data return considerations is an important facet of this study and should be clearly identified at an early date.

5. It is recommended that detailed design of the terminal descent capsule(s), as well as other hardware items, be avoided, although sufficient analysis to obtain conceptual designs, recommend alternative approaches where appropriate, and identify problem areas is clearly required by the Work Statement.

6. Although not required by the Work Statement, the use of a Mission Effectiveness Model is acceptable to JPL insofar as it is used as a logical means of comparing alternate system designs and instrument mechanizations. The technique should not be used for re-evaluating the science mission relative to alternate ones.

7. It is recognized that a number of questions regarding the determination of heat shield weights remain to be resolved. It is recommended that the Contractor continue its effort, together with JPL, to resolve these questions. A separate TDM will be written to cover this area in more detail. From the meeting discussions, it is mutually understood that the Contractor will not be inhibited from performing the tasks of the Study Plan if the major questions are resolved by Sept. 25.

B. TECHNICAL DIRECTIVE MEMORANDUM 2, DATED 9/29/69

This TDM relates to two subjects - 1) Venus atmospheric models, and 2) use of supersonic decelerators.

1) As called for in the Statement of Work the contractor has submitted a recommended range of atmospheric models (MCR-69-488, part I) for consideration by JPL. JPL hereby approves the recommendations with the following comments and exceptions:

a. The limiting atmospheric models should consist of the MMC-Lower and V5M tabulations, except that the surface conditions for MMC-Lower should be consistent with a mean surface radius (R_o) of 6050 $\pm$ 5 km. These conditions result in an approximate surface pressure range of 70 to 125 bars for MMC-Lower, compared to the 150 bars for V5M.

b. Since the V5M model, based on NASA SP-8011, appears high in pressure with respect to the Mariner 5 occultation data and the recent models published by Avduevsky, et al (Venera 5 and 6), it is recommended that the R_o be limited to 6050 km and that no isothermal models be considered in connection with model V5M. This latter condition results in a disapproval of the contractor's recommendation for use of model V5/ISO.

c. An isothermal lower atmosphere at about 620°K should be considered in connection with the MMC-Lower model.

d. Consistency with items 1)a, b, and c above results in the following approximate surface conditions for tradeoff of subsystem design penalties in regard to a terminal descent capsule (P_o = surface pressure, T_o = surface temperature):

ATM Model	R_o (km)	P_o (bars)	T_o (°K)
MMC-Lower	6045	125	803
MMC-Lower (ISO)	6050	106	618
MMC-Lower (ISO)	6045	150	618
V5M	6050	150	755

2) The contractor has brought up the question of supersonic auxiliary decelerators for use in this study. JPL hereby provides the following guidelines:

a. The contractor should consider designs and flight conditions consistent with multiple, successful flight tests of similar designs. Military, as well as NASA experience, should be considered.

b. The Final Engineering Report should include technical information covering at least the following in regard to any auxiliary decelerators that the contractor proposes: (i) test experience, (ii) type of qualification, if any (e.g., man rated), (iii) test program requirements for the baseline mission of this study, (iv) sterilization constraints consistent with the Statement of Work, Art. 1, part (b) (4) (D).



C. TECHNICAL DIRECTIVE MEMORANDUM 3, DATED 10/3/69

The following items relating to heat shield design are covered in this TDM: 1) heat protection of the afterbody, 2) forebody heat shield weights, 3) test-facility limitations, 4) ejection of aeroshell, and 5) aerodynamic shear and pressure gradient.

1) Afterbody heat protection was not intended to be included in the JPL heat shield weights of section document 131-05. This is because the heat protection required depends on back cover configuration and structural materials, neither of which are specified in the contract.

2) The forebody heat shield weights of section document 131-05 have been revised under conditions and exceptions specified therein, and as discussed between JPL and the contractor. The revised weights and explanatory information have been sent under separate cover on 2 October to meet the time scale orally agreed upon on 24 September.

3) It is recognized that the NASA ground-test capability for heat shield materials is inadequate to simulate the heat transfer rates corresponding to conditions in table 1 of section document 131-05. The contractor should keep aware of this circumstance but not be constrained on that basis alone from proposing entry and vehicle characteristics that result in heating conditions exceeding facility capabilities. These cases, when desirable from other mission considerations, should be recognized as implying higher risk, and the Final Engineering Report should so specify. JPL will add additional calculation results to figure 14 (to be figure 17 in revised section document 131-05) in order to aid the contractor in this regard.

4) Consideration of aeroshell ejection at the time of an auxiliary decelerator deployment is acceptable to JPL within the guidelines for auxiliary decelerators given in item 2) of TDM No. 2. A method of accomplishing the aeroshell ejection (i.e., separation from the terminal descent package) should be shown in the applicable configuration drawings and briefly described in the Final Engineering Report.

5) Maximum aerodynamic shear has been calculated by equation 5, page 3-156 of the AVCO Venus Probe Study, Book I, and presented in tabular and graphical form in the transmittal of 2 October. This information should enable the contractor to select a material on a shear level basis. For the effect of pressure gradient it is not evident from the AVCO report (book II, pp.

4-249, 250) that the effects are well understood or that they are applicable to materials other than Avcoat 5026-39/HC-G such as X-6300 carbon phenolic. The comments made on page 3-73 of AVCO Book I suggest that the problem is primarily related to a low density heat shield ablator Because of the lack of information, the contractor may wish to select large nose radii for probes appropriate to the use of Avcoat 5026-39/HC-G ablator material, although the difficulty in simulating the stagnation point radiative heating environment is accentuated.

D. TECHNICAL DIRECTIVE MEMORANDUM 4, DATED 10/20/69

(Pursuant to review of the first Monthly Progress Report and additional discussions)

1. Regarding the trial probe synthesis, the Contractor should continue his efforts to define subsystem and system requirements, with particular emphasis toward mechanizing the communication link and on-board data handling system needed to return the information resulting from the combination of instrumented probes selected. This mechanization will include: 1) evaluating the compatibility of the DSN with the data rates, number of probes, and timing involved, 2) quantifying the performance of the selected radio systems as affected by the probe configurations and probe locations at Venus, and 3) establishing limits of probe-axis misalignment with the descent trajectory beyond which data return would be significantly degraded.

2. In utilizing JPL Document No. 611-1 for tracking and ground data system capability, it is expected that the Contractor will identify problem areas and suggest improvements that would be of particular benefit to the mission defined in this contract.

A. LIST OF OBSERVABLES

0.1 Determine the planetocentric radius (or altitude above a reference sphere) of the probe during the subsonic portion of its descent.

0.2 Determine the planetocentric radius of the probe during the supersonic/hypersonic portion of its descent.

0.3 Determine a pressure-temperature reference for the probe.

1 Identify the ionic species present in the upper atmosphere, and determine their number density profiles.

2 Identify the neutral gas constituents in the upper atmosphere, and determine their number density profiles.

3 Determine the electron number density and electron temperature profiles in the upper atmosphere.

4 Determine the UV radiation flux profiles at several wavelengths.

5 Determine the number densities and sizes of any cloud or haze particles versus altitude above the main cloud top.

6 Determine the wind shear profiles above and through the tops of the main cloud deck.

7 Determine the composition of any cloud or haze particles above the main cloud tops.

8 Determine pressure, temperature, and density profiles from above the clouds to the surface over several widely separated points on planet.

9 Identify the minor atmospheric constituents, and determine their number density profiles.

10 Determine the precise (±0.5%) concentration of CO_2 at several altitudes between cloud tops and surface.

11 Determine the abundances and isotopic ratios of the rare gases, e.g., Ne^{20}, Ne^{22}, A^{36}, A^{38}, A^{40}, etc.

12 Locate the top of the visible cloud layer with respect to pressure, temperature, and radius over several widely separated points on the planet.

13 Locate (with respect to pressure, temperature, and radius) and determine the vertical extent of all cloud layers between the surface and cloud tops.

14 Determine the chemical composition of the cloud particles in each cloud layer.

15 Determine the number density and size distribution of the cloud particles versus altitude within each cloud layer.

16 Determine the physical state (liquid, solid) of the cloud particles versus altitude in each cloud layer.

17 Determine the visible radiation fluxes (direct, diffuse) at several wavelengths versus altitude over several widely separated points on the light side.

18 Determine the upward and downward thermal IR radiation fluxes at several wavelengths versus altitude over several widely separated points on the planet.

19 Determine the general circulation pattern of the atmosphere at several altitudes.

20 Determine the horizontal and vertical wind profiles near the subsolar and antisolar points and a pole.

21 Determine the magnitude and frequency spectrum of the turbulence versus altitude near the subsolar, polar, and antisolar points.

22 Search for transient light phenomena during descent.

B. SCIENCE QUESTIONS

SCIENCE QUESTION 0.1

Determine the planetocentric radius (or altitude above a reference sphere) of the probe during the subsonic portion of its descent.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Altitude Radar Or	1.0
With no radar but a radar-pressure correlation on another probe and pressure measurement on this probe Or	0.9
With no radar and no radar-pressure correlation on another probe but with pressure on this probe	0.2

SUPPORTING MEASUREMENTS — If missing, reduce value to:

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-2

PRIMARY TARGETS

Targets Are: Not applicable

Proportion of Total Value Determined by Primary Targets:

Use Target Curve

Use Summation Scheme

SECONDARY TARGETS

Targets Are: Not applicable

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 0.2

Determine the planetocentric radius of the probe during the supersonic/ hypersonic portion of its descent.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Accelerometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5
High Altitude Mass Spectrometer	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6200	0.5	6130		

CUMULATIVE VALUE PROFILE APPLICABLE C-1

PRIMARY TARGETS

Targets Are: Not applicable

Proportion of Total Value Determined by Primary Targets:

Use Target Curve

Use Summation Scheme

SECONDARY TARGETS

Targets Are: Not applicable

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 0.3

Determine a pressure-temperature reference for the probe.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Pressure and Temperature	1.0

SUPPORTING MEASUREMENTS — If missing, reduce value to:

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
	Not applicable			

CUMULATIVE VALUE PROFILE APPLICABLE None

PRIMARY TARGETS

Targets Are: Not applicable

Proportion of Total Value Determined by Primary Targets:

Use Target Curve

Use Summation Scheme

SECONDARY TARGETS

Targets Are: Not applicable

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 1

Identify the ionic species present in the upper atmosphere, and determine their number density profiles.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Ion Mass Spectrometer	0.714
UV Photometer	0.286

SUPPORTING MEASUREMENTS	If missing, reduce value to:
High Altitude Reference	0.5
Electron Number Density (Question 3)	0.8

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6300	10	6250	5	6150

CUMULATIVE VALUE PROFILE APPLICABLE C-3

PRIMARY TARGETS

Targets Are: Subsolar

Proportion of Total Value Determined by Primary Targets: 0.8

Use Target Curve P-1

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Any other lightside area

Use Target Curve S-1

Use Linear Accumulation Rate of: 0.333

SCIENCE QUESTION 2

Identify the neutral gas constituents in the upper atmosphere, and determine their number density profiles.

APPLICABLE INSTRUMENTS	Proportion of Contribution
High Altitude Mass Spectrometer	0.714
UV Photometer	0.286

SUPPORTING MEASUREMENTS	If missing, reduce value to:
High Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6300	10	6250	5	6150

CUMULATIVE VALUE PROFILE APPLICABLE C-3

PRIMARY TARGETS

Targets Are: Subsolar point

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-2

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Any lightside area

Use Target Curve S-1

Use Linear Accumulation Rate of: 0.333

SCIENCE QUESTION 3

Determine the electron number density and electron temperature profiles in the upper atmosphere.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Electron Temperature and Density Probe	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to.
High Altitude Reference	0.5
Ion Number Density Profile (Question 1)	0.8

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6300	10	6250	5	6150

CUMULATIVE VALUE PROFILE APPLICABLE C-3

PRIMARY TARGETS

Targets Are: Subsolar

Proportion of Total Value Determined by Primary Targets: 0.8

Use Target Curve P-1

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Any lightside area

Use Target Curve S-1

Use Linear Accumulation Rate of: 0.333

SCIENCE QUESTION 4

Determine the UV radiation flux profiles at several wavelengths.

APPLICABLE INSTRUMENTS	Proportion of Contribution
UV Photometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
High Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6300	10	6250	5	6150

CUMULATIVE VALUE PROFILE APPLICABLE C-4

PRIMARY TARGETS

Targets Are: Subsolar point

Proportion of Total Value Determined by Primary Targets: 0.75

Use Target Curve P-3

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Near terminator

Use Target Curve S-2

Use Linear Accumulation Rate of: 0.333

SCIENCE QUESTION 5

Determine the number densities and sizes of any cloud or haze particles versus altitude above the main cloud top.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Cloud Particle Number, Density, and Size	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
High Altitude Reference	0.5
Pressure-Temperature Reference	0.9

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6150	1	6120		

CUMULATIVE VALUE PROFILE APPLICABLE C-5

PRIMARY TARGETS

Targets Are: Lightside

Proportion of Total Value Determined by Primary Targets: 0.6

Use Target Curve P-4

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Darkside

Use Target Curve S-3

Use Linear Accumulation Rate of: 1.0

SCIENCE QUESTION 6

Determine the wind shear profiles above and through the tops of the main cloud deck.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Accelerometers	0.5

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Time Reference	0.4
Pressure	0.8

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6150	0.5	6110		

CUMULATIVE VALUE PROFILE APPLICABLE C-6

PRIMARY TARGETS

Targets Are: Subsolar

Proportion of Total Value Determined by Primary Targets: 0.5

Use Target Curve P-5

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Equatorial terminators, pole, and antisolar point

Use Target Curve S-4

Use Linear Accumulation Rate of: 0.25

SCIENCE QUESTION 7

Determine the composition of any cloud or haze particles above the main cloud tops.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Cloud Particle Composition	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
High Altitude Reference	0.8
Pressure-Temperature Reference	0.7

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6150	1	6120		

CUMULATIVE VALUE PROFILE APPLICABLE C-5

PRIMARY TARGETS

Targets Are: **Lightside**

Proportion of Total Value Determined by Primary Targets: 0.6

Use Target Curve P-4

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: **Darkside**

Use Target Curve S-3

Use Linear Accumulation Rate of: 1.0

SCIENCE QUESTION 8

Determine pressure, temperature, and density profiles from above the clouds to the surface over several widely separated points on planet.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Pressure Sensors	0.4
Temperature Sensors	0.4
Mass Spectrometer to Give Value for Mean Molecular Weight	0.2
SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.2

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-7

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 9

Identify the minor atmospheric constituents, and determine their number density profiles.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Mass Spectrometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Pressure	0.8
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	1.0	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-8

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primaries

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 10

Determine the precise (±0.5%) concentration of CO_2 at several altitudes between cloud tops and the surface.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Mass Spectrometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5
Pressure-Temperature Reference	0.8

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	20	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-8

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 1.0

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: None

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 11

Determine the abundances and isotopic ratios of the rare gases, e.g., Ne^{20}, Ne^{22}, A^{36}, A^{38}, A^{40}, etc.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Isotope ratios require special mass spectrometer not available in RFP instrument list.	
Abundance of N, N, A, K can be found with available neutral particle mass spectrometer	0.5
SUPPORTING MEASUREMENTS	If missing, reduce value to:
Pressure-Temperature Reference	0.8

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	20	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-8

PRIMARY TARGETS

Targets Are: Any target

Proportion of Total Value Determined by Primary Targets: 1.0

Use Target Curve P-7

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: None

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 12

Locate the top of the visible clouds with respect to pressure, temperature, and radius over several widely separated points on the planet.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Nephelometer	0.5
Pressure Sensor	0.3
Temperature Sensor	0.2
SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.2

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	0.5	6110		

CUMULATIVE VALUE PROFILE APPLICABLE C-9

PRIMARY TARGETS

Targets Are: **Subsolar, polar, and antisolar**

Proportion of Total Value Determined by Primary Targets: 0.8

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: **Between primary targets**

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 13

Locate (with respect to pressure, temperature, and radius) and determine the vertical extent of all cloud layers between the surface and the cloud tops.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Nephelometer	0.8
Thermal Radiometer	0.2

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Pressure-Temperature Reference	0.5
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6110	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-10

PRIMARY TARGETS

Targets Are: **Subsolar, polar, and antisolar**

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: **Between primary targets**

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 14

Determine the chemical composition of the cloud particles in each cloud layer.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Cloud Particle Composition	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5
Pressure-Temperature Reference	0.2

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	5.0	6115	2.0	6050

CUMULATIVE VALUE PROFILE APPLICABLE C-11

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 15

Determine the number density and size distribution of the cloud particles versus altitude within each cloud layer.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Cloud Particle Number, Density, & Size	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6120	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-10

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.90

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.3

SCIENCE QUESTION 16

Determine the physical state (liquid, solid) of the cloud particles versus altitude in each cloud layer.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Evaporimeter-Condensimeter	0.75

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Pressure-Temperature Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6120	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-11

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 17

Determine the visible radiation fluxes (direct, diffuse) at several wavelengths versus altitude over several widely separated points on the light side.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Visible Radiometer (Solar)	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	1.0	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-8

PRIMARY TARGETS

Targets Are: Subsolar, evening terminator, morning terminator, and pole

Proportion of Total Value Determined by Primary Targets: 1.0

Use Target Curve P-8

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: None

Use Target Curve

Use Linear Accumulation Rate of:

SCIENCE QUESTION 18

Determine the upward and downward thermal IR radiation fluxes at several wavelengths versus altitude over several widely separated points on the planet.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Thermal Radiometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	0.5	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-8

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-6

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 19

Determine the general circulation pattern of the atmosphere at several altitudes.

APPLICABLE INSTRUMENTS	Proportion of Contribution
BVS with transponder plus any additional instrumentation required to locate positior on planet	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Pressure-Temperature Reference	0.8
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)

CUMULATIVE VALUE PROFILE APPLICABLE C-12

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.75

Use Target Curve P-9

Use Summation Scheme PAR = 2

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-7

Use Linear Accumulation Rate of: 1.0

SCIENCE QUESTION 20

Determine the horizontal and vertical wind profiles near the subsolar and antisolar points and a pole.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Accelerometers	0.25
Transponder	0.5
Drift Radar	0.25
SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	1	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-13

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-9

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 21

Determine the magnitude and frequency spectrum of the turbulence versus altitude near the subsolar, polar, and antisolar points.

APPLICABLE INSTRUMENTS	Proportion of Contribution
Accelerometers	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.5

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6130	1.0	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-13

PRIMARY TARGETS

Targets Are: Subsolar, polar, and antisolar

Proportion of Total Value Determined by Primary Targets: 0.9

Use Target Curve P-9

Use Summation Scheme PAR = 3

SECONDARY TARGETS

Targets Are: Between primary targets

Use Target Curve S-5

Use Linear Accumulation Rate of: 0.5

SCIENCE QUESTION 22

Search for transient light phenomena during descent

APPLICABLE INSTRUMENTS	Proportion of Contribution
Solar Radiometer	1.0

SUPPORTING MEASUREMENTS	If missing, reduce value to:
Low Altitude Reference	0.75

REQUIRED MEASUREMENT INTERVAL

Radius (km)	Interval (km)	Radius (km)	Interval (km)	Radius (km)
6110	1.0	6050		

CUMULATIVE VALUE PROFILE APPLICABLE C-11

PRIMARY TARGETS

Targets Are: Any target

Proportion of Total Value Determined by Primary Targets: 0.0

Use Target Curve P-7

Use Summation Scheme --

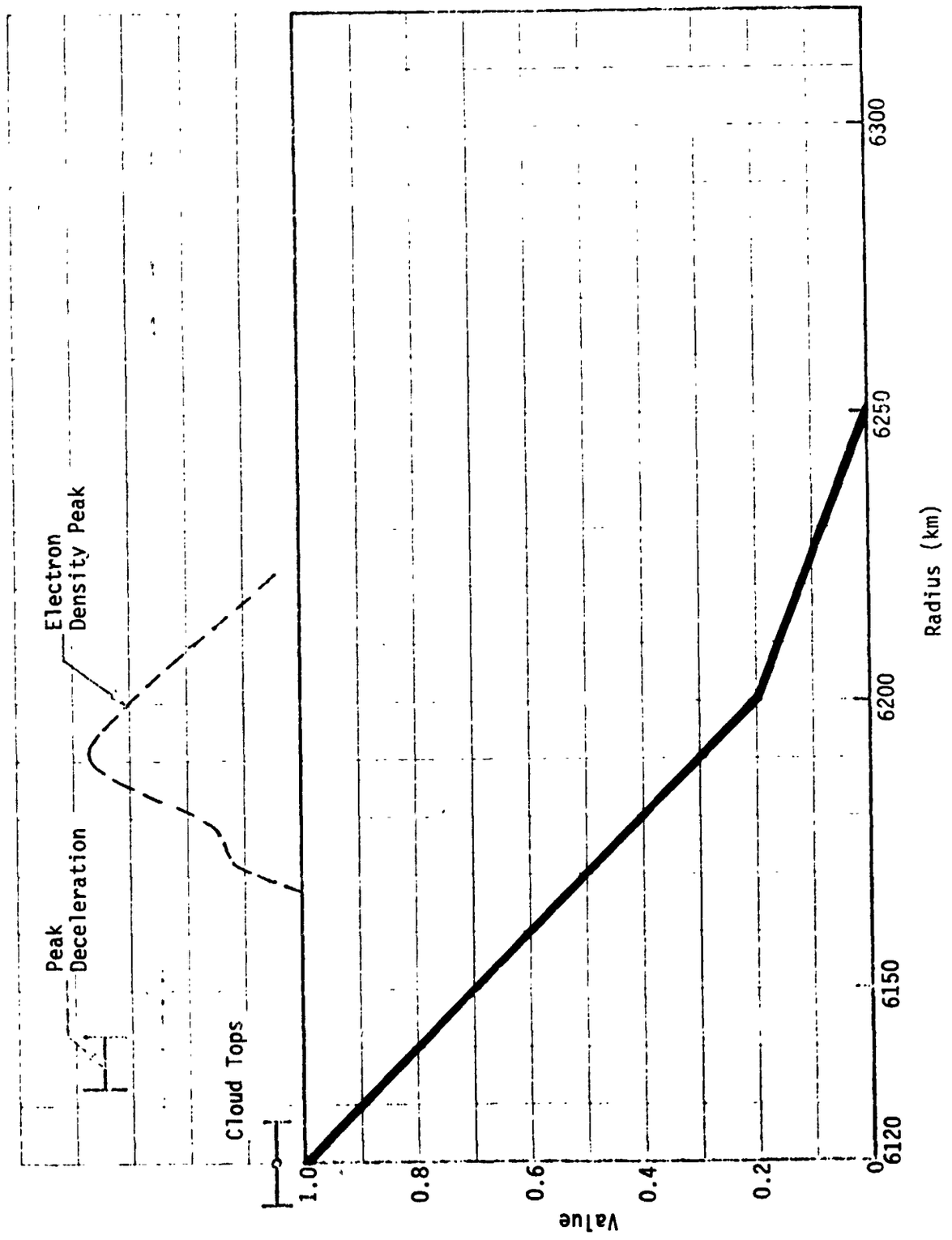
SECONDARY TARGETS

Targets Are: Any target

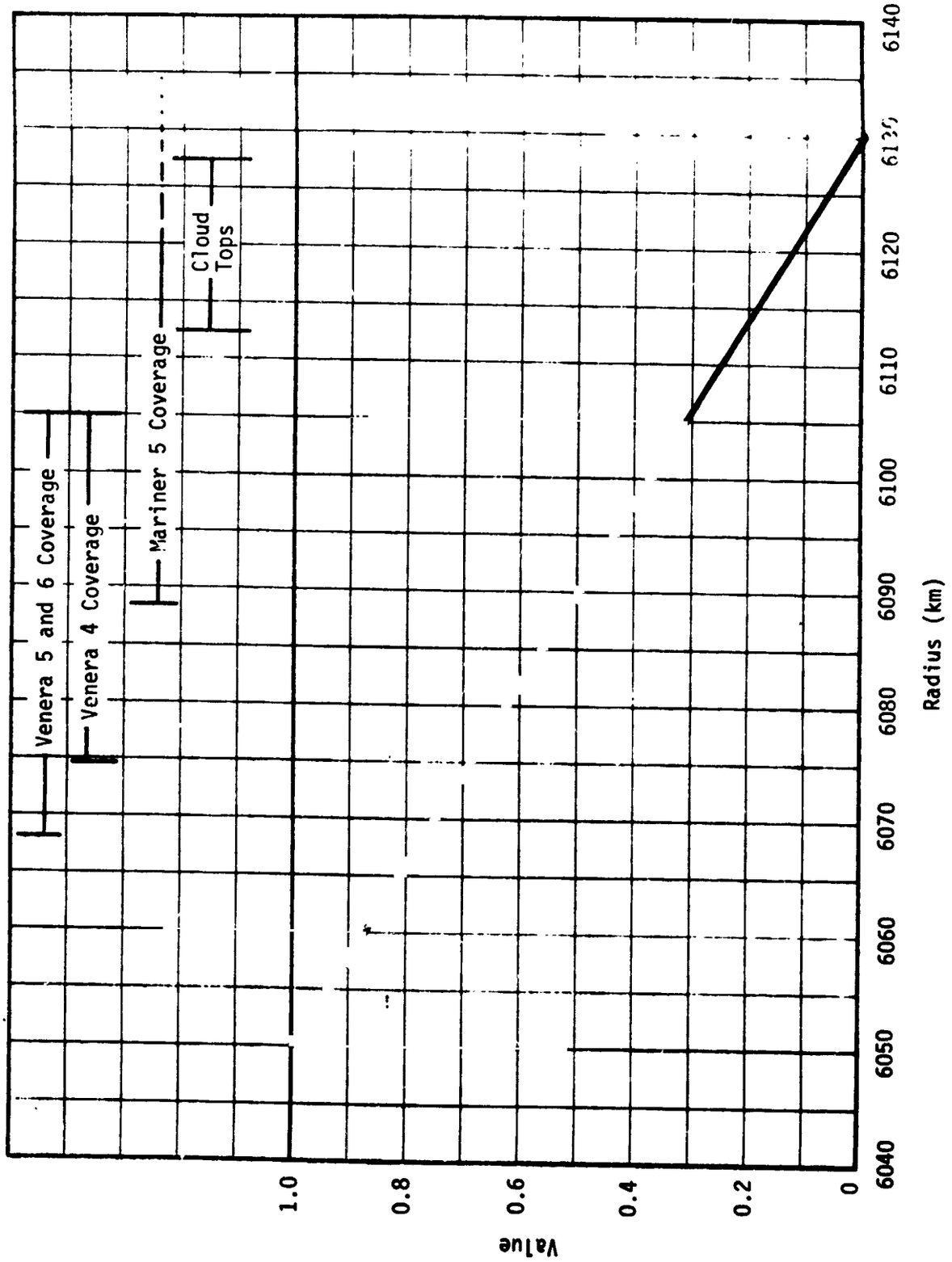
Use Target Curve S-8

Use Linear Accumulation Rate of: 0.5

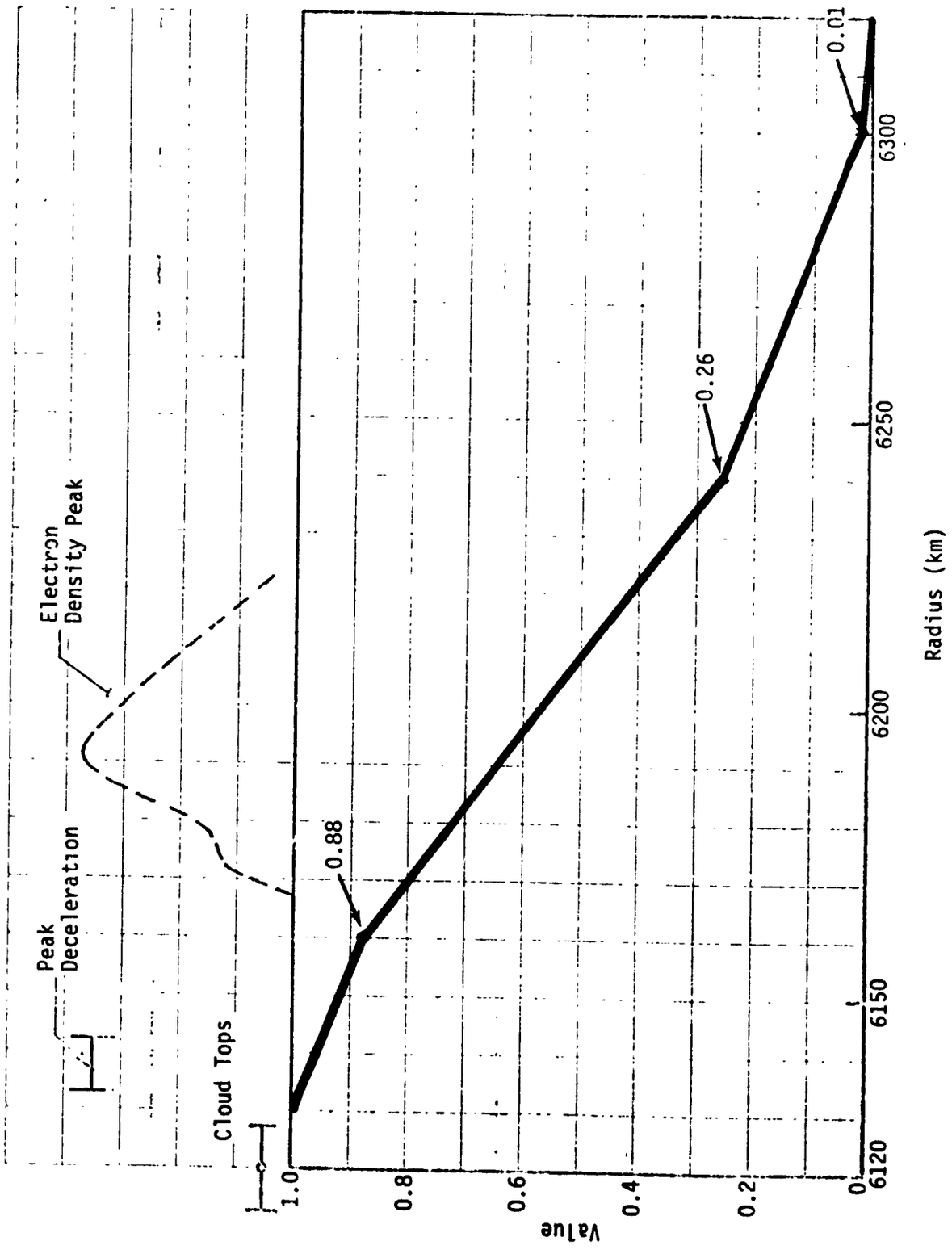
CUMULATIVE VALUE PROFILE C-1



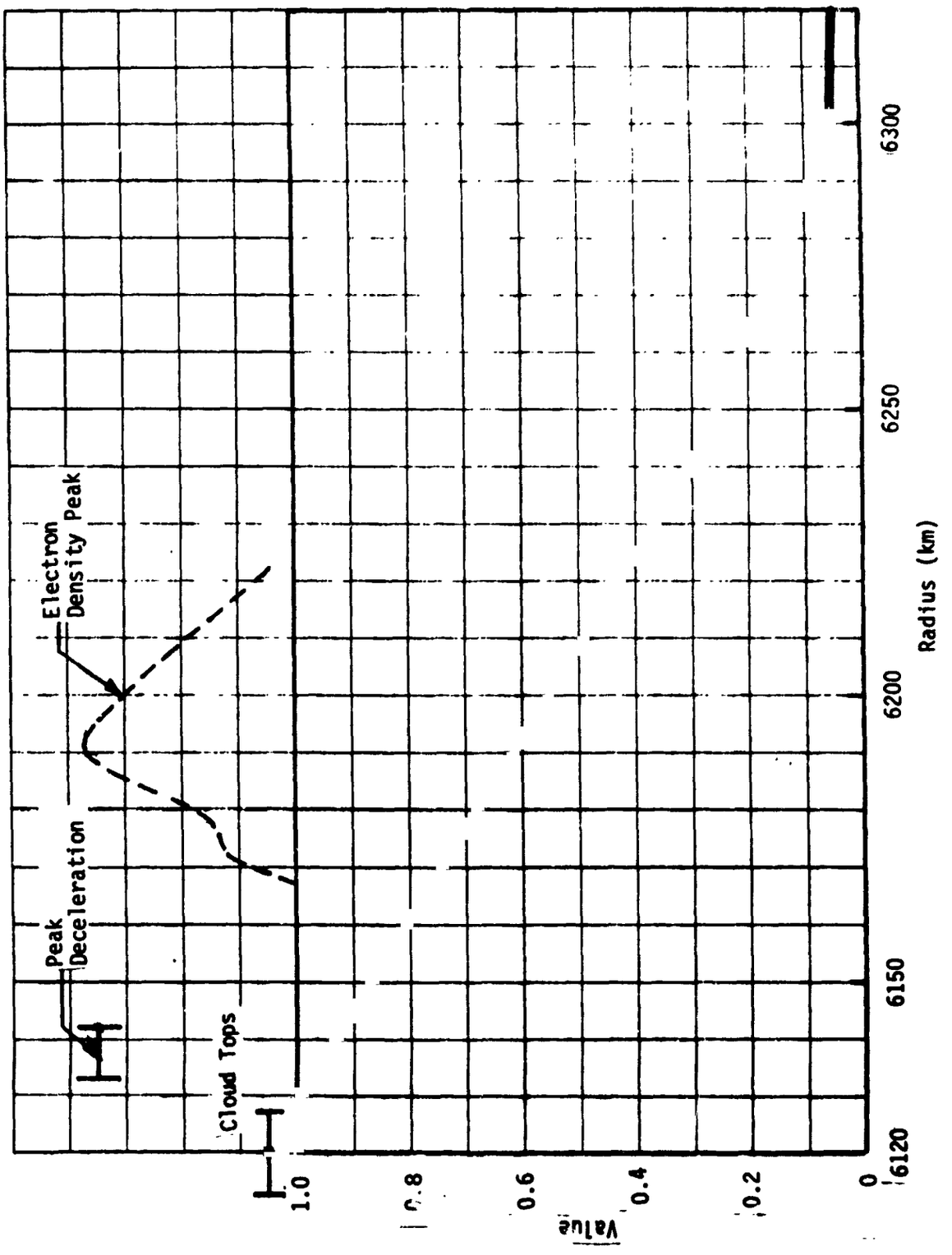
CUMULATIVE VALUE PROFILE C-2



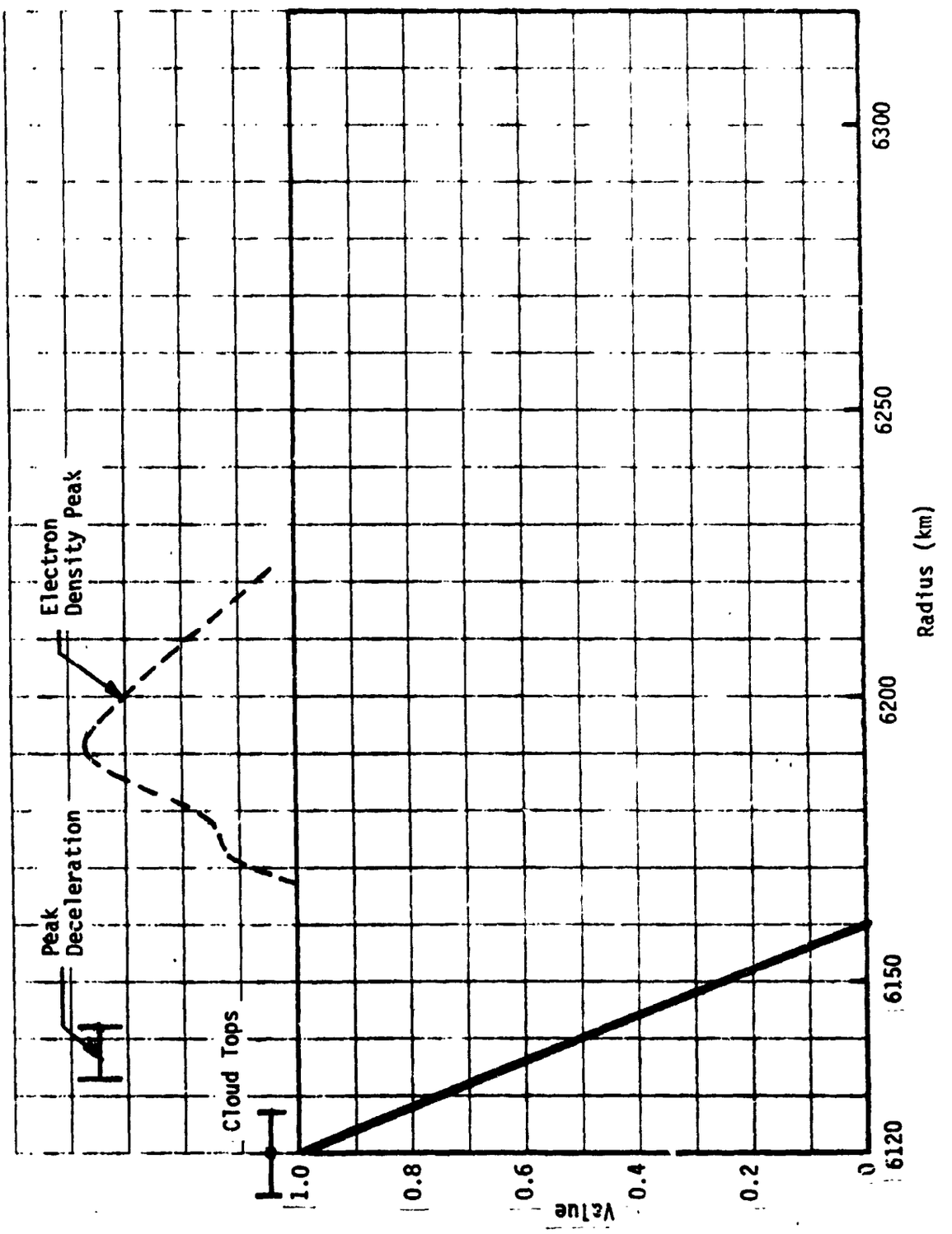
CUMULATIVE VALUE PROFILE C-3



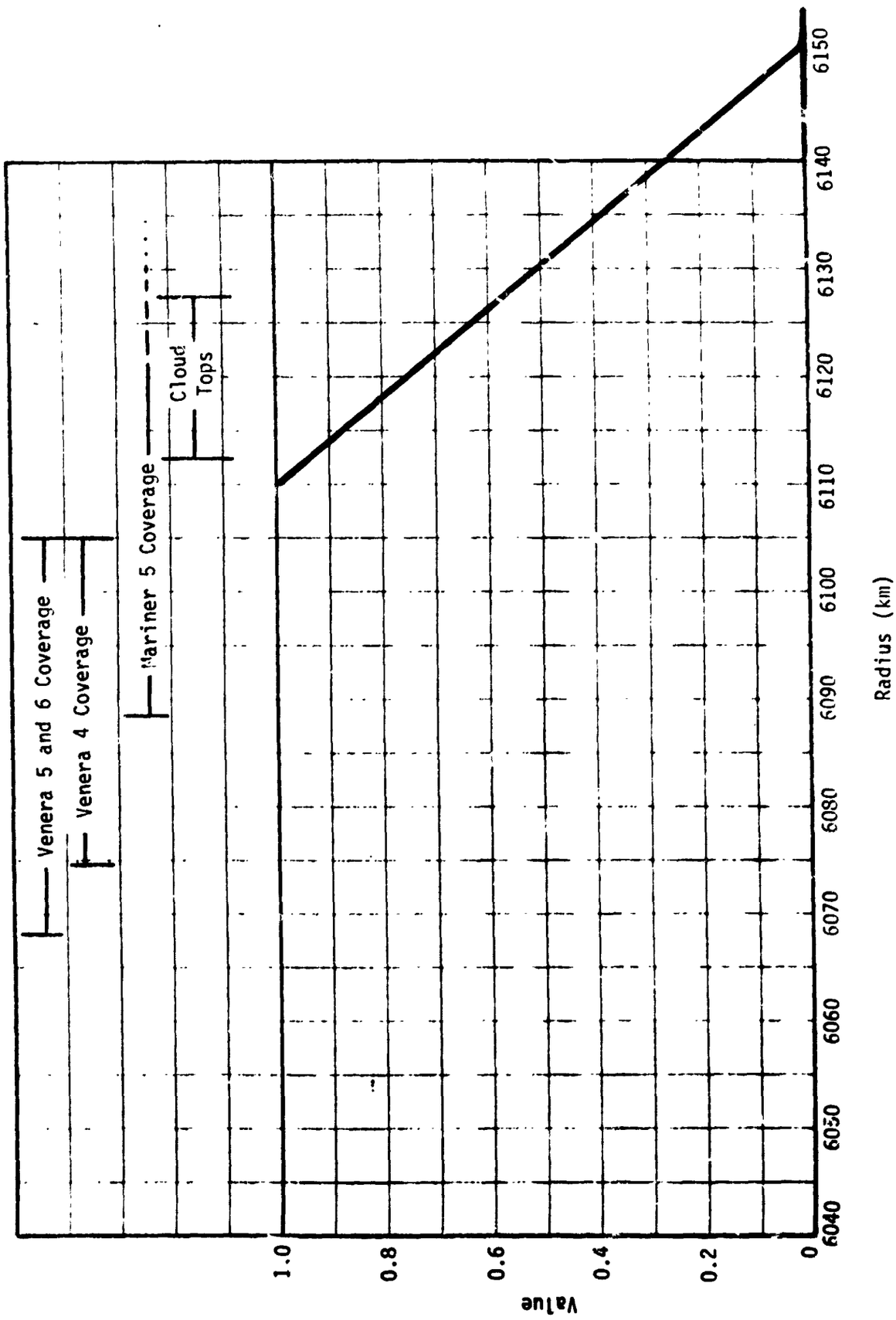
CUMULATIVE VALUE PROFILE C-4



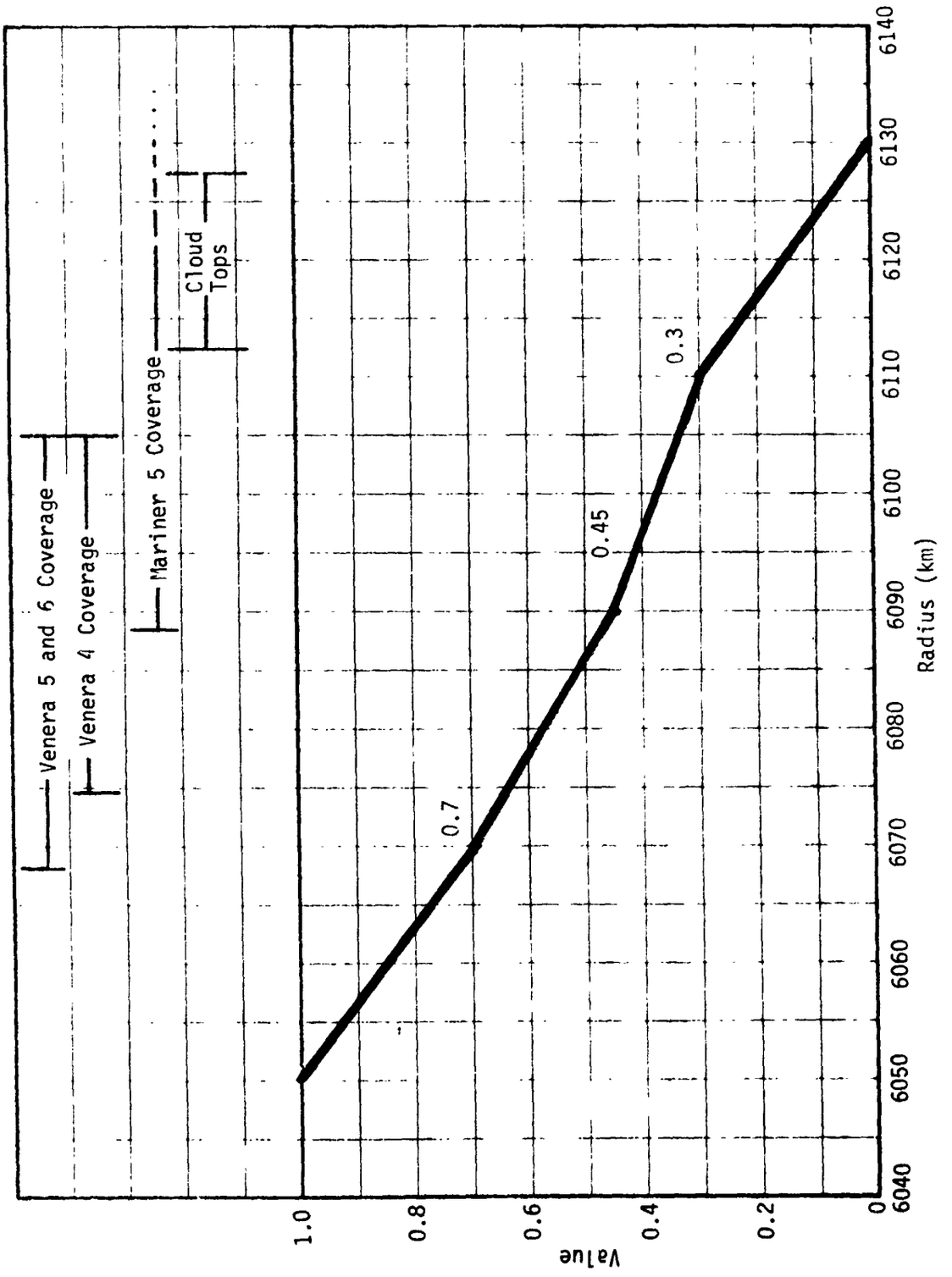
CUMULATIVE VALUE PROFILE C-5



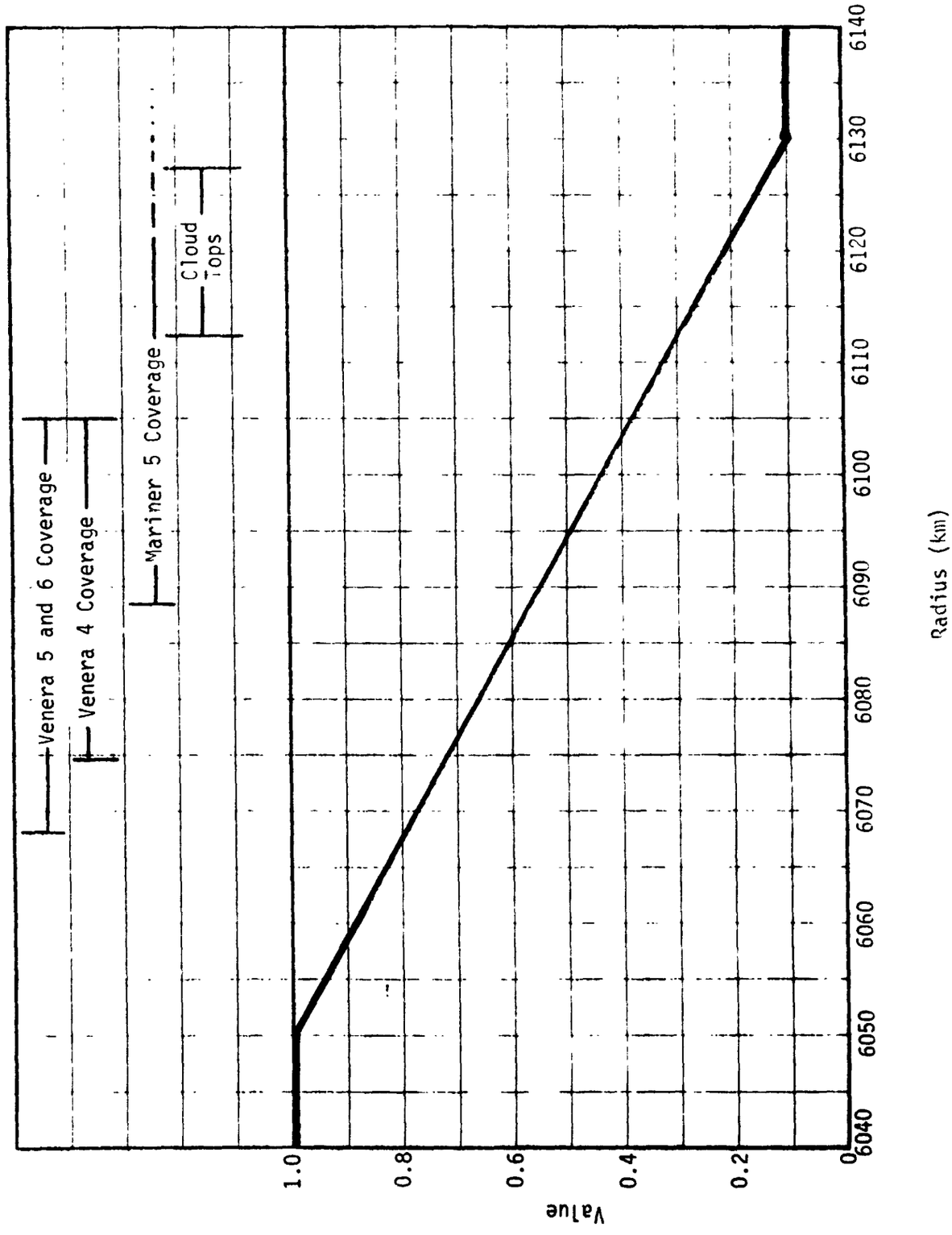
CUMULATIVE VALUE PROFILE C-6



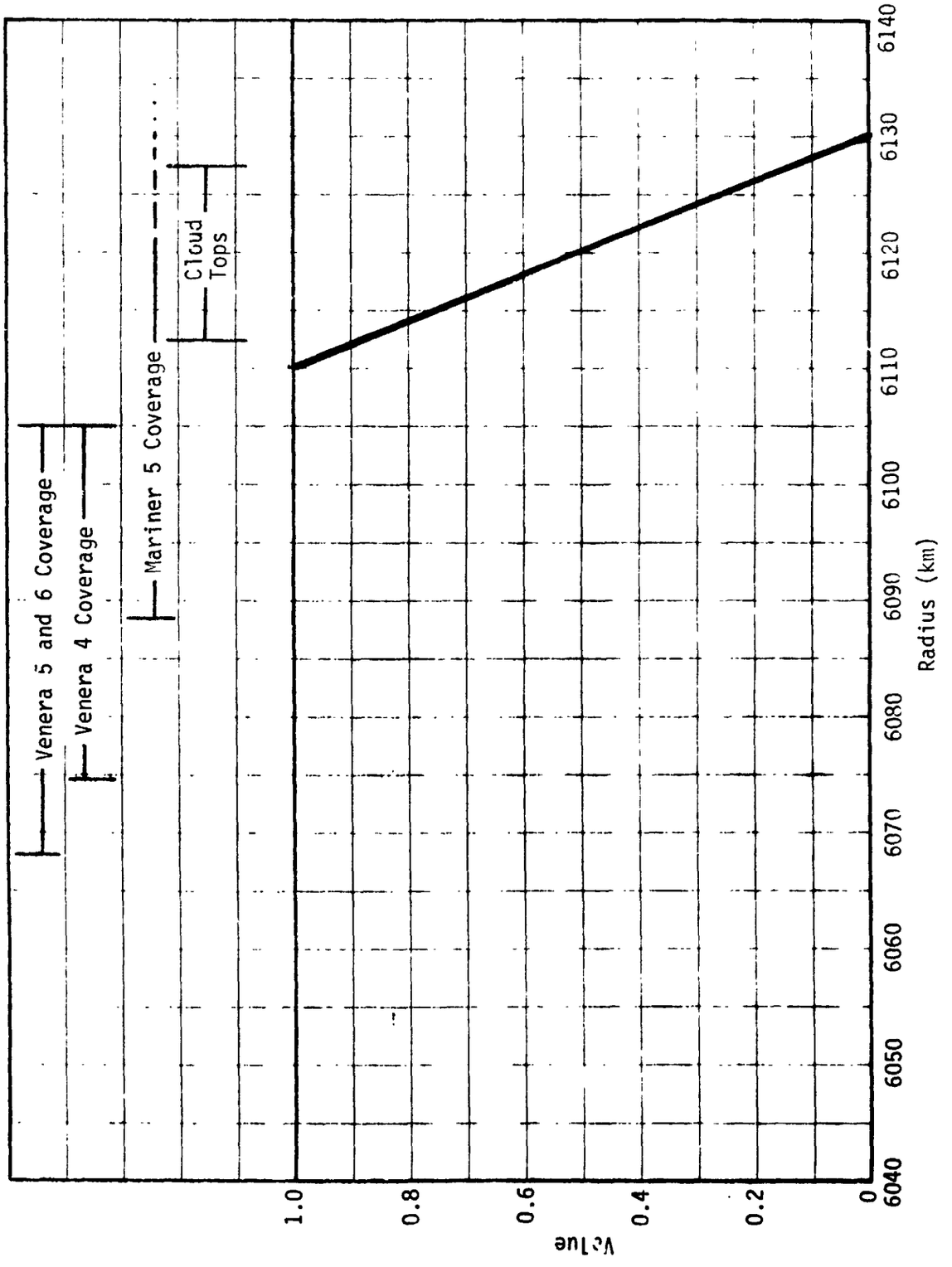
CUMULATIVE VALUE PROFILE C-7



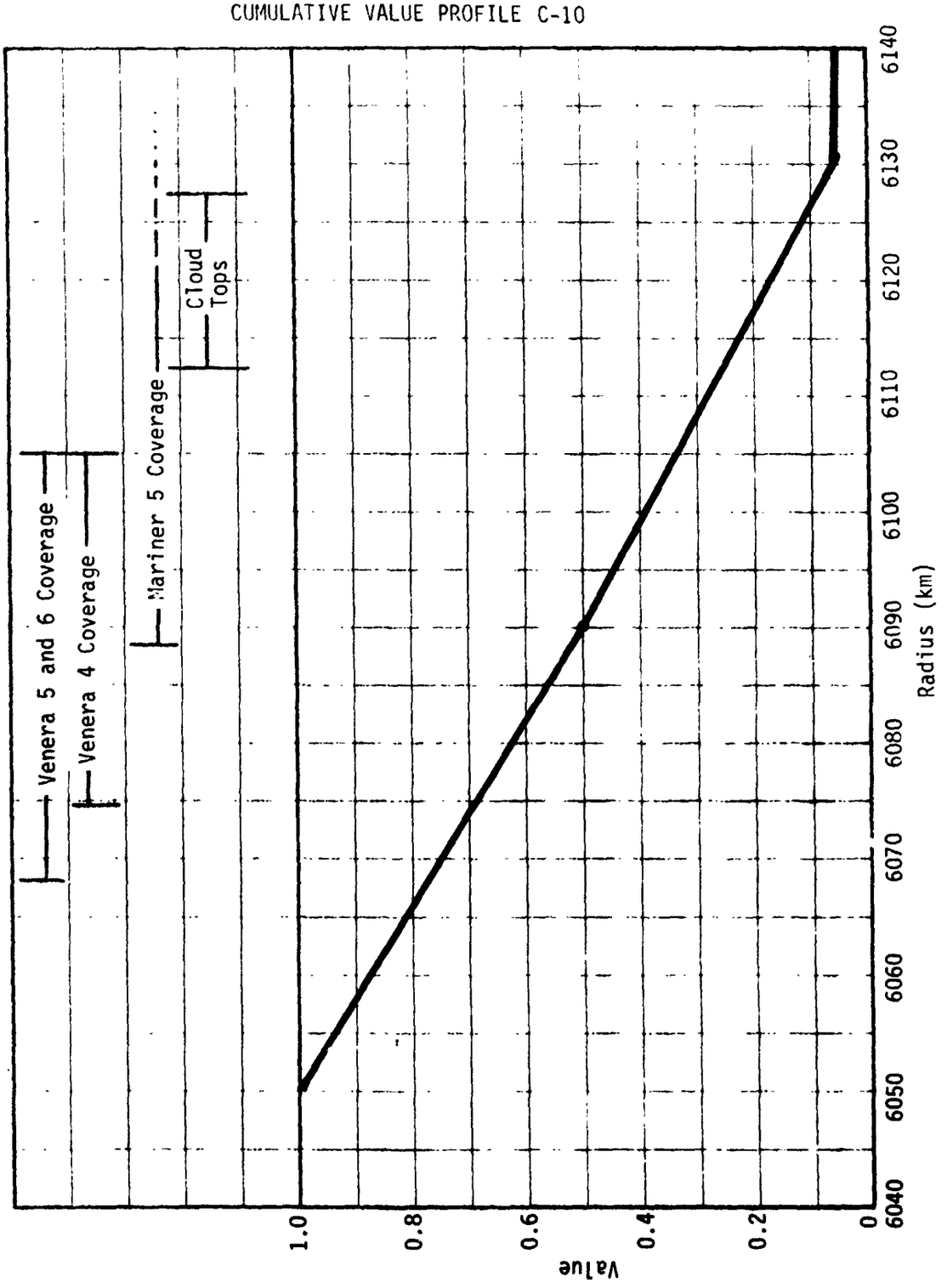
CUMULATIVE VALUE PROFILE C-8



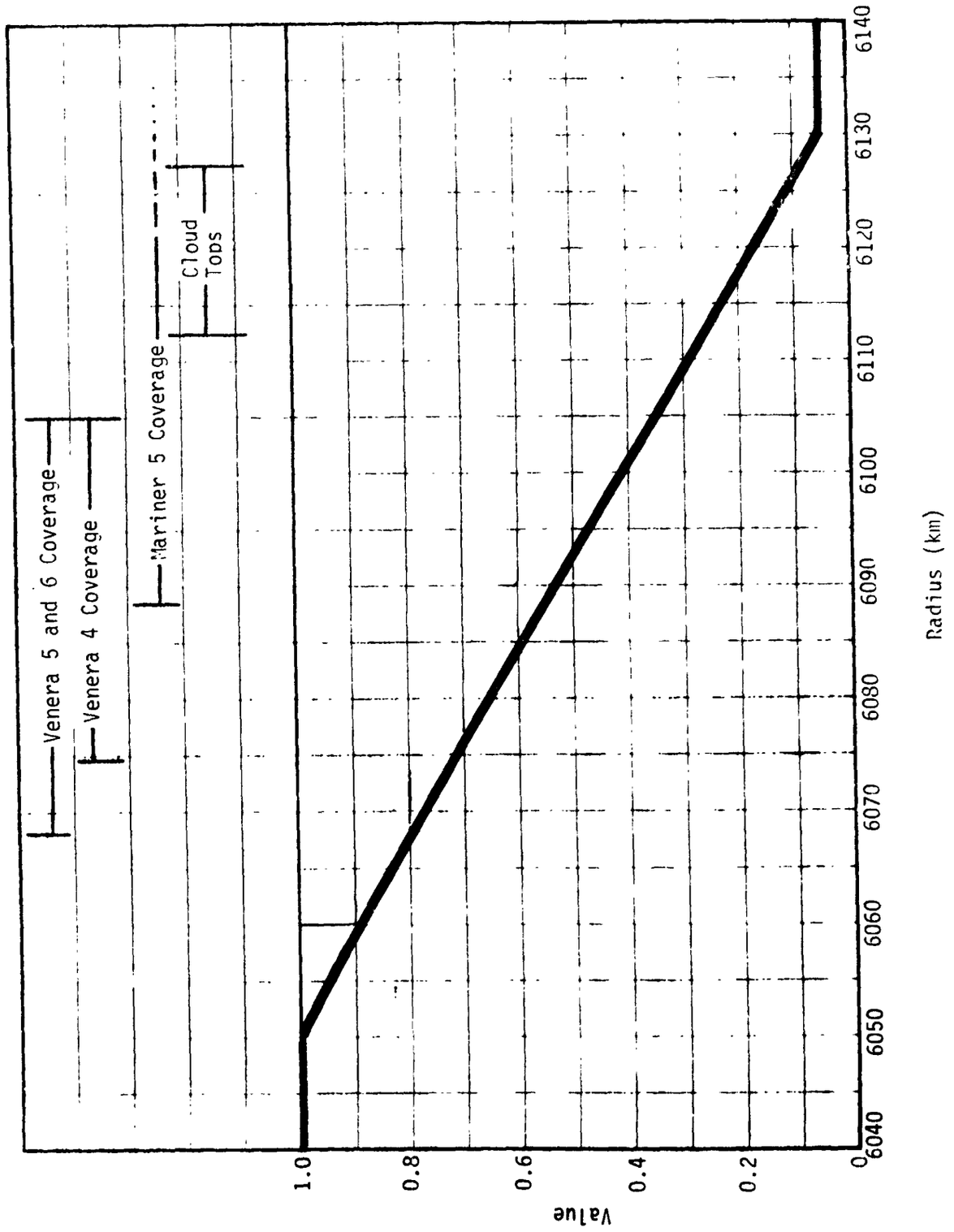
CUMULATIVE VALUE PROFILE C-9



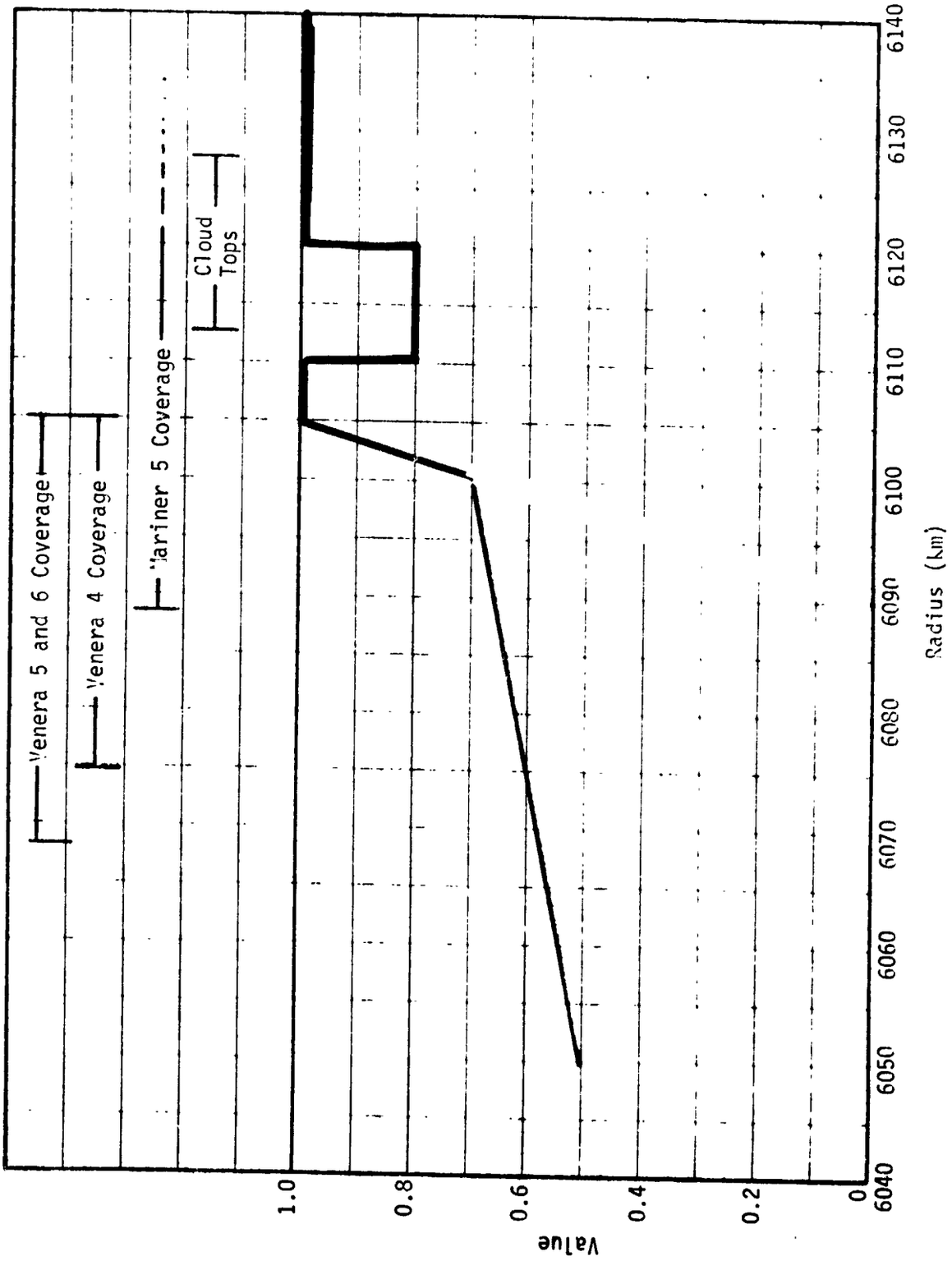
CUMULATIVE VALUE PROFILE C-10



CUMULATIVE VALUE PROFILE C-11

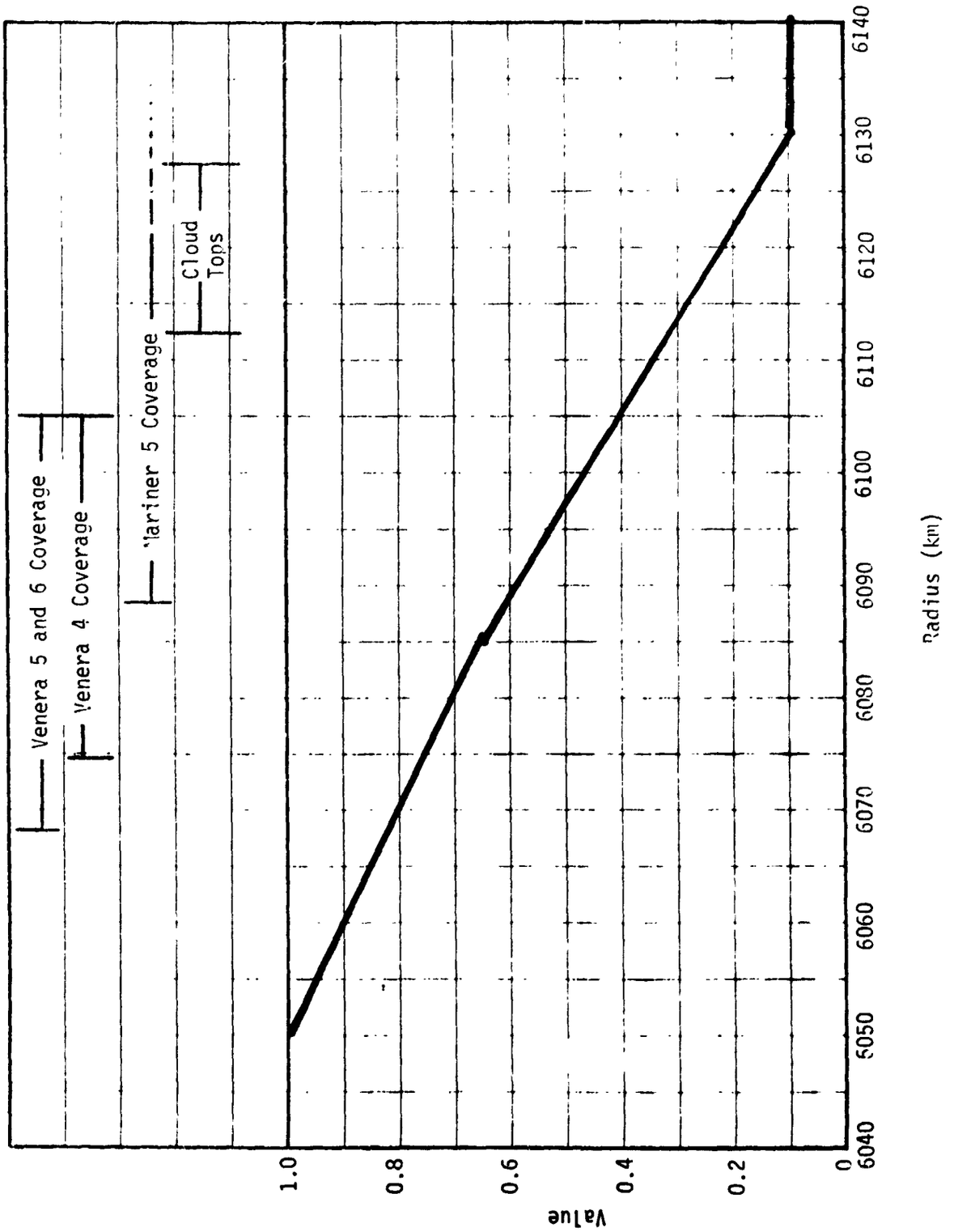


CUMULATIVE VALUE PROFILE C-12



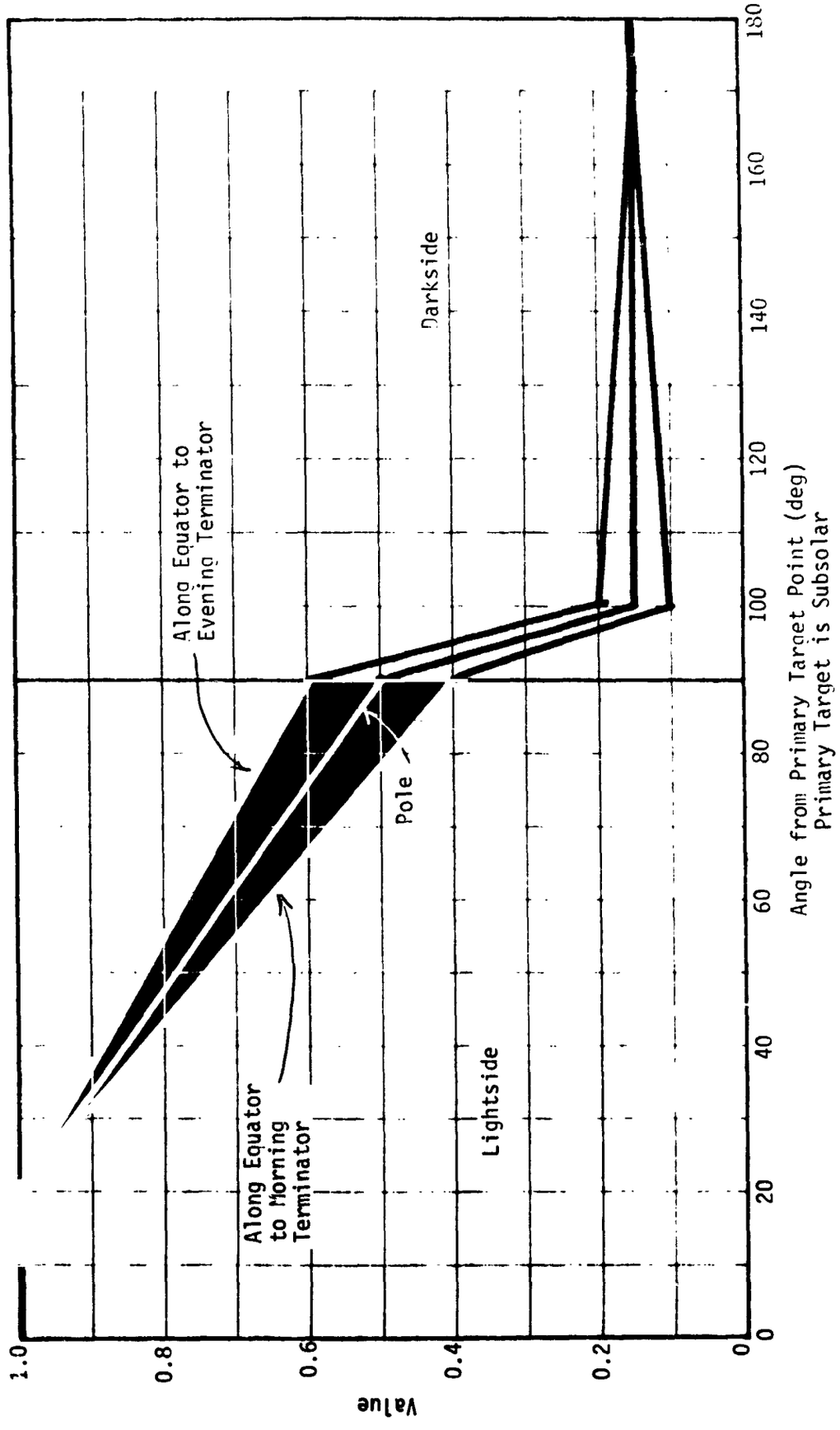
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CUMULATIVE VALUE PROFILE C-13

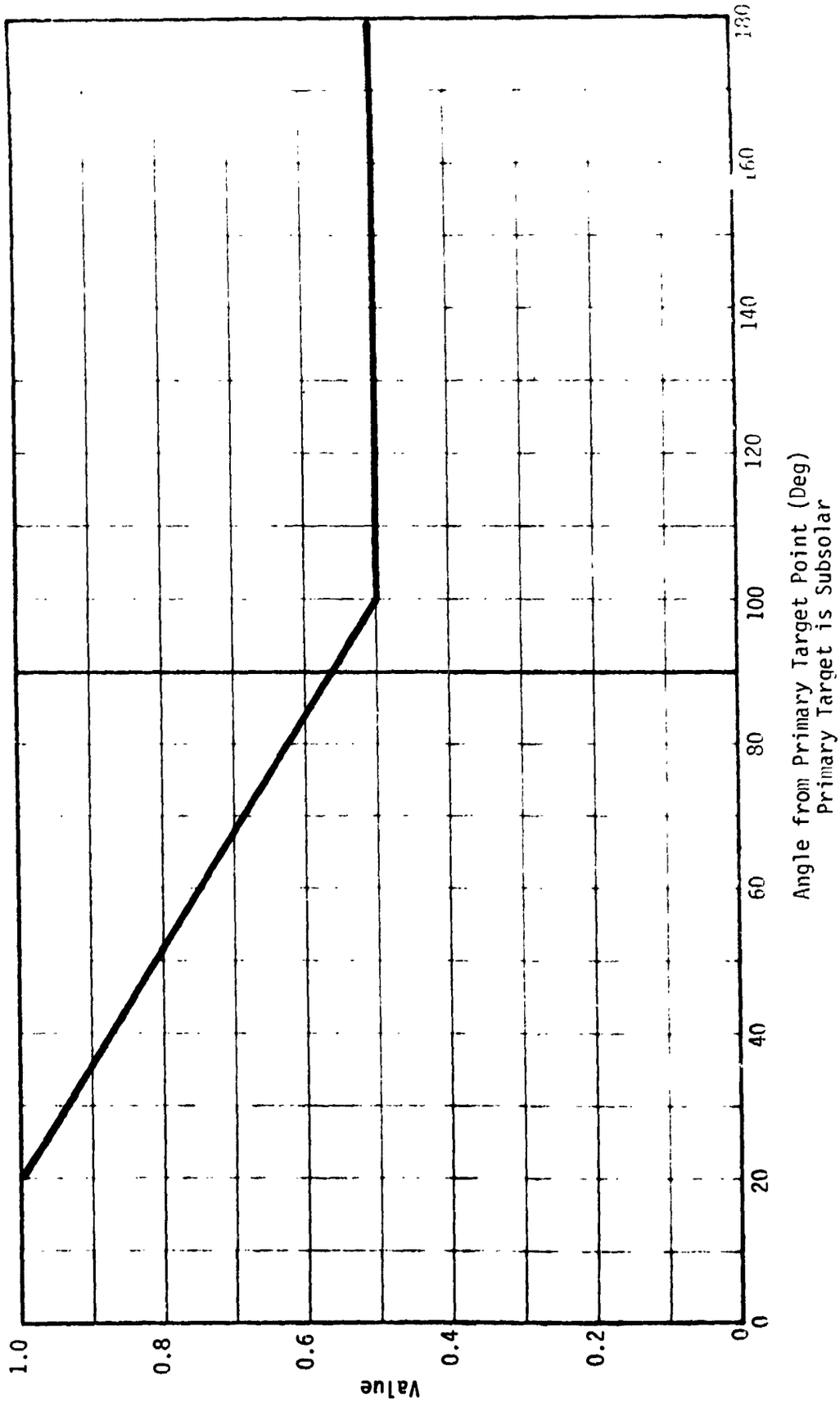


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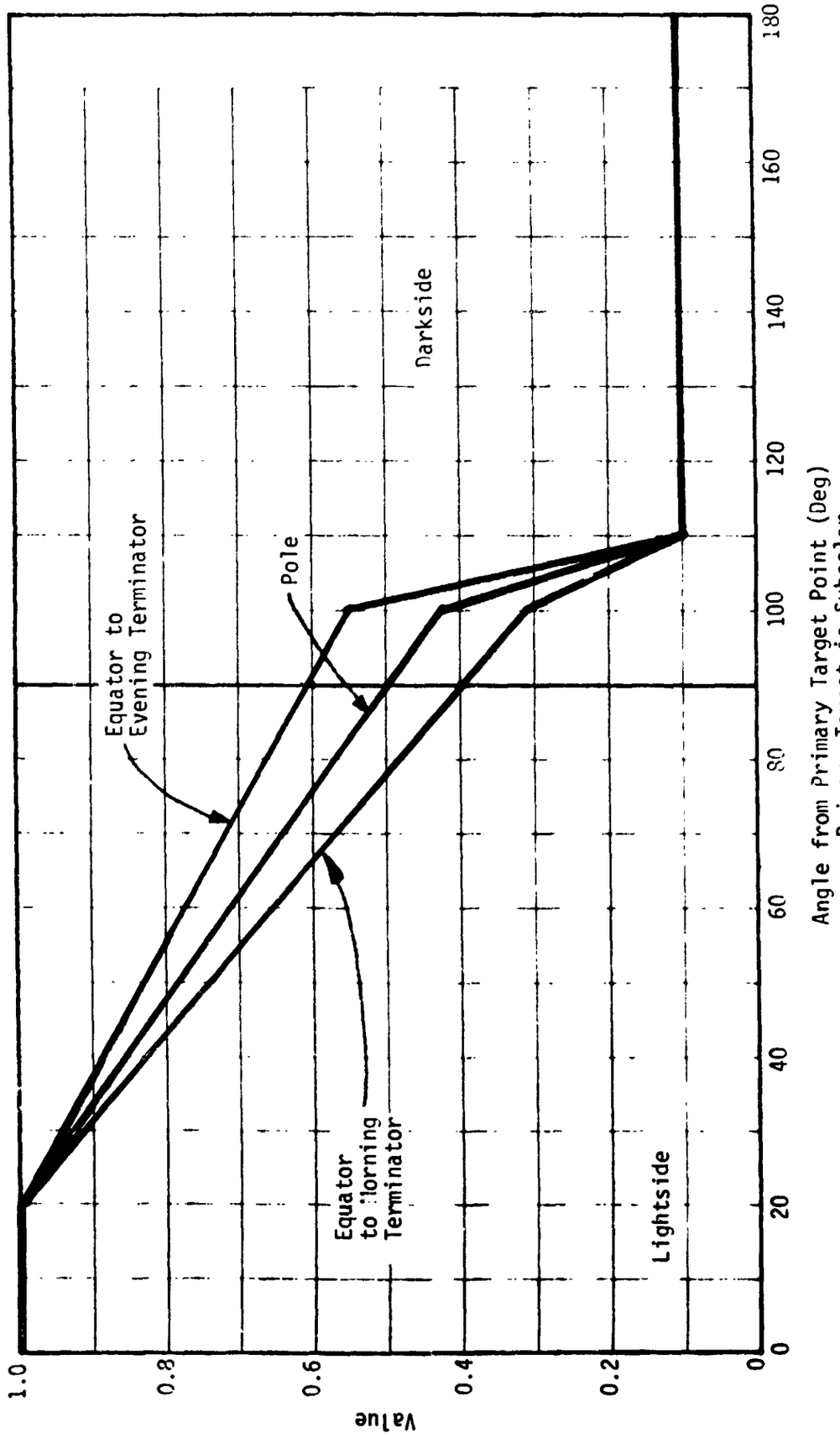
PRIMARY TARGET CURVES P-1



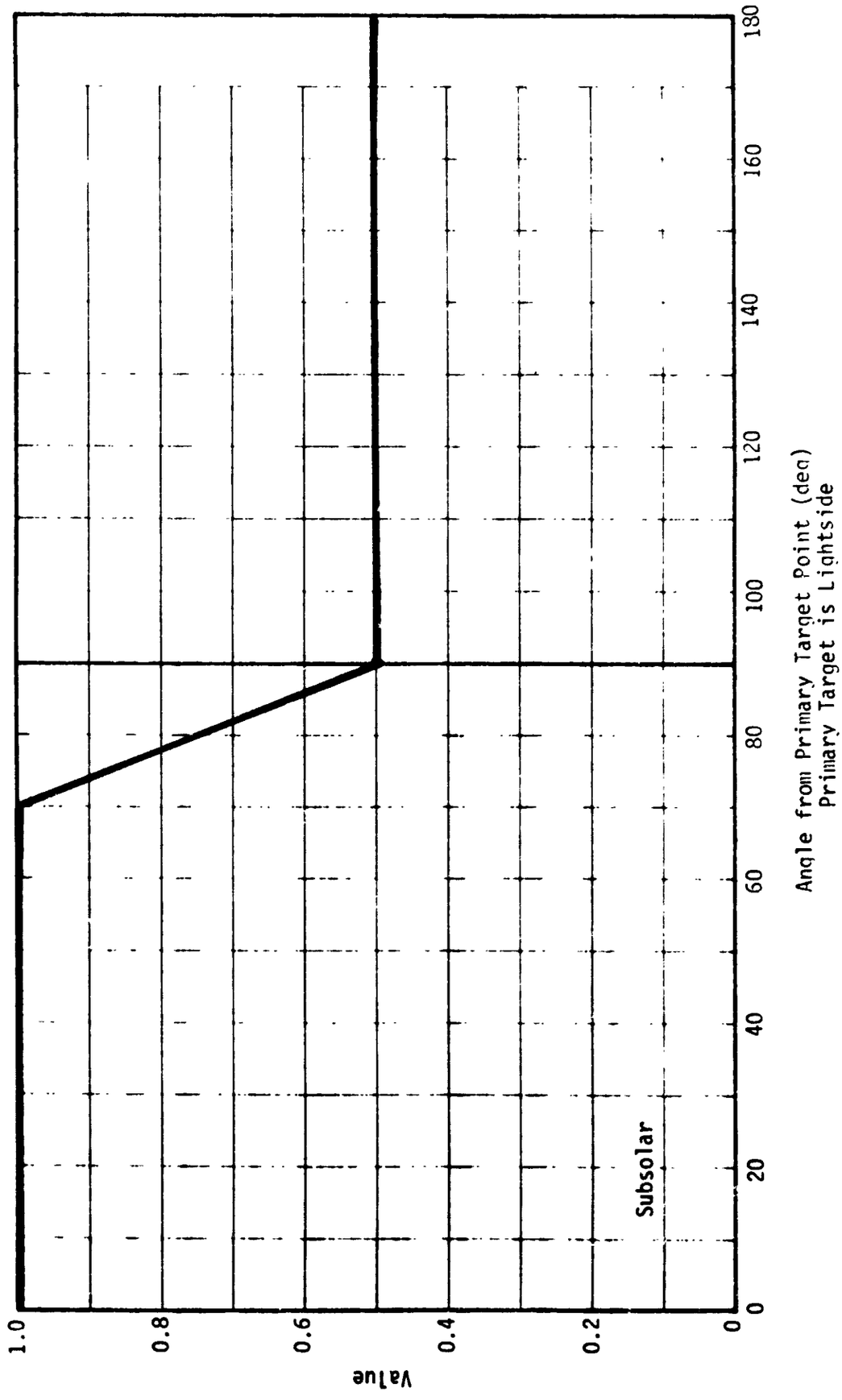
PRIMARY TARGET CURVES P-2



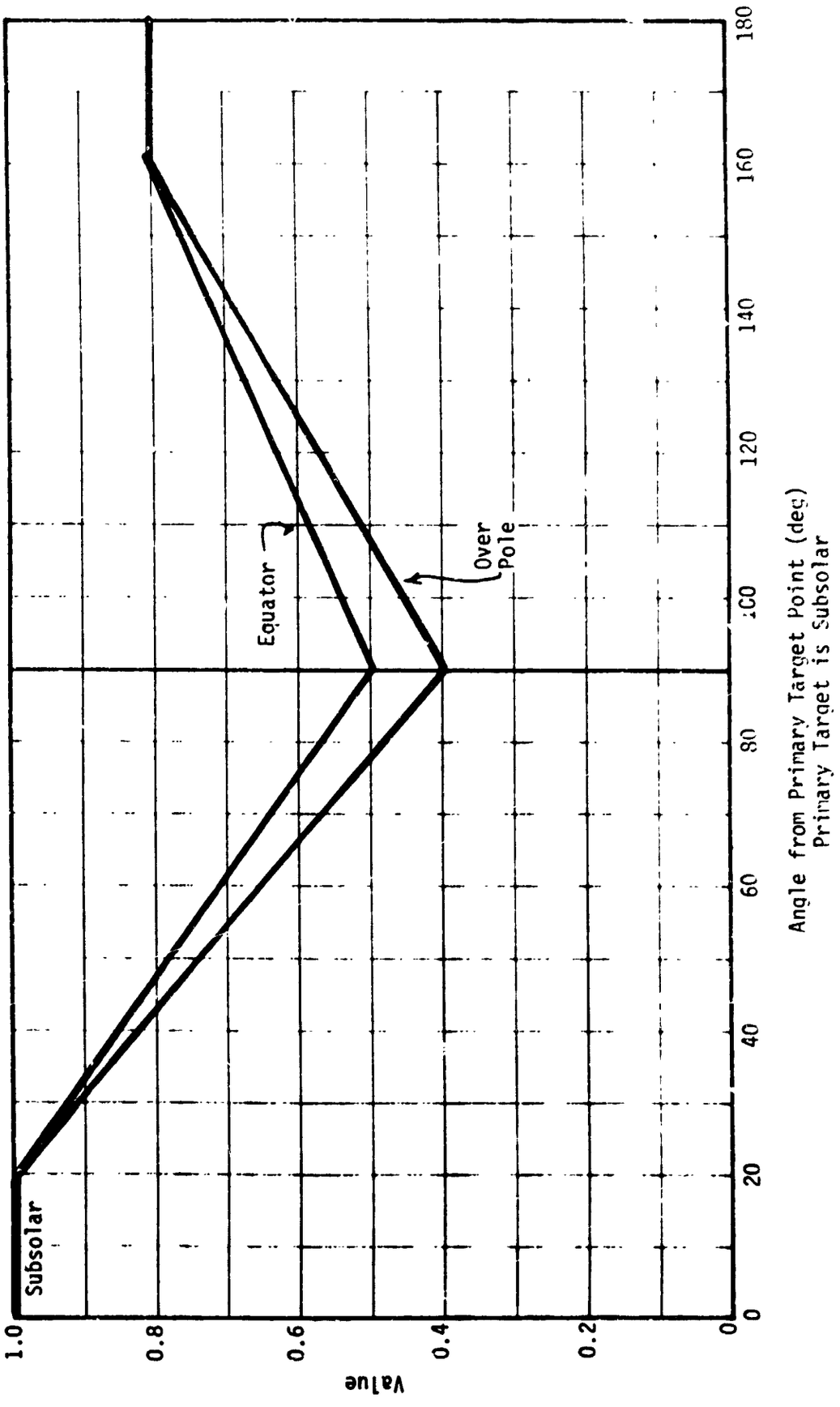
PRIMARY TARGET CURVES P-3



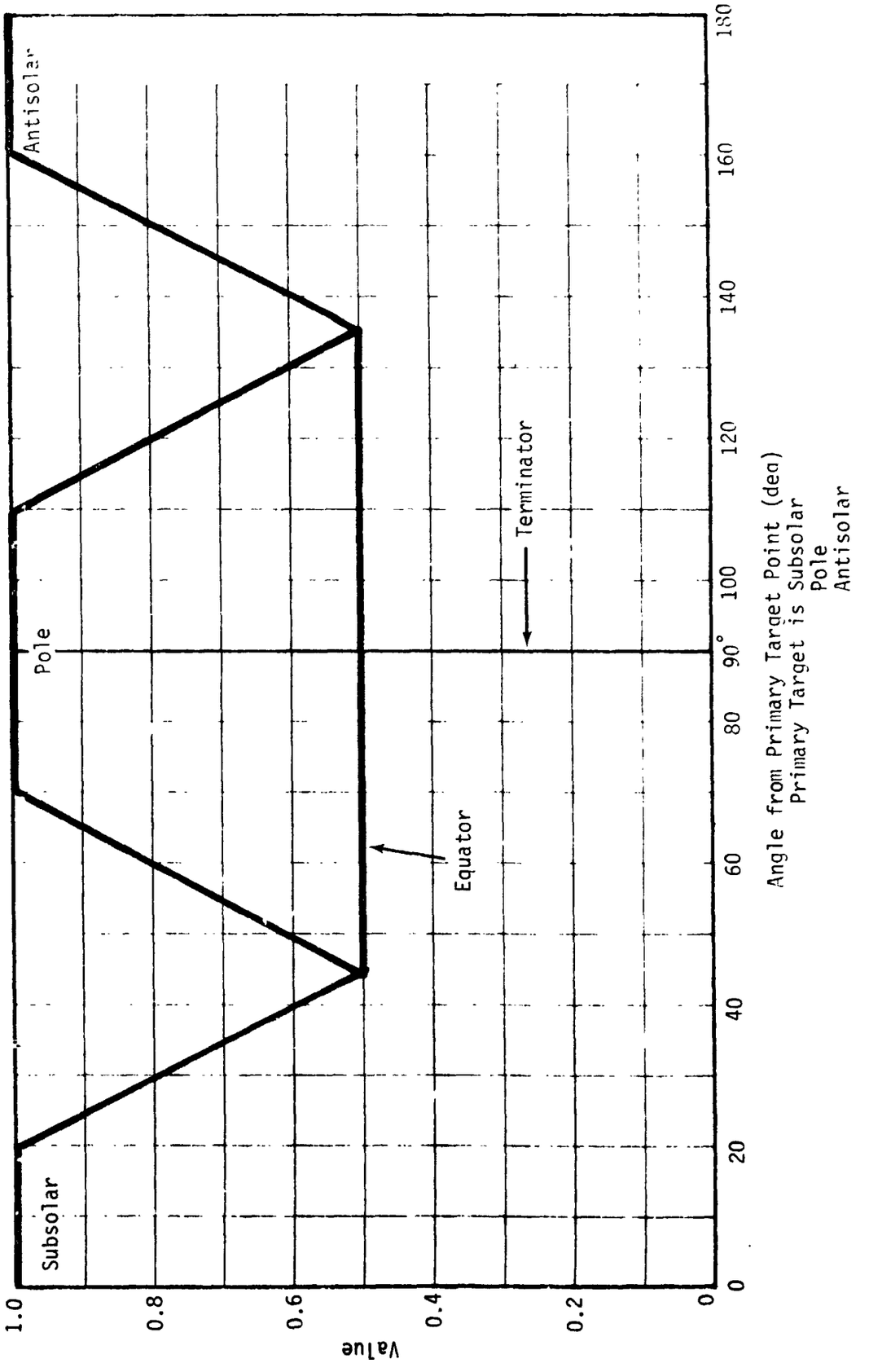
PRIMARY TARGET CURVES P-4



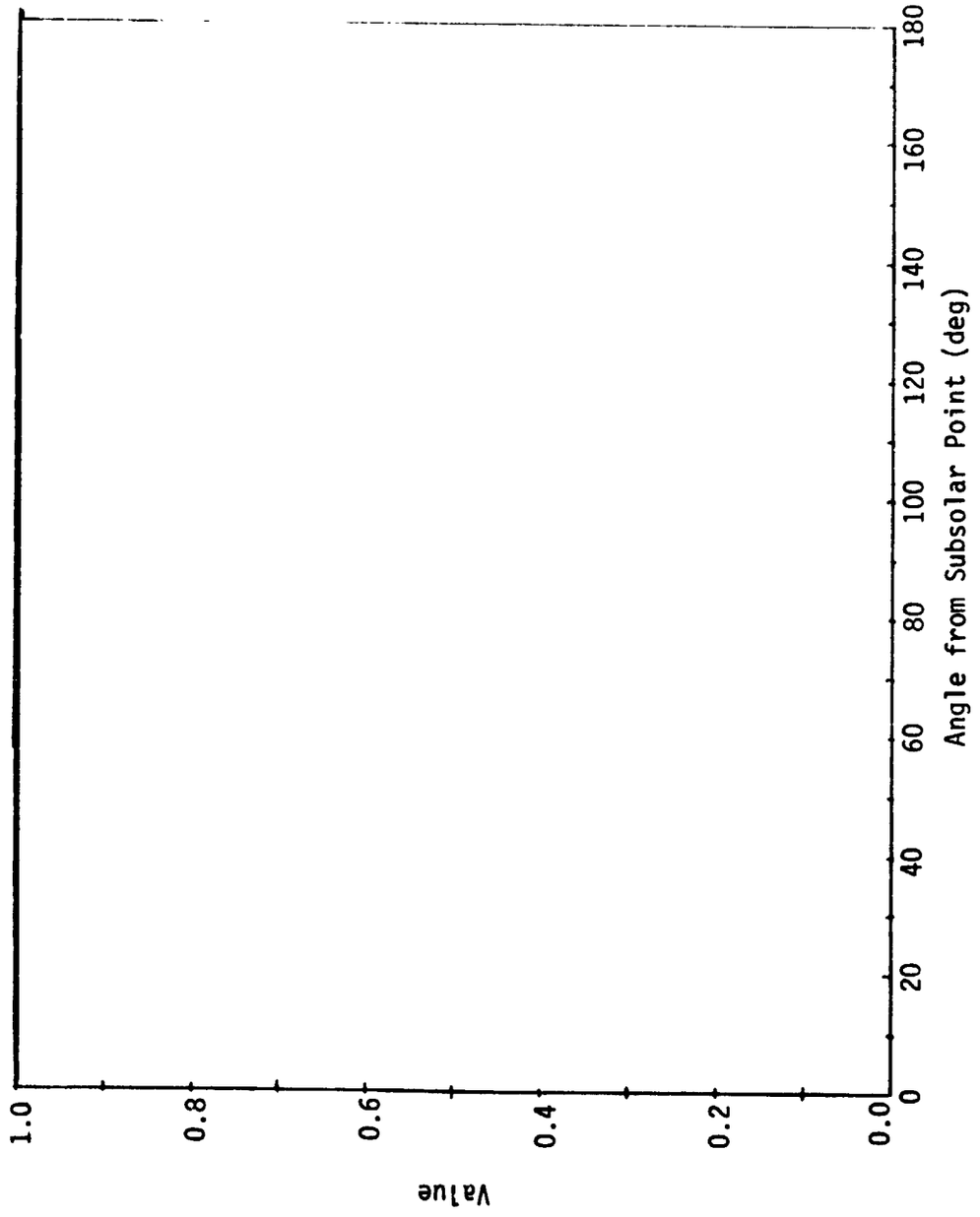
PRIMARY TARGET CURVES P-5



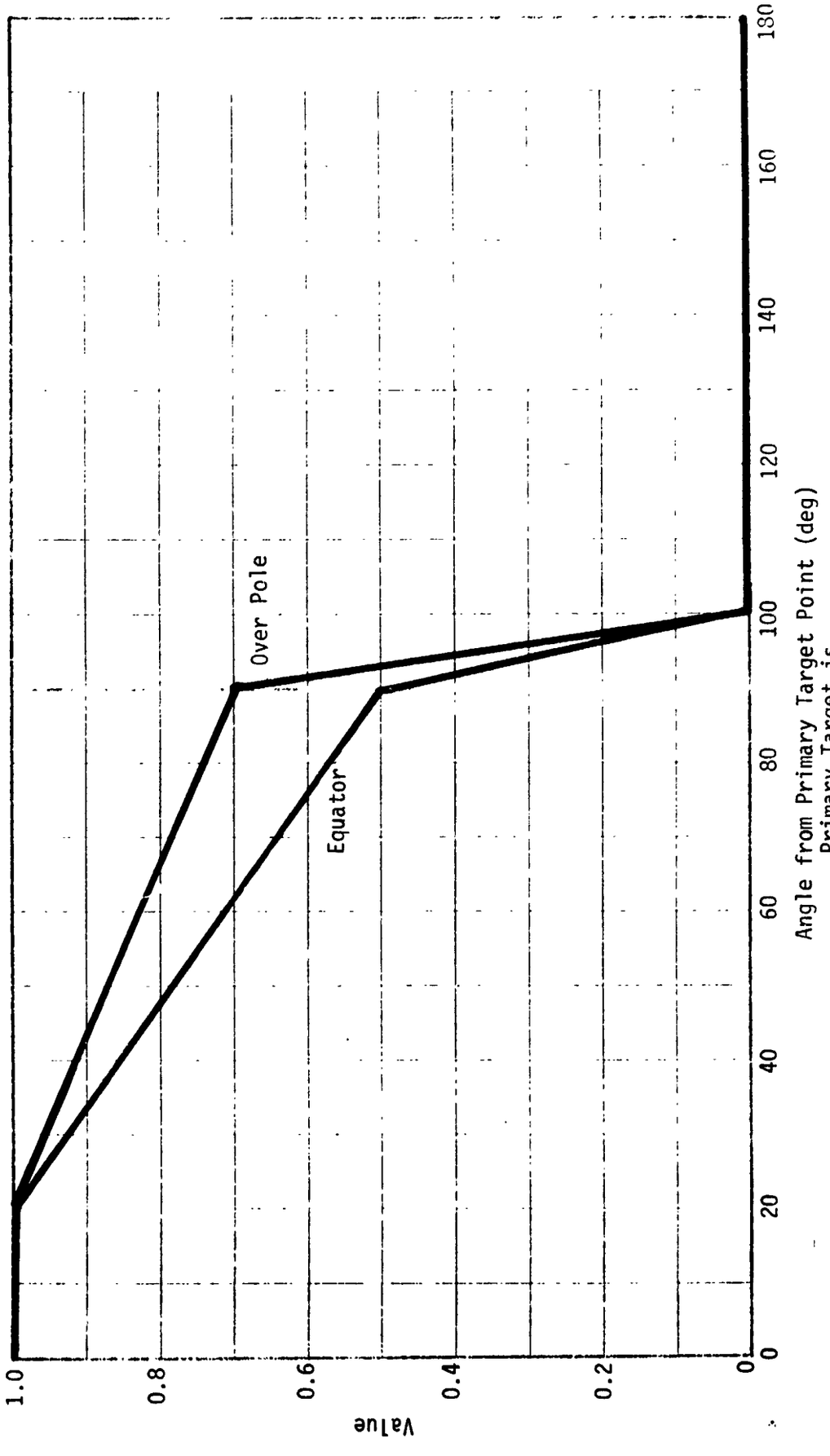
PRIMARY TARGET CURVES P-6



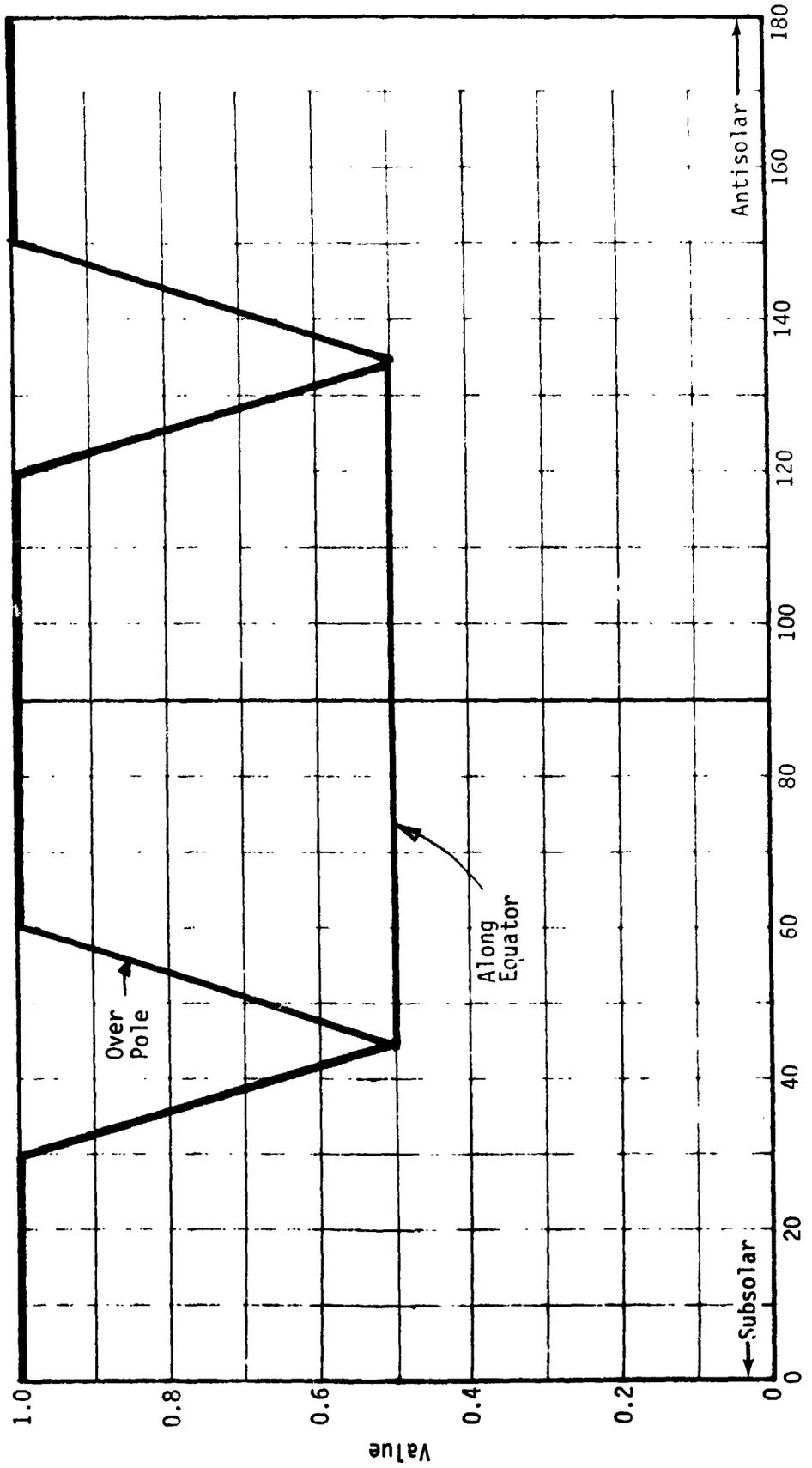
PRIMARY TARGET CURVES P-7



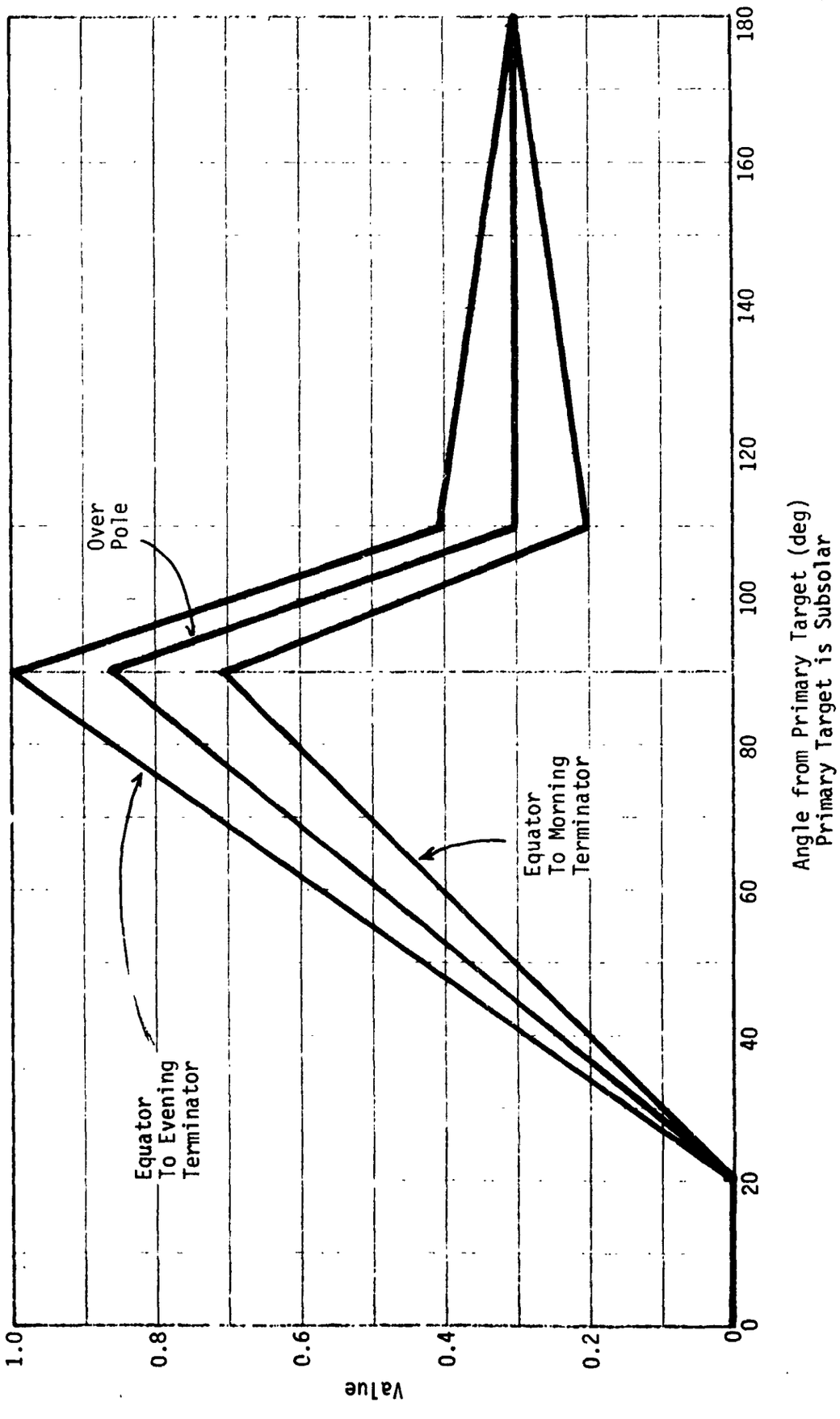
PRIMARY TARGET CURVES P-8



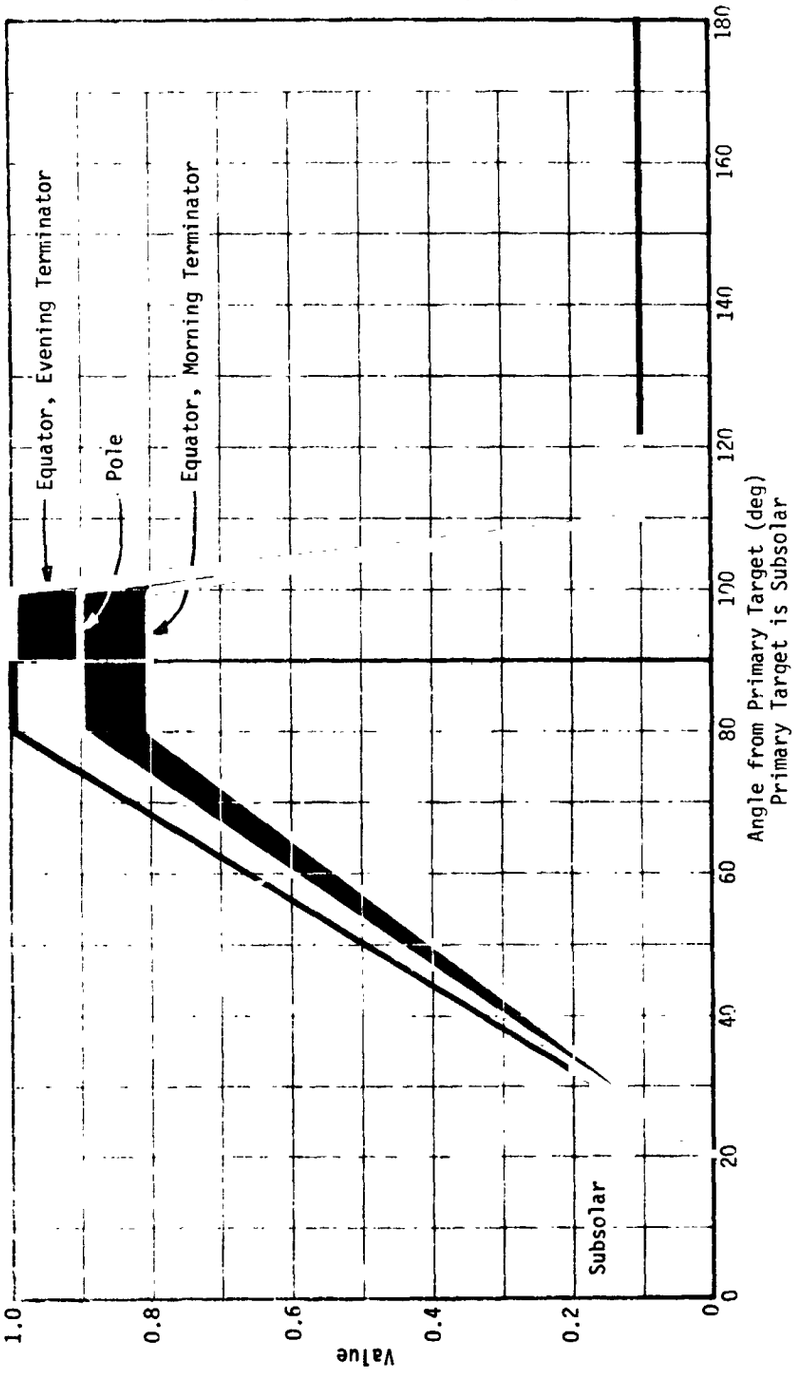
PRIMARY TARGET CURVES P-9



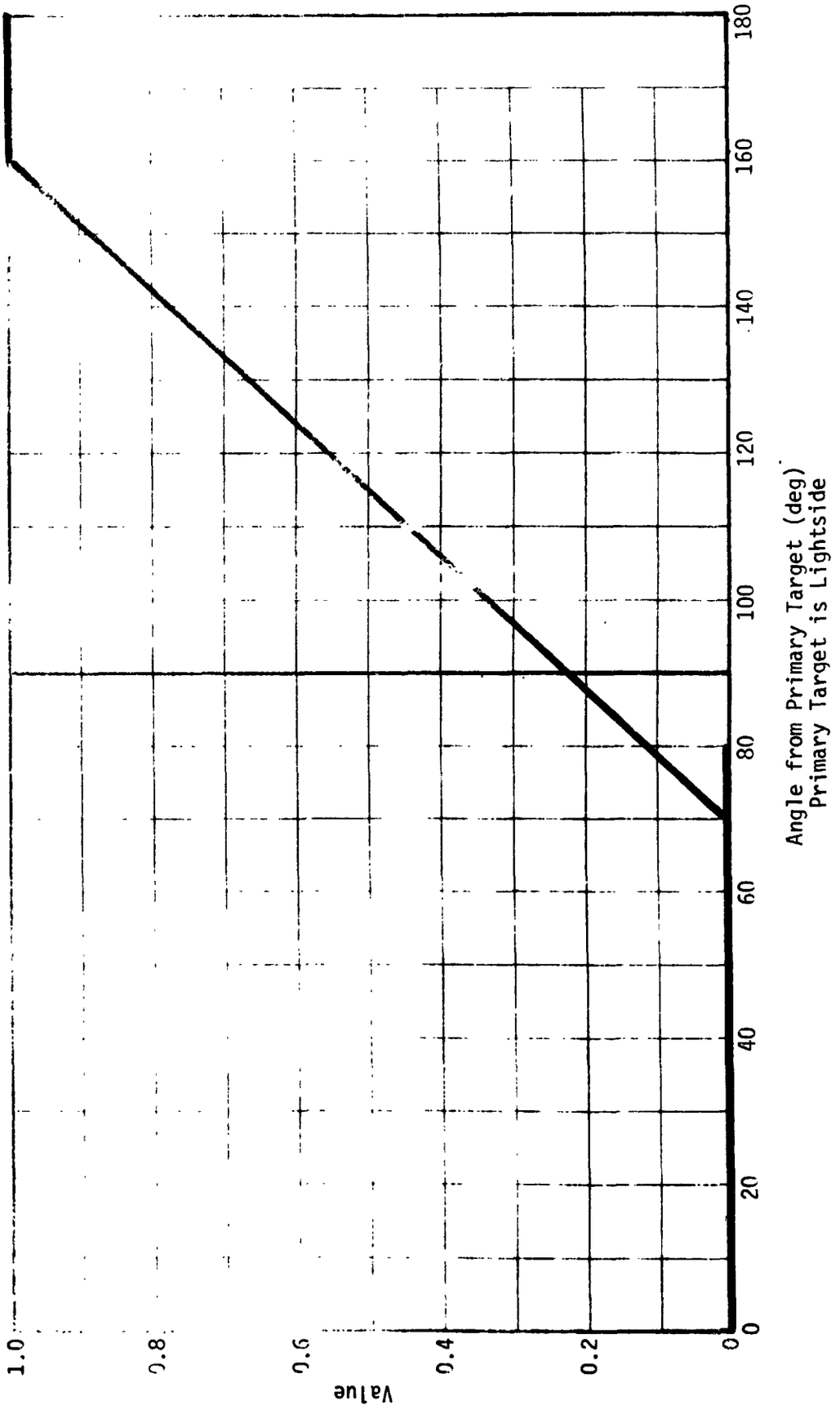
SECONDARY TARGET CURVES S-1



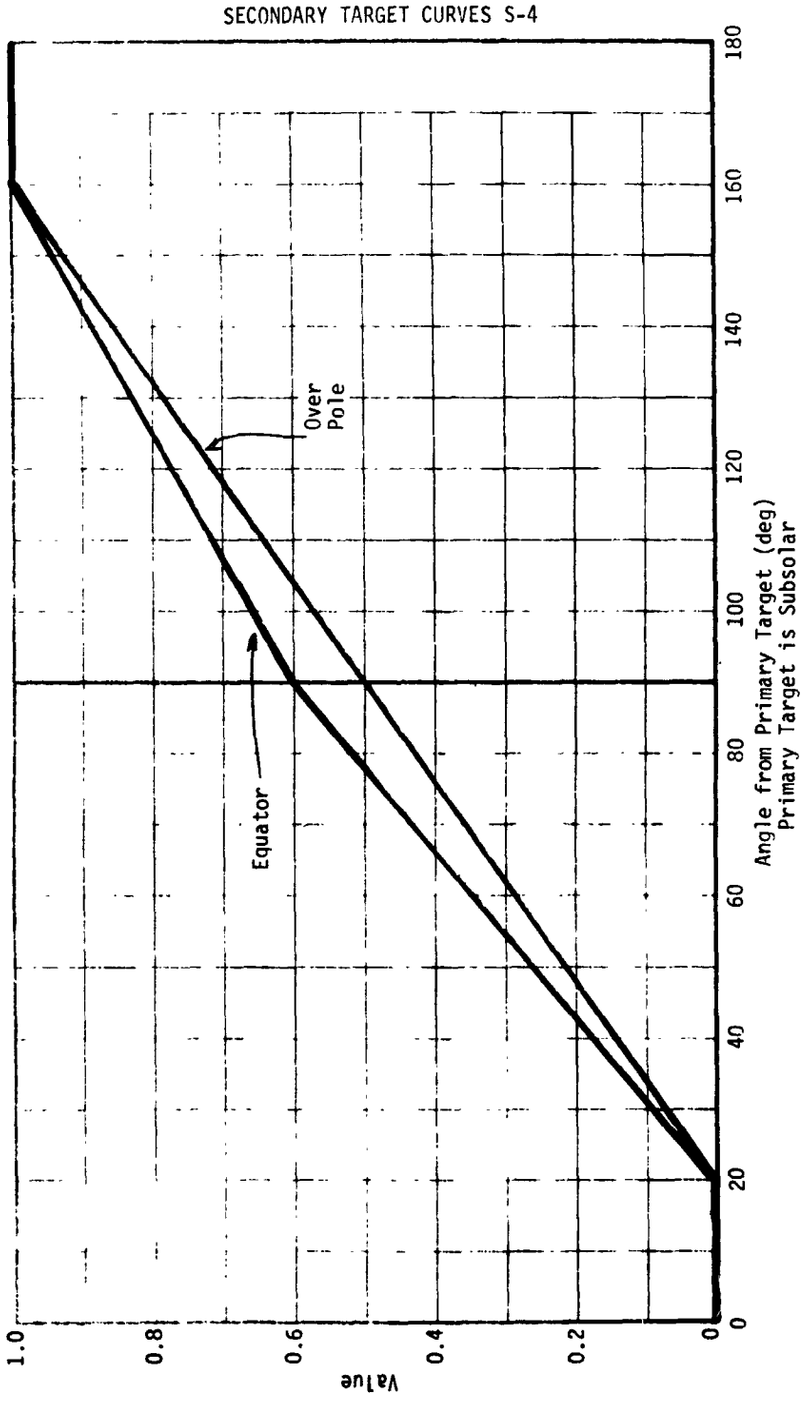
SECONDARY TARGET CURVES S-2



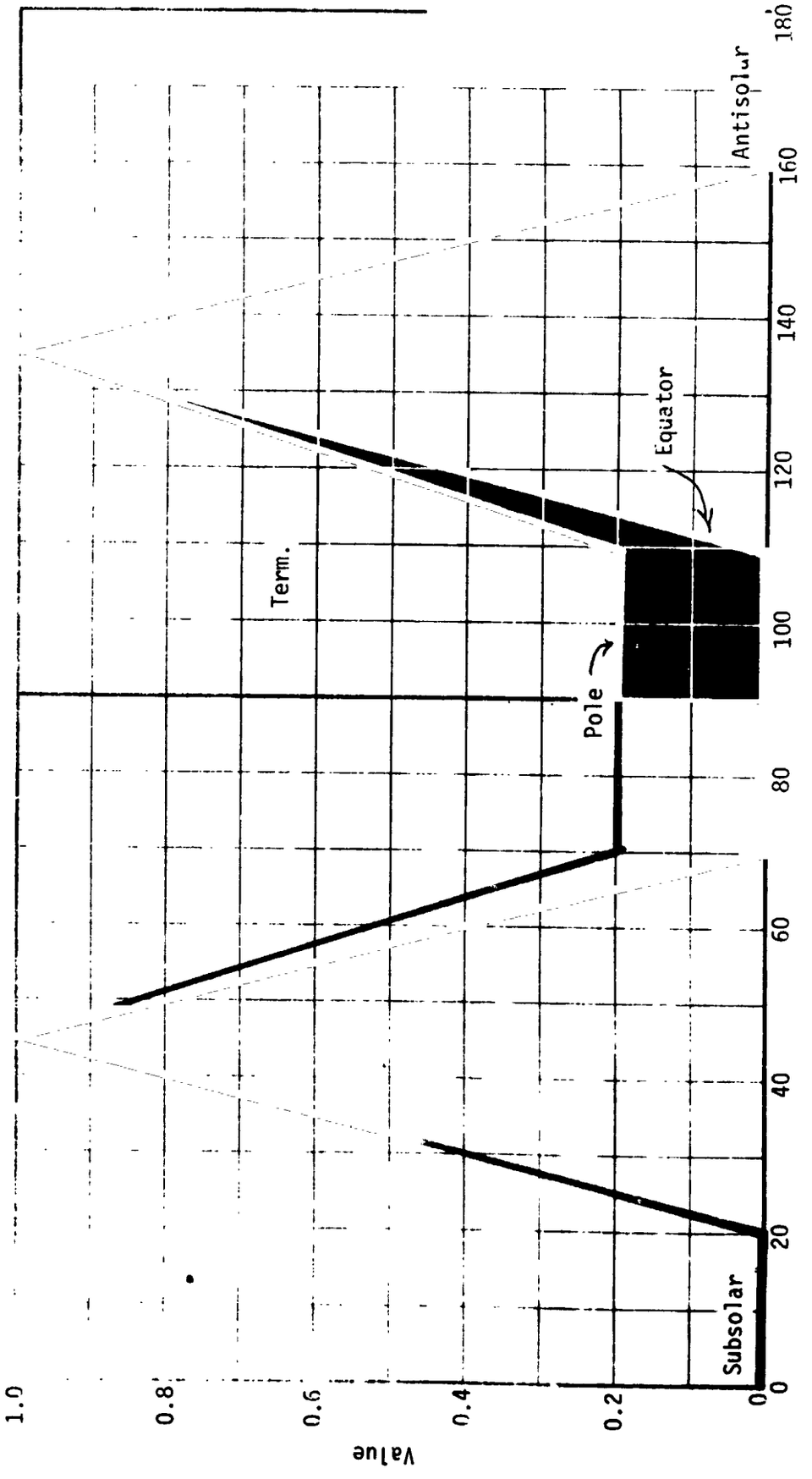
SECONDARY TARGET CURVES S-3



SECONDARY TARGET CURVES S-4

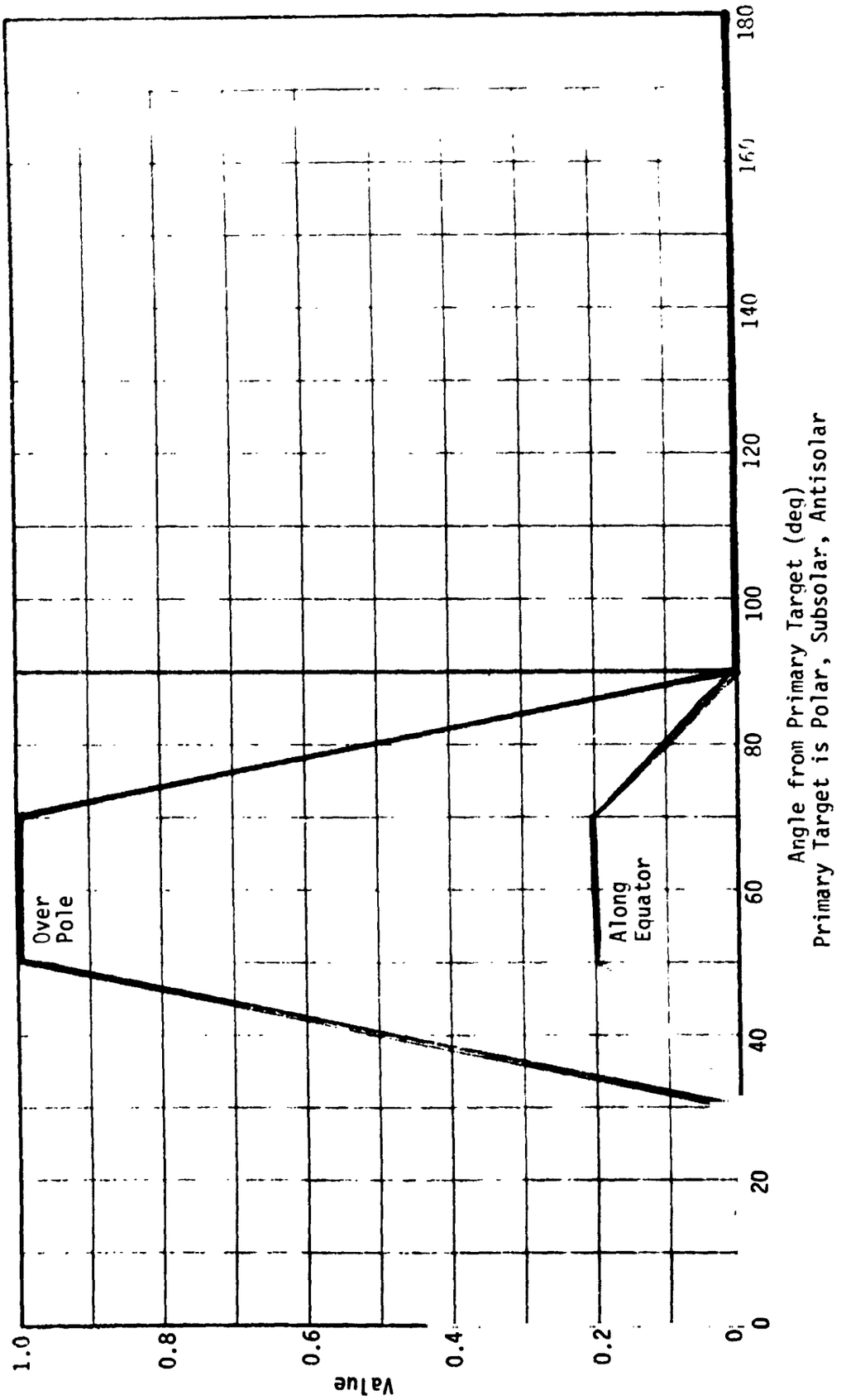


SECONDARY TARGET CURVES S-5

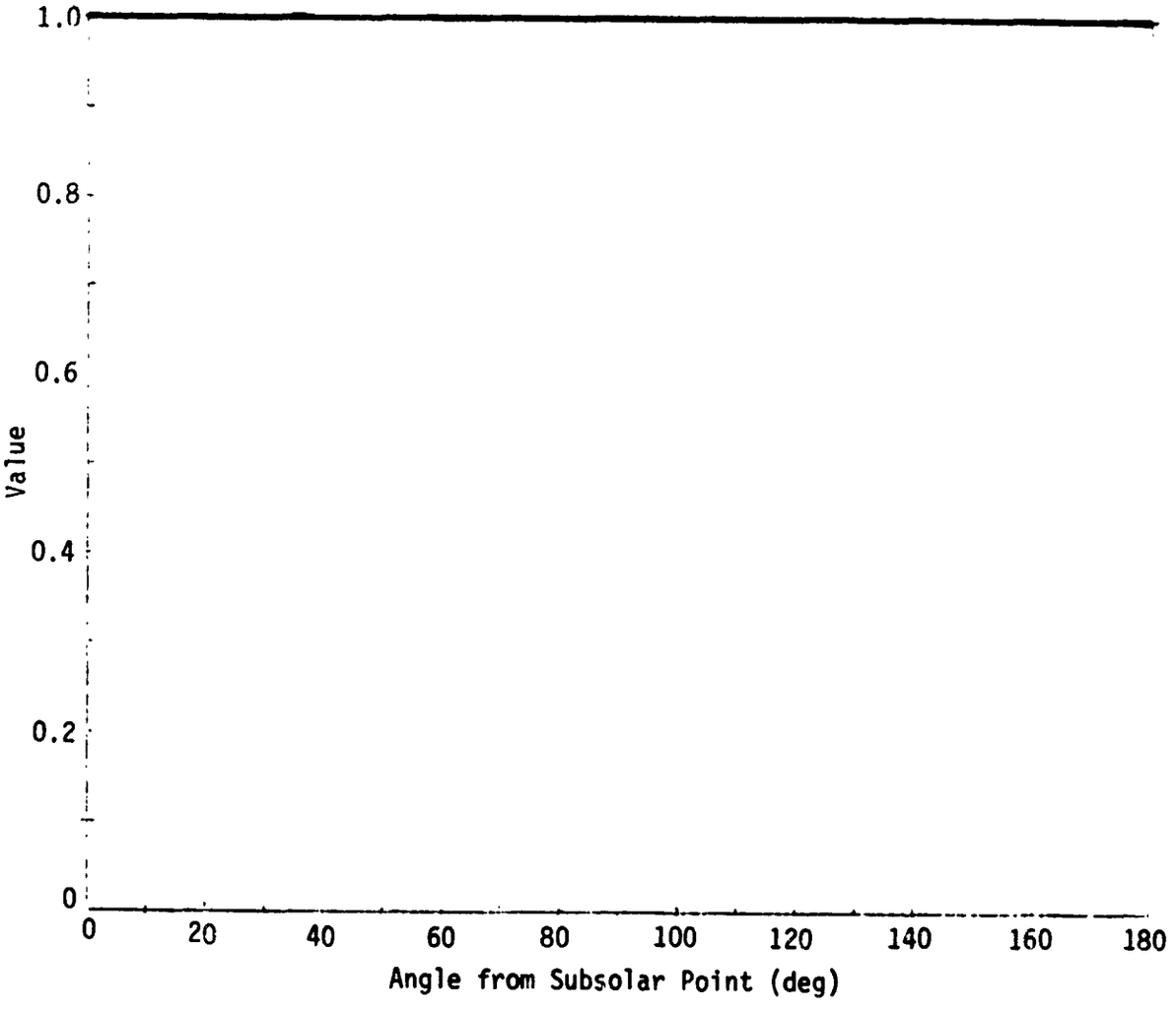


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SECONDARY TARGET CURVES S-7



SECONDARY TARGET CURVES S-8



A. GENERAL DESCRIPTION

1. Introduction

The Venus multiple probe evaluation model is a digital program specifically designed to evaluate the effectiveness with which various competing mission configurations answer the questions which form the science objectives for the 1975 Venus opportunity. The program is written in FORTRAN IV and is arranged such that an IBM 1130 computer with a disk memory can be used to ensure a rapid turn-around time.

A scientific analysis has been made for 22 questions to be answered about the Venus atmosphere. This analysis includes the contributions of instruments and target sites in answering the questions. Numerical information from the scientific analysis is stored in permanent files in the 1130 computer.

The mission configuration (probes, instruments, and characteristics), which is input for evaluation, is stored in a set of temporary files. An evaluation is made by the model for each question. The values for the different questions are added to give the total value for the mission. The switches on the 1130 computer are used for selecting alternatives in the program for calculations or outputs.

A mainline program, nine subroutine programs, and an auxiliary program compose the model. The purpose of the various subprograms is described below.

2. Mainline Program - MISEL

The mainline program reads mission input date, provides appropriate mission data printouts, stores mission data in the proper disk

files, and directs the program through the various calculation subroutines. The only calculation performed by MISEL is the trigonometric transformation of the probe site's latitude and longitude to a more convenient distance (PSI) and inclination angle (THETA) around the reference point (chosen as the subsolar point).

3. Target Value Subroutine - TAV1(ISI,K,PSI,THETA,TV)

When called, this subroutine reads the target value curves for the kth question from Permanent File 8. The curves are values for various planet locations (PSI, THETA). The subroutine performs a two-dimensional interpolation in the indicated set of curves (with ISI = 1 for primary target zones and ISI = 2 for secondary zones). The interpolation is made for the input values of PSI and THETA, and the desired target value (TV) is returned to the calling program.

4. Sampling Factor Subroutine - SAMPL(I,J,K,SF)

When called, this subroutine compares the designed measurement range and sampling interval in seconds for the jth instrument on the ith probe with the required measurement range and radius interval for the kth question. The subroutine reads the design range and time interval from Temporary File 3 for the jth instrument on the ith probe, reads the descent time profile for the ith probe from File 2, and calculates the varying design radius interval. After reading the required delta radius list from Permanent File 7, the sampling interval ratio (VAL) -- a ratio of the required-to-design radius interval -- is determined, and all such ratios are averaged to provide a measure of how well the instrument sampling compares with the requirement.

This subroutine also reads the cumulative value profile for the kth question from Permanent File 6, and, utilizing this curve, the difference in the cumulative values for the top of the measurement range and the bottom provides a fraction of the total

measurement achieved by the instrument. This fraction is called the sampling range fraction (VALP). The product of this fraction and the sampling interval ratio is the sampling factor (SF), which is returned to the calling program. If Switch 6 is on, these three values are printed out each time the subroutine is called. A secondary switch option prints out only VALP and VAL, and is used with an auxiliary program that is not described in this document.

5. Calculation Subroutines - CAL1 thru CAL7

The calculation subroutines have the primary purpose of finding the fraction of the question which has been answered by the mission configuration (question value) and a secondary purpose of determining the relative contributions of the various instruments and probes. The computer core memory capacity limits these subroutines to about four questions. The purpose of the seven subroutines is listed below.

Subroutine	Use
CAL1	Calculates low- and high-altitude references and a pressure/temperature reference for each probe. These values are a prerequisite to many of the questions to follow.
CAL2	Calculates question values for questions 1, 2, 3, and 4.
CAL3	Calculates Q(5), Q(6), Q(7), and Q(8).
CAL4	Calculates Q(9), Q(10), Q(11), and Q(12).
CAL5	Calculates Q(13), Q(14), Q(15), Q(16), and Q(17).
CAL6	Calculates Q(18), Q(19), Q(20), Q(21), and Q(22).
CAL7	Receives the accumulated question values allotted to the altitude and pressure/temperature references and further divides these values among the various pressure, temperature, acceleration, high-altitude mass spectrometer, and altitude radar instruments.

6. Permanent File Loading Program

An auxiliary program, not directly a part of the model, is used to read card data into the permanent files while a second portion of this program reads the information just filed and provides a data printout.

B. DATA INPUT MODES

Two data input modes are available by using Data Switch 5.

1. Multiple Case Mode (Switch 5 On)

Successive sets of mission configuration data can be evaluated, or a single set of data can be run with two or more computational options in effect.

2. Single Case Mode (Switch 5 Off)

A single set of mission data is read and evaluated; the program is then recycled to accept and evaluate any pertinent data changes to single probes in sequence.

C. COMPUTATIONAL OPTIONS

Four computational options are available; these are listed below.

1. Ideal Case (Switches 2 and 3 On)

With this option, Subroutines TAV1 and SAMPL are switched out; therefore, no degradation is calculated for the distance between the ideal target zones and the actual entry sites, nor is the degradation calculated for the measurement range and sampling interval.

2. Sampling Factor Only (Switch 2 On and Switch 3 Off)

With this option, the target value subroutine is switched out, but the sampling factor is computed.

3. Target Value Only (Switch 2 Off and Switch 3 On)

With this option, the sampling factor subroutine is switched out, but the target value is computed.

4. All Degradation Computed (Switches 2 and 3 Off)

Both targeting and sampling degradations are computed.

D. PRINTOUT OPTIONS

1. Printout of Mission Data (Switch 7 Off)

The program normally prints the input mission configuration data, including the number and title of each probe, and the probe's target point, reliability, and descent time profile. For each instrument, the instrument index, title of the instrument value index and sampling range, and time interval are printed. With Switch 7 on, the time-consuming printout of this information is omitted.

2. Printout of Probe-Instrument Map (Switch 4 On)

As a replacement for the complete mission data printout, a probe-instrument map (a matrix of all the instrument index values for all the instruments) is printed. This map is then a concise listing of all the mission instruments, probe by probe.

3. Printout of Relative Instrument Value (Switch 1 Off)

The relative contribution of each instrument, the target value, and the contribution of each probe is normally printed out for each question and for each probe. When Switch 1 is turned on, only the calculated value for the question is printed.

4. Printout of Sampling Factor Data (Switch 6 On)

With Switch 6 on, the probe index, the instrument index, the question index, the sampling range fraction, the sampling interval ratio, and the resulting sampling factor are printed out each time the subroutine SAMPL is called. This option provides visibility into the sampling factor calculation.

E. SUMMARY OF COMPUTER SWITCH OPTIONS

The switches are arranged so that normal operation is obtained with all switches turned off. A brief summary of the switch meanings is tabulated below:

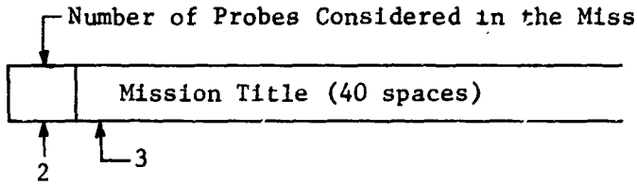
Switch Number	Effect of Switch	
	Switch On	Switch Off
1		Relative Value of Instrument Output
2		Value Degraded by Target Site
3		Value Degraded by Sampling Factor
4	Probe-Instrument Map	
5	Multiple Case Mode	Single Case Mode
6	I, J, K, VALP, VAL, SF Output	
7		Mission Data Output
8	VALP, VAL Output	

F. INPUT DATA FORMAT

Only five types of data input cards are required for the evaluation program. Those inputs requiring fixed-point integers are

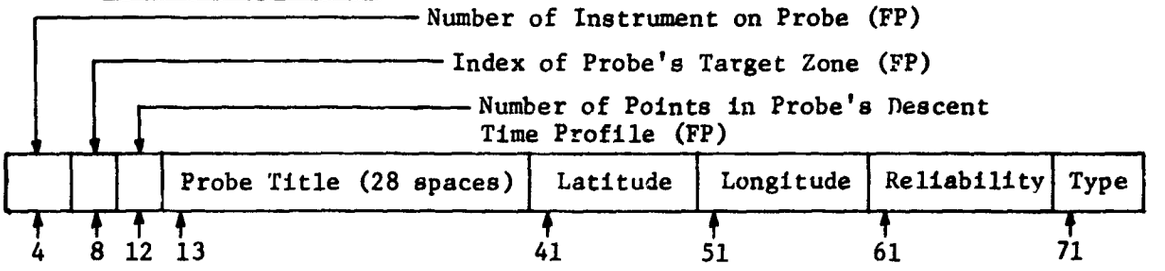
marked with (FP), and must be right-adjusted in the indicated field. All other numbers must contain a decimal point. The space left for titles can be left blank if so desired.

1. Mission Card



The mission title should be centered in the 40-character field. A maximum of 10 probes is provided for.

2. Probe Data Card



The number of instruments refers to the number listed. For example, using the single input mode case, a 2 in Column 4 would mean that changes are being made to two instruments, and that one of the instruments could be eliminated by giving it a value of zero while the other instrument could be added to the subject probe.

An aribtrarily-assigned index number for each of five ideal target zones are listed below:

1. Subsolar Zone
2. Polar Zone;
3. Evening Terminator Zone;
4. Morning Terminator Zone;
5. Antisolar Zone;

These index numbers are assigned to each probe on the basis of the zone closest to the probe's actual entry point. Due to the

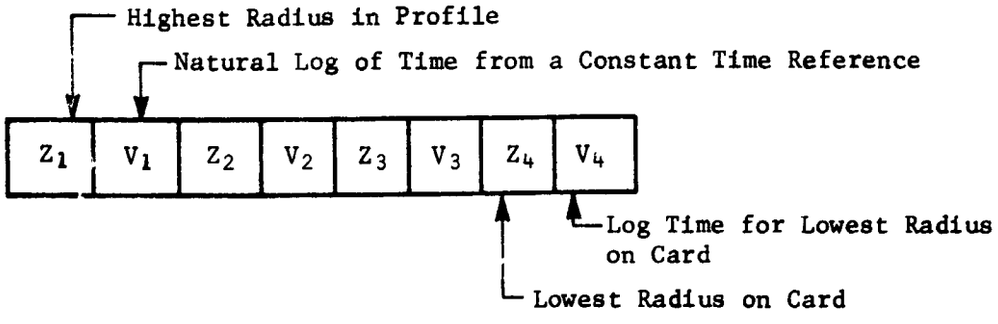
importance of the subsolar point, at least one probe of each distinctive type, closest to the subsolar point, is always designated with a number 1.

Core space is provided for 20 pairs of points in the descent time profile. The probe title should begin in Column 13. The latitude and longitude are given in decimal degrees, measured in plus and minus directions from the subsolar point. The value of type is assigned as follows:

0 = Descent Probe;

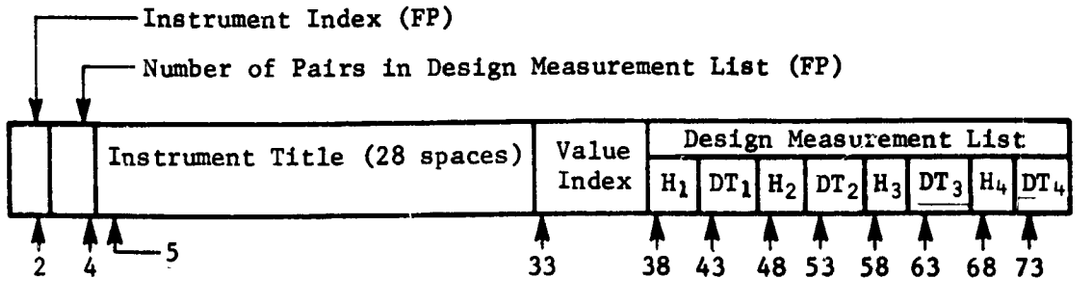
1 = Balloon Probe.

3. Descent Time Card



The program is limited to 20 pairs of points, four on a card.

4. Instrument Card



Space is provided for four pairs of numbers in the design measurement list.

The Instrument Index is a set of arbitrarily-assigned numbers as follows:

1. Accelerometer;
2. Pressure Sensor;
3. Temperature Sensor;
4. Mass Spectrometer;
5. Thermal Radiometer;
6. Solar Radiometer;
7. Nephelometer;
8. Cloud Particle Number, Density and Size;
9. Cloud Particle Composition;
10. Evaporimeter/Condensimeter;
11. Altitude Radar;
12. Drift Radar;
13. Transponder;
14. Ion Mass Spectrometer;
15. High-Altitude Mass Spectrometer;
16. Electron Density and Temperature;
17. UV Photometer.

The instrument title should start in Column 5.

An assigned value index of 1.0 means the instrument is on the probe and is working perfectly. Similarly, a value of zero indicates the instrument never works. Values between 1.0 and 0.0 can be assigned to indicate various levels of instrument complexity or reliability.

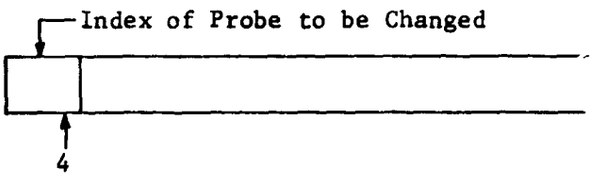
The meaning of the symbols in the Design Measurements List can be illustrated by the following examples:

1) 6030. 10. 6120. 20. 6050. 20.
   H_1 DT_1 H_2 DT_2 H_3 DT_3
   The instrument is started at a radius of 6130 km and sampled every 10 sec until the radius is 6120 km; at this time, the sampling rate is decreased to once every 20 sec until impact (when radius is 6050 km);
2) 6150. 10. 6130. 9999. 6100. 20. 6050.
   H_1 DT_1 H_2 DT_2 H_3 DT_3 H_4
   In this example, the instrument is turned on at a radius of 6150 km and sampled every 10 sec until the radius is 6130 km; at this time, the instrument is

turned off (accomplished by having a large time interval, DT_2). The instrument is again sampled from 6100 km to 6050 km every 20 sec. Note that the last time interval is not required.

For ballon probes, the flotation radius is entered as H_2 (H_3, if there are two balloons at the same location). H_1 is made to read the same as the last height listed (either H_2 or H_3). The values of DT are not used.

5. Change Card



When the blank card that normally follows a set of mission data cards contains a number in Column 4, it indicates to the program that a change is to be made in some of the data pertaining to the probe having that index number. The index number involved is not the ideal target zone index that may be assigned to several probes, but rather the order number of the probe original listing, which is not a card input.

A change card must be used when Switch 5 is on (multiple case mode).

G. ASSEMBLY OF DATA INPUT

1. Single Case Mode (Switch 5 Off)

Mission Card

Probe Card Velocity Card Velocity Card	At least one, but not more than five cards.
Instrument Card Instrument Card Probe Card	One card required for each instrument on the probe.
	Repeat the above for each probe in the mission.
Change Card	Only needed if the mission is to be changed.
Probe Card	Required even if the change is only velocity or instrument.
Velocity Cards	Required.
Instrument Card	At least one required; instruments added with normal instrument card or deleted by repeating the same instrument card with value set to zero.
Multiple Case Mode (Switch 5 On)	For this mode, the same sequence of cards is required up to the change card. Instead of the change card, a blank card is required between missions. The same mission can be reloaded more conveniently if two blank cards are placed at the end of the mission

H. TEMPORARY FILES

Files 1 thru 4 are loaded by Subroutine MISEL while the mission data are being read in. File 5 is set to zero by CALl, and is added to by subsequent subroutines. A brief description of the content of these five files is given below:

1. File 1

This file stores the input mission data of PSI, THETA, reliability, and type for each probe.

2. File 2

This file stores the input descent time profile for each probe.

3. File 3

This file stores the input design measurement list for each instrument on each probe.

4. File 4

This file stores the input value index for each instrument on each probe.

5. File 5

This file stores the calculated values for each instrument on each probe which are accumulated for each question.

I. PERMANENT FILES

The permanent files contain data pertaining to a part of the questions that make up the science objectives of the mission. Once it has been determined that the values accurately define the questions, the permanent files will not be altered so that true comparisons can be made between competing mission configurations. The four permanent files are described below.

1. File 6 - Cumulative Value Profile

Each question primarily refers to a given phenomenon to be measured. The relative value of each sampling of the measurement varies greatly as the probe descends through the atmosphere. The cumulative value curve is the integral of these relative values. It has a value of one at the surface and of zero at an infinitely high altitude. Note that there are a total of 26 sets of points;

the first four provide information for calculating the altitude and pressure/temperature references in CAL1. Space is provided for a maximum of 10 pairs of points for each curve.

2. File 7 - Required Delta Radius List

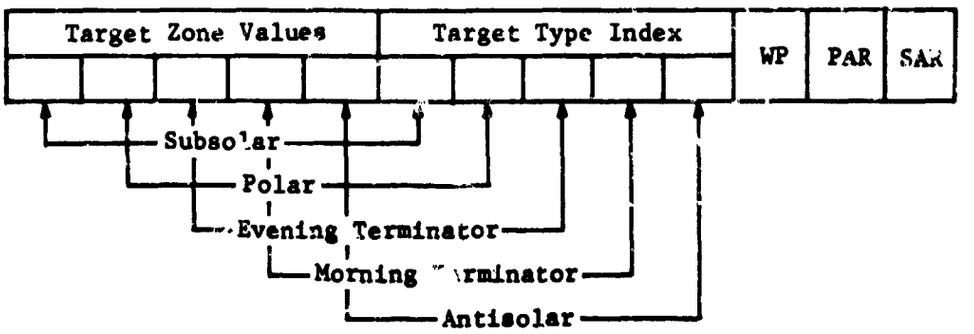
The pairs of points in this list give the radius (km) and the radius interval (km) that should be sampled. Space is provided in the program for five pairs of points (four different sampling intervals). Again, the first four sets of entries are used to calculate the altitude and pressure/temperature references.

3. File 8 - Target Value Curves

In these curves, values are first given for each question for the primary target zones (ISI = 1), and then for the secondary target zones (ISI = 2). The values are for points on three great circles passing through the subsolar and antisolar points. The first (WV1) passes through the evening terminator, the second (WV2) crosses the pole, and the third (WV3) passes through the morning terminator. Values are given for various distances from the subsolar point (WPSI). Space is provided for eight sets of points on each curve.

4. File 9 - Targeting Parameters

For each question, this file provides 13 values relating to targeting.



The first 10 numbers are pairs of values relating to the five possible ideal target sites. The first number of each pair is the target value to be used for that ideal target site in the event that the target values are not calculated (Switch 2 on). The number in each pair is an index for that ideal target site; this number is set to 1 if the site is a primary site for the particular question, but is set to 2 if the site is secondary for that question.

The eleventh value, WP, is the fraction of the total question value that is obtainable from primary target sites. The last two values, PAR and SAR, are the primary and secondary accumulation rates for determining the manner in which the value from each probe is accumulated to obtain the question value.

J. SAMPLE PROGRAM PRINTOUT

Table E-1 shows a partial printout of a sample mission. The printout has been annotated to illustrate the various output and program options.

K. PROGRAM COMPUTATIONAL SCHEME

The actual method of computing the value achieved for each question can best be understood by referring to the program flow diagrams (Fig. E-1, Sheets 1 thru 29) and to the symbol chart (Table E-2). Sheets 1 and 2 of Fig. E-1 provide an overview of the computational scheme and the interfaces between the various subprograms.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

Table E-1 Mission Effectiveness Venus Probe Trail Mission

	LAT	LONG	REL	DESCENT VELOCITY (RADIUS(KM)-VELOCITY(M/SEC))							
SMALL BALLISTIC PROBE SUBSLR	0.0	0.0	0.90	6160.	4500.	6135.	4500.	6120.	102.	6090.	34.
				6050.	9.	6040.	0.				

		VALUE	SAMPLING RATE (STARTING RADIUS(KM)-INTERVAL(SEC))							
2	PRESSURE SENSOR	1.00	6130.	0.05	6120.	0.45	6050.	0.45	0.	0.00
3	TEMPERATURE SENSOR	1.00	6130.	0.05	6120.	0.45	6050.	0.45	0.	0.00
1	ACCELEROMETER	1.00	6200.	0.05	6120.	0.45	6050.	0.45	0.	0.00
6	SOLAR RADIOMETER	1.00	6130.	0.05	6120.	0.45	6050.	0.45	0.	0.00
5	THERMAL RADIOMETER	1.00	6130.	0.05	6120.	0.45	6050.	0.45	0.	0.00
13	TRANSPONDER	1.00	6130.	0.10	6120.	0.90	6050.	0.90	0.	0.00

MISSION DATA PRINTOUT SWITCH #7 OFF →

PROBE-INSTRUMENT MAP

ROBE	ACC	P	T	M/S	TR	SR	N	CPN	CPC	E/C	AR	DR	XPR	ION	HMS	ELC	UV				VALUE
1	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
3	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
4	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
5	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	
7	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
8	0.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

PROBE-INSTRUMENT MAP PRINTED SWITCH #4 ON ↑

PRINTOUT OF COMPUTATIONAL OPTIONS IN EFFECT SWITCHES 2 & 3

TARGETING VALUE ON ← → SAMPLING FACTOR ON

PROBE	HIGH ALTITUDE REFERENCE	PRESSURE/TEMPERATURE	LOW ALTITUDE REFERENCE
1	0.380	0.810	0.690
2	0.380	0.810	0.690
3	0.380	0.810	0.690
4	0.000	0.810	0.690
5	0.000	0.810	0.690
6	0.841	0.810	0.969
7	0.000	0.639	0.613
8	0.000	0.639	0.613

PROBE REFERENCE VALUES ALWAYS PRINTED

ESTION 1 RELATIVE VALUE CONTRIBUTED BY EACH INSTRUMENT

ROBE	TV	ACC	P	T	M/S	TR	SR	N	CPN	CPC	E/C	AR	DR	XPR	ION	HMS	ELC	UV	ALTH	P/T	ALTL	VALUE
1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
2	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
3	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
4	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
5	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
6	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
7	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
8	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
																						0.375

RELATIVE VALUE PRINTED IF SWITCH #1 IS OFF ↑

ONLY QUESTION TOTAL WHEN ON →

QUESTION 2 VALUE 0.507
QUESTION 3 VALUE 0.375
QUESTION 4 VALUE 0.353
QUESTION 5 VALUE 0.643
QUESTION 6 VALUE 0.490
QUESTION 7 VALUE 0.773

I= 6 J= 2 K= 8 ACCUMULATED VALUE= 1.000 DELTA HEIGHT VALUE= 0.999 SAMPLING VALUE= 0.999

SAMPLING FACTOR OUTPUT OBTAINED WHEN SWITCH #6 IS ON

QUESTION 8 VALUE 0.835
QUESTION 9 VALUE 0.301
QUESTION 10 VALUE 0.334
QUESTION 11 VALUE 0.257
QUESTION 12 VALUE 0.702
QUESTION 13 VALUE 0.651
QUESTION 14 VALUE 0.586
QUESTION 15 VALUE 0.313
QUESTION 16 VALUE 0.239
QUESTION 17 VALUE 0.532
QUESTION 18 VALUE 0.882
QUESTION 19 VALUE 0.000
QUESTION 20 VALUE 0.761
QUESTION 21 VALUE 0.925
QUESTION 22 VALUE 0.999

TOTAL MISSION VALUE ALWAYS PRINTED →

TOTAL MISSION VALUE 12.243

SUMMARY OF ACCUMULATED INSTRUMENT VALUES

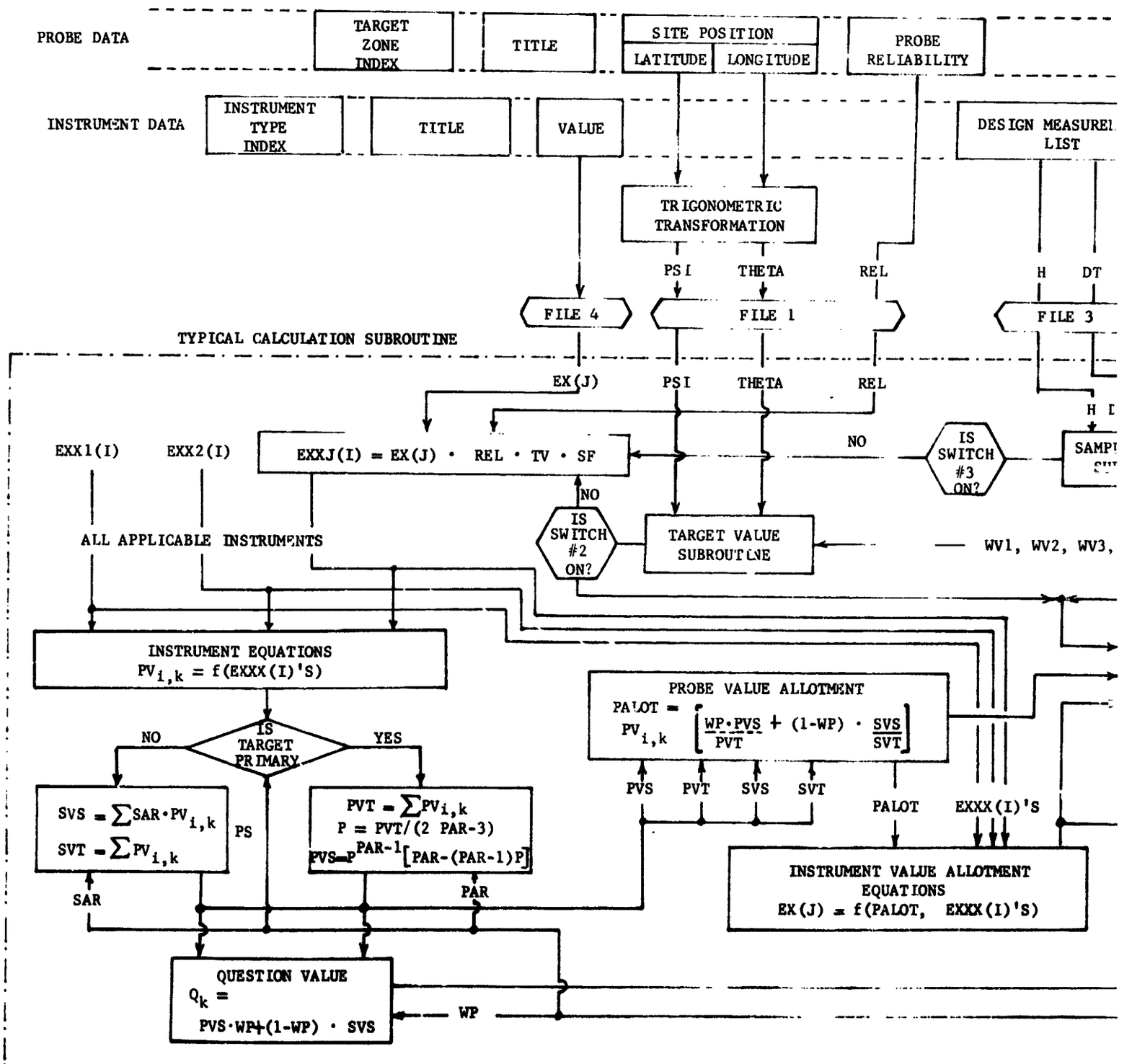
ROBE	ACC	P	T	M/S	TR	SR	N	CPN	CPC	E/C	AR	DR	XPR	ION	HMS	ELC	UV				VALUE
1	0.46	0.44	0.08	0.00	0.21	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.642
2	0.39	0.41	0.08	0.00	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.407
3	0.27	0.34	0.08	0.00	0.21	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.102
4	0.00	0.51	0.19	0.00	0.00	0.30	0.23	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.734
5	0.00	0.02	0.00	0.00	0.00	0.15	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.205
6	0.54	0.40	0.19	0.69	0.20	0.25	0.13	0.71	0.43	0.18	0.53	0.03	0.06	0.21	0.42	0.29	0.48	0.00	0.00	0.00	5.835
7	0.00	0.01	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.157
8	0.00	0.01	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.157

BREAKDOWN OF TOTAL MISSION VALUE TO INDIVIDUAL INSTRUMENTS ALWAYS PRINTED

PRECEDING PAGE BLANK NOT FILMED.

EVALUATION MODEL

TOP LEVEL FLOW DIAGRAM



FOLDOUT FRAME

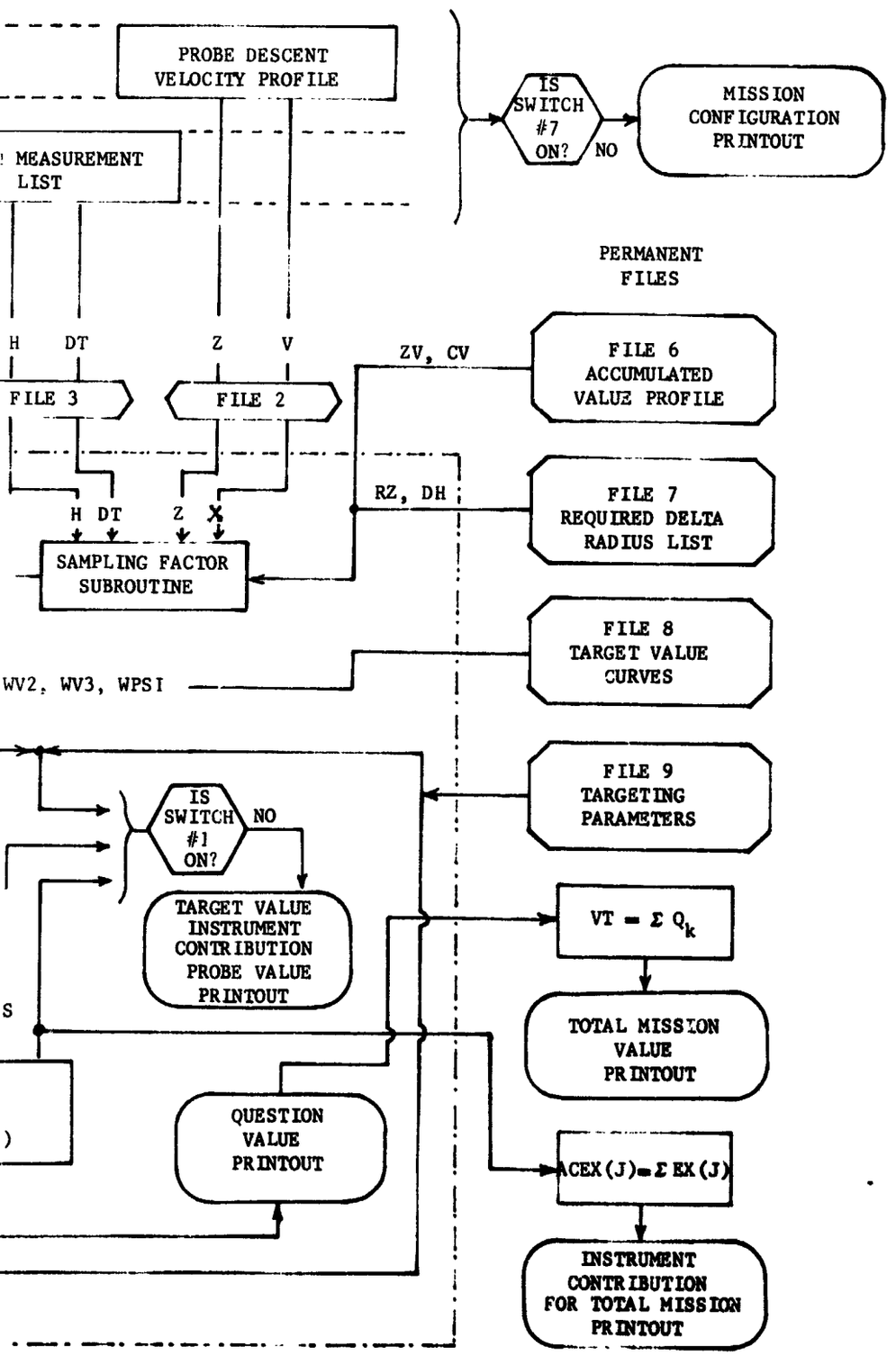
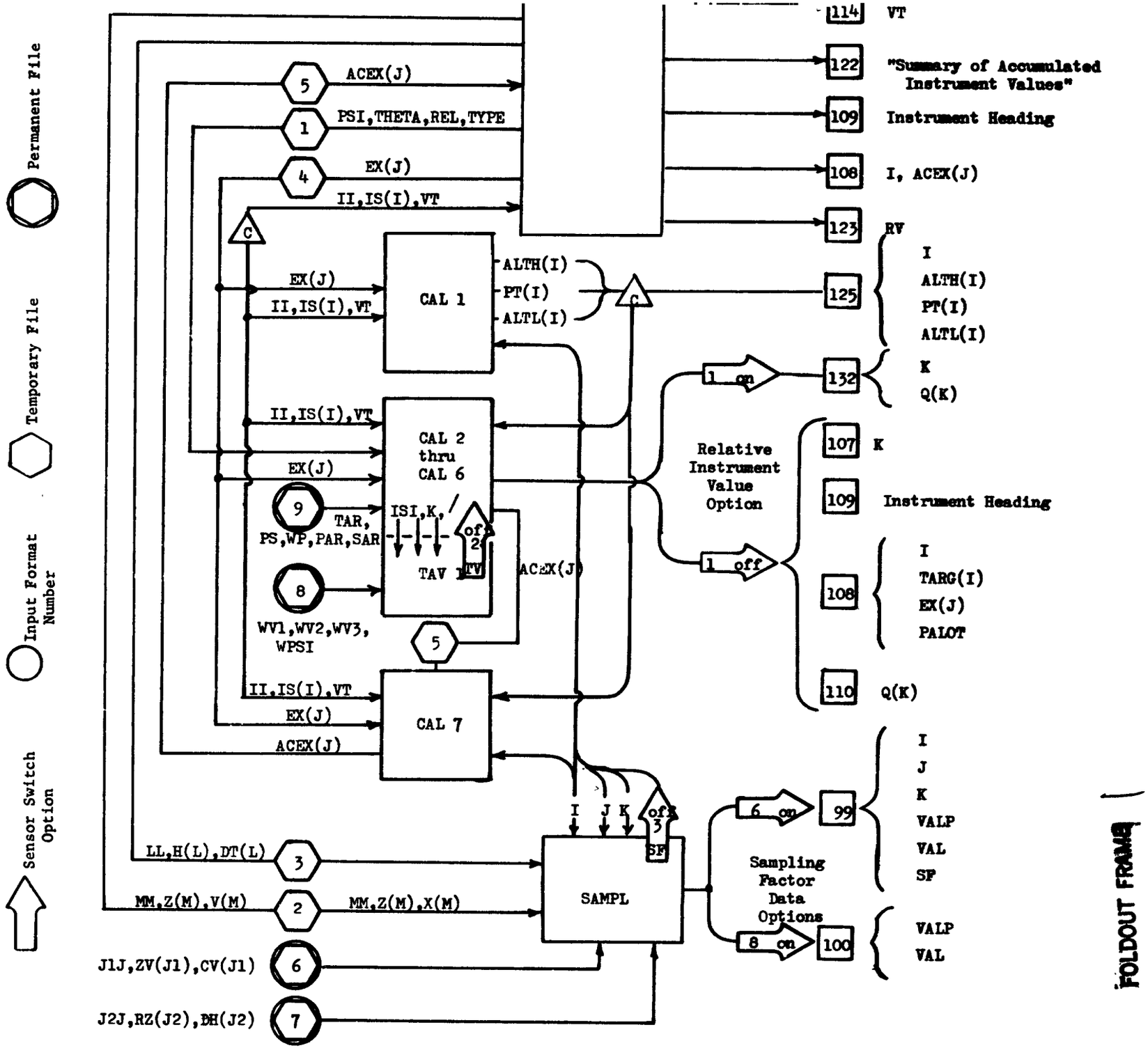


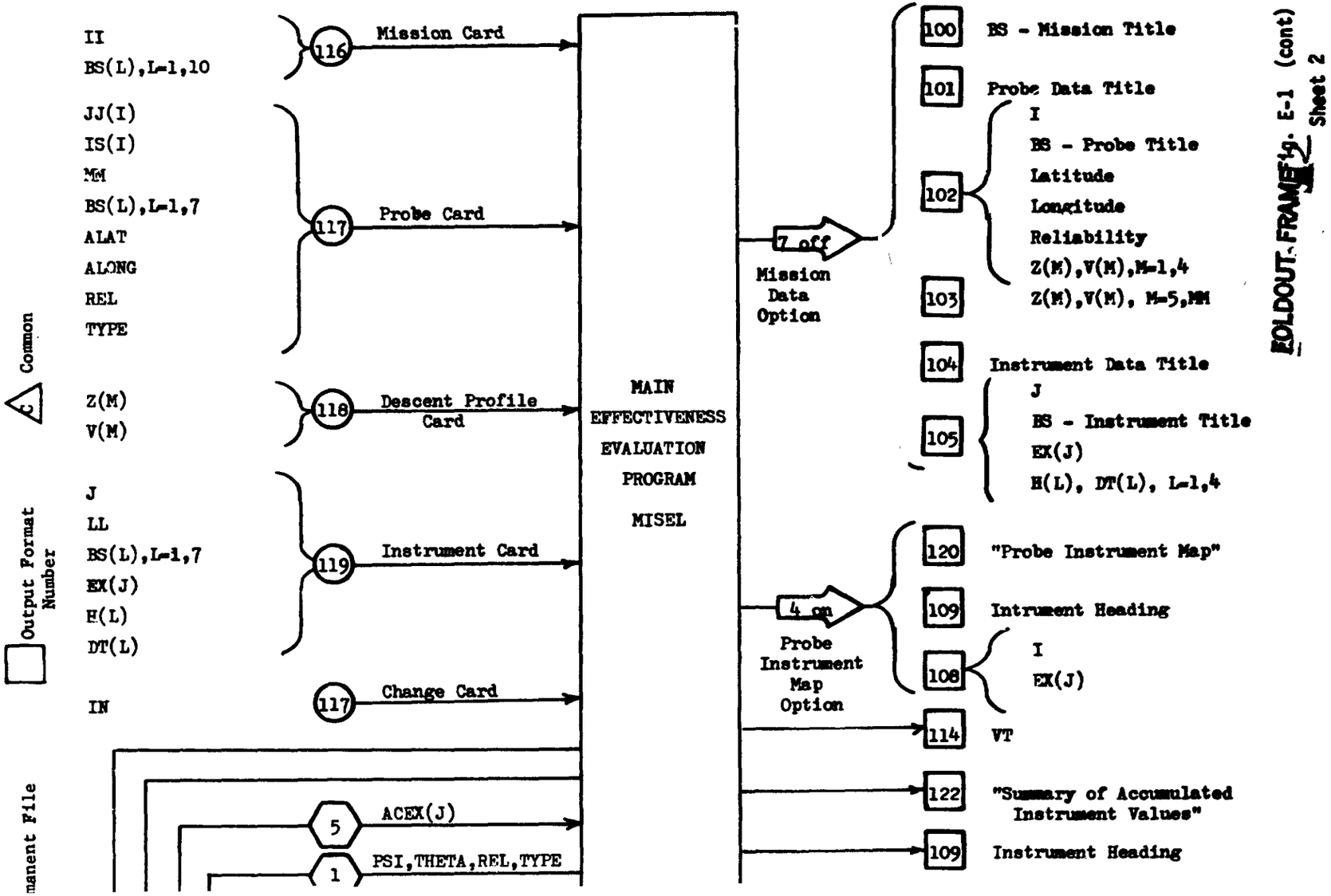
Fig. E-1 Program Flow Diagrams

Sheet 1 2

FOLDOUT FRAME



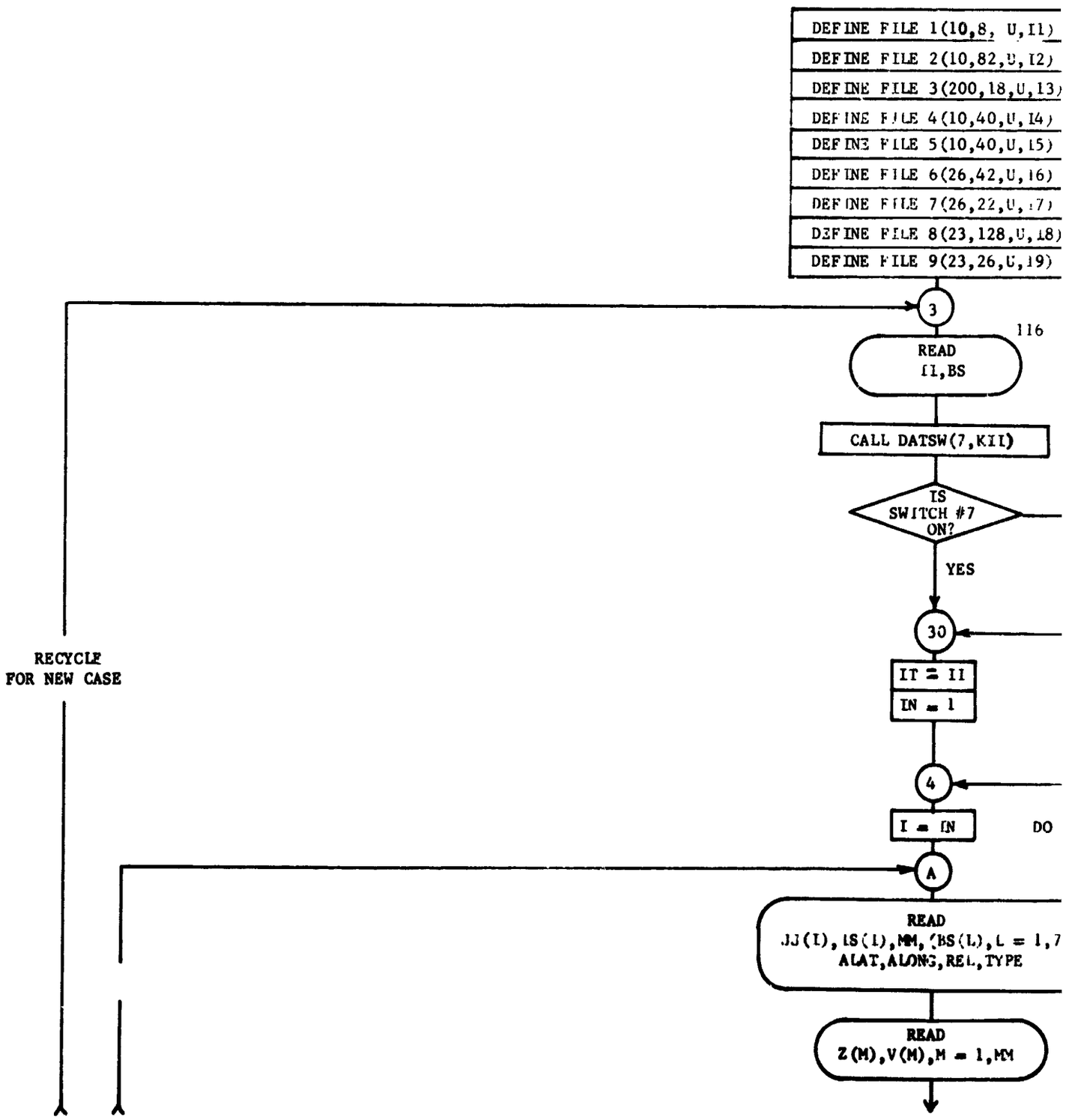
FOLDOUT FRAME



FOLDOUT FRAME 2

E-1 (cont)
Sheet 2

MAIN EVALUATION PROGRAM



FOLDOUT FRAME

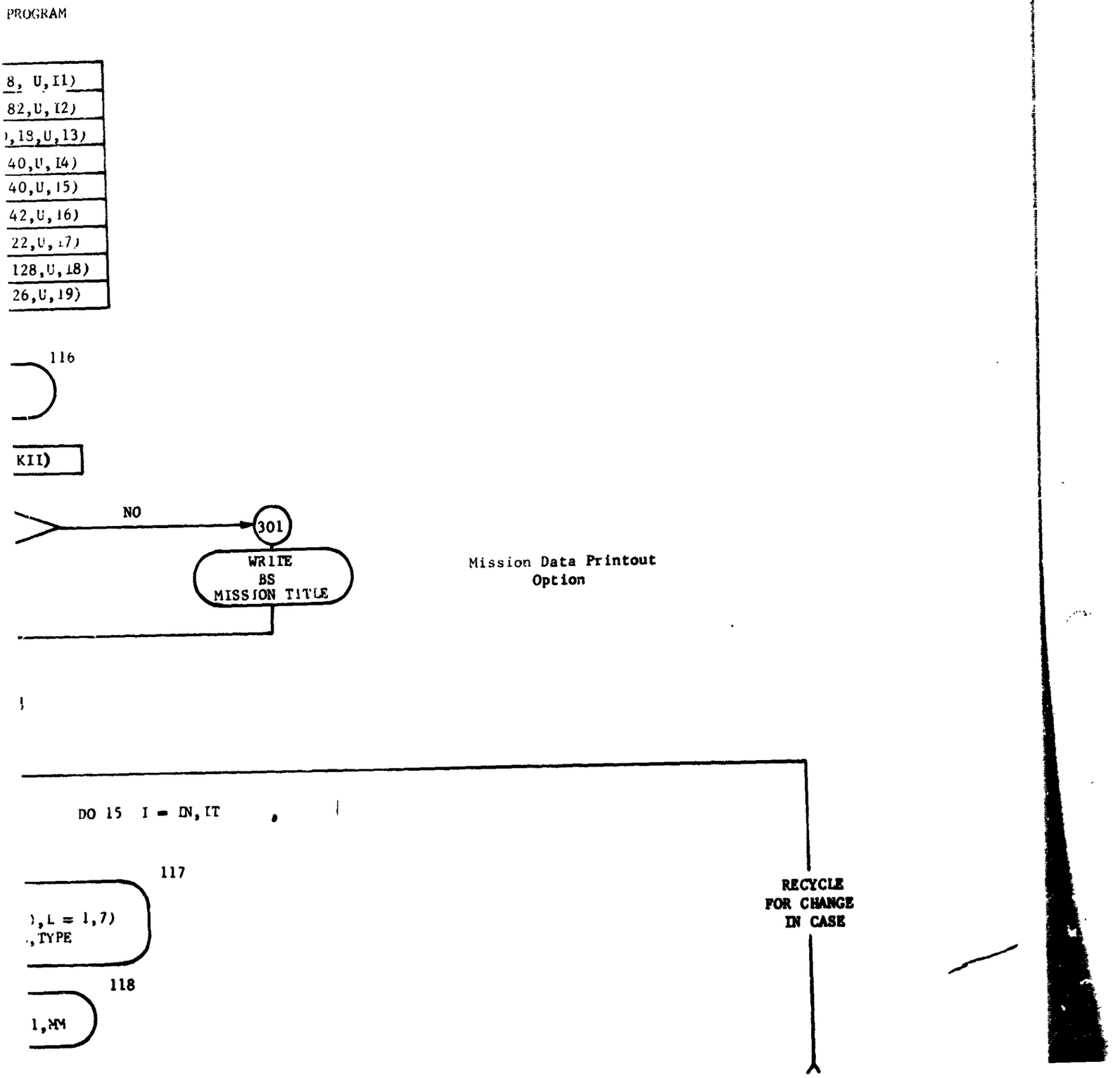
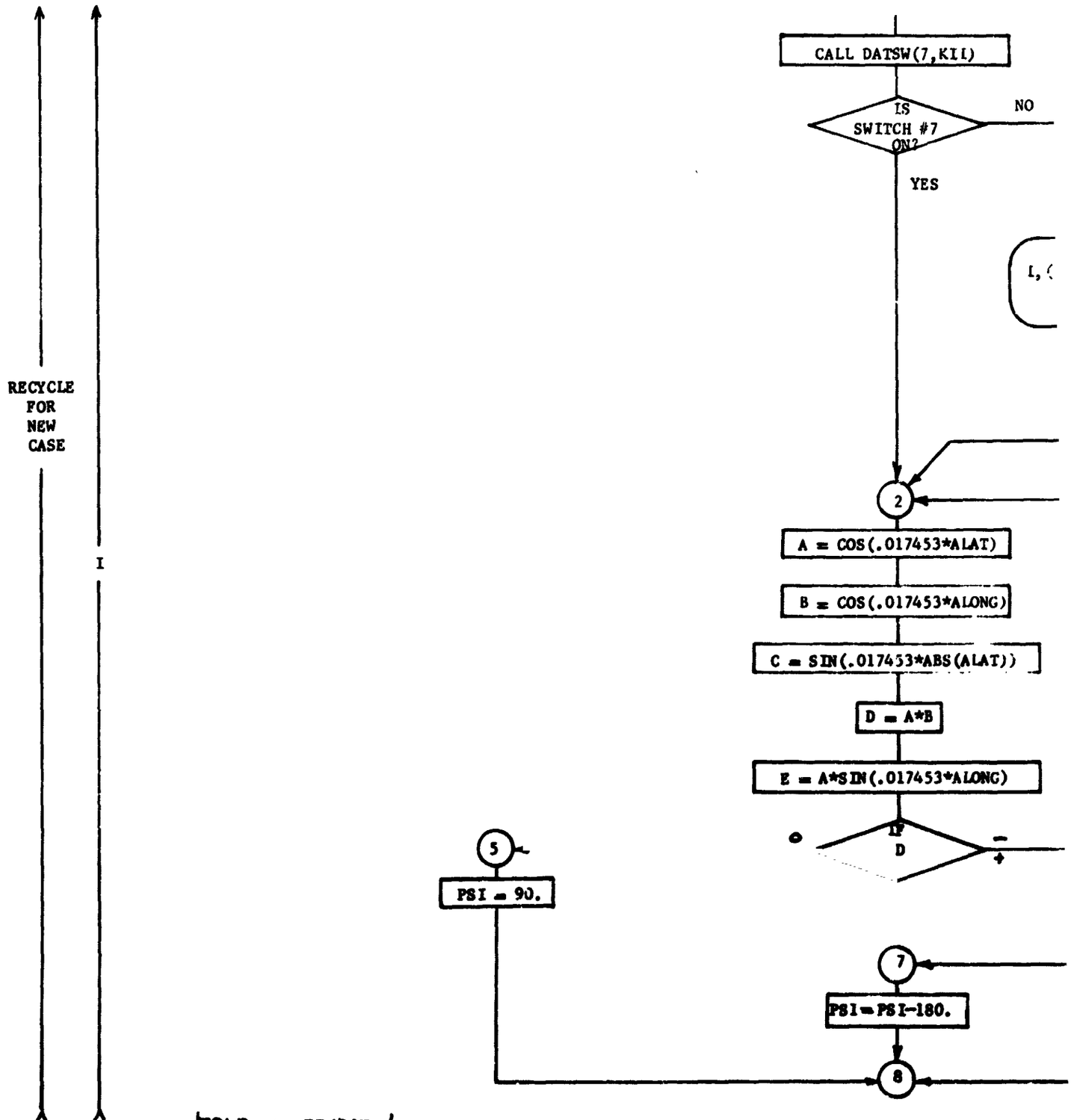


Fig. E-1 (cont)
Sheet 3

FOLDOUT FRAME 2

MAIN EVALUATION PROGRAM



FOLDOUT FRAME 1

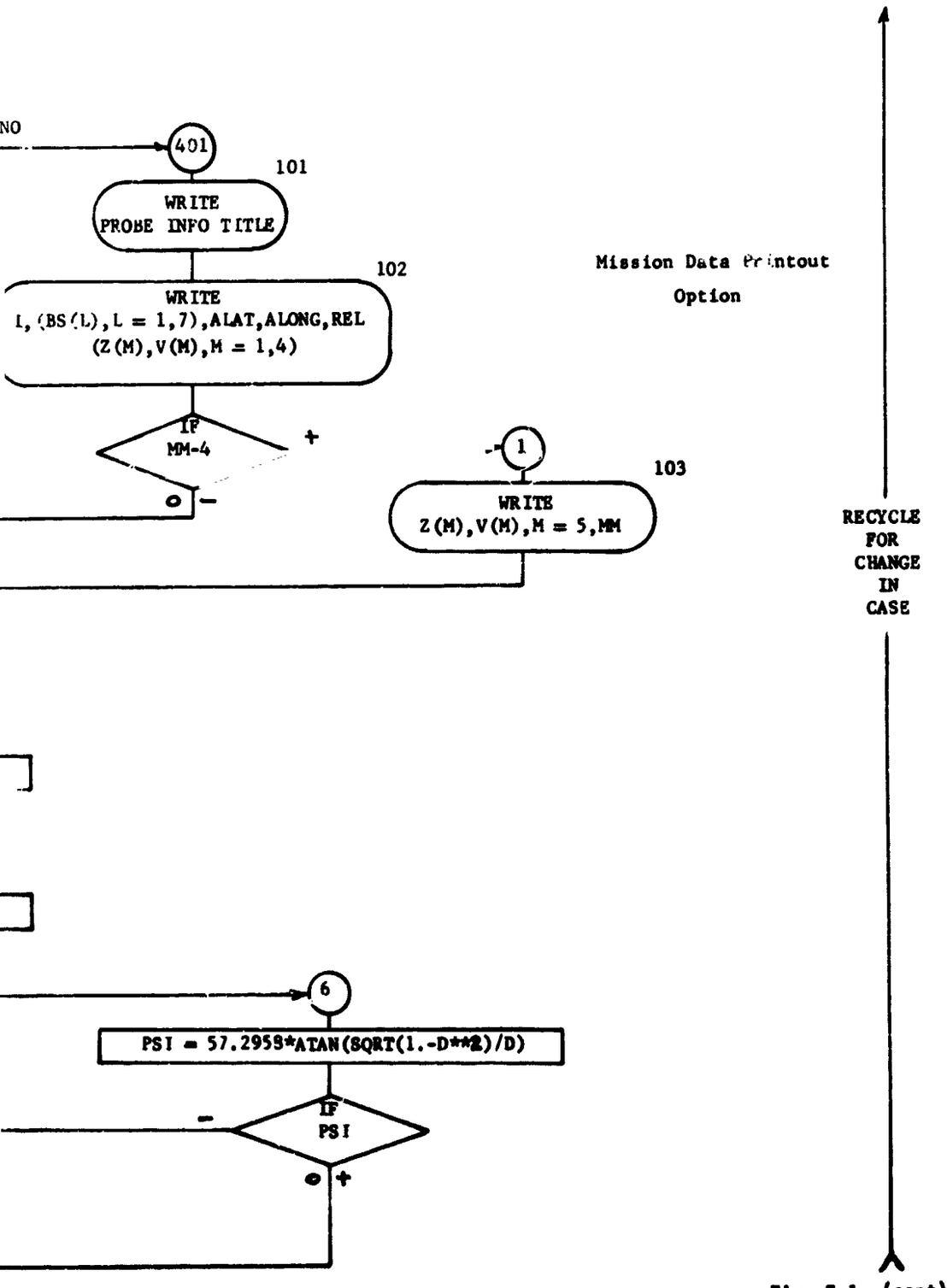
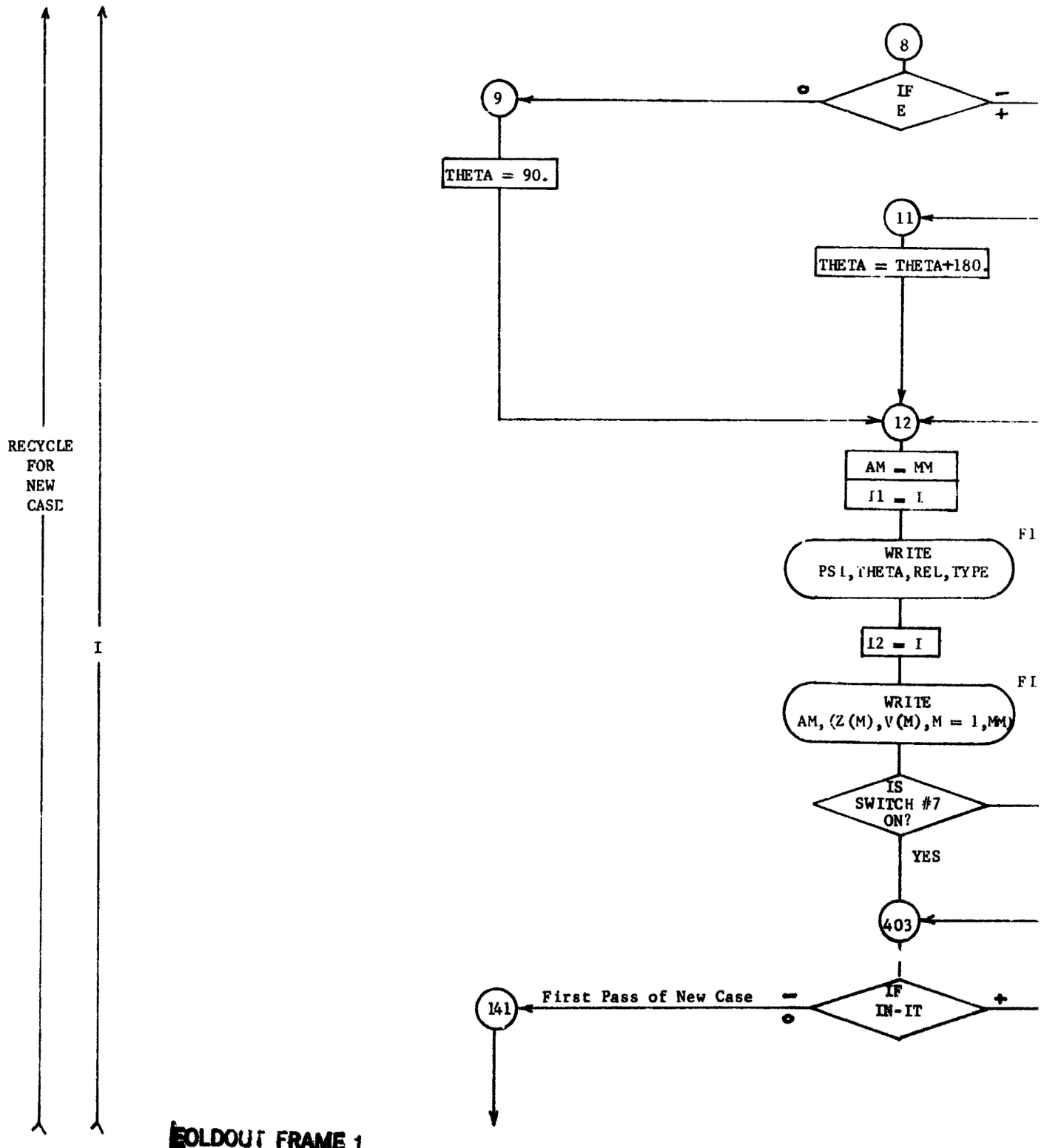


Fig. E-1 (cont)

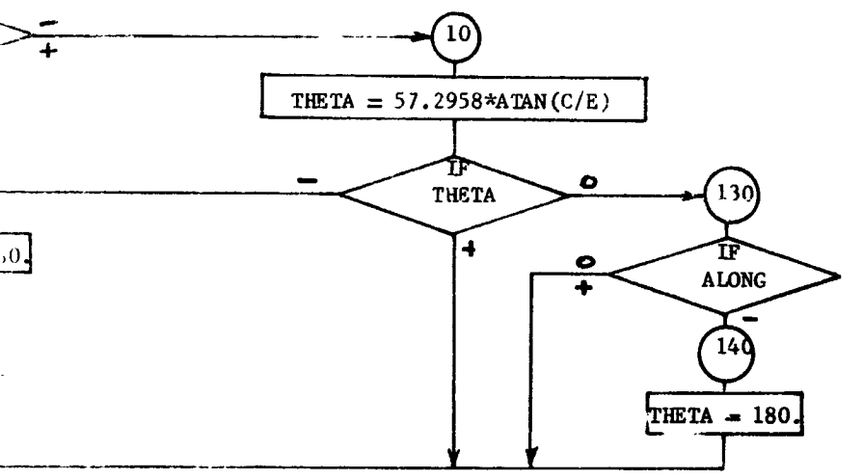
FOLDOUT FRAME 2 Sheet 4

MAIN EVALUATION PROGRAM



FOLDOUT FRAME 1

OGRAM



RECYCLE FOR CHANGE IN CASE

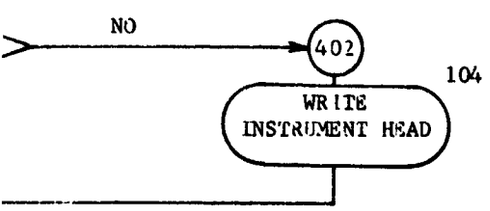
FILE 1

'PE

FILE 2

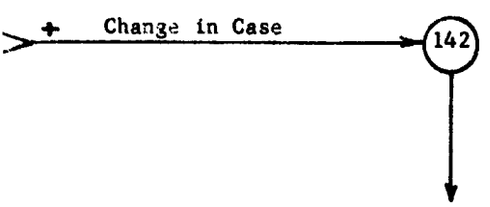
1,MM)

NO



Mission Data Printout Option

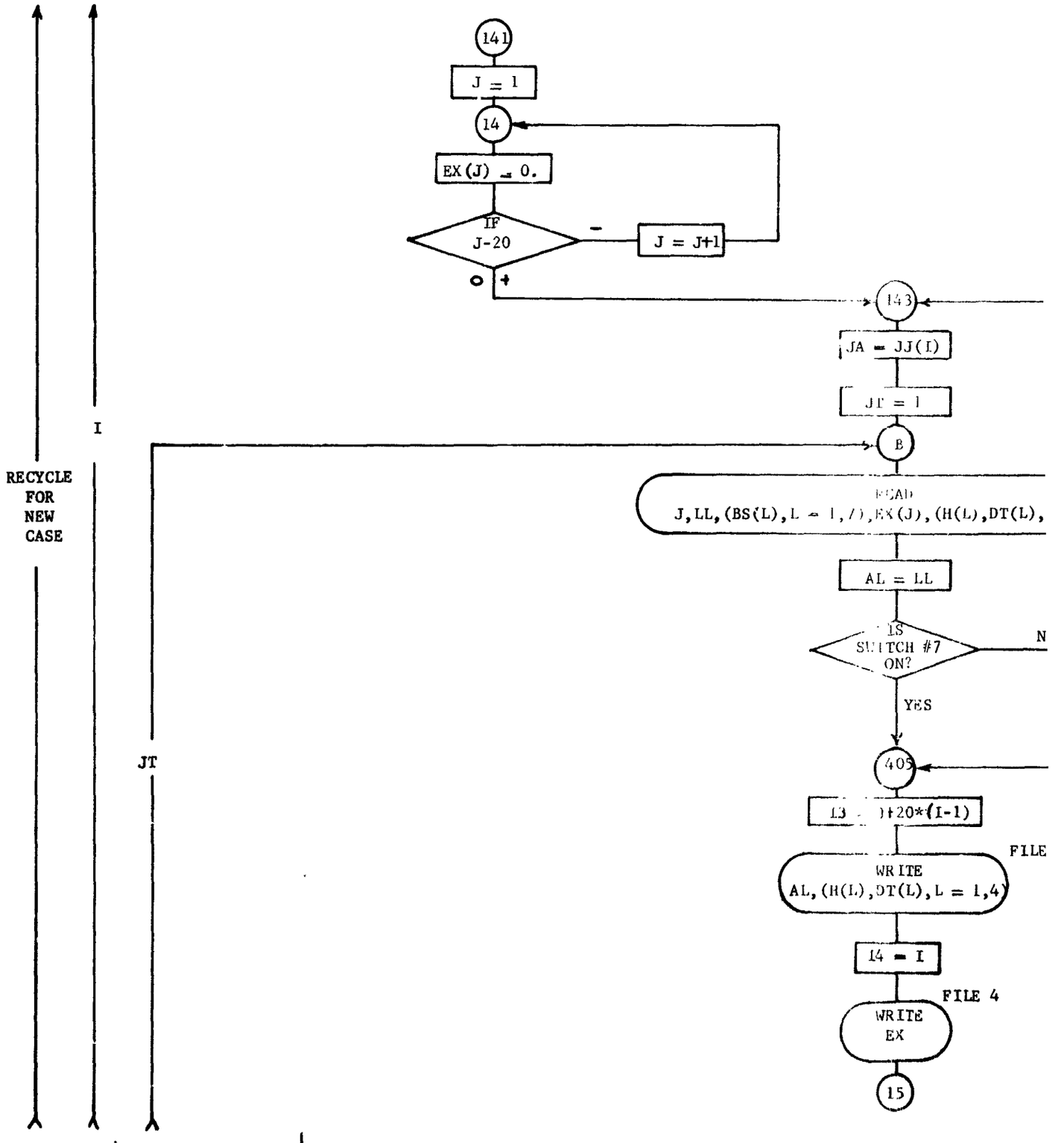
+ Change in Case



FOLDOUT FRAME 2

Fig. E-1 (cont)
Sheet 5

MAIN EVALUATION PROGRAM



FOLDOUT FRAME

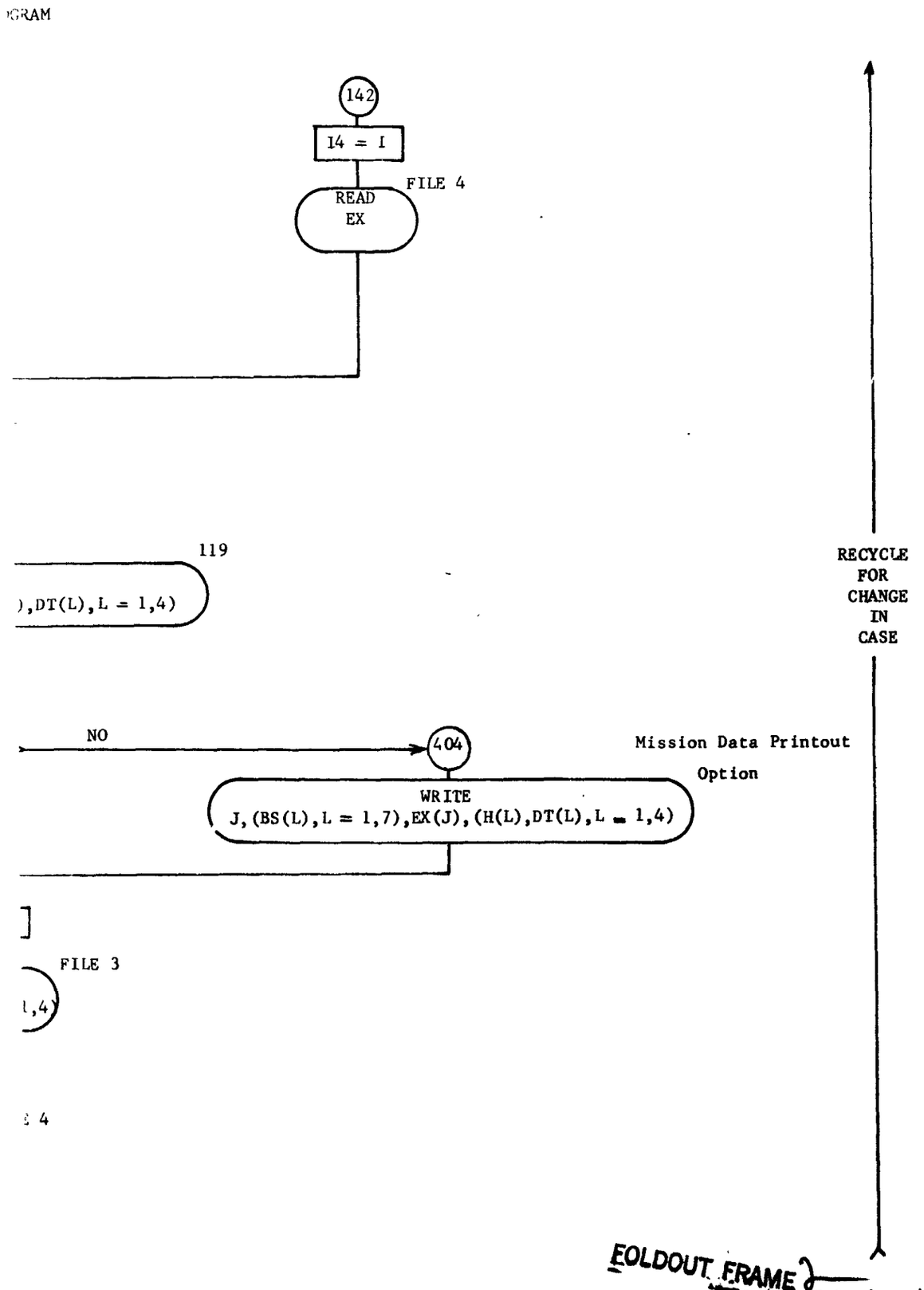
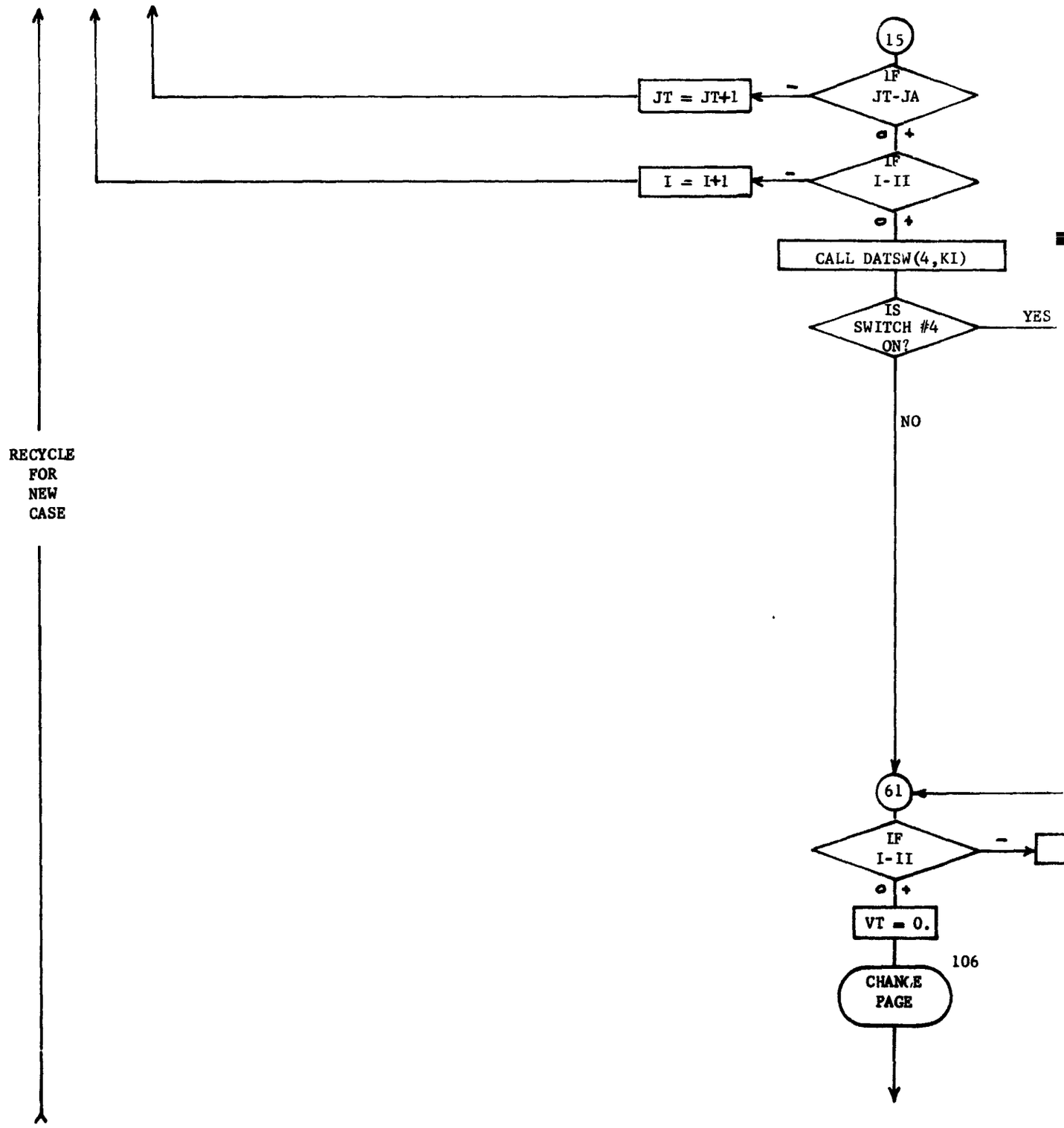


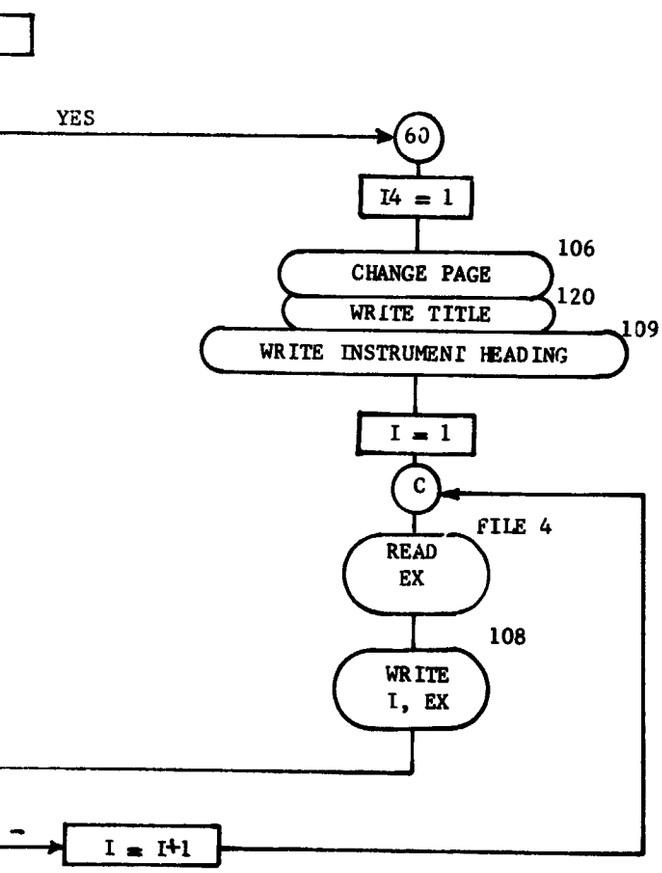
Fig. E-1 (cont)
Sheet 6

MAIN EVALUATION PROGRAM



FOLDOUT FRAME

AM



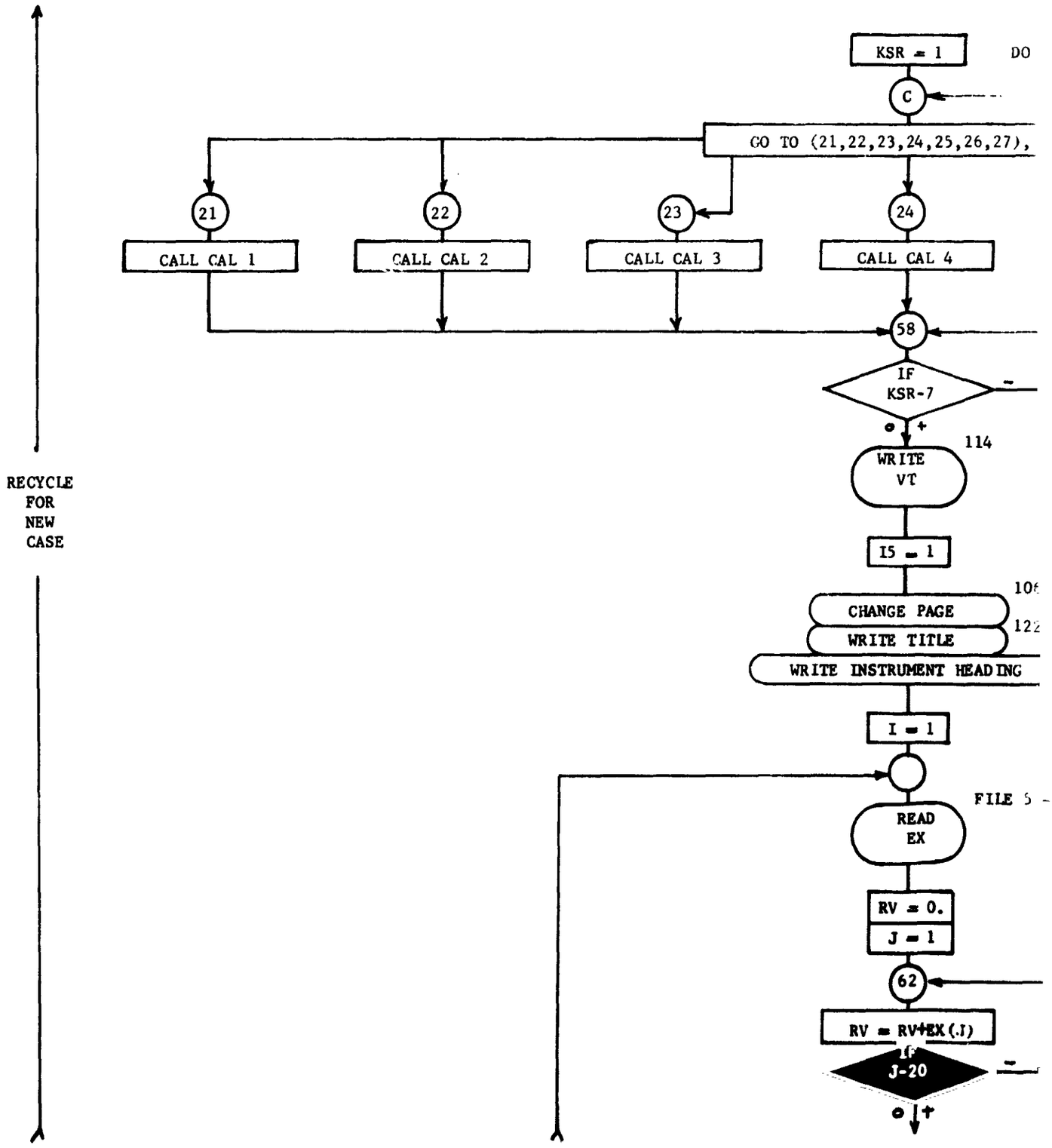
Probe-Instrument Map Option

RECYCLE FOR CHANGE IN CASE

FOLDOUT FRAME

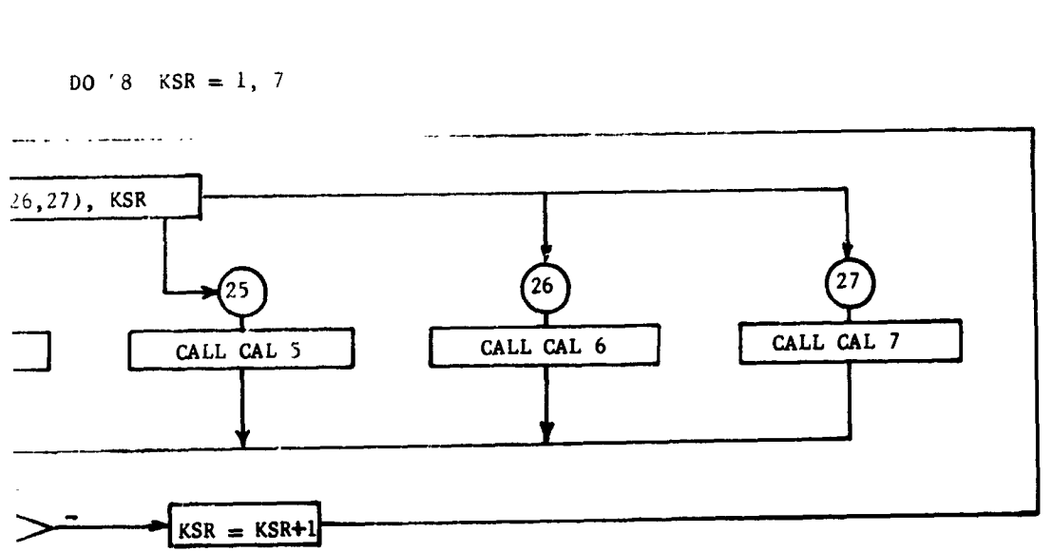
(cont)

MAIN EVALUATION PROGRAM



FOLDOUT FRAME

ROGRAM



114

RECYCLE FOR CHANGE OF CASE

106
122
109
EAD ING

FILE 5

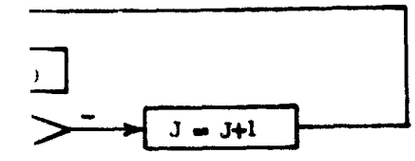
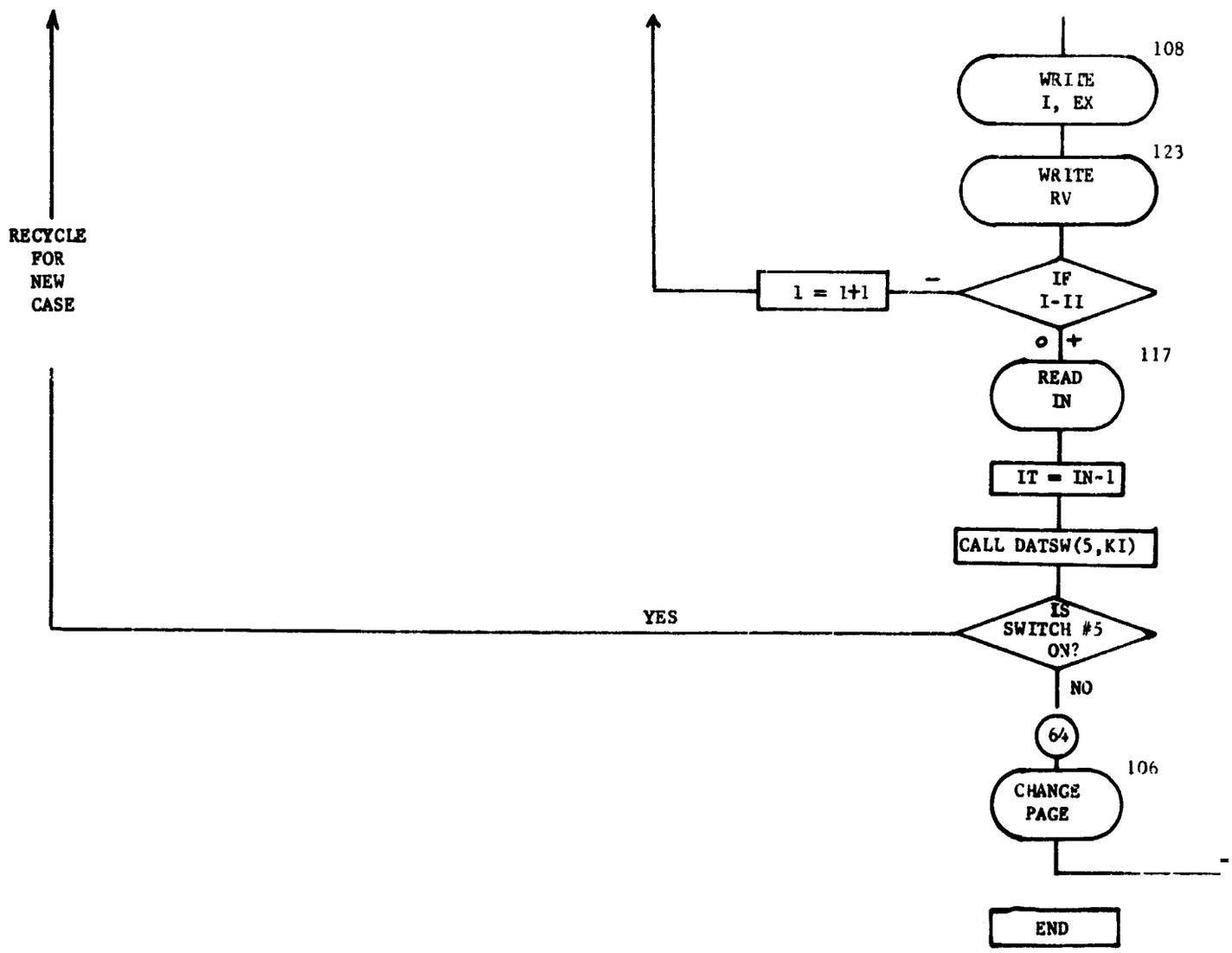


Fig. E-1 (cont)

FOLDOUT FRAME 2 Sheet 8

MAIN EVALUATION PROGRAM



FOLDOUT FRAME

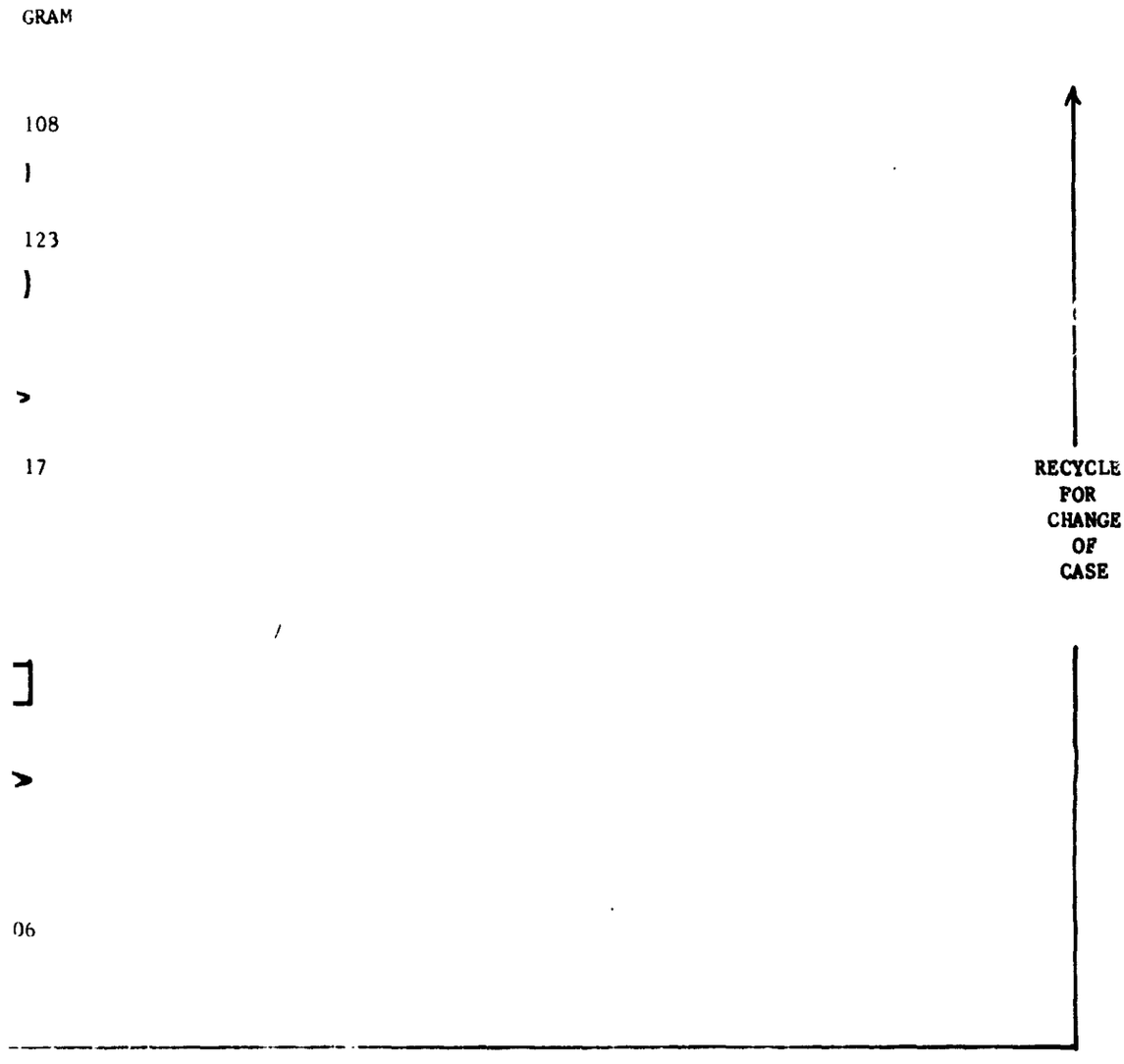
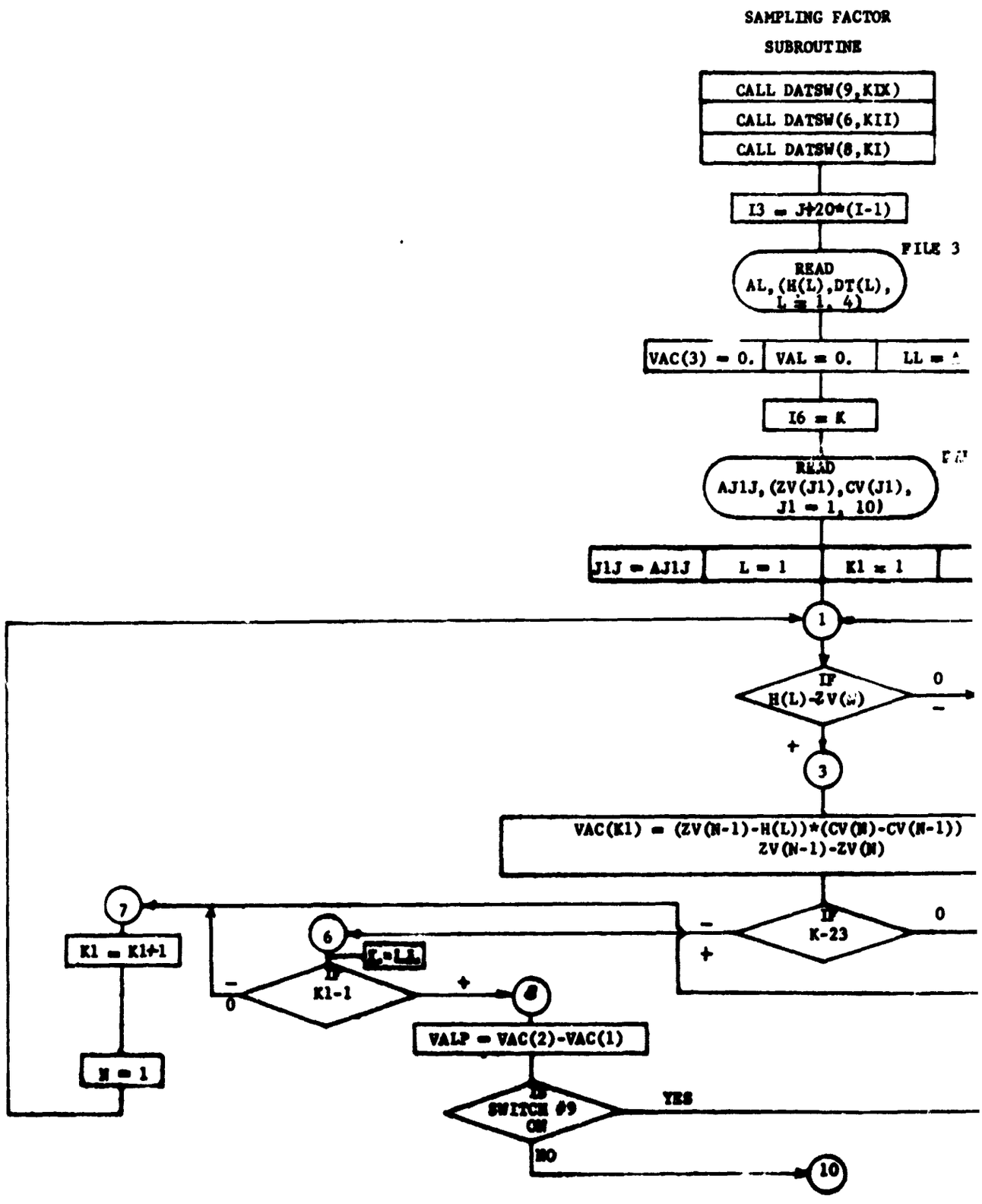


Fig. E-1 (cont)
Sheet 9

FOLDOUT FRAME 2



FOLDOUT FRAME 1

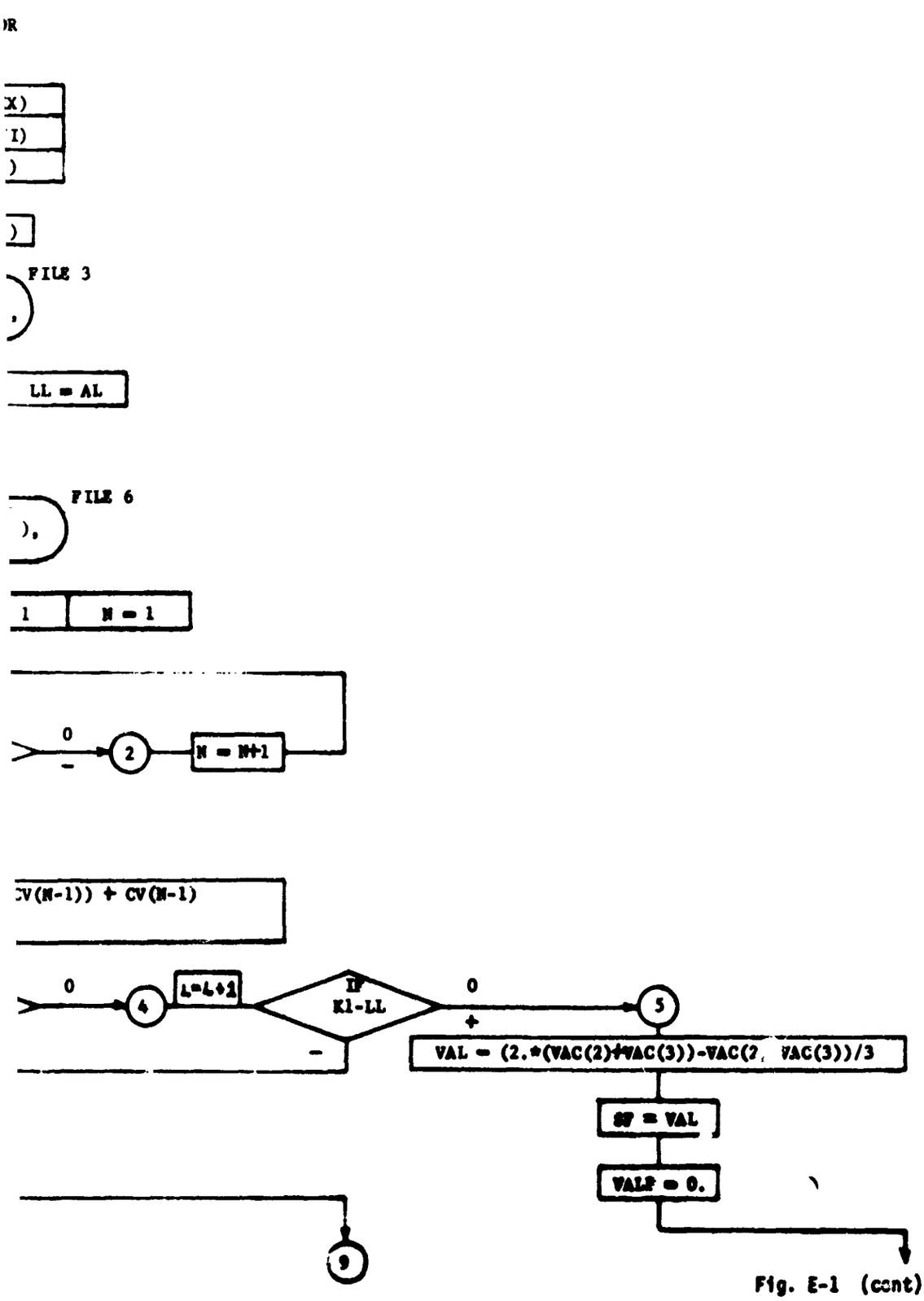
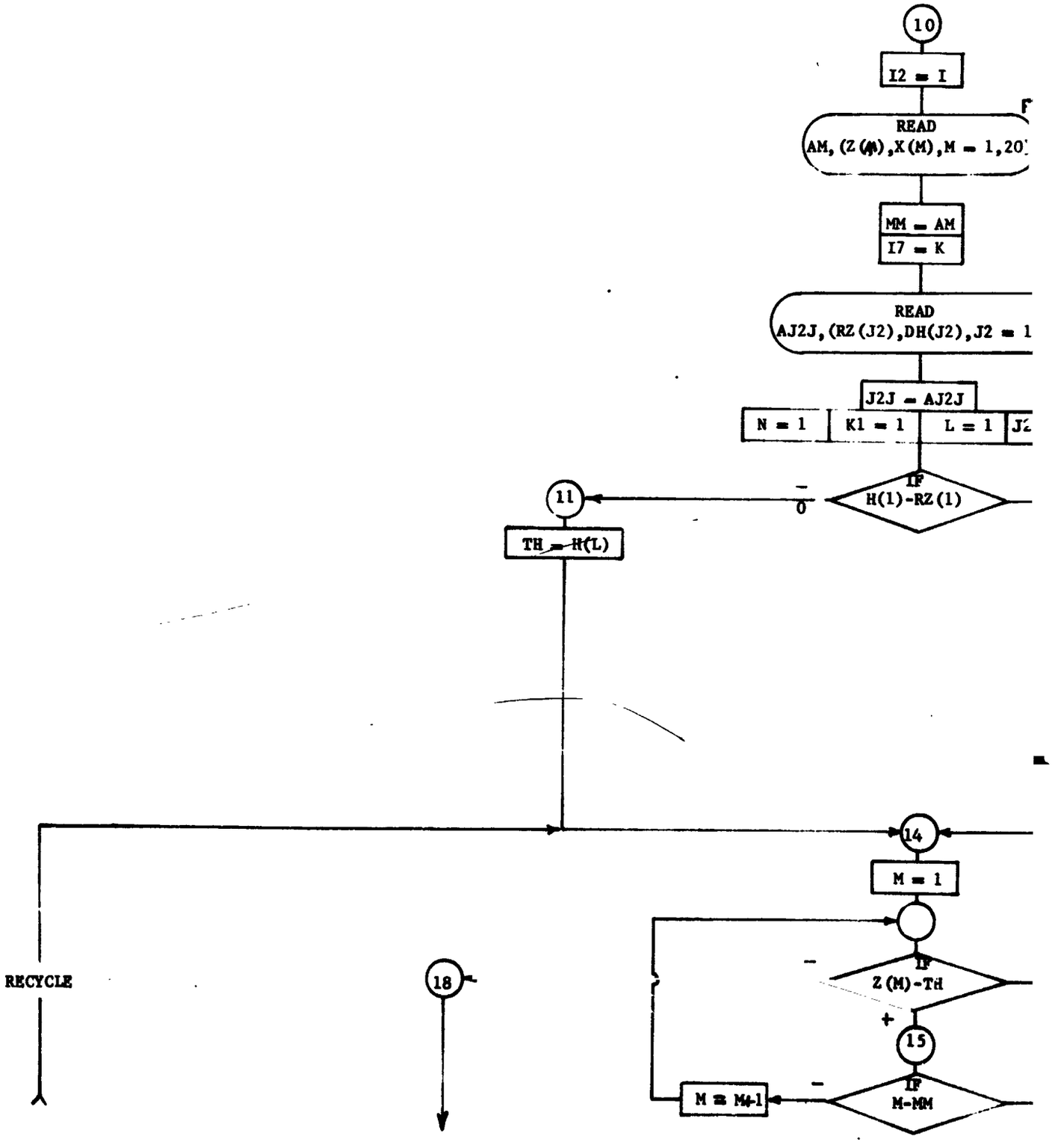


Fig. E-1 (cont)
Sheet 10

FOLDOUT FRAME 2

SAMPLING FACTOR

SUBROUTINE



FOLDOUT FRAME

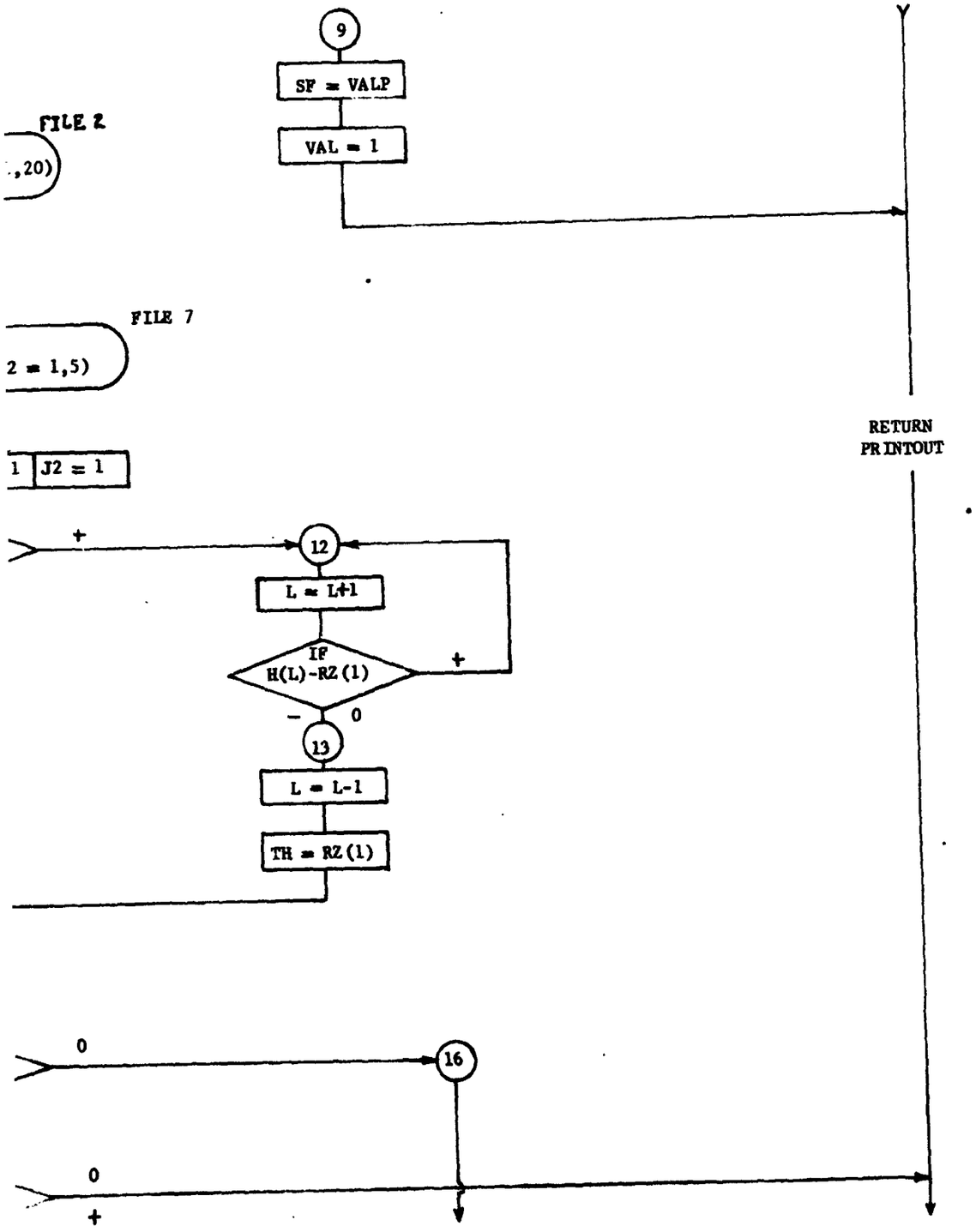
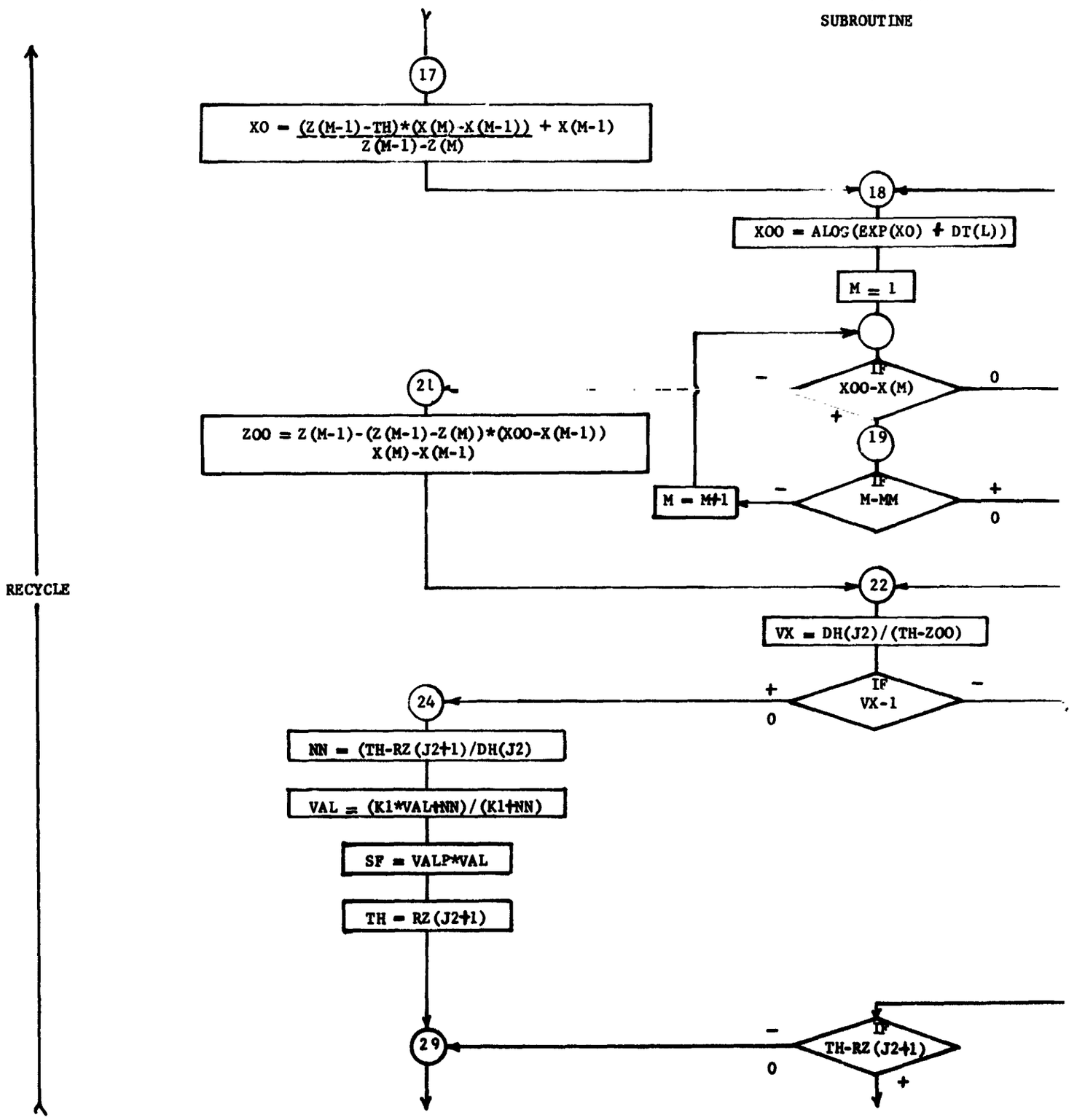


Fig. E-1 (cont)

FOLDOUT FRAME 2 Sheet 11

SAMPLING FACTOR
SUBROUTINE



FOLDOUT FRAME

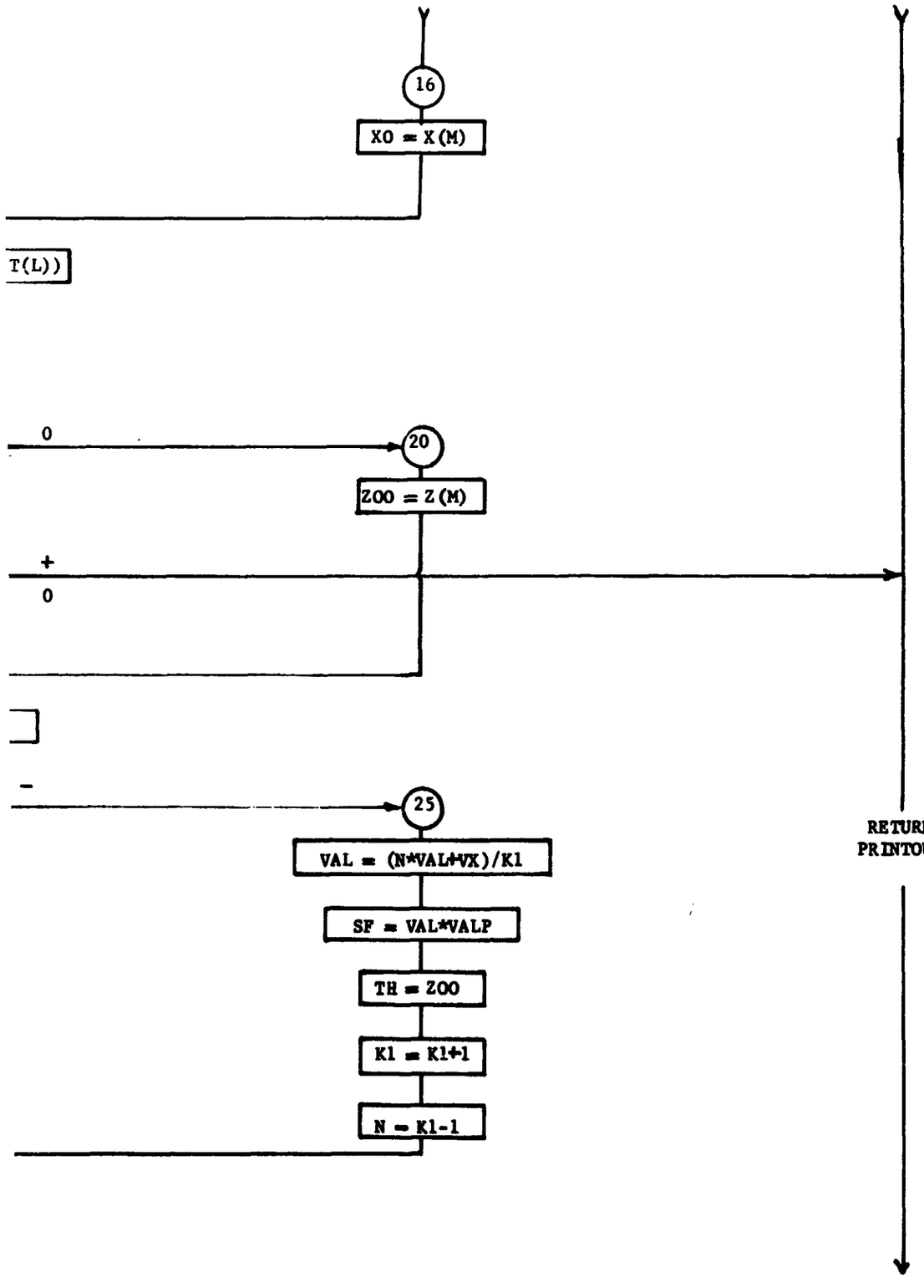
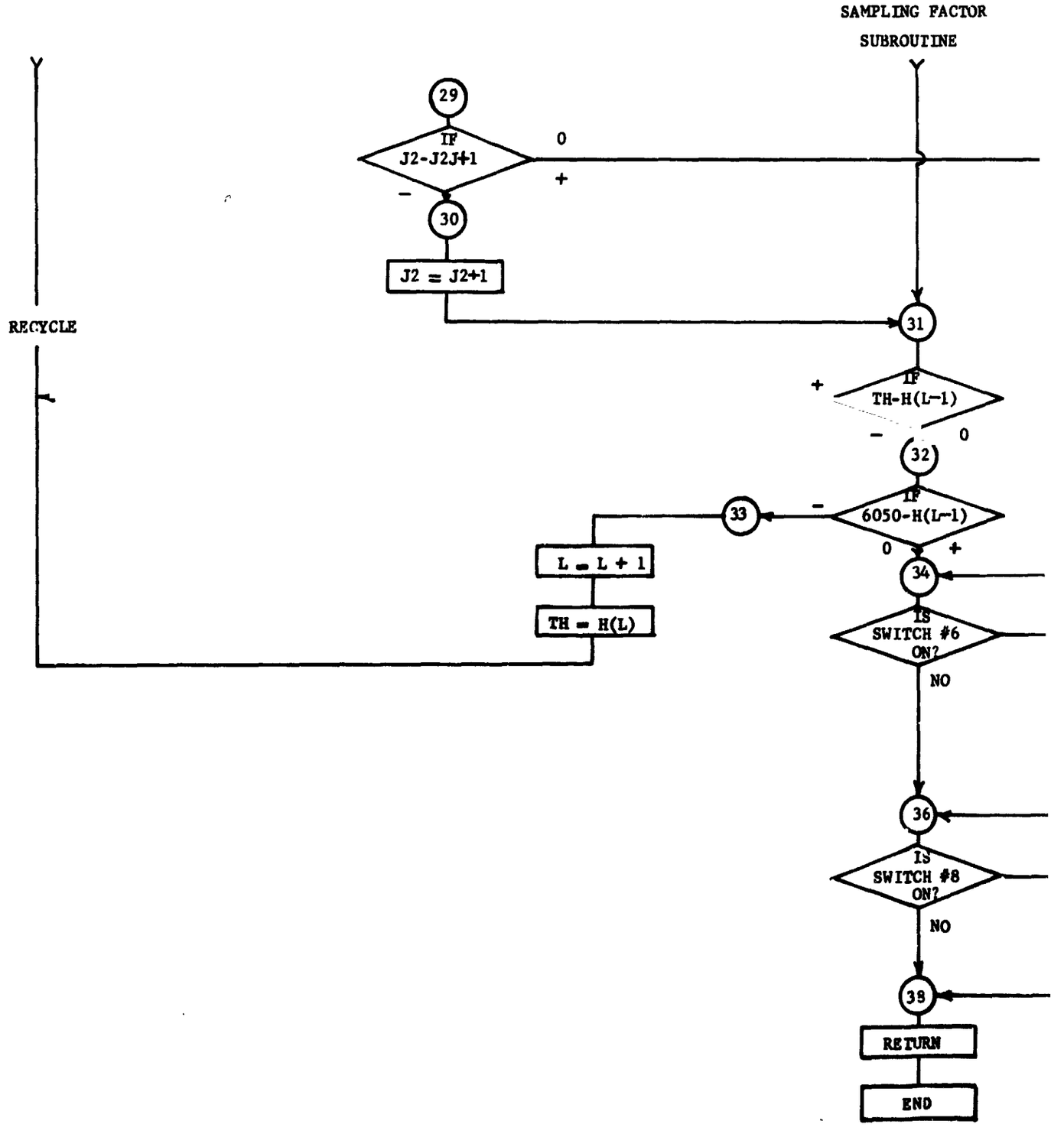


Fig. E-1 (cont)
Sheet 12

FOLDOUT FRAME 7



FOLDOUT FRAME /

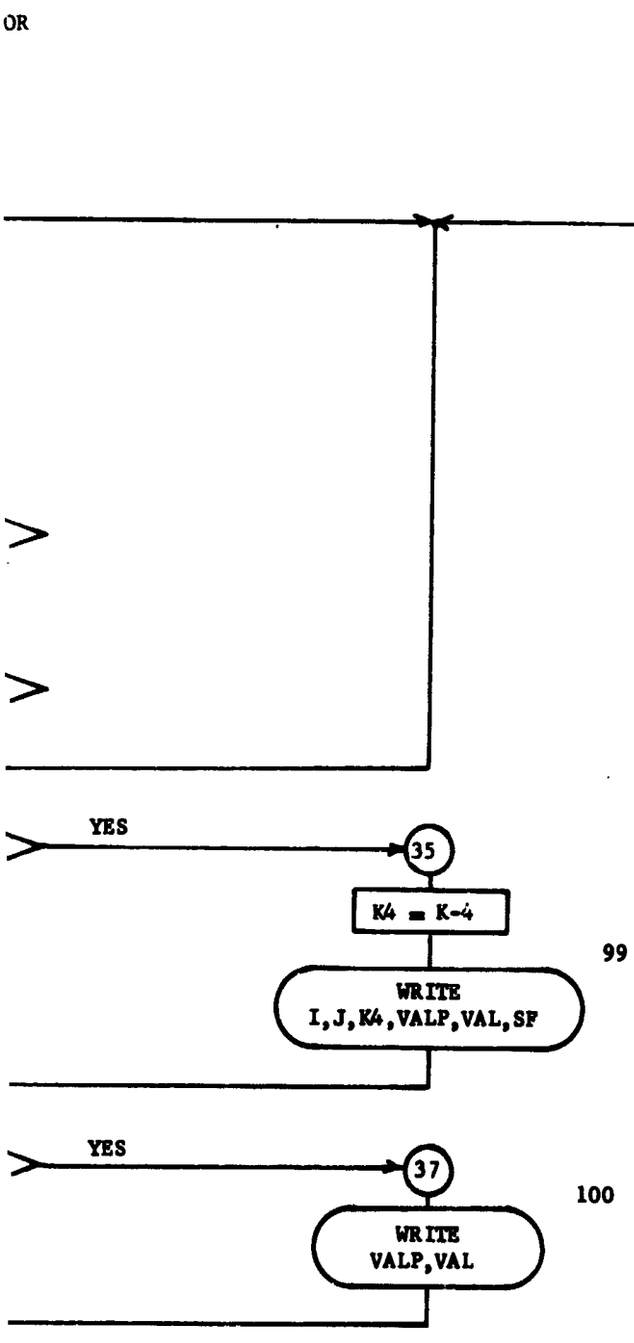
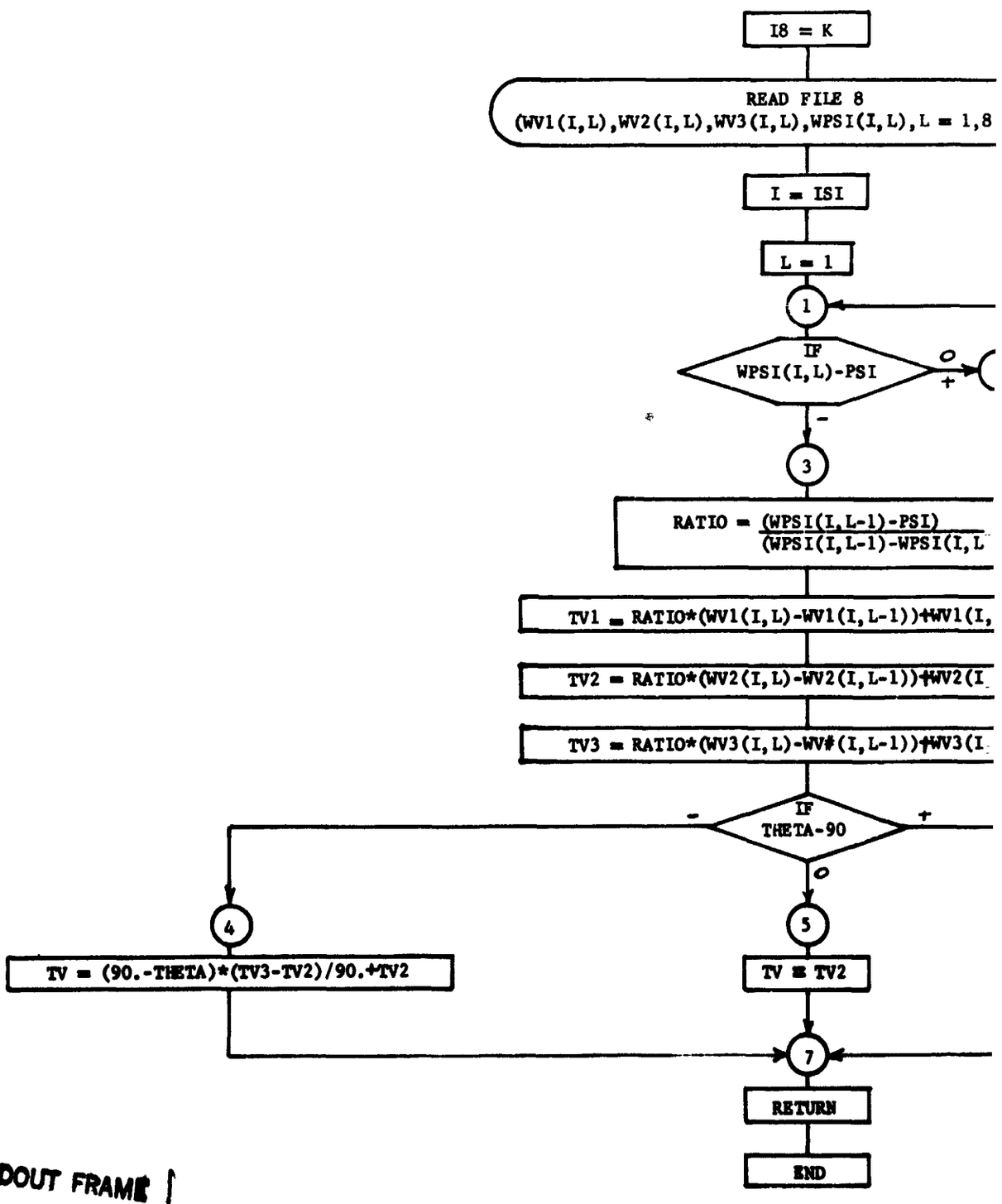


Fig. E-1 (cont)
Sheet 13

FOLDOUT FRAME

TARGETING SUBROUTINE

TAV1



FOLDOUT FRAME 1

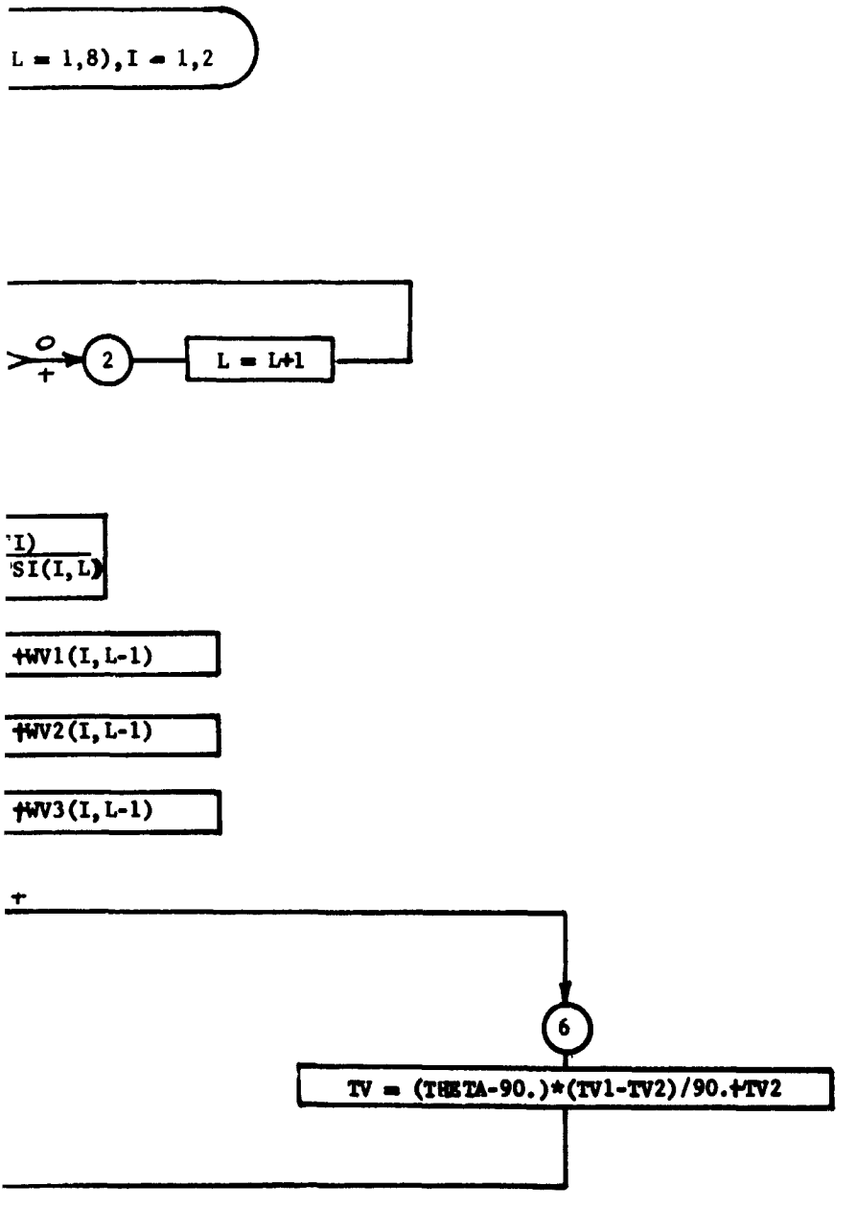
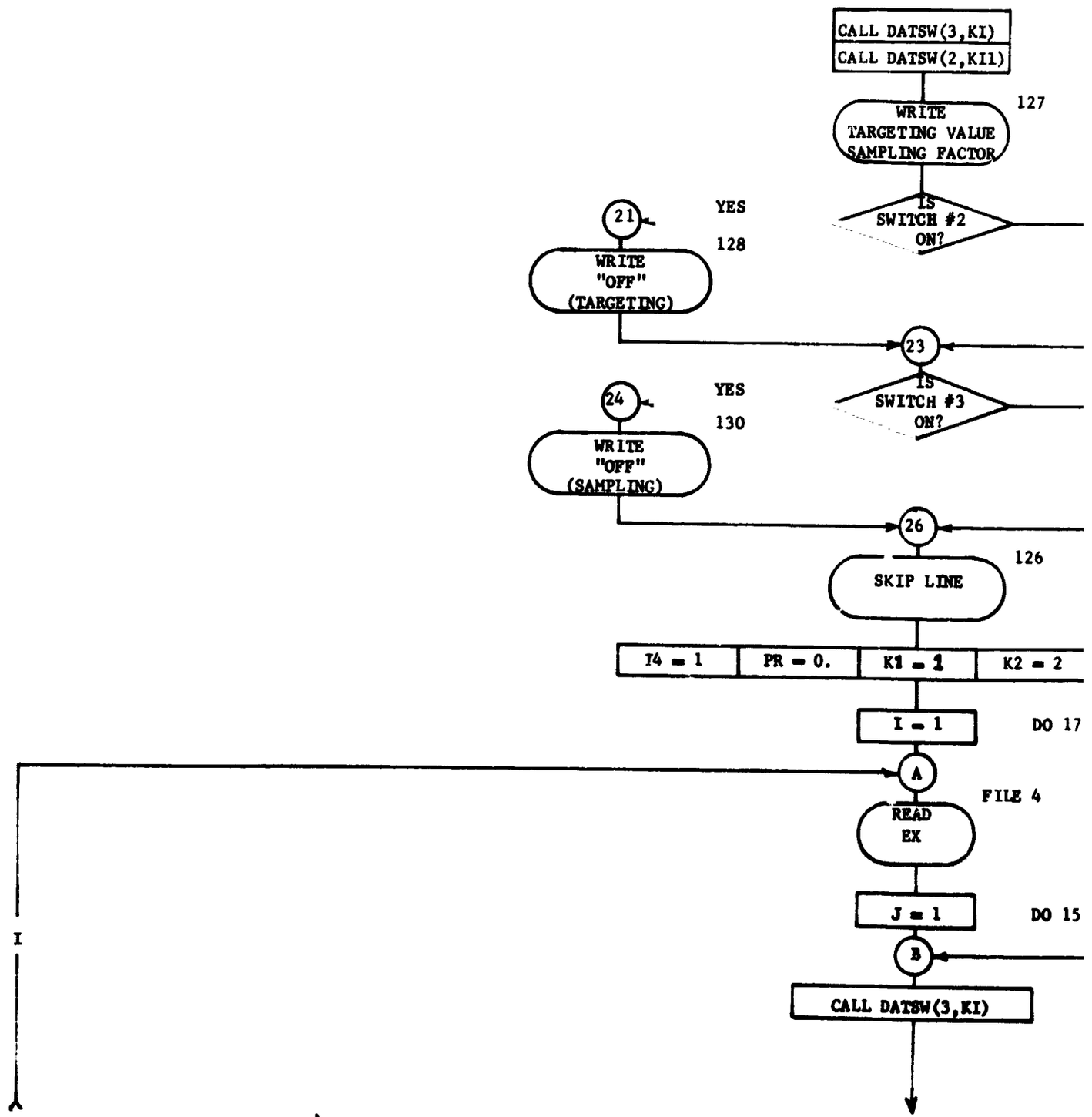


Fig. E-1 (cont)
Sheet 14

FOLDOUT FRAME 2

CALCULATION SUBROUTINE CAL



FOLDOUT FRAME 1

JTINE CAL 1

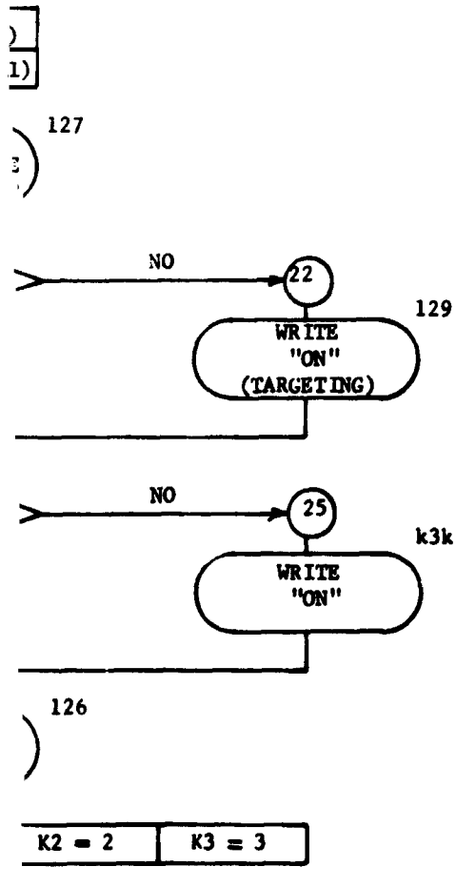
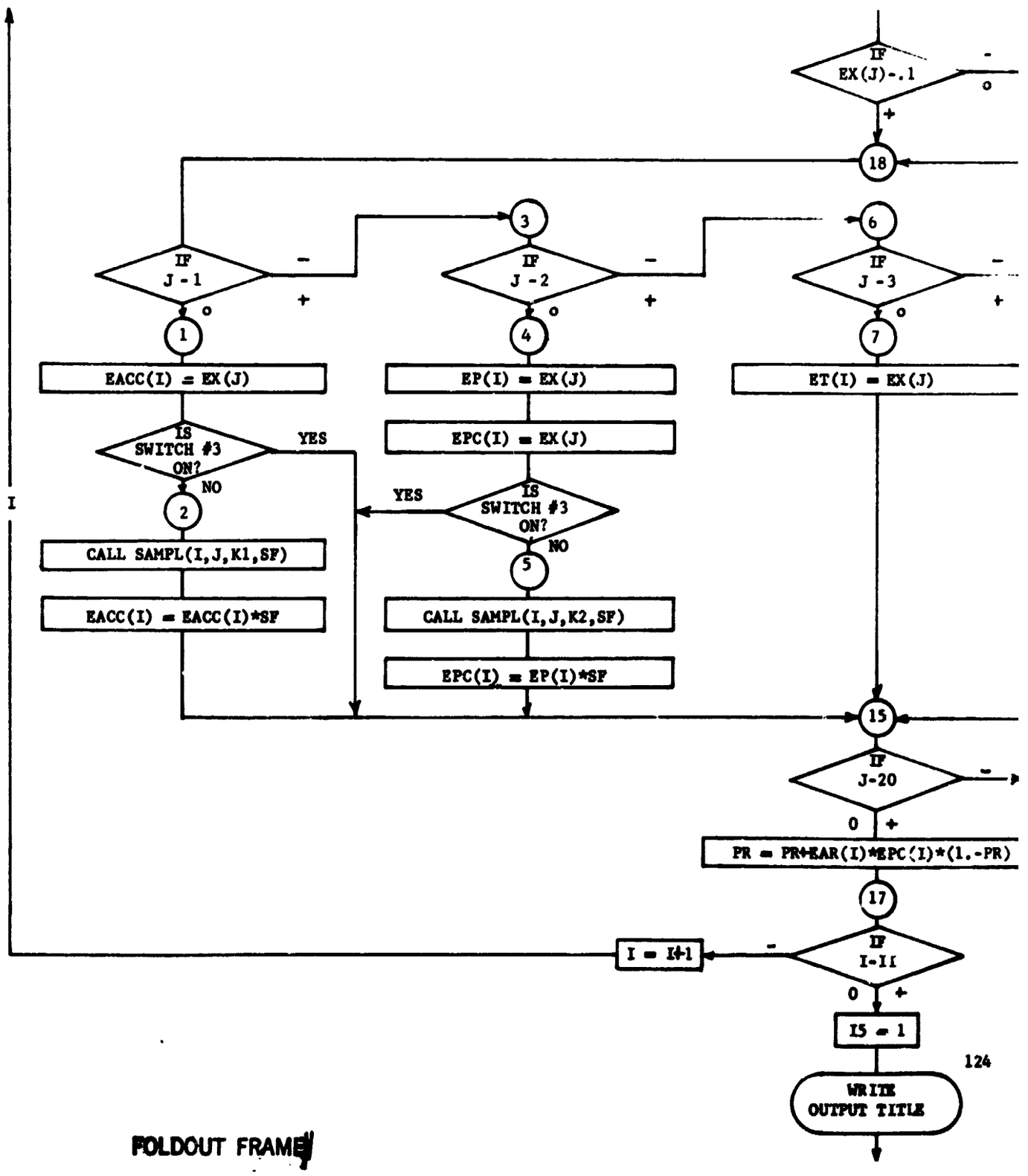


Fig. E-1 (cont)

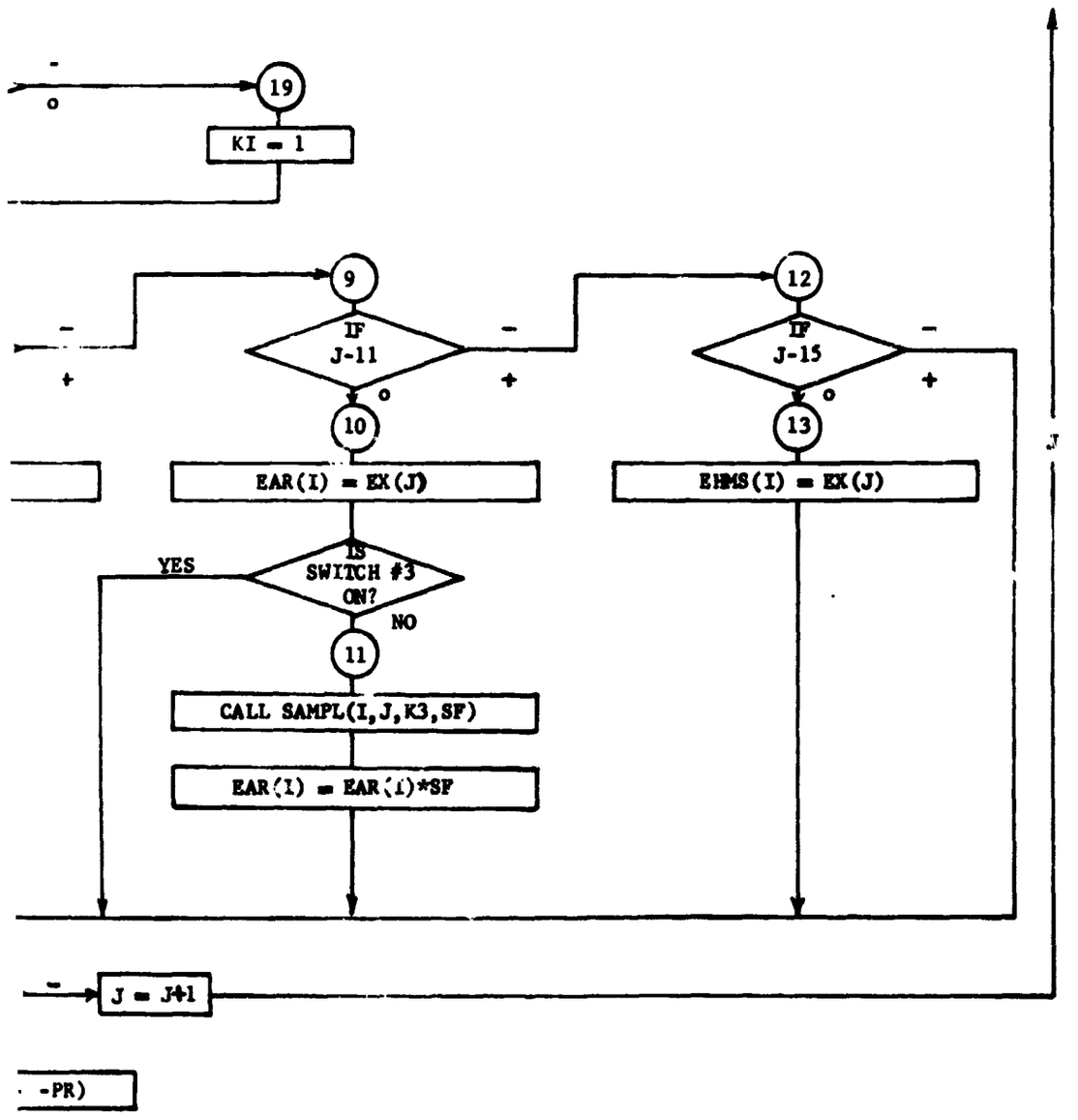
FOLDOUT FRAME 2 Sheet 15

CALCULATION SUBROUTINE CAL 1



FOLDOUT FRAME

CAL 1



FOLDOUT FRAME 2

Fig. E-1 (cont)
Sheet 16

CALCULATION SUBROUTINE CAL 1

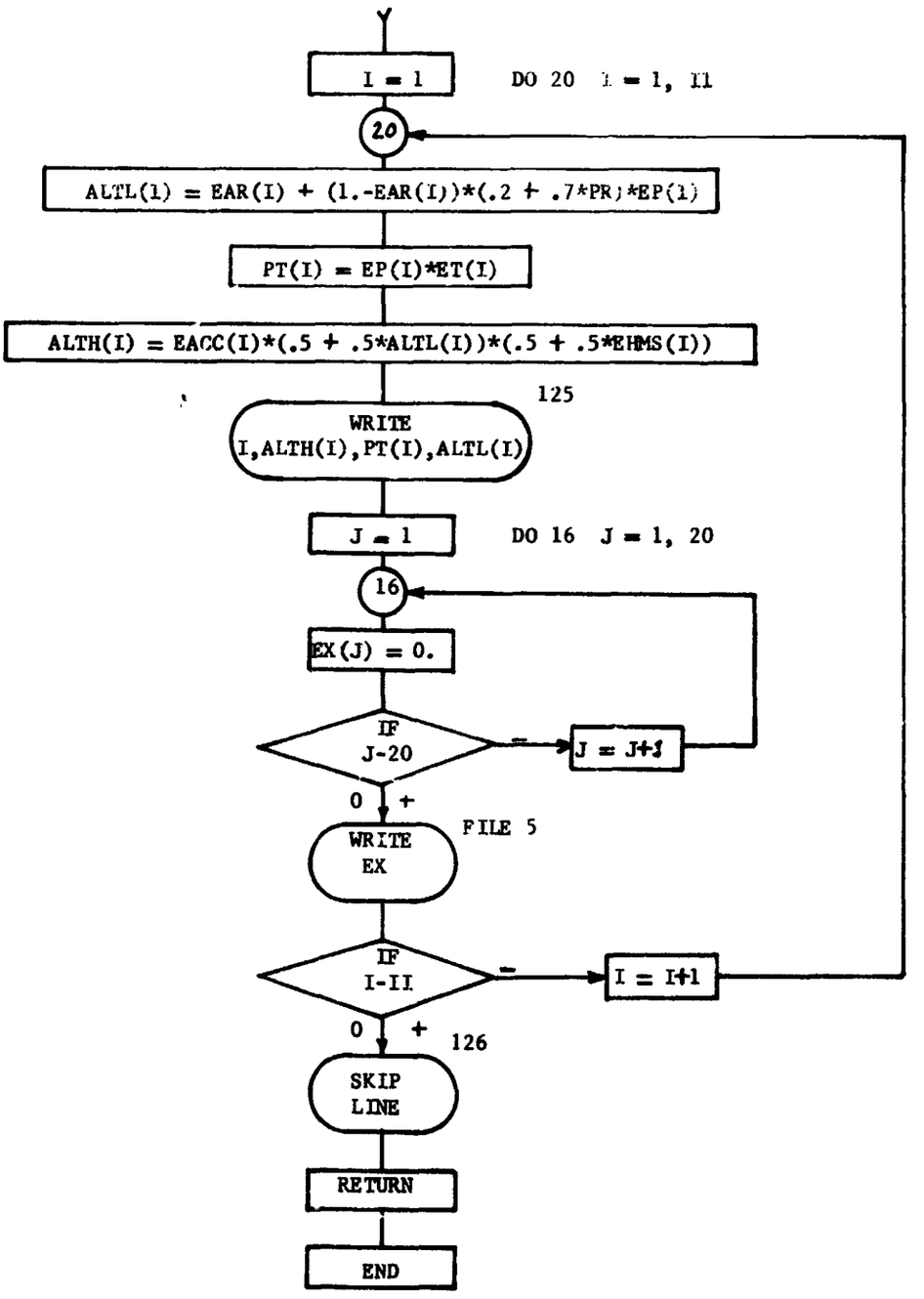


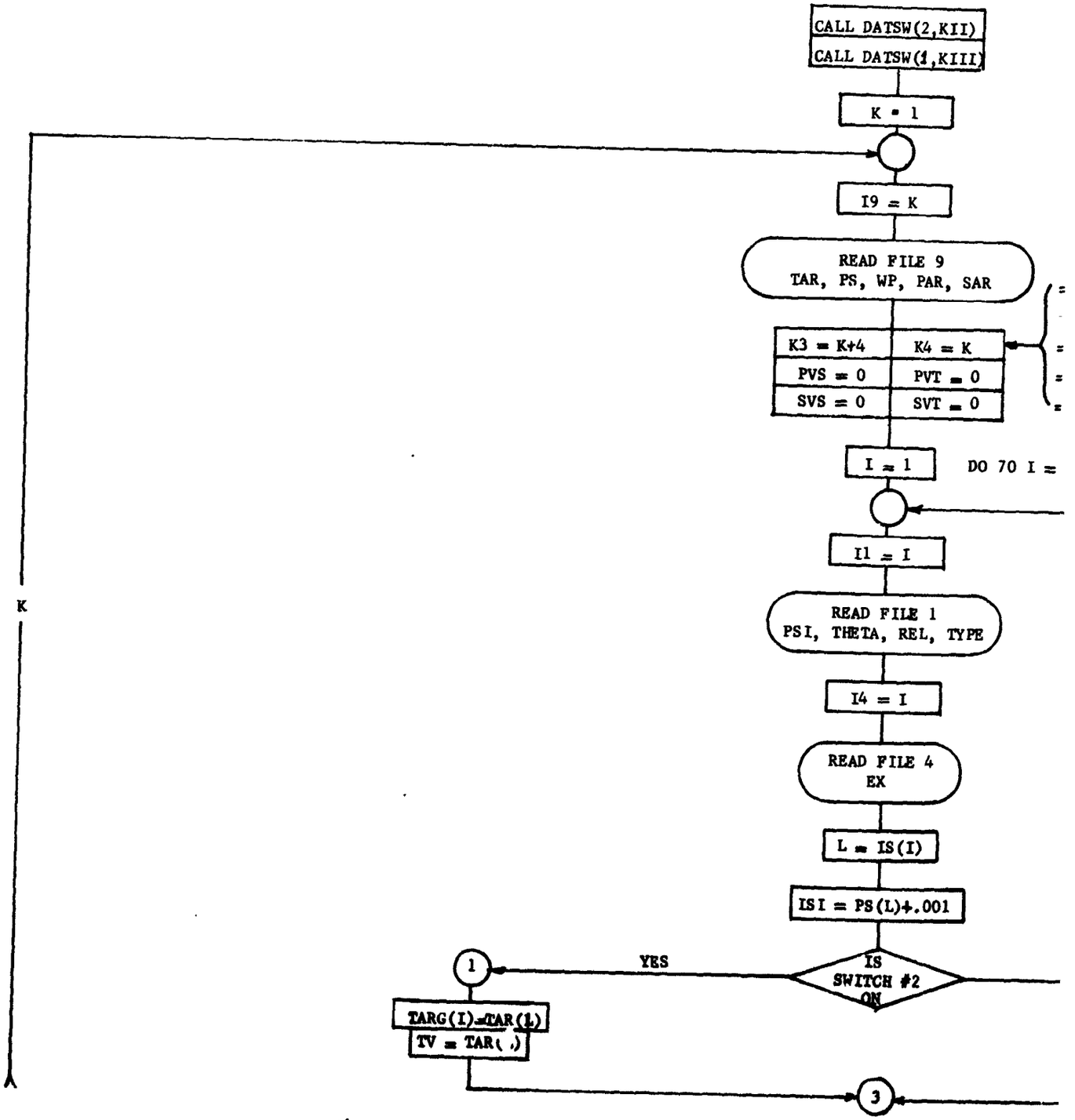
Fig. E-1 (cont)
Sheet 17

FOLDOUT FRAME

(cont)

t 17

FOLDOUT FRAME 2



FOLDOUT FRAME

RU CAL 6

DO 95 K = 1, 4 for CAL 2
DO 95 K = 5, 8 for CAL 3
DO 95 K = 9, 12 for CAL 4
DO 95 K = 13, 17 for CAL 5
DO 95 K = 18, 22 for CAL 6

AR
= K for CAL 2
= K-4 for CAL 3
= K-8 for CAL 4
= K-12 for CAL 5
= K-17 for CAL 6

DO 70 I = 1, II

PE

NO

2

CALL TAV1(ISI,K,PSI,THETA,TV)

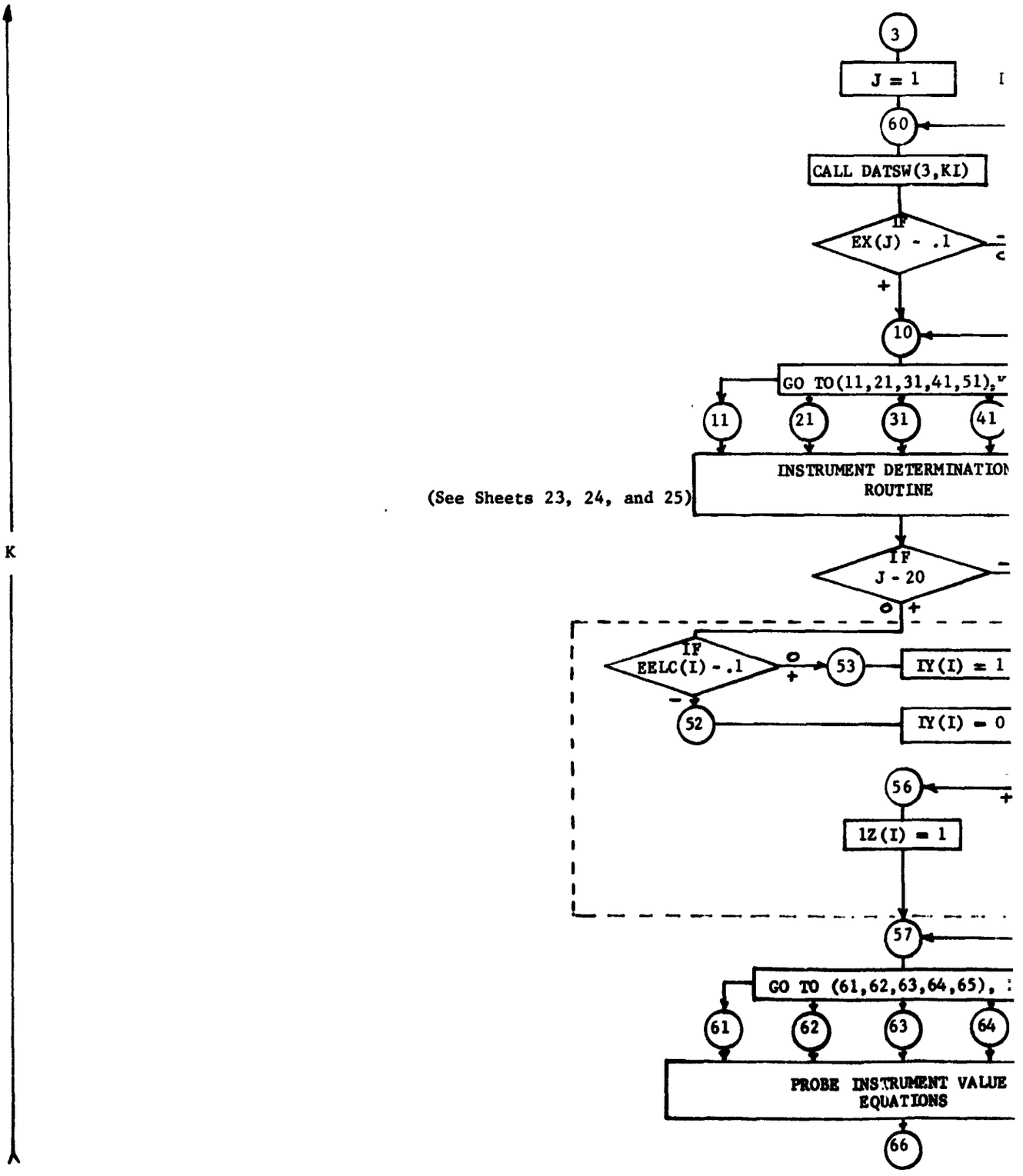
TARG(I)= TV

Target Value Option

I

Fig. E-1 (cont)

FOLDOUT FRAME 2 Sheet 18



FOLDOUT FRAME

2 THRU CAL 6

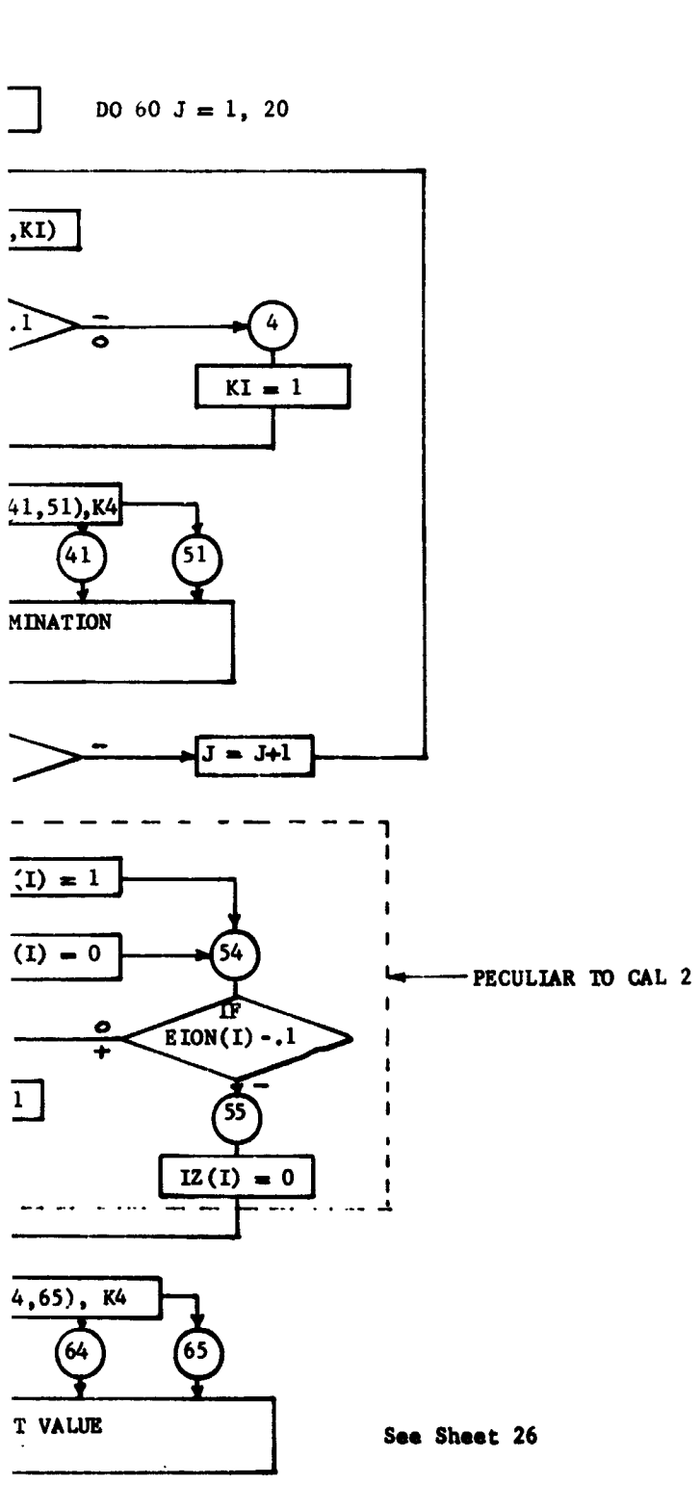
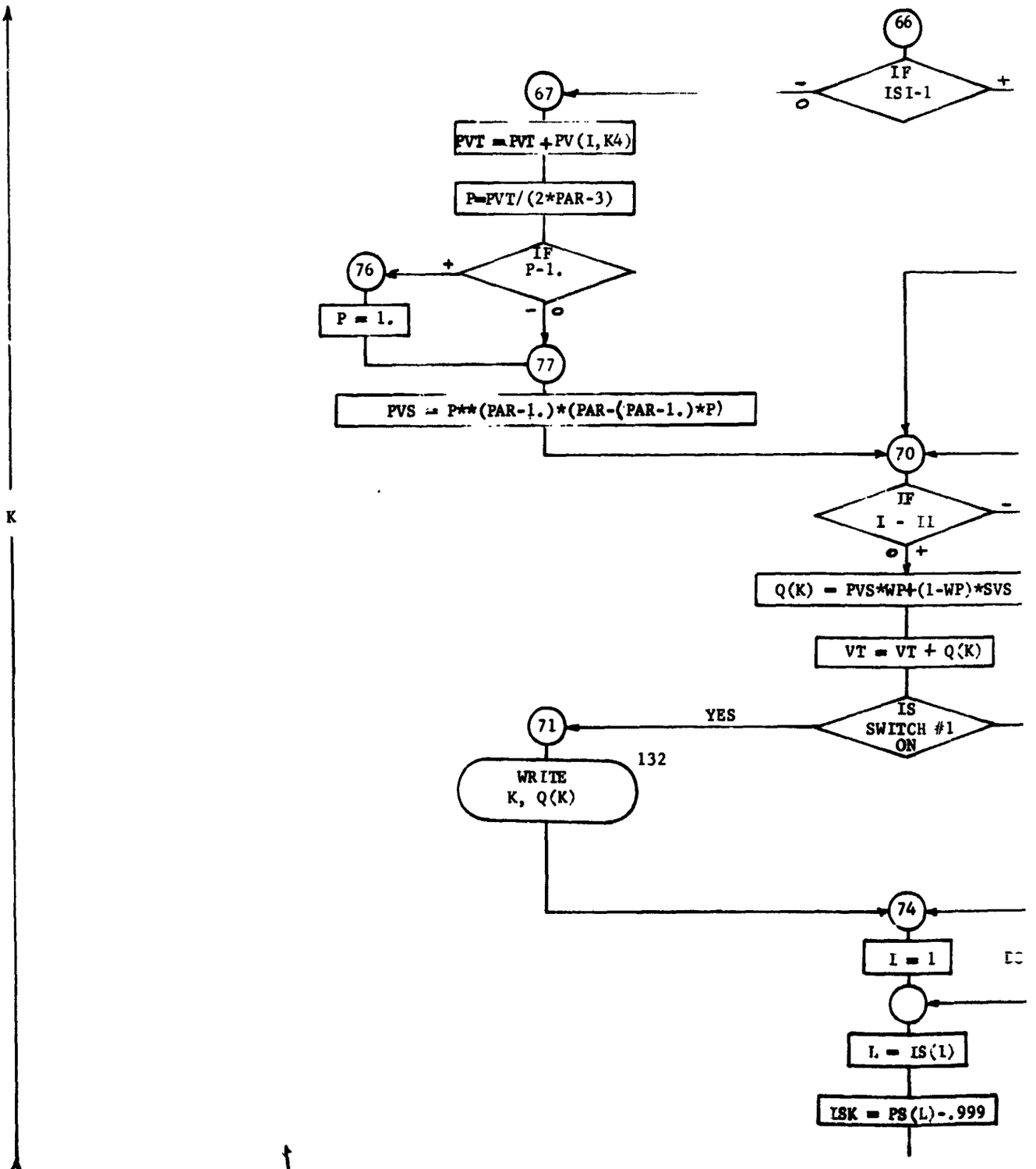




Fig. E-1 (cont)

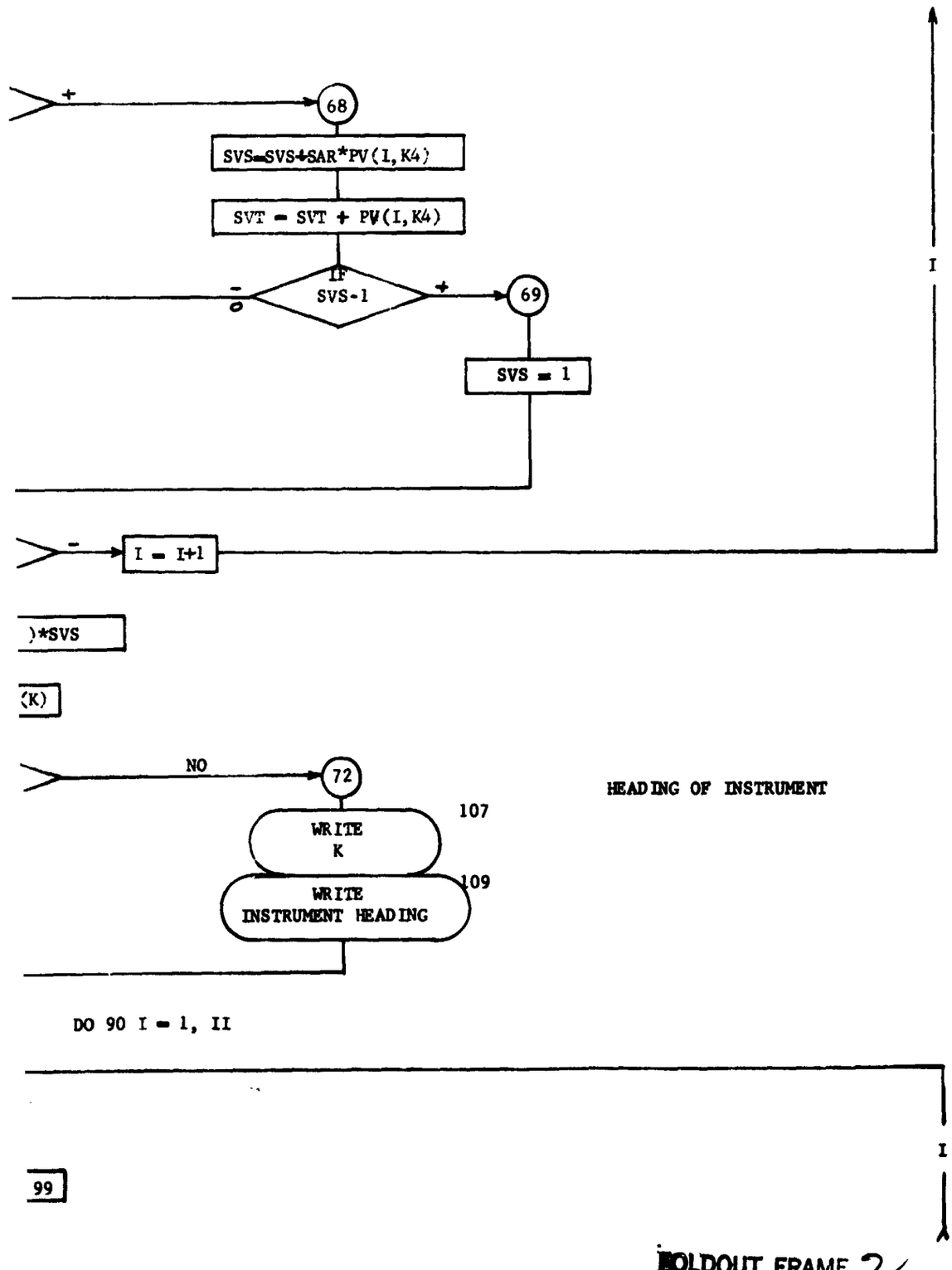
BOLDOUT FRAME

SUBROUTINE CAL 2 THRU CA



FOLDOUT FRAME

:HRU CAL 6

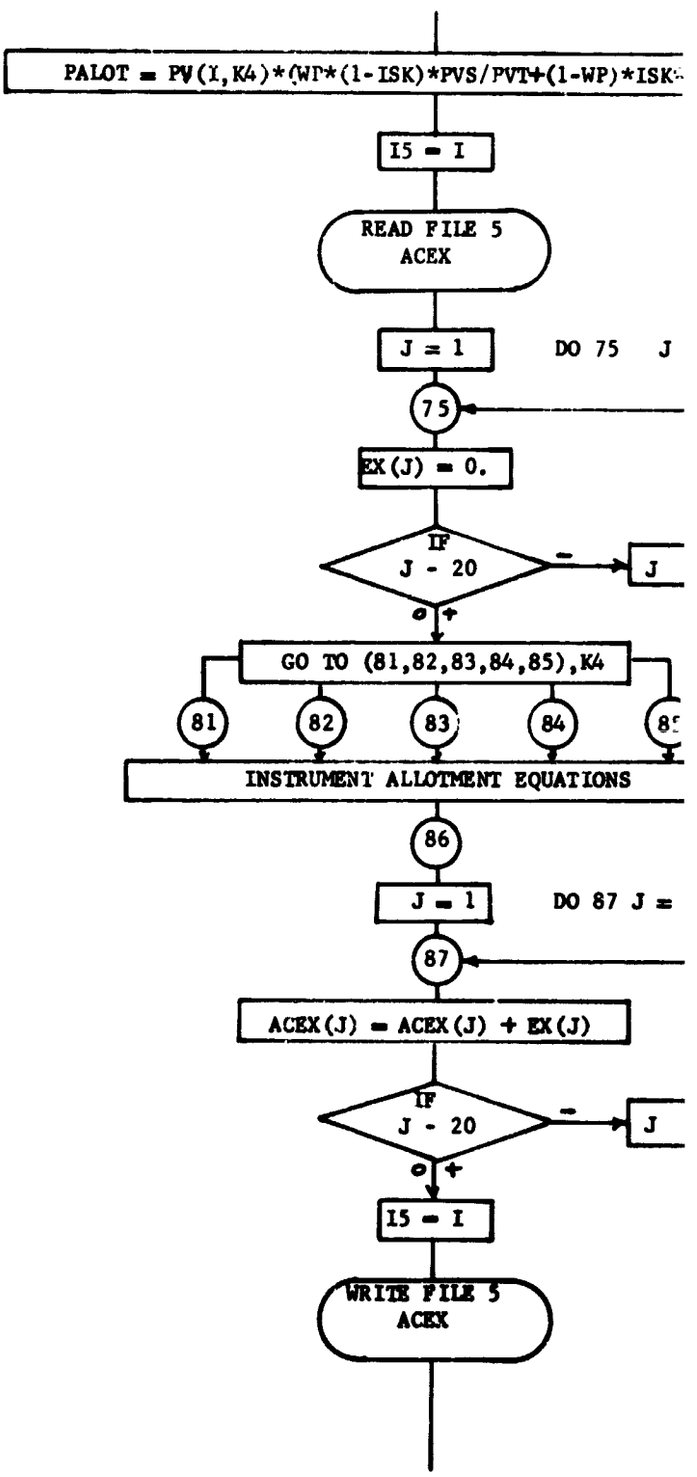


FOLDOUT FRAME 2

Fig. E-2 (cont)

Sheet 20

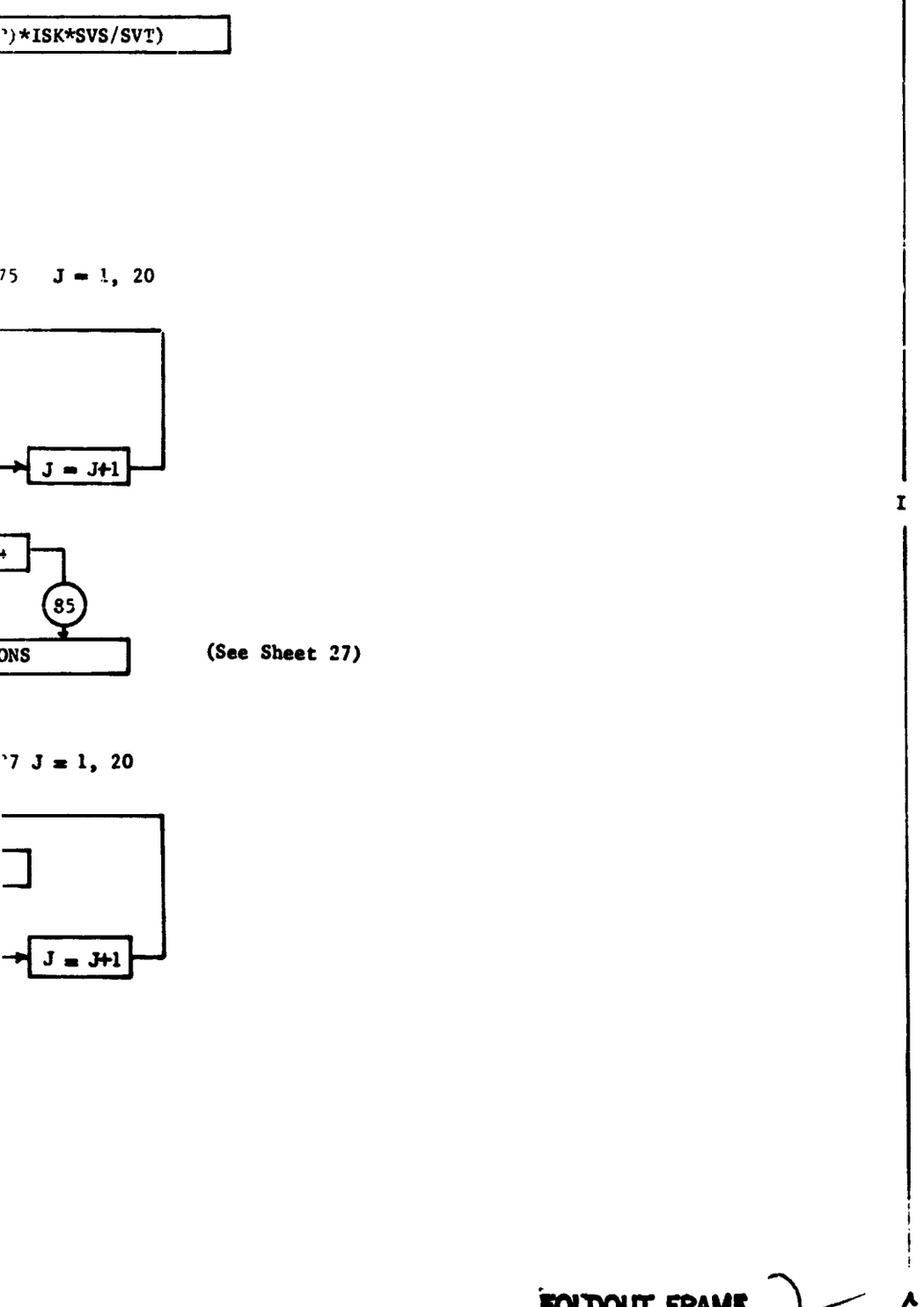
SUBROUTINES CAL 2 THRU CAL 6



K

FOLDOUT FRAME

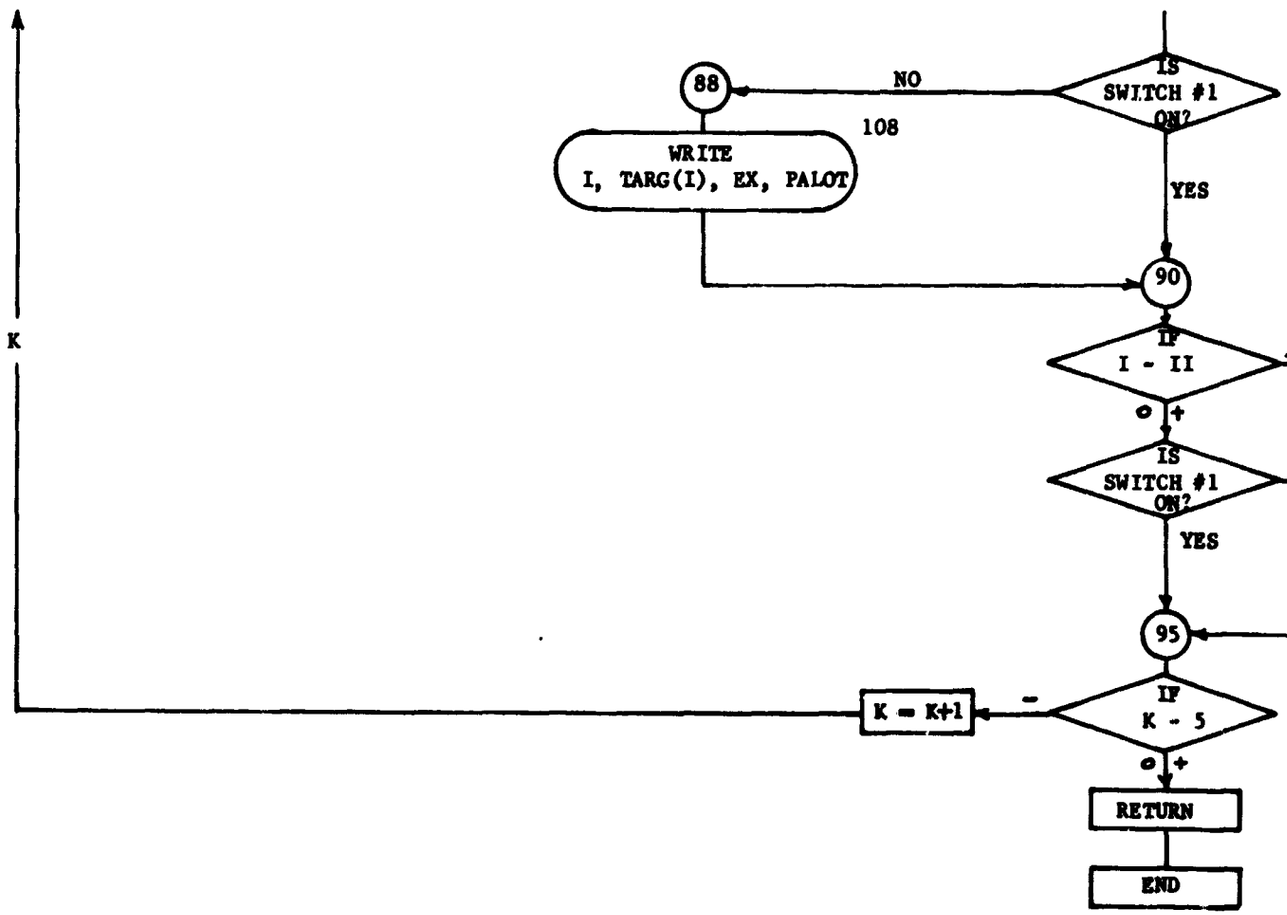
L 6



FOLDOUT FRAME

Fig. E-1 (cont)

Sheet 21



FOLDOUT FRAME

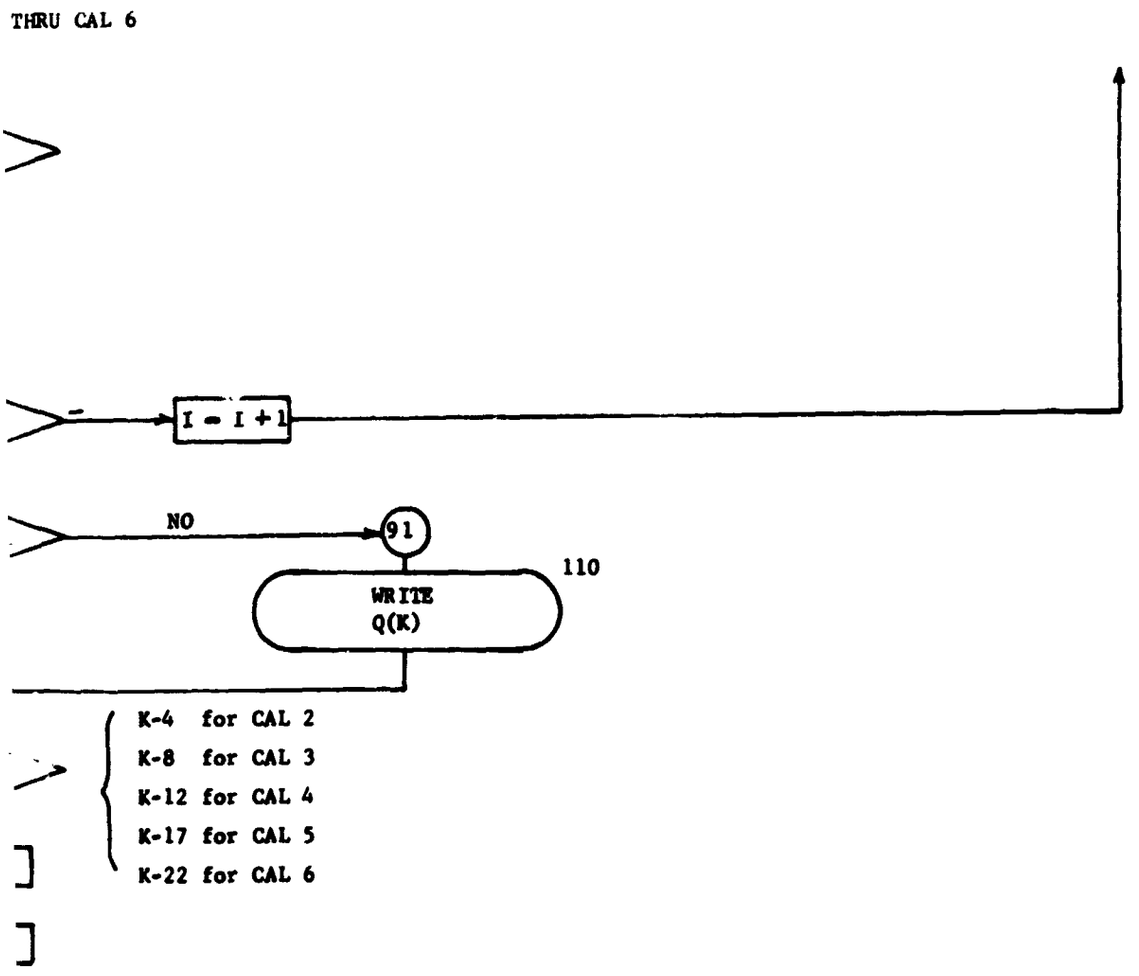
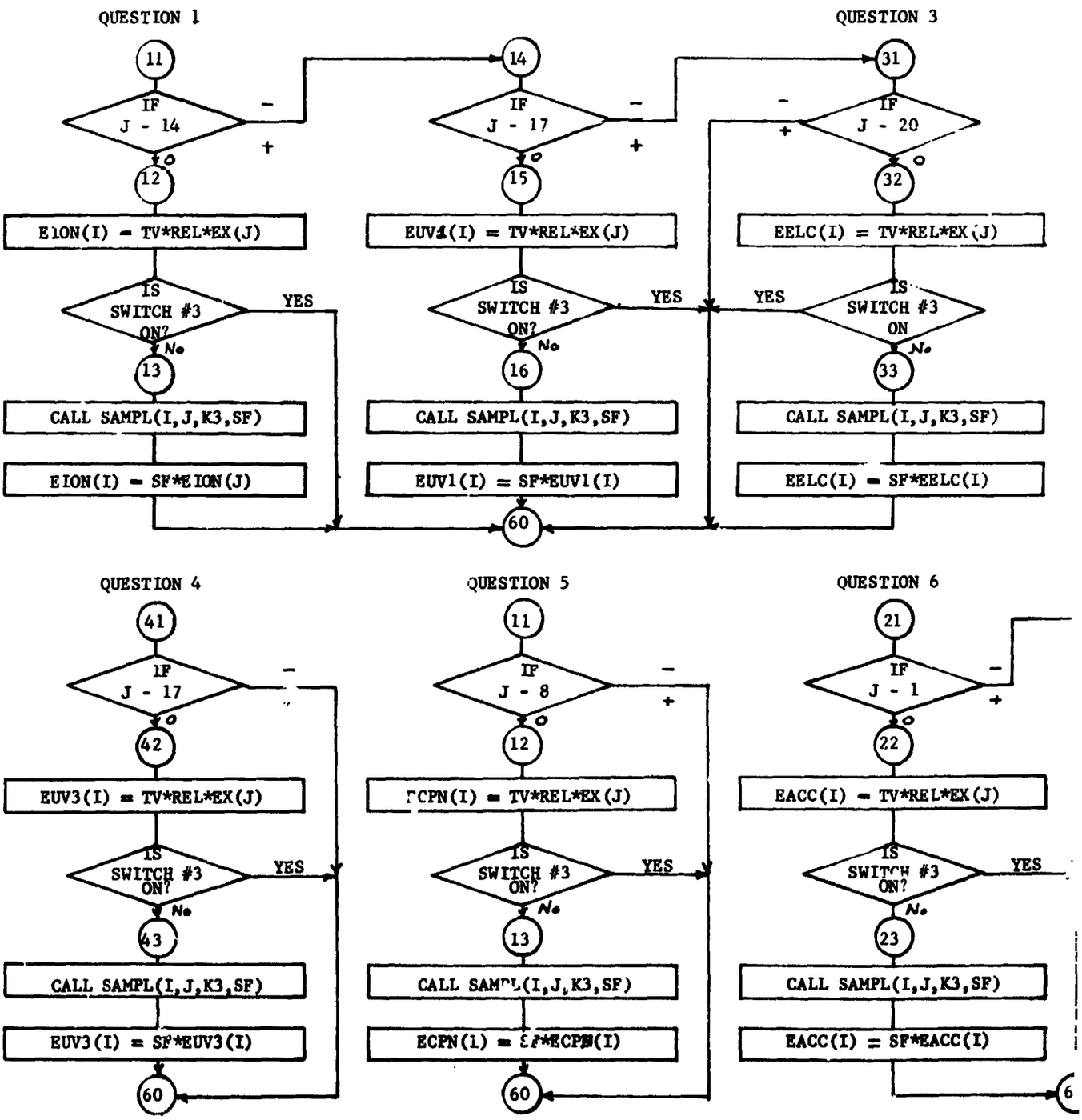


Fig. E-1 (cont)
Sheet 22

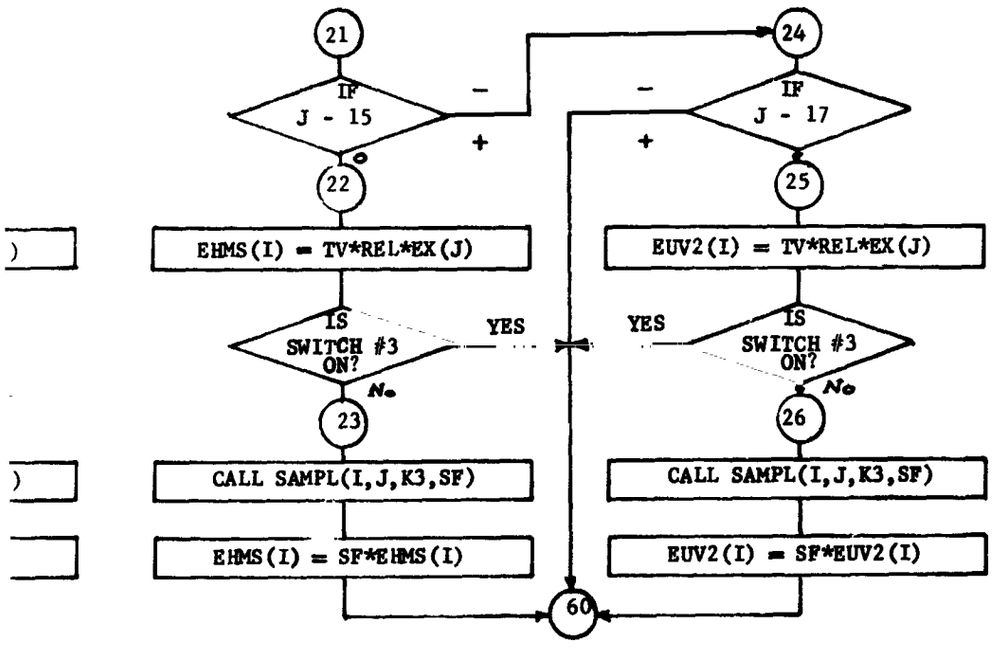
DEFECTIVE ERASURE



FOLDOUT FRAME

CAL 6

QUESTION 2



QUESTION 7

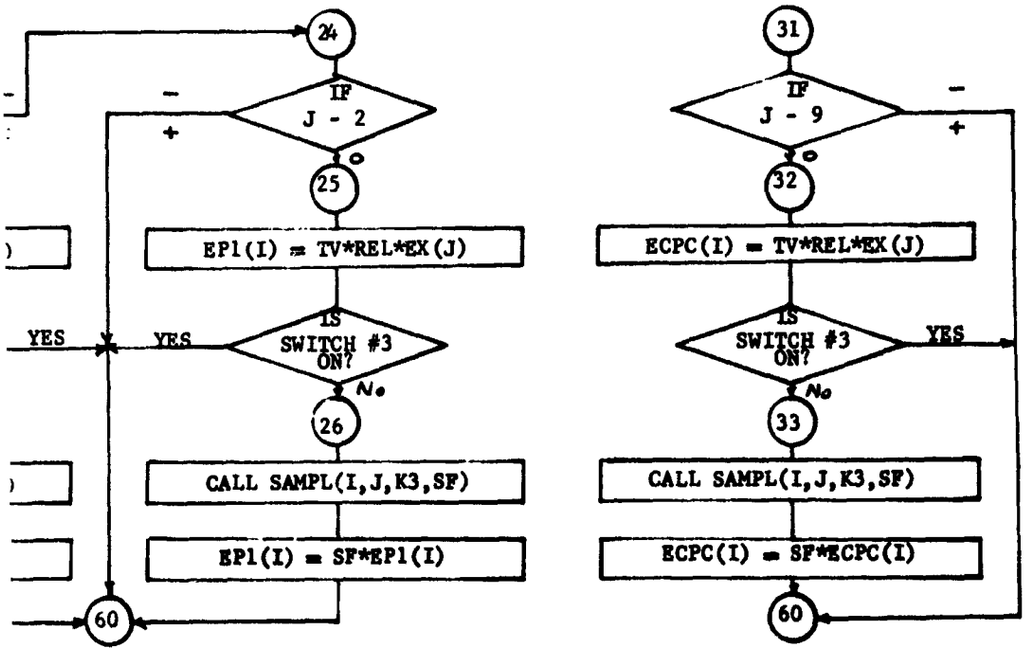
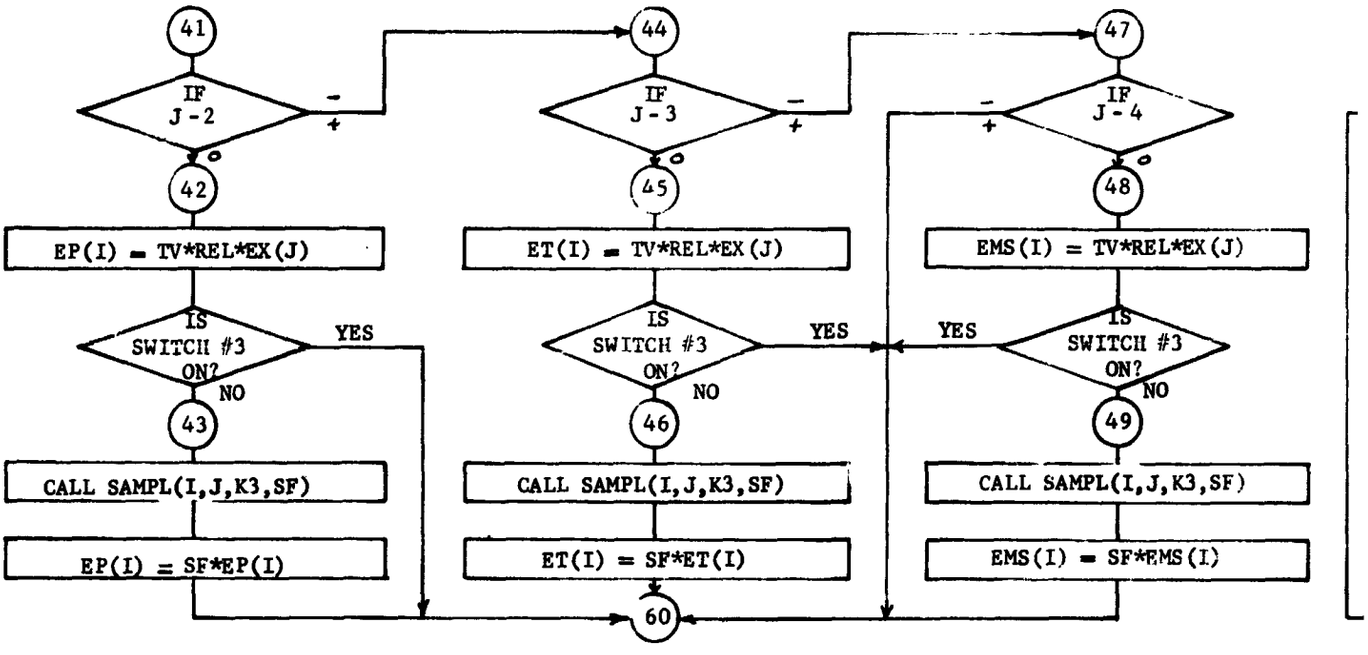


Fig. E-1 (cont)

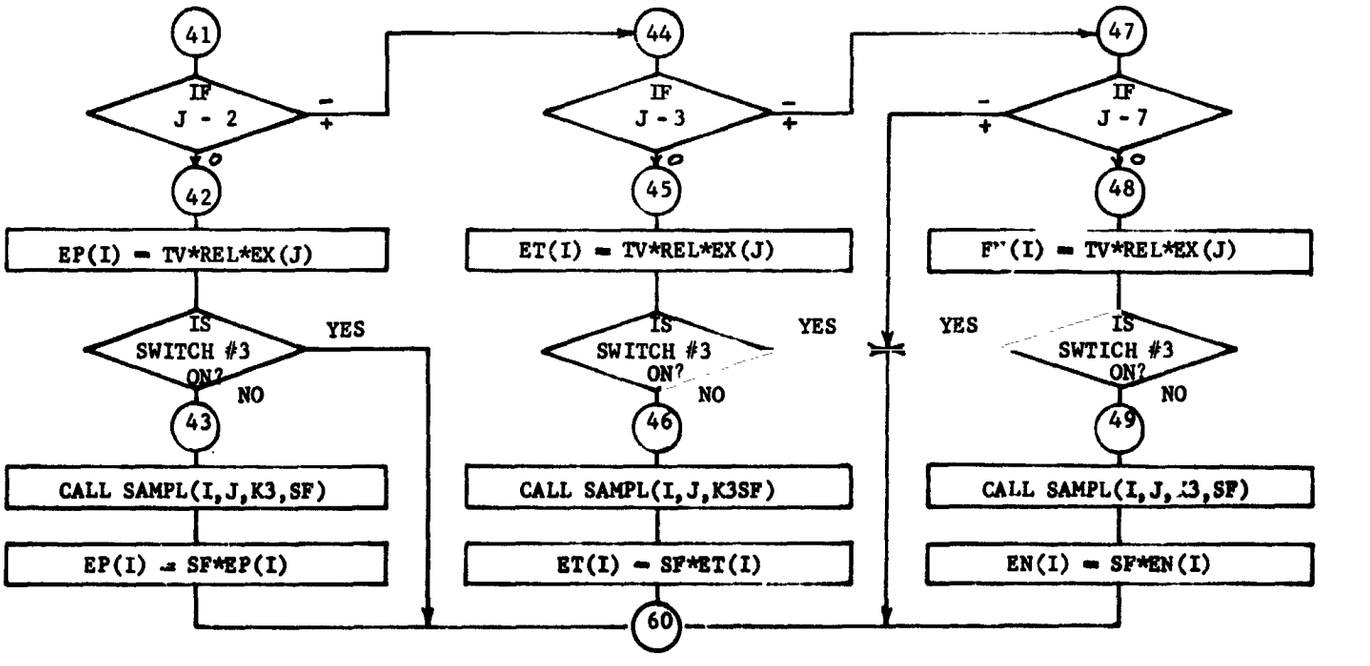
Sheet 23

BOLDOUT FRAME

QUESTION 8



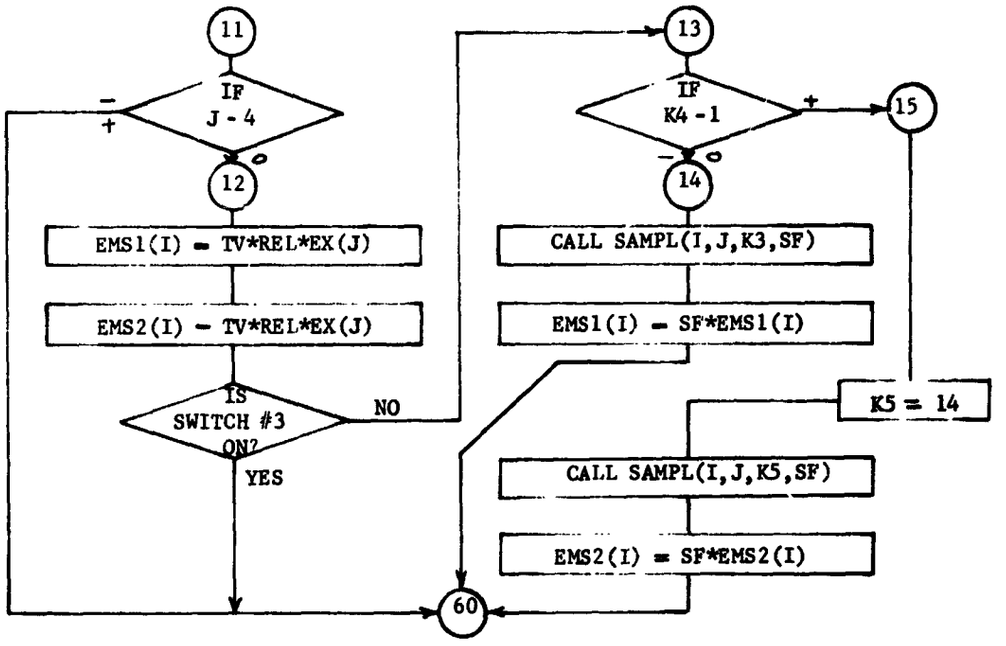
QUESTION 12



BOLDOUT FRAME

CAL 6

QUESTION 9, 10, 11



QUESTION 13

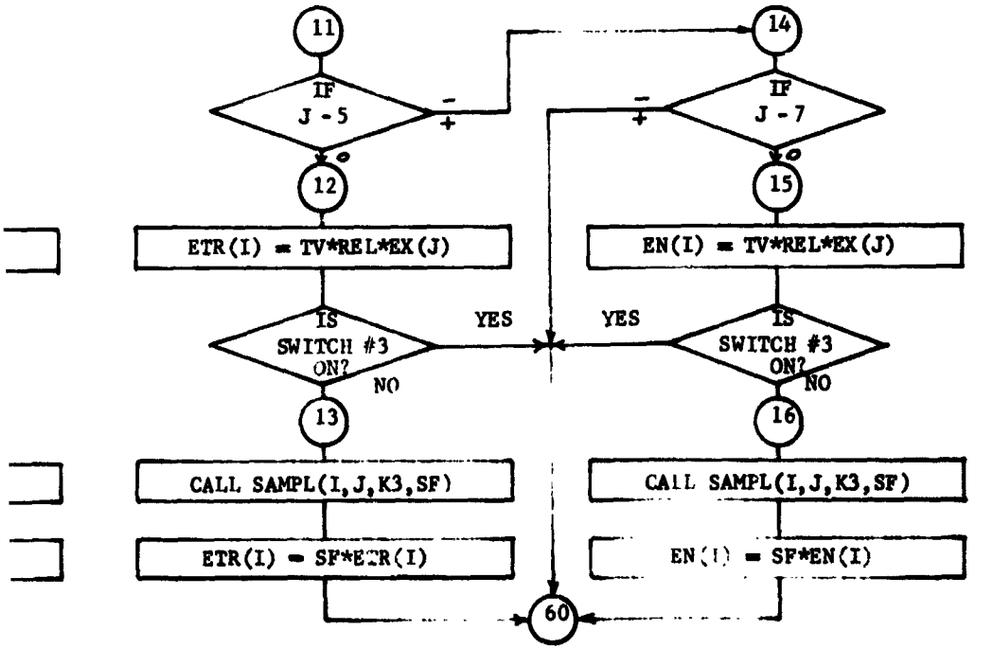
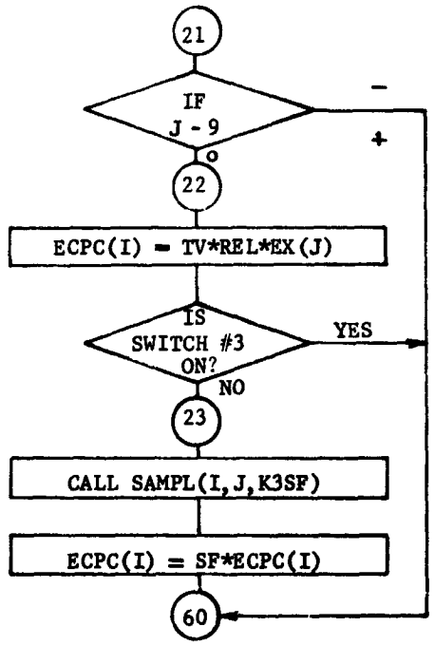


Fig. E-1 (cont)

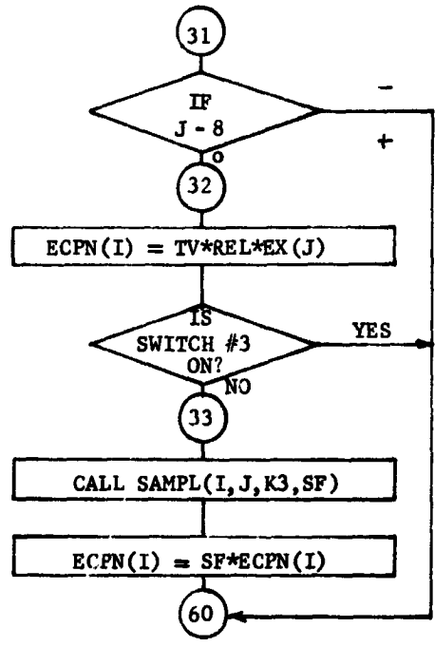
Sheet 24

FOLDOUT FRAME 2

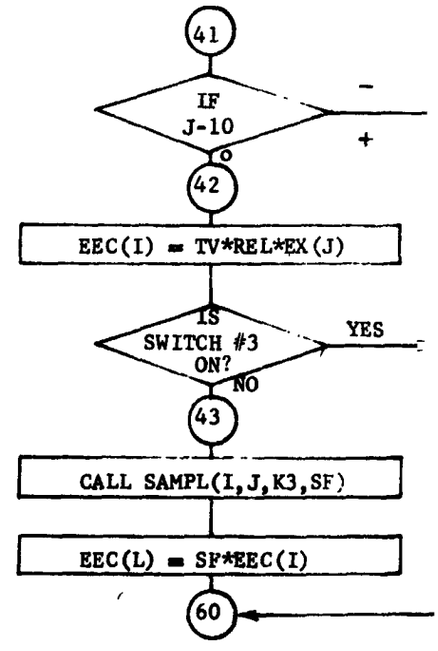
QUESTION 14



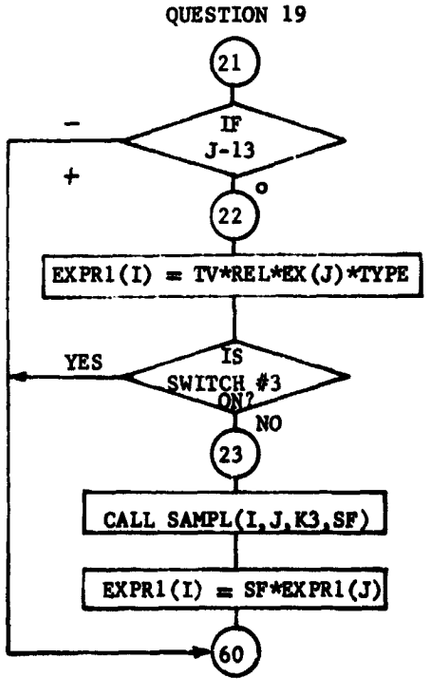
QUESTION 15



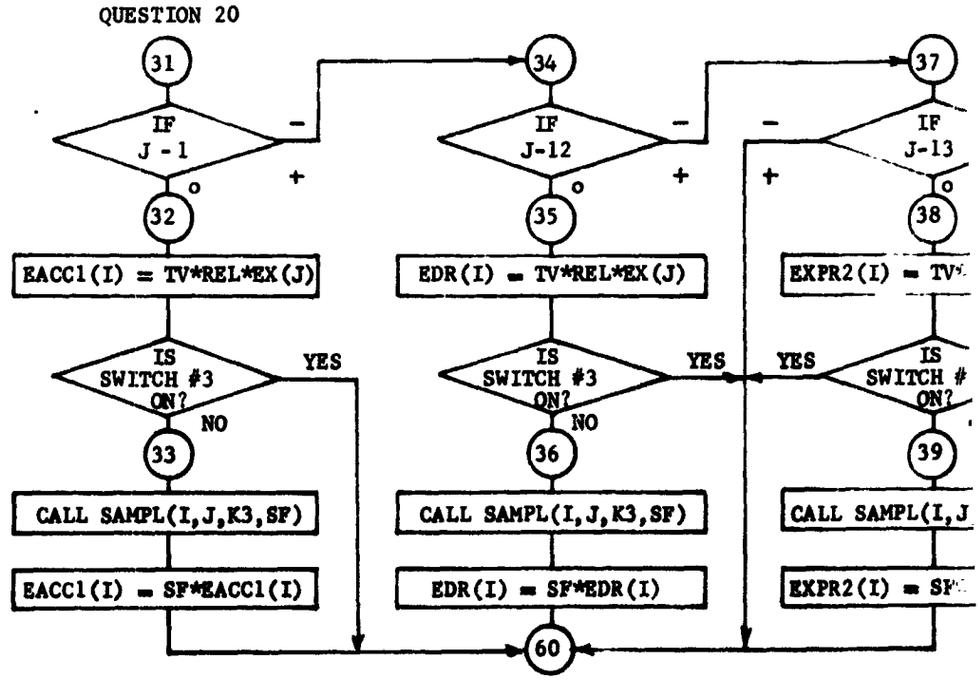
QUESTION 16



QUESTION 19



QUESTION 20



BOLDOUT FRAME

CAL 6

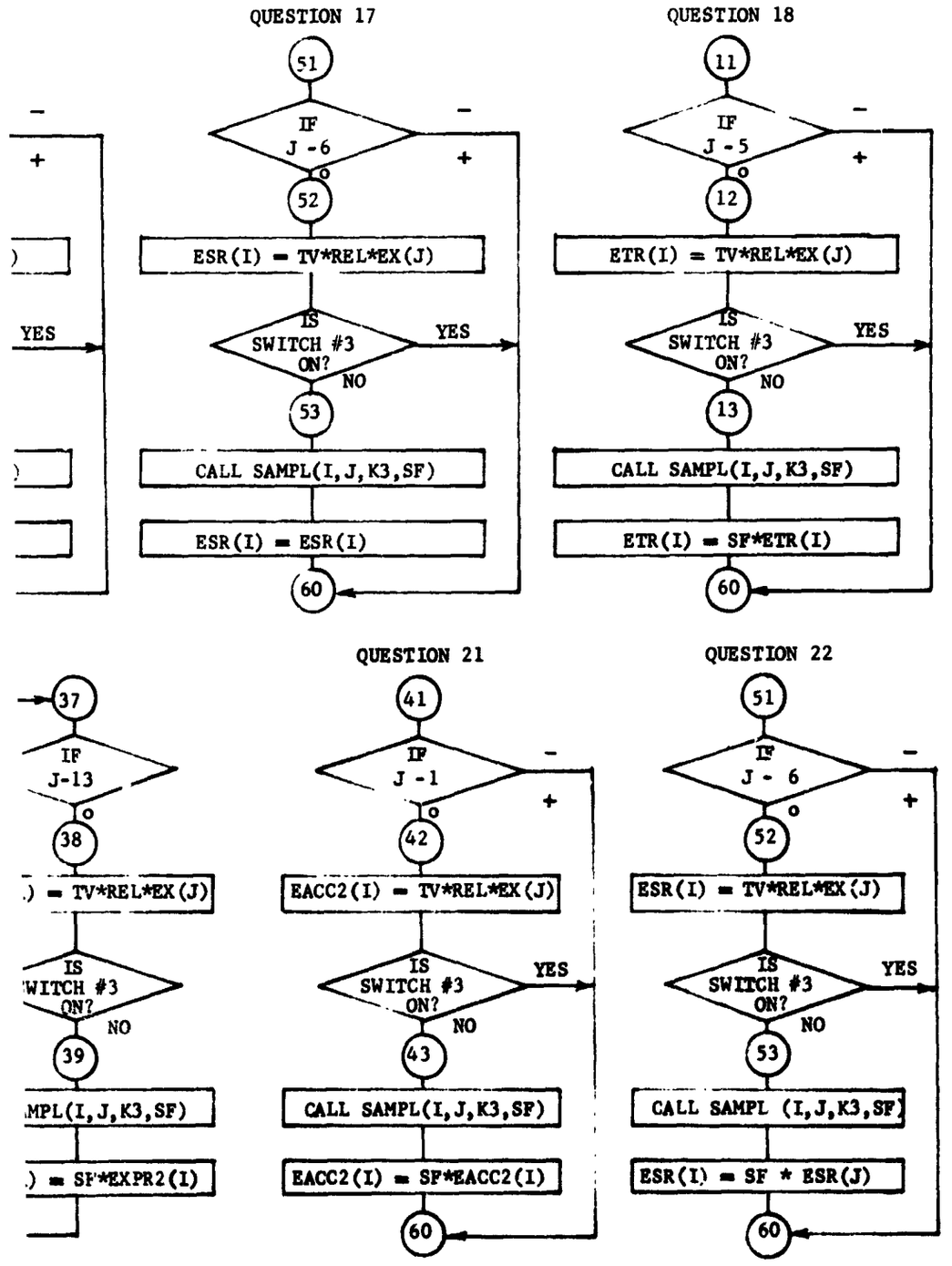
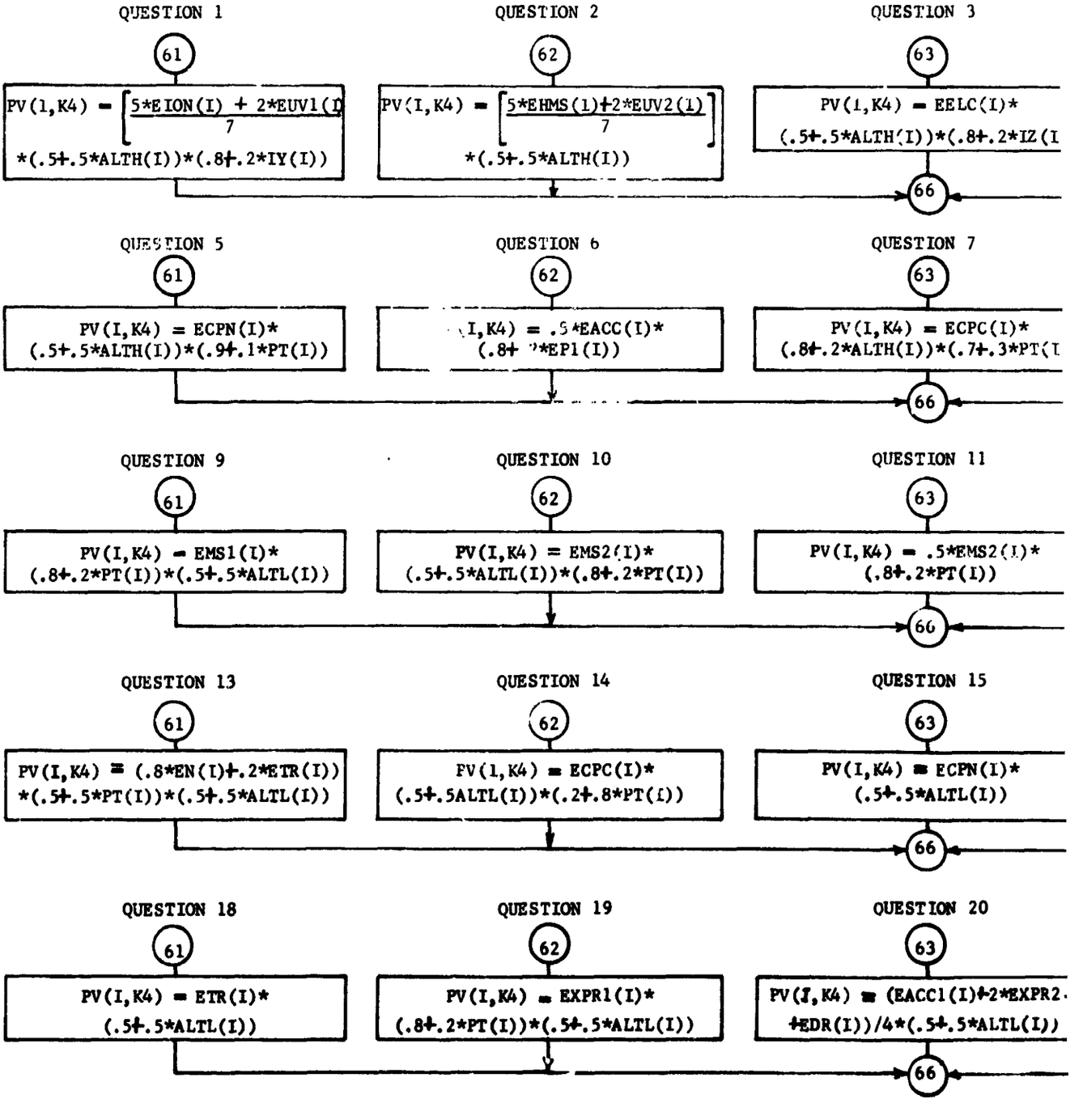


Fig. E-1 (cont)

Sheet 25
FOLDOUT FRAME 2



FOLDOUT FRAME

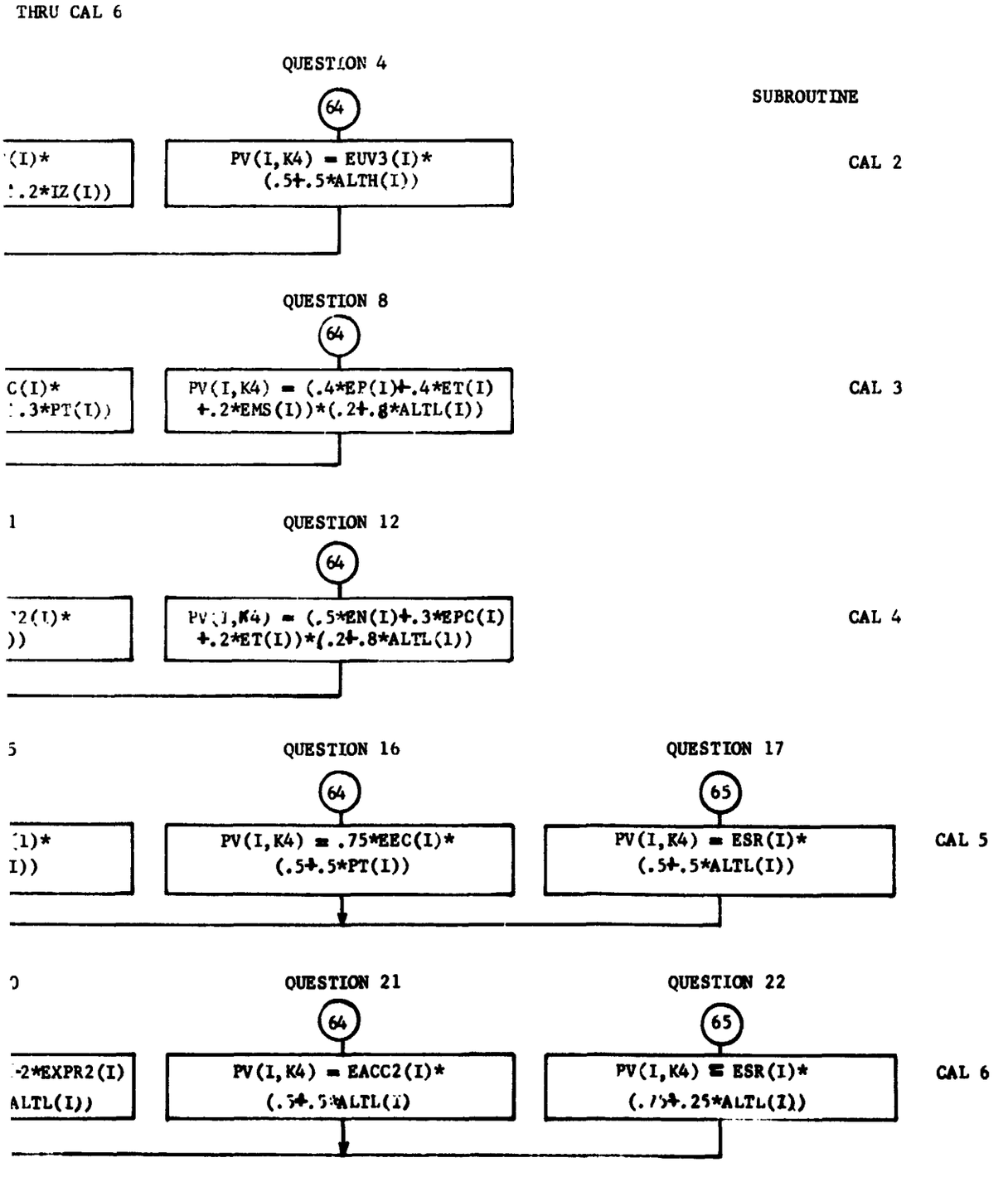
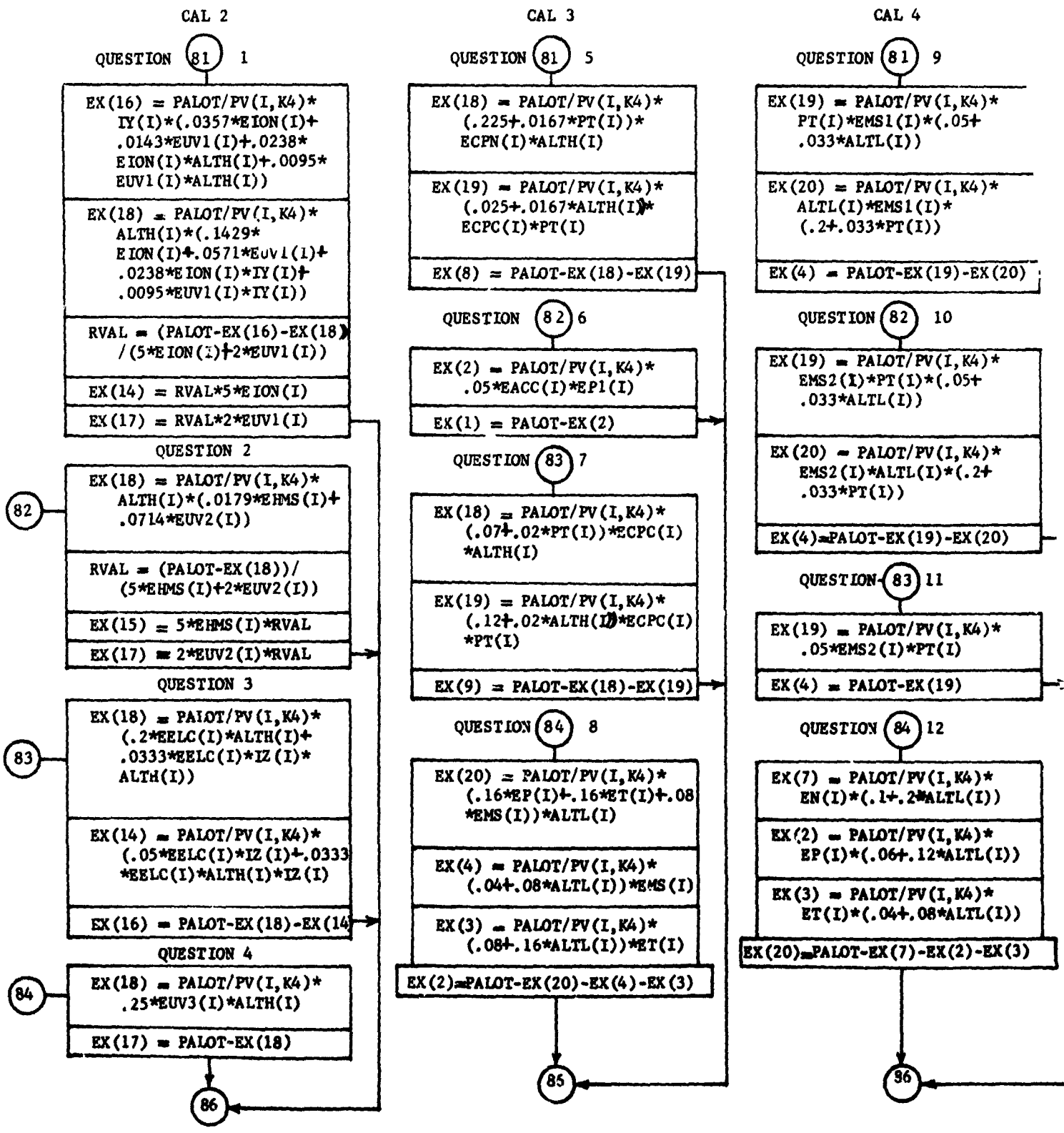


Fig. E-1 (cont)
Sheet 26

FOLDOUT FRAME 2

SUBROUTINES CAL 2 THRU CAL



FOLDOUT FRAME

CAL 6

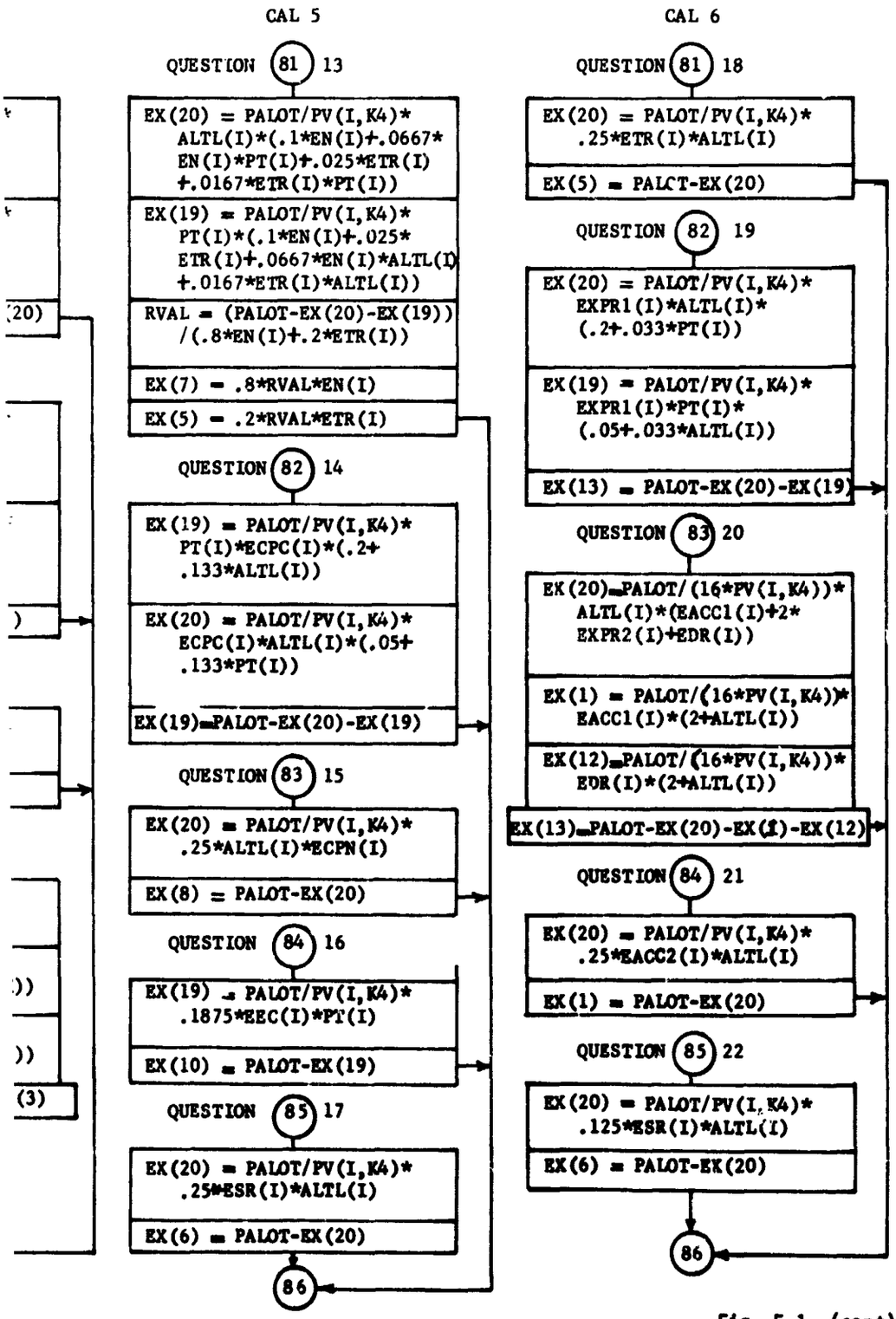
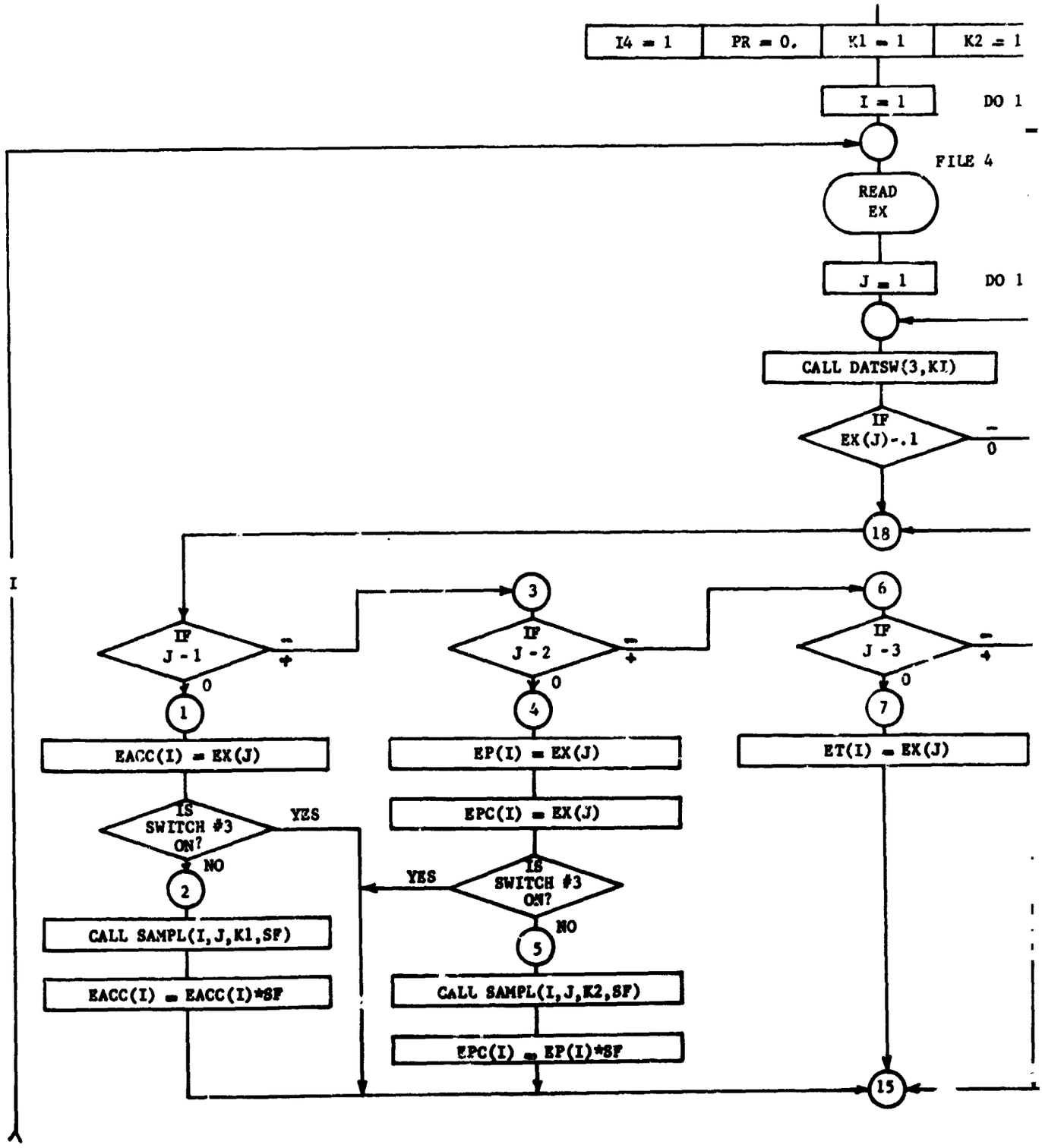


Fig. E-1 (cont)
Sheet 27

FOLDOUT FRAME

CALCULATION SUBROUTINE

CAL 7



FOLDOUT FRAME 1

SROUTINE

K2 = 1 | K3 = 3

DO 16 I = 1, II

FILE 4

DO 15 J = 1, 20

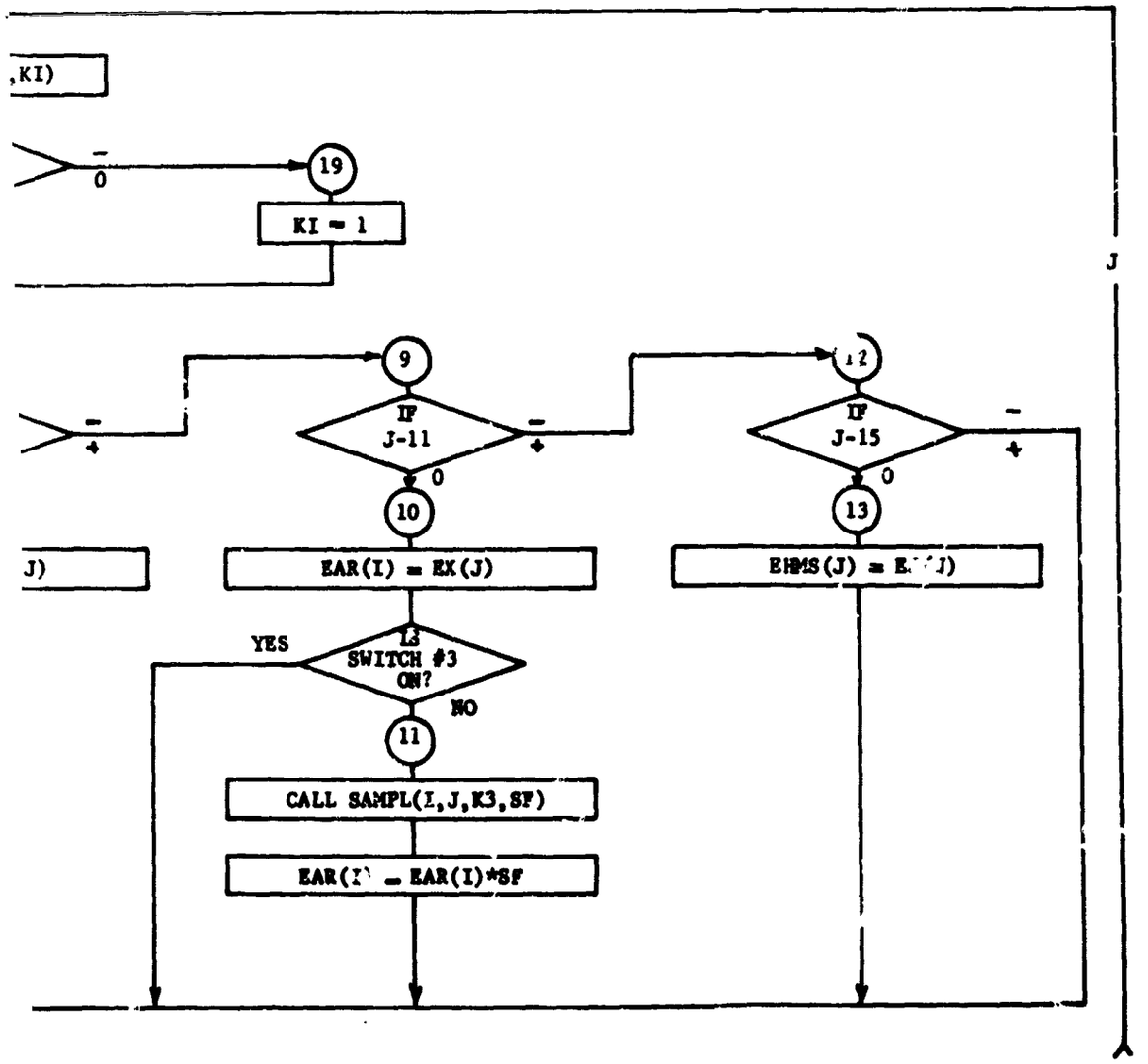


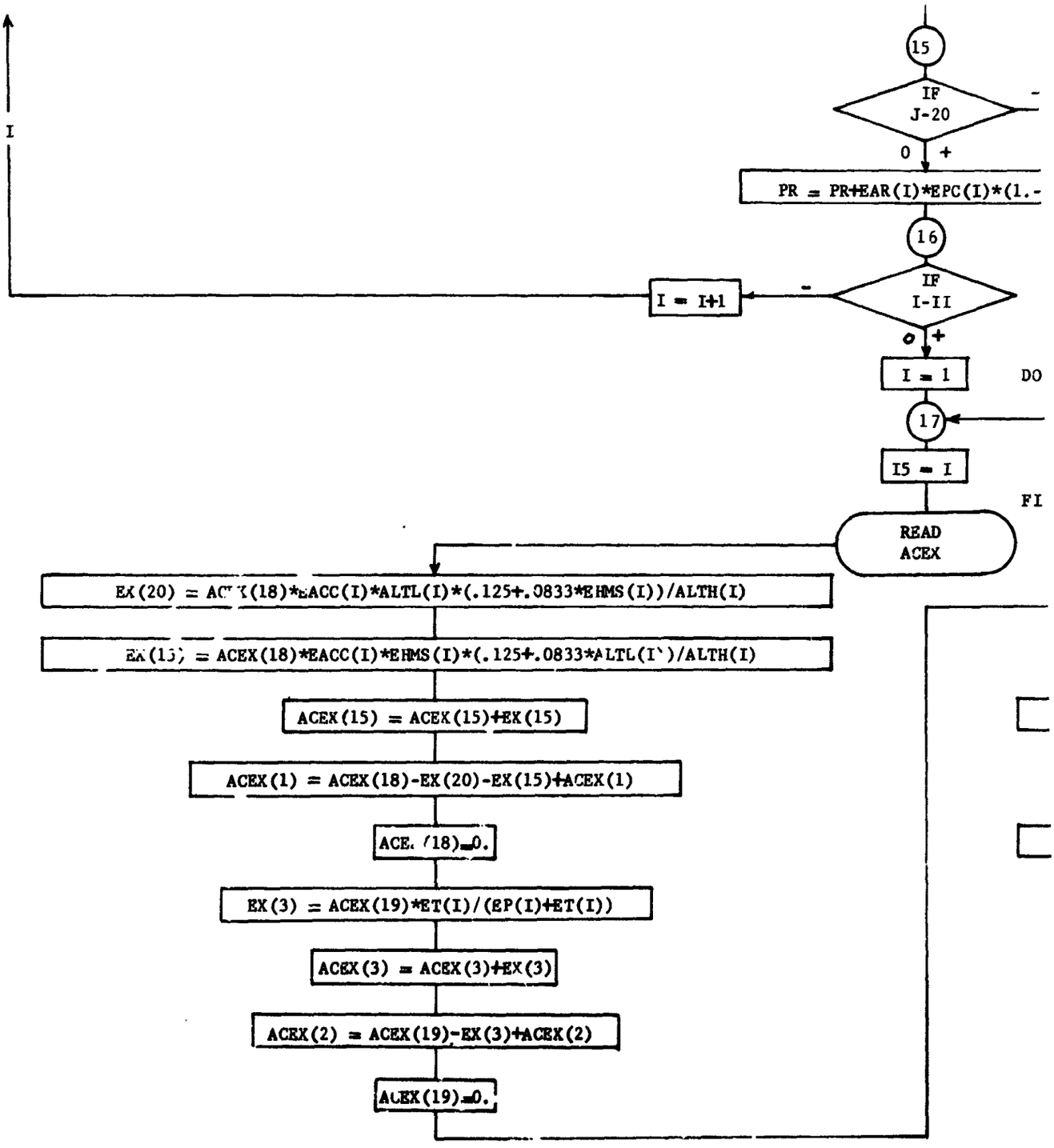
Fig. E-1 (cont)

FOLDOUT FRAME 2

Sheet 28

CALCULATION SUBROUTI

CAL 7



FOLDOUT FRAME

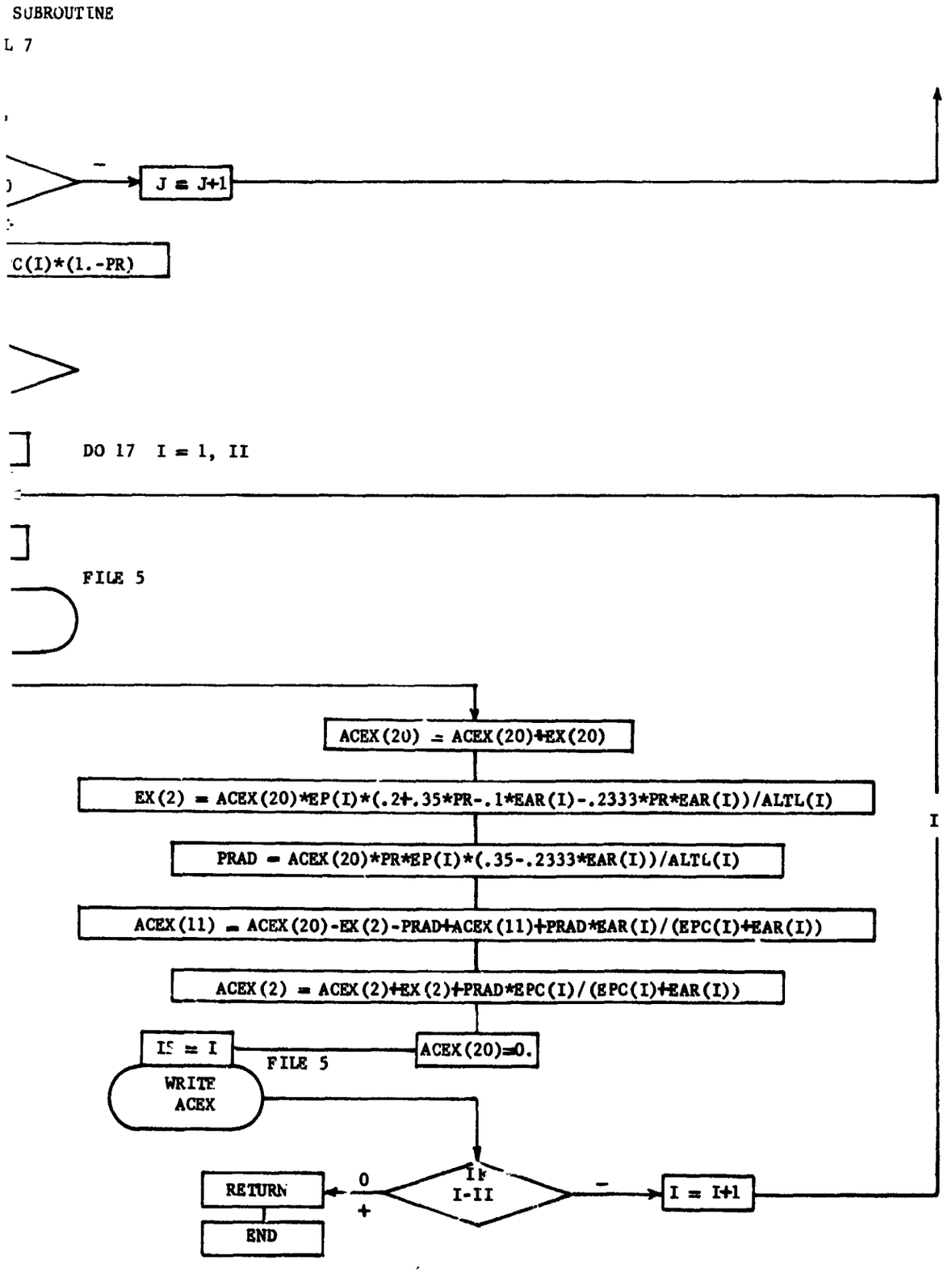


Fig. E-1 (concl)
Sheet 29

FOLDOUT FRAME 2

Table E-2 Symbol Chart

Symbol	Definition	Program Usage				
		MISEL	SAMPL	TAV1	CAL1/7	CAL2/6
A	Cosine of Entry Site Latitude	X				
ACEX(J)	Accumulated Value of the jth instrument		X			
AJ1J	Number of Points in Cumulative Value Profile ($\leq$10)		X			
AJ2J	Number of Points in Required Radius List ($\leq$5)		X			
AL	Number of Points in Design Measurement List ($\leq$4) = LL	X				
ALAT	Entry Site Latitude	X				
ALONG	Entry Site Longitude	X				
ALTh(I)	Value of High-Altitude Reference on i^{th} Probe				X	X
ALTL(I)	Value of Low-Altitude Reference on i^{th} Probe				X	X
AM	Number of Points in Descent Time Profile ($\leq$20)	X				
B	Cosine of Entry Site Longitude	X				
BS(L)	Remarks or Title: 40 Characters for Mission Title, 28 Characters for Probe or Instrument Title	X				
C	Sine of the Absolute Value of Entry Site Longitude	X				
CAL1-7	Calculation Subroutines 1 thru 7	X			X	X
CV(J1)	$J1^{th}$ Value in Cumulative Value Profile		X			
D	A*B = Cosine of PSI	X				
DH(K2)	Delta Radius (km) in Required Radius List		X			
DT(L)	L^{th} Time Interval (sec) between Samples in Design Measurement List	X	X			
E	Cosine of Latitude * Sine of Longitude	X				
EACC(I)	Accelerometer Instrument Value Q_6				X	X
EACC1(I)	Accelerometer Instrument Value Q_{20}					X
EACC2(I)	Accelerometer Instrument Value Q_{21}					X
EAR(I)	Altitude Radar Instrument Value (Altitude Reference)				X	
ECPC(I)	Cloud Composition Instrument Value Q_7 Q_{14}				X	
ECPN(I)	Cloud Particle Number, Density and Size Q_5 Q_{15}				X	
EDR(I)	Drift Radar Instrument Value Q_{20}					X
EEC(I)	Evaporimeter/Condensimeter Value Q_{16}				X	
EELC(I)	Electron Density and Temperature Value Q_1 Q_3				X	
EHMS(I)	High-Altitude Mass Spectrometer Value Q_2				X	X
EION(I)	Ion Mass Spectrometer Instrument Value Q_1					X
EMS(I)	Mass Spectrometer Instrument Value Q_8					X
EMS1(I)	Mass Spectrometer Instrument Value Q_9					X
EMS2(I)	Mass Spectrometer Instrument Value Q_{10} Q_{11}					X
EN(I)	Nephelometer Instrument Value Q_{12} Q_{13}					X
EP(I)	Pressure Gauge Instrument Value Q_8 Q_{12} (Altitude Reference)				X	X

Table E-2 (cont)

Symbol	Definition	Program Usage				
		MISEL	SAMPL	TAV1	CAL1/7	CAL2/6
EPC(I)	Pressure Gauge Instrument Value (Altitude Reference)				X	
EP1(I)	Pressure Gauge Instrument Value $Q_{\_}$					X
ESR(I)	Solar Radiometer Instrument Value Q_{1} $Q_{\_}$					X
ET(I)	Temperature Gauge Instrument Value $Q_{\_}$ $Q_{1\_}$				X	X
ETR(I)	Thermal Radiometer Instrument Value Q_{13} Q_{18}					X
EUV1(I)	UV Photometer Instrument Value Q_{1}					X
EUV2(I)	UV Photometer Instrument Value $Q_{\_}$					X
EUV3(I)	UV Photometer Instrument Value $Q_{\_}$					X
EX(J)	Value Index for j^{th} Instrument	X				
EXPR1(I)	Transponder Instrument Value Q_{19}					X
EXPR2(I)	Transponder Instrument Value Q_{20}					X
H(L)	Radius (km) at which an Instrument Either Starts, Stops, or Changes Its Sampling Rate	X	X			
I	Probe Index	X	X		X	X
I	Target Type Index: ISI = 1 (Primary); ISI = 2 (Secondary)			X		
II	Number of Probes in Mission	X			X	X
IN	Index Number of Probe Affected by Configuration Change	X				
IS(I)	Target Zone Index for i^{th} Probe: 1 = Subsolar; 2 = Polar; 3 = Evening Terminator 4 = Morning Terminator 5 = Antisolar	X				X
ISI	Target Type Index: 1 = Primary; 2 = Secondary			X		X
ISK	Target Type Binary: 0 = Primary; 1 = Secondary					X
IT	Number of Probes in Mission	X				
IY(I)	= 1 when EELC(I) = 0.1					X
IZ(I)	= 1 when EION(I) = 0.1					X
I1	Data File Record Index	X				
I2	Data File Record Index	X	X			
I3	Data File Record Index	X	X			
I4	Data File Record Index	X			X	X
I5	Data File Record Index	X			X	X
I6	Data File Record Index		X			
I7	Data File Record Index		X			
I8	Data File Record Index			X		
I9	Data File Record Index					X

Table E-2 (cont)

Symbol	Definition	Program Usage				
		MISEL	SAMPL	TAV1	CAL1/7	CAL2/6
J	Instrument Index: 1 = Accelerometer; 2 = Pressure Sensor; 3 = Temperature Sensor; 4 = Mass Spectrometer 5 = Thermal Radiometer 6 = Solar Radiometer; 7 = Nephelometer; 8 = Cloud Particle Number, Density and Size; 9 = Cloud Particle Composition; 10 = Evaporimeter/Condensimeter; 11 = Altitude Radar; 12 = Drift Radar; 13 = Transponder; 14 = Ion Mass Spectrometer; 15 = High-Altitude Mass Spectrometer; 16 = Electron Density and Temperature; 17 = UV Photometer; 18 = High-Altitude Reference; 19 = Point Reference; 20 = Low-Altitude Reference	X	X		X	X
JA	Number of Instruments Carried on Probe	X				
JJ(I)	Number of INstruments on i^{th} Probe	X				
JT	Numberical Index of Instruments	X				
J1	Index of Points in Cumulative Value Profile		X			
J2	Index of Points in Required Delta Radius List		X			
J1J	Number of Points in Cumulative Value Profile		X			
J2J	Number of Points in Required Delta Radius List		X			
K	Question Index - Question Number		X	X		X
KI	Sense Switch Indicators 5 (MISEL), 8 (SAMPL), and 3 (CAL1/7)	X	X		X	X
KII	Sense Switch Indicators 7 (MISEL), 6 (SAMPL), and 2 (CAL1/7)	X	X		X	X
KIII	Sense Switch Indicator 1					X
KIV	Sense Switch Indicator 4	X				
KIX	Sense Switch Indicator 9		X			
KSR	Index Controlling Use of Subroutines	X				
K1	Index of Cumulative Value (Also Number of Sampling Interval Ratios Averaged)		X			
K1	Question Index = 1 for Accelerometer				X	
K2	Question Index = 2 for Pressure Gauge				X	
K3	Question Index = 3 for Altitude Radar				X	
K4	Question Index = K in CAL 2 = K - 4 in CAL 3 = K - 8 in CAL 4 = K - 12 in CAL 5 = K - 17 in CAL 6					X
L	Index for Remarks	X				
L	Index for Design Measurement List	X	X			

Table E-2 (cont)

Symbol	Definition	Program Usage				
		MISEL	SAMPL	TAV1	CAL1/7	CAL2/6
L	Index for Target Value Curves			X		
L	Index Equal to IS(I) and Used for Target Zone Index for Variables PS and TAR					X
LL	Number of Points in Design Measurement List	X	X			
M	Index of Descent Time Profile Points	X	X			
MM	Number of Points in Descent Time Profile	X	X			
N	Index of Points in Cumulative Value Profile		X			
N	Number of Sampling Interval Ratios Averaged Less One		X			
NN	Number of Sampling Intervals from Radius where Ratio = 1.0 to End of Measurement Range		X			
P	Total Probe Value (when PAR = 2) Total Probe Value/3 (when PAR = 3)					X
PALOT	Value Allotted to Probe under Consideration					X
PAR	Primary Accumulation Rate					X
PR	Probability of at Least One Radar-Pressure Correlation				X	
PRAD	Value Allotted to Radar-Pressure Combination				X	
PS(L)	Target Type: 1 = Primary; 2 = Secondary					X
PSI	Angle of Entry from Subsolar Point (deg)	X		X		X
PT(I)	Pressure-Temperature Reference of ith Probe				X	X
PV(I,K)	Probe Instrument Value for i^{th} Probe with Regard to k^{th} Question					X
PVS	Special Summation of Probe Instrument Value					X
PVT	Total of Probe Instrument Value					X
Q(K)	Fraction of the Value Achieved for the kth Question					X
RATIO	PSI Interpolation Ratio in Target Value Curves			X		
REL	Reliability of Probe	X				X
RV	Total Value Achieved by Probe	X				
RZ(J2)	Radius in $J2^{th}$ Pair of Points in Required Delta Radius List		X			
SAR	Accumulation Rate for Secondary Targets					X
SF	Sampling Factor		X		X	X
SVS	Special Summation of Probe Instrument Values for Secondary Targets					X
SVT	Total of Probe Instrument Values for Secondary Targets					X
TAR(L)	Target Value for L^{th} Ideal Target Site					X
TARG(I)	Target Value for i^{th} Probe					X
TH	Trial Radius (km)		X			
THETA	Inclination Angle Measured Counterclockwise around Subsolar Point	X		X		X

Table E-2 (concl)

Symbol	Definition	Program Usage				
		MISEL	SAMPL	TAV1	CAL1/7	CAL2/6
TV	Target Value			X		X
TV1	Target Value for PSI Measured along Evening Terminator Great Circle			X		
TV2	Target Value for PSI Measured along Polar Great Circle			X		
TV3	Target Value for PSI Measured along Morning Terminator Great Circle			X		
TYPE	Probe type: = 0 for Descent Probes; = 1 for Balloon Probes	X				X
V(M)	M^{th} Value of Time (Log of Seconds) in Descent Time Profile	X				
VAC(K1)	$K1^{th}$ Value Interpolated in Cumulative Value Profile		X			
VAL	Sampling Interval Ratio		X			
VALP	Sampling Range Fraction		X			
VT	Total Mission Value	X				X
VX	Single-Point Sampling Interval Ratio		X			
WP	Fraction of Question Value from Primary Targets					X
WPSI(I,L)	Value of PSI in Target Value Curves			X		
WV1(I,L)	Target Value along Great Circle through Evening Terminator			X		
WV2(I,L)	Target Value along Great Circle through Pole			X		
WV3(I,L)	Target Value along Great Circle through Morning Terminator			X		
X(M)	M^{th} Value of Time (Log of Seconds) in Descent Time Profile		X			
XO	Log of Time in Seconds Corresponding to a Radius of TH in Descent Profile		X			
XOO	Log of Time after Sampling Time Interval		X			
Z(M)	M^{th} Radius in Descent Time Profile	X	X			
ZOO	Radius Corresponding to XOO in Descent Time Profile		X			
ZV(J1)	$J1^{th}$ Radius in Cumulative Value Profile		X			

The first step is the reading of the mission and probe input data shown on Sheet 3 and the transformation of the probe entry latitude and longitude into PSI and THETA on Sheets 4 and 5 (note that the important mission facts are stored in Temporary Files 1 and 2). On Sheet 6, the information on each instrument is read and stored in Temporary Files 3 and 4. Sheet 8 shows the routing through the seven calculation subroutines.

1. Determining Altitude and P-T References

The first step in computing the actual value is diagrammed on Sheet 16. This consists of a search for the five instruments (on the probe in question) which form the basis of the pressure-temperature reference and both the high- and low-altitude references. At least one of these references is used to obtain the question value for all questions except Question 6.

The pressure-temperature reference has a value of one for any probe that carries both a pressure sensor and a temperature sensor. The low-altitude reference is one with a perfectly performing altitude radar; but when there is a pressure gauge instead of a radar, the reference is 20%. This reference approaches 90% if a pressure gauge-altitude radar pair is found on any other mission probe.

The high-altitude reference is provided by an accelerometer carried onboard the probe, but may be reduced by a factor of 0.5 if there is no low-altitude reference to tie the accelerometer profile to the ground. The high altitude reference can also be reduced by a second 0.5 factor if there is no mass spectrometer aboard the probe to calibrate the accelerometer.

2. Determine the Instrument Value

Each of the calculation subroutines, CAL 2 thru CAL 6, which find the value achieved for each question, is basically similar, and the first step is to obtain an instrument value, EXXX. The

XXXs are the instrument initials; for example, EACC(I) is the instrument value of the accelerometer on the ith probe. The instrument value is a product of the probe reliability, probe target value, the instrument's sampling factor, and the instrument's value index, EX_j. The instrument index, EX_j, is normally set to 1 if the instrument is carried on the probe, and to zero if it is not. Values between zero and one are permissible to account for differences in instrument complexity. The probe reliability is also an input, but the sampling factor and target value must be calculated in the appropriate subroutine as discussed below. Sheet 15 of Fig. E-1 indicates an instrument determination routine in which the instrument value is obtained. The specific routines used for each question are diagrammed in Sheets 23 thru 25.

3. Determine the Value of the Probe's Instruments

Once the instrument values have been obtained for all the applicable instruments, these values are inserted in an instrument equation that provides the logical and functional relationships between the various instruments dealing with a specific question. Once this equation is evaluated, the result is the probe instrument value for the ith probe in regard to the kth question, $PV_{i,k}$. Sheet 26 of Fig. E-1 diagrams the probe instrument value equations for each of the 22 questions.

4. Summation of Probe Value

Several methods of summing the effects of multiple probes in answering science questions are required. In one kind of question, the answer is basically obtained from a single measurement, providing that the given measurement is perfectly made. With less than perfect sampling rates, less than ideal target sites, and less than perfect reliability, a single measurement will provide less than a complete answer. For this type of question, it is desirable to have the first probe provide a large proportion of the answer and to add other probes to drive the value of the answer asymptotically toward one.

Other questions involve the concept of spatial distribution so that a complete answer is not possible unless several measurements are made at differing locations. With this type of question, the first probe alone provides less than its proportionate share of the value. The second probe measurement, on the other hand, provides more than its proportionate share because the spatial distribution has largely been accomplished. For this kind of question, an "S" curve is desired for the summation scheme. Figure E-2 plots a family of summation curves, which are available from a single summation equation, by using different accumulation rates, PAR. The total probe value, PVT, is the simple addition of the value achieved by each probe with regard to a given question. The probe value summation, PVS, is the desired summation of the effects of the various probes, as given by the following equation:

$$PVS = \left(\frac{PVT}{2\ PAR - 3}\right)^{(PAR-1)} \left[PAR - (PAR-1)\ \frac{PVT}{(2\ PAR - 3)}\right].$$

It is apparent that various values of PAR are possible; however, only two were adopted for use -- PAR = 2 for the single measurement-type question, and PAR = 3 for the questions requiring spatial distribution.

The above discussion refers to the more important primary target zones. In the case of the secondary target zones, the summation is always linear, and SVS, the summation of the secondary value, is a fraction, SAR, of the total secondary probe value, SVT. Therefore,

$$SVS = SAR \cdot SVT.$$

The summation of the probe value $PV_{i,k}$ is diagrammed on Sheet 20 of Fig. E-1.

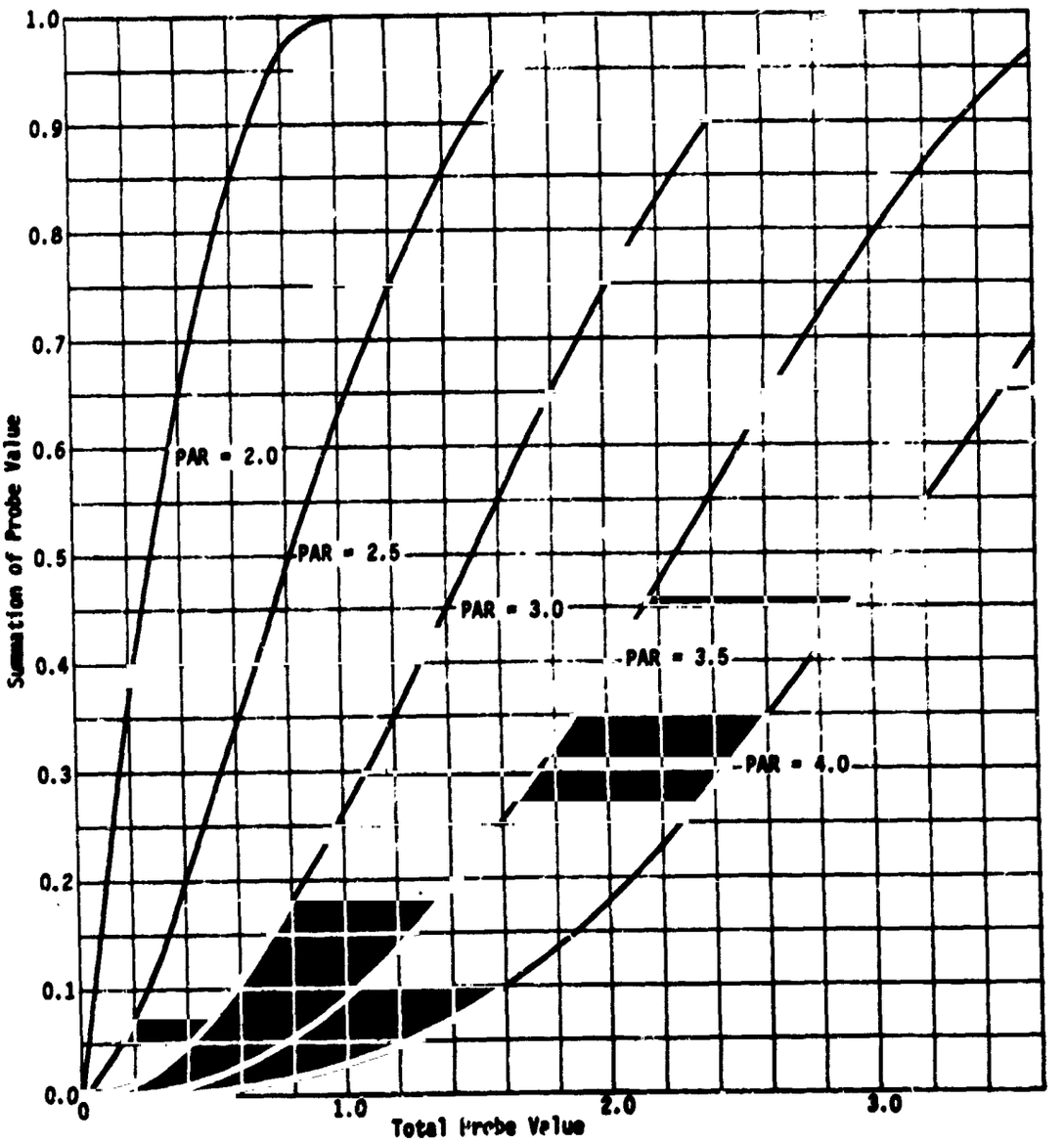


Fig. E-2 Effect of PAR on Summation Scheme

5. Calculation of Question Value

The question value is calculated using a single equation shown on Sheet 20 of Fig. E-1; the value of the kth question, Q_k, is found by

$$Q_k = WP \cdot PVS + (1 - WP) \cdot SVS,$$

where

WP = Fraction of the value obtained from primary targets;
PVS = Summation of the value from primary targets;
SVS = Summation of the value from secondary targets.

Since the first term of this equation is the value accrued from primary target probes, the value which may be properly allotted to the kth probe is the fraction, $PV_{i,k/PVT}$, of the value mentioned. A similar fraction is allotted to a secondary target probe, and the pair of values can be combined in a single equation by defining an index number, ISK, which as a value of 0 for primary target sites and a value of 1 for secondary target sites:

$$\text{Value allotted to probe} = \frac{PV_{i,k}}{PVT} \cdot WP \cdot PVS\ (1 - ISK) + \frac{PV_{i,k}}{SVT} (1 - WP)SVS \cdot ISK.$$

On Sheet 21 of Fig. E-1, the value allotted to a given probe, PALOT, is found and is then further subdivided between the appropriate instruments. Sheet 27 diagrams all the equations that are used to accomplish this further allocation. Note that some of the value is allotted to Instruments 18, 19, and 20, even though there are only 17 instruments. The variables EX_{18}, EX_{19}, and EX_{20} are the values allotted to the high-altitude reference, the pressure-temperature reference, and the low-altitude reference, respectively. The experiment value, EX_j, for the jth instrument is then summed with similar values to obtain the accumulated experiment value, $ACEX_j$, for the jth instrument with

regard to all questions. The array of $ACEX_j$ is always printed out, but the values of EX_j are printed for each question and probe only when Switch 1 is turned off. The final task accomplished by the calculation subroutines CAL 2 thru CAL 6 is to print out the total question value as diagrammed on Sheet 22 of Fig. E-1.

6. Allotment of the Reference Values

Calculation Subroutine CAL 7, diagrammed on Sheets 28 and 29 of Fig. E-1, has the sole purpose of allotting the value accumulated for $ACEX_{18}$, $ACEX_{19}$, and $ACEX_{20}$ between the five contributing types of instruments. Once this has been accomplished, control is returned to the mainline program, which then prints the total value contributed by each instrument, as well as the sum of all instruments carried on that probe (the value contributed by the particular probe). When the values for each probe are printed, the program is free to recycle in either of the two possible modes of operation.

7. Target Value Subroutine - TAV1

Sheet 14 of Fig. E-1 diagrams the manner in which this subroutine interpolates a value from the target value curves. As described above, there are eight possible sets of points along three great circles. TV1 is the target value for a given value of PSI on the circle running through the evening terminator; TV2 and TV3 are the target values for a given value of PSI on the circles running through the pole and the morning terminator, respectively. A linear interpolation is made between these three values, depending on the input value of THETA.

8. Sampling Factor Subroutine - SAMPL

This subroutine first determines the proper value for the sampling range fraction, VALP. The highest and lowest radii in the design measurement list are used to do this; it is between

these two radii that the particular instrument makes its measurements. The difference in the value interpolated from the cumulative value profile for these two radii is then the fraction of the total desired vertical range which has been measured. This interpolation scheme, as welll as the special handling given question 19, which requires the use of a balloon, are diagrammed in Sheet 10 of Fig. E-1.

In this later case, the cumulative value profile is given a different meaning; the values are those attached to various balloon flotation heights. A single balloon at a given location produces 2/3 of the possible value, and a second balloon proviues the remainder.

Sheets 11 and 12 of Fig. E-1 diagram the method of determining the ratio of the required delta radius to the particular one actually experienced, VX. On the same figure, all such ratios for a given instrument are averaged to find the sampling interval ratio, VAL. The product of this ratio and the sampling range fraction, VALP, gives the sampling factor that is returned to the calling subroutine.

APPENDIX F

MODEL ATMOSPHERE TABULATIONS

The equations used to compute the atmospheric profiles are derived from the hydrostatic equations:

$$dP = -\rho g dr, \qquad [F-1]$$

the ideal gas law:

$$P = \rho RT/M, \qquad [F-2]$$

and the assumption that the temperature profile can be represented by a series of linear segments

$$T = T_o + \gamma(r - r_o), \qquad [F-3]$$

where $\gamma = dT/dr = (T - T_o)/(r - r_o)$. Equations [F-1] and [F-2] combine to give

$$\ln \frac{P}{P_o} = -\int_{r_o}^{r} \frac{mg}{RT}\, dr, \qquad [F-4]$$

where m, g, and T are functions of the radius.

The acceleration of gravity is given by:

$$g = GM/r^2 = g_o\, r_o^2/r^2 \qquad [F-5]$$

where GM = 324,859.6 km^3/sec^2 for Venus. If the mean molecular mass is constant with altitude, Equation [F-3] can be substituted in [F-4] and the integration gives:

$$\ln\left(\frac{P}{P_o}\right) = -\frac{mg_o}{R\gamma}\ln\left[1 - \frac{\gamma(r - r_o)}{T_o}\right]\Bigg/\left(\frac{T_o}{r_o\gamma} - 1\right)^2$$

$$-\frac{mg_o}{R\gamma}(r - r_o)\Bigg/r\left(\frac{T_o}{r_o\gamma} - 1\right)$$

$$-\frac{mg_o}{R\gamma}\ln\left(\frac{r_o}{r}\right)\Bigg/\left(\frac{T_o}{r_o\gamma} - 1\right)^2 \qquad [F-6]$$

If the mean molecular mass varies with altitude, the quantity T/m (the so-called molecular scale temperature) can be assumed to vary linearly over short enough altitude intervals and Equation [F-6] can be used with the substitution of m_o for m and T_o/m_o for T_o. The lapse rate γ is now defined as:

$$\gamma = \frac{d(T/m)}{dr} = \frac{(T/m - T_o/m_o)}{(r - r_o)} \qquad [F-7]$$

In the event that γ is zero, Equation [F-7] is replaced by the simpler expression.

$$\frac{P}{P_o} = \exp\left[-\frac{m_o g_o}{RT_o} Z\Big/\left(1 + \frac{Z}{r_o}\right)\right] \qquad [F-8]$$

where $Z = (r - r_o)$.

Thus, the calculation of the atmospheric profiles requires a specification of an initial pressure and the temperature and mean molecular weight profiles. In reproducing the NASA SP-8011 Models V2 and V5, the molecular scale temperature T/m was assumed to vary linearly between the tabular values given in SP-8011. The reason for the deviations of the computed pressures and

densities from the tabular values of SP-8011 is that the changes in the temperature lapse rates do not occur at the altitudes tabulated in SP-8011 but at intermediate altitudes.

The models used in the study (MMC and V5) are tabulated in Tables F-1 and F-2.

TABLE F-1

VENUS MODEL ATMOSPHERE NO MMC-LOWER DATE 11 SEPT 1969

MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE

INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS

PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
-5.000	-16.404	803.33	0.12660E 09	0.12494E 03	0.81902E-01	0.15891E 00
-4.000	-13.123	795.66	0.11949E 09	0.11793E 03	0.78049E-01	0.15144E 00
-3.000	-9.842	788.00	0.11272E 09	0.11124E 03	0.74344E-01	0.14425E 00
-2.000	-6.561	780.33	0.10627E 09	0.10488E 03	0.70782E-01	0.13734E 00
-1.000	-3.280	772.66	0.10014E 09	0.98837E 02	0.67360E-01	0.13070E 00
0.000	0.000	765.00	0.94314E 08	0.93080E 02	0.64072E-01	0.12432E 00
1.000	3.280	757.33	0.88769E 08	0.87608E 02	0.60916E-01	0.11819E 00
2.000	6.561	749.66	0.83500E 08	0.82408E 02	0.57886E-01	0.11231E 00
3.000	9.842	742.00	0.78497E 08	0.77470E 02	0.54980E-01	0.10667E 00
4.000	13.123	734.33	0.73747E 08	0.72783E 02	0.52193E-01	0.10127E 00
5.000	16.404	726.66	0.69241E 08	0.68335E 02	0.49520E-01	0.96086E-01
6.000	19.685	719.00	0.64968E 08	0.64118E 02	0.46960E-01	0.91118E-01
7.000	22.965	711.33	0.60918E 08	0.60122E 02	0.44507E-01	0.86359E-01
8.000	26.246	703.66	0.57083E 08	0.56336E 02	0.42159E-01	0.81803E-01
9.000	29.527	696.00	0.53451E 08	0.52752E 02	0.39912E-01	0.77443E-01
10.000	32.808	688.33	0.50016E 08	0.49362E 02	0.37763E-01	0.73273E-01
11.000	36.089	680.66	0.46767E 08	0.46156E 02	0.35708E-01	0.69285E-01
12.000	39.370	673.00	0.43698E 08	0.43126E 02	0.33744E-01	0.65475E-01
13.000	42.650	665.33	0.40799E 08	0.40265E 02	0.31869E-01	0.61836E-01
14.000	45.931	657.66	0.38062E 08	0.37565E 02	0.30079E-01	0.58361E-01
15.000	49.212	650.00	0.35482E 08	0.35018E 02	0.28369E-01	0.55046E-01
15.000	49.212	650.00	0.35482E 08	0.35018E 02	0.28369E-01	0.55046E-01
16.000	52.493	642.00	0.33048E 08	0.32616E 02	0.26753E-01	0.51910E-01
17.000	55.774	634.00	0.30755E 08	0.30353E 02	0.25211E-01	0.48918E-01
18.000	59.055	626.00	0.28596E 08	0.28222E 02	0.23740E-01	0.46065E-01
19.000	62.335	618.00	0.26564E 08	0.26217E 02	0.22339E-01	0.43345E-01
20.000	65.616	610.00	0.24654E 08	0.24331E 02	0.21004E-01	0.40755E-01
21.000	68.897	602.00	0.22858E 08	0.22559E 02	0.19734E-01	0.38290E-01
22.000	72.178	594.00	0.21173E 08	0.20896E 02	0.18525E-01	0.35944E-01
23.000	75.459	586.00	0.19592E 08	0.19336E 02	0.17376E-01	0.33715E-01
24.000	78.740	578.00	0.18110E 08	0.17873E 02	0.16284E-01	0.31596E-01
25.000	82.020	570.00	0.16723E 08	0.16504E 02	0.15247E-01	0.29585E-01
25.000	82.020	570.00	0.16723E 08	0.16504E 02	0.15247E-01	0.29585E-01
26.000	85.301	561.48	0.15424E 08	0.15222E 02	0.14276E-01	0.27701E-01
27.000	88.582	552.96	0.14209E 08	0.14023E 02	0.13354E-01	0.25912E-01
28.000	91.863	544.44	0.13073E 08	0.12902E 02	0.12479E-01	0.24213E-01
29.000	95.144	535.92	0.12012E 08	0.11855E 02	0.11649E-01	0.22603E-01
30.000	98.425	527.40	0.11023E 08	0.10879E 02	0.10862E-01	0.21077E-01
31.000	101.706	518.88	0.10102E 08	0.99703E 01	0.10118E-01	0.19632E-01
32.000	104.986	510.37	0.92448E 07	0.91239E 01	0.94140E-02	0.18266E-01
33.000	108.267	501.85	0.84477E 07	0.83372E 01	0.87483E-02	0.16974E-01
34.000	111.548	493.33	0.77076E 07	0.76069E 01	0.81197E-02	0.15754E-01
35.000	114.829	484.81	0.70214E 07	0.69296E 01	0.75267E-02	0.14604E-01
36.000	118.110	476.29	0.63859E 07	0.63024E 01	0.69679E-02	0.13520E-01
37.000	121.391	467.77	0.57982E 07	0.57223E 01	0.64418E-02	0.12499E-01
38.000	124.671	459.25	0.52554E 07	0.51866E 01	0.59471E-02	0.11539E-01
38.500	126.312	455.00	0.50000E 07	0.49346E 01	0.57110E-02	0.11081E-01

TABLE F-1 (cont.)

VENUS MODEL ATMOSPHERE NO MMC-LOWER DATE 11 SEPT 1969
MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE
INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE KM	ALTITUDE KFT	TEMP KELVIN	PRESSURE DYNE/CM2	PRESSURE ATM	MASS DENSITY G/CM3	MASS DENSITY SLUG/FT3
39.000	127.952	450.40	0.47547E 07	0.46925E 01	0.54863E-02	0.10645E-01
40.000	131.233	441.20	0.42930E 07	0.42379E 01	0.50569E-02	0.98121E-02
41.000	134.514	432.00	0.38680E 07	0.38174E 01	0.46533E-02	0.90290E-02
42.000	137.795	422.80	0.34774E 07	0.34319E 01	0.42744E-02	0.82938E-02
43.000	141.076	413.60	0.31190E 07	0.30782E 01	0.39192E-02	0.76045E-02
44.000	144.356	404.40	0.27908E 07	0.27543E 01	0.35866E-02	0.69591E-02
45.000	147.637	395.20	0.24909E 07	0.24583E 01	0.32756E-02	0.63558E-02
46.000	150.918	386.00	0.22173E 07	0.21883E 01	0.29854E-02	0.57926E-02
47.000	154.199	376.80	0.19683E 07	0.19426E 01	0.27149E-02	0.52677E-02
48.000	157.480	367.60	0.17422E 07	0.17195E 01	0.24632E-02	0.47794E-02
49.000	160.761	358.40	0.15374E 07	0.15173E 01	0.22294E-02	0.43258E-02
50.000	164.041	349.20	0.13523E 07	0.13346E 01	0.20127E-02	0.39053E-02
51.000	167.322	340.00	0.11855E 07	0.11700E 01	0.18121E-02	0.35162E-02
51.000	167.322	340.00	0.11855E 07	0.11700E 01	0.18121E-02	0.35162E-02
52.000	170.603	331.42	0.10357E 07	0.10221E 01	0.16241E-02	0.31513E-02
53.000	173.884	322.85	0.90176E 06	0.88991E 00	0.14514E-02	0.28163E-02
54.000	177.165	314.28	0.78212E 06	0.77189E 00	0.12933E-02	0.25094E-02
54.500	178.805	310.00	0.72336E 06	0.71385E 00	0.12194E-02	0.23660E-02
55.000	180.446	306.33	0.67592E 06	0.66698E 00	0.11465E-02	0.22246E-02
56.000	183.727	299.00	0.58189E 06	0.57428E 00	0.10114E-02	0.19624E-02
57.000	187.007	291.66	0.49918E 06	0.49265E 00	0.88946E-03	0.17258E-02
58.000	190.288	284.33	0.42658E 06	0.42100E 00	0.77970E-03	0.15128E-02
59.000	193.569	277.00	0.36306E 06	0.35831E 00	0.68118E-03	0.13217E-02
60.000	196.850	269.66	0.30768E 06	0.30366E 00	0.59298E-03	0.11505E-02
61.000	200.131	262.33	0.25958E 06	0.25619E 00	0.51426E-03	0.99784E-03
62.000	203.412	255.00	0.21796E 06	0.21511E 00	0.44422E-03	0.86194E-03
62.000	203.412	255.00	0.21796E 06	0.21511E 00	0.44422E-03	0.86194E-03
63.000	206.692	252.81	0.18242E 06	0.18004E 00	0.37501E-03	0.72765E-03
64.000	209.973	250.62	0.15246E 06	0.15046E 00	0.31614E-03	0.61342E-03
65.000	213.254	248.43	0.12722E 06	0.12555E 00	0.26613E-03	0.51638E-03
66.000	216.535	246.25	0.10599E 06	0.10461E 00	0.22370E-03	0.43406E-03
67.000	219.816	244.06	0.88176E 05	0.87023E-01	0.18776E-03	0.36432E-03
68.000	223.097	241.87	0.73234E 05	0.72276E-01	0.15735E-03	0.30531E-03
69.000	226.377	239.68	0.60725E 05	0.59931E-01	0.13166E-03	0.25547E-03
70.000	229.658	237.50	0.50269E 05	0.49612E-01	0.11000E-03	0.21343E-03
71.000	232.939	235.31	0.41544E 05	0.41000E-01	0.91753E-04	0.17803E-03
72.000	236.220	233.12	0.34274E 05	0.33826E-01	0.76407E-04	0.14825E-03
73.000	239.501	230.93	0.28227E 05	0.27857E-01	0.63522E-04	0.12325E-03
74.000	242.782	228.75	0.23205E 05	0.22901E-01	0.52721E-04	0.10229E-03
75.000	246.062	226.56	0.19042E 05	0.18793E-01	0.43681E-04	0.84755E-04
76.000	249.343	224.37	0.15597E 05	0.15393E-01	0.36127E-04	0.70098E-04
77.000	252.624	222.18	0.12751E 05	0.12584E-01	0.29826E-04	0.57872E-04
78.000	255.905	220.00	0.10404E 05	0.10268E-01	0.24579E-04	0.47691E-04
79.000	259.186	217.91	0.84732E 04	0.83624E-02	0.20217E-04	0.39228E-04
80.000	262.467	215.62	0.68865E 04	0.67964E-02	0.16598E-04	0.32205E-04
81.000	265.748	213.43	0.55854E 04	0.55124E-02	0.13600E-04	0.26388E-04

TABLE F-1 (cont)

VENUS MODEL ATMOSPHERE NO MMC-LOWER DATE 11 SEPT 1969
MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE
INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS.

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
82.000	269.028	211.25	0.45207E 04	0.44616E-02	0.11121E-04	0.21579E-04
83.000	272.309	209.06	0.36512E 04	0.36034E-02	0.90765E-05	0.17611E-04
84.000	275.590	206.87	0.29425E 04	0.29040E-02	0.73921E-05	0.14343E-04
85.000	278.871	204.68	0.23661E 04	0.23351E-02	0.60075E-05	0.11656E-04
86.000	282.152	202.50	0.18982E 04	0.18734E-02	0.48718E-05	0.94529E-05
87.000	285.433	200.31	0.15194E 04	0.14995E-02	0.39421E-05	0.76490E-05
88.000	288.713	198.12	0.12133E 04	0.11974E-02	0.31827E-05	0.61754E-05
89.000	291.994	195.93	0.96653E 03	0.95389E-03	0.25636E-05	0.49742E-05
90.000	295.275	193.75	0.76803E 03	0.75798E-03	0.20601E-05	0.39973E-05
91.000	298.556	191.56	0.60875E 03	0.60079E-03	0.16515E-05	0.32045E-05
92.000	301.837	189.37	0.48125E 03	0.47496E-03	0.13207E-05	0.25626E-05
93.000	305.118	187.18	0.37945E 03	0.37449E-03	0.10535E-05	0.20441E-05
94.000	308.398	185.00	0.29837E 03	0.29447E-03	0.83021E-06	0.16264E-05
95.000	311.679	182.81	0.23397E 03	0.23091E-03	0.66514E-06	0.12905E-05
96.000	314.960	180.62	0.18294E 03	0.18055E-03	0.52638E-06	0.10213E-05
97.000	318.241	178.43	0.14263E 03	0.14076E-03	0.41542E-06	0.80605E-06
98.000	321.522	176.25	0.11087E 03	0.10942E-03	0.32692E-06	0.63433E-06
99.000	324.803	174.06	0.85917E 02	0.84794E-04	0.25652E-06	0.49774E-06
100.000	328.083	171.87	0.66372E 02	0.65504E-04	0.20069E-06	0.38940E-06
101.000	331.364	169.68	0.51108E 02	0.50439E-04	0.15653E-06	0.30371E-06
102.000	334.645	167.50	0.39224E 02	0.38711E-04	0.12170E-06	0.23614E-06
103.000	337.926	165.31	0.30002E 02	0.29609E-04	0.94320E-07	0.18301E-06
104.000	341.207	163.12	0.22868E 02	0.22569E-04	0.72857E-07	0.14136E-06
105.000	344.488	160.93	0.17368E 02	0.17141E-04	0.56087E-07	0.10882E-06
106.000	347.769	158.75	0.13143E 02	0.12971E-04	0.43027E-07	0.83486E-07
107.000	351.049	156.56	0.99081E 01	0.97785E-05	0.32889E-07	0.63816E-07
108.000	354.330	154.37	0.74404E 01	0.73431E-05	0.25048E-07	0.48601E-07
109.000	357.611	152.18	0.55650E 01	0.54923E-05	0.19004E-07	0.36874E-07
110.000	360.892	150.00	0.41453E 01	0.40911E-05	0.14362E-07	0.27867E-07
110.000	360.892	150.00	0.41453E 01	0.40911E-05	0.14362E-07	0.27867E-07
111.000	364.173	154.16	0.30939E 01	0.30535E-05	0.10430E-07	0.20237E-07
112.000	367.454	158.33	0.23275E 01	0.22971E-05	0.76399E-08	0.14823E-07
113.000	370.734	162.50	0.17641E 01	0.17410E-05	0.56421E-08	0.10947E-07
114.000	374.015	166.66	0.13466E 01	0.13290E-05	0.41992E-08	0.81478E-08
115.000	377.296	170.83	0.10349E 01	0.10213E-05	0.31484E-08	0.61090E-08
116.000	380.577	175.00	0.80049E 00	0.79002E-06	0.23772E-08	0.46126E-08
117.000	383.858	179.16	0.62296E 00	0.61481E-06	0.18070E-08	0.35062E-08
118.000	387.139	183.33	0.48764E 00	0.48127E-06	0.13823E-08	0.26822E-08
119.000	390.419	187.50	0.38386E 00	0.37884E-06	0.10639E-08	0.20644E-08
120.000	393.700	191.66	0.30378E 00	0.29980E-06	0.82370E-09	0.15982E-08
121.000	396.981	195.83	0.24163E 00	0.23847E-06	0.64126E-09	0.12442E-08
122.000	400.262	200.00	0.19314E 00	0.19062E-06	0.50190E-09	0.97385E-09
123.000	403.543	204.16	0.15511E 00	0.15308E-06	0.39484E-09	0.76613E-09
124.000	406.824	208.33	0.12513E 00	0.12349E-06	0.31213E-09	0.60568E-09
125.000	410.104	212.50	0.10138E 00	0.10005E-06	0.24795E-09	0.48110E-09
126.000	413.385	216.66	0.82483E-01	0.81405E-07	0.19784E-09	0.38389E-09

TABLE F-1 (cont)

VENUS MODEL ATMOSPHERE NO MMC-LOWER DATE 11 SEPT 1969
MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE
INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
127.000	416.666	220.83	0.67375E-01	0.66494E-07	0.15856E-09	0.30765E-09
128.000	419.947	225.00	0.55246E-01	0.54524E-07	0.12760E-09	0.24760E-09
129.000	423.228	229.16	0.45469E-01	0.44874E-07	0.10311E-09	0.20007E-09
130.000	426.509	233.33	0.37556E-01	0.37065E-07	0.83650E-10	0.16230E-09
131.000	429.790	237.50	0.31127E-01	0.30720E-07	0.68114E-10	0.13216E-09
132.000	433.070	241.66	0.25885E-01	0.25546E-07	0.55666E-10	0.10801E-09
133.000	436.351	245.83	0.21594E-01	0.21312E-07	0.45652E-10	0.88581E-10
134.000	439.632	250.00	0.18071E-01	0.17835E-07	0.37567E-10	0.72893E-10
135.000	442.913	254.16	0.15169E-01	0.14970E-07	0.31016E-10	0.60181E-10
136.000	446.194	258.33	0.12769E-01	0.12602E-07	0.25688E-10	0.49843E-10
137.000	449.475	262.50	0.10779E-01	0.10638E-07	0.21341E-10	0.41409E-10
138.000	452.755	266.66	0.91244E-02	0.90051E-08	0.17782E-10	0.34504E-10
139.000	456.036	270.83	0.77440E-02	0.76427E-08	0.14860E-10	0.28833E-10
140.000	459.317	275.00	0.65892E-02	0.65030E-08	0.12452E-10	0.24162E-10
140.000	459.317	275.00	0.65892E-02	0.65030E-08	0.12452E-10	0.24162E-10
141.000	462.598	286.25	0.56317E-02	0.55581E-08	0.10224E-10	0.19839E-10
142.000	465.879	297.50	0.48429E-02	0.47795E-08	0.84601E-11	0.16415E-10
143.000	469.160	308.75	0.41881E-02	0.41333E-08	0.70497E-11	0.13678E-10
144.000	472.440	320.00	0.36409E-02	0.35933E-08	0.59131E-11	0.11473E-10
145.000	475.721	331.25	0.31807E-02	0.31391E-08	0.49902E-11	0.96827E-11
146.000	479.002	342.50	0.27913E-02	0.27548E-08	0.42355E-11	0.82183E-11
147.000	482.283	353.75	0.24601E-02	0.24279E-08	0.36142E-11	0.70127E-11
148.000	485.564	365.00	0.21768E-02	0.21483E-08	0.30995E-11	0.60140E-11
149.000	488.845	376.25	0.19334E-02	0.19081E-08	0.26706E-11	0.51819E-11
150.000	492.125	387.50	0.17233E-02	0.17008E-08	0.23113E-11	0.44847E-11
151.000	495.406	398.75	0.15411E-02	0.15210E-08	0.20087E-11	0.38975E-11
152.000	498.687	410.00	0.13826E-02	0.13645E-08	0.17525E-11	0.34005E-11
153.000	501.968	421.25	0.12440E-02	0.12278E-08	0.15348E-11	0.29780E-11
154.000	505.249	432.50	0.11225E-02	0.11078E-08	0.13489E-11	0.26173E-11
155.000	508.530	443.75	0.10156E-02	0.10023E-08	0.11894E-11	0.23079E-11
156.000	511.811	455.00	0.92121E-03	0.90916E-09	0.10522E-11	0.20416E-11
157.000	515.091	466.25	0.83759E-03	0.82664E-09	0.93362E-12	0.18115E-11
158.000	518.372	477.50	0.76332E-03	0.75334E-09	0.83079E-12	0.16120E-11
159.000	521.653	488.75	0.69715E-03	0.68804E-09	0.74131E-12	0.14383E-11
160.000	524.934	500.00	0.63806E-03	0.62972E-09	0.66321E-12	0.12868E-11
160.000	524.934	500.00	0.63806E-03	0.62972E-09	0.66321E-12	0.12868E-11
161.000	528.215	503.12	0.58474E-03	0.57709E-09	0.60401E-12	0.11719E-11
162.000	531.496	506.25	0.53617E-03	0.52916E-09	0.55042E-12	0.10680E-11
163.000	534.776	509.37	0.49192E-03	0.48548E-09	0.50190E-12	0.97384E-12
164.000	538.057	512.50	0.45157E-03	0.44566E-09	0.45792E-12	0.88851E-12
165.000	541.338	515.62	0.41475E-03	0.40933E-09	0.41804E-12	0.81113E-12
166.000	544.619	518.75	0.38114E-03	0.37616E-09	0.38185E-12	0.74091E-12
167.000	547.900	521.87	0.35045E-03	0.34587E-09	0.34899E-12	0.67716E-12
168.000	551.181	525.00	0.32239E-03	0.31818E-09	0.31914E-12	0.61925E-12
169.000	554.461	528.12	0.29674E-03	0.29286E-09	0.29201E-12	0.56660E-12
170.000	557.742	531.25	0.27327E-03	0.26970E-09	0.26733E-12	0.51861E-12

TABLE F-1 (cont)

VENUS MODEL ATMOSPHERE NO MYC-LOWER DATE 11 SEPT 1969
MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE
INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
171.000	561.023	534.37	0.25178E-03	0.24849E-09	0.24487E-12	0.47513E-12
172.000	564.304	537.50	0.23210E-03	0.22907E-09	0.22442E-12	0.43545E-12
173.000	567.585	540.62	0.21407E-03	0.21127E-09	0.20578E-12	0.39929E-12
174.000	570.866	543.75	0.19753E-03	0.19495E-09	0.18880E-12	0.36633E-12
175.000	574.146	546.87	0.18236E-03	0.17997E-09	0.17330E-12	0.33626E-12
176.000	577.427	550.00	0.16843E-03	0.16623E-09	0.15916E-12	0.30882E-12
177.000	580.708	553.12	0.15565E-03	0.15361E-09	0.14624E-12	0.28376E-12
178.000	583.989	556.25	0.14390E-03	0.14202E-09	0.13444E-12	0.26087E-12
179.000	587.270	559.37	0.13310E-03	0.13136E-09	0.12366E-12	0.23994E-12
180.000	590.551	562.50	0.12316E-03	0.12155E-09	0.11379E-12	0.22080E-12
181.000	593.832	565.62	0.11402E-03	0.11253E-09	0.10477E-12	0.20329E-12
182.000	597.112	568.75	0.10561E-03	0.10423E-09	0.96507E-13	0.18725E-12
183.000	600.393	571.87	0.97864E-04	0.96585E-10	0.88937E-13	0.17256E-12
184.000	603.674	575.00	0.90723E-04	0.89537E-10	0.81999E-13	0.15910E-12
185.000	606.955	578.12	0.84139E-04	0.83039E-10	0.75637E-13	0.14676E-12
186.000	610.236	581.25	0.78067E-04	0.77046E-10	0.69801E-13	0.13543E-12
187.000	613.517	584.37	0.72464E-04	0.71516E-10	0.64445E-13	0.12504E-12
188.000	616.797	587.50	0.6729.E-04	0.66411E-10	0.59526E-13	0.11550E-12
189.000	620.078	590.62	0.62513E-04	0.61696E-10	0.55007E-13	0.10673E-12
190.000	623.359	593.75	0.58099E-04	0.57339E-10	0.50854E-13	0.98673E-13
191.000	626.640	596.87	0.54018E-04	0.53312E-10	0.47034E-13	0.91262E-13
192.000	629.921	600.00	0.50245E-04	0.49588E-10	0.43521E-13	0.84445E-13
193.000	633.202	603.12	0.46753E-04	0.46142E-10	0.40287E-13	0.78170E-13
194.000	636.482	606.25	0.43522E-04	0.42952E-10	0.37309E-13	0.72391E-13
195.000	639.763	609.37	0.40529E-04	0.39999E-10	0.34565E-13	0.67068E-13
196.000	643.044	612.50	0.37757E-04	0.37263E-10	0.32037E-13	0.62162E-13
197.000	646.325	615.62	0.35188E-04	0.34728E-10	0.29705E-13	0.57639E-13
198.000	649.606	618.75	0.32806E-04	0.32377E-10	0.27555E-13	0.53466E-13
199.000	652.887	621.87	0.30597E-04	0.30197E-10	0.25570E-13	0.49615E-13
200.000	656.167	625.00	0.28548E-04	0.28174E-10	0.23738E-13	0.46060E-13
200.000	656.167	625.00	0.28548E-04	0.28174E-10	0.23738E-13	0.46060E-13
201.000	659.448	625.00	0.26640E-04	0.26292E-10	0.22152E-13	0.42983E-13
202.000	662.729	625.00	0.24861E-04	0.24536E-10	0.20673E-13	0.40112E-13
203.000	666.010	625.00	0.23201E-04	0.22898E-10	0.19292E-13	0.37434E-13
204.000	669.291	625.00	0.21653E-04	0.21370E-10	0.18005E-13	0.34935E-13
205.000	672.572	625.00	0.20208E-04	0.19944E-10	0.16803E-13	0.32604E-13
206.000	675.853	625.00	0.18860E-04	0.18613E-10	0.15683E-13	0.30430E-13
207.000	679.133	625.00	0.17602E-04	0.17372E-10	0.14637E-13	0.28400E-13
208.000	682.414	625.00	0.16429E-04	0.16214E-10	0.13661E-13	0.26507E-13
209.000	685.695	625.00	0.15334E-04	0.15133E-10	0.12751E-13	0.24741E-13
210.000	688.976	625.00	0.14312E-04	0.14125E-10	0.11901E-13	0.23092E-13
211.000	692.257	625.00	0.13359E-04	0.13184E-10	0.11108E-13	0.21554E-13
212.000	695.538	625.00	0.12470E-04	0.12307E-10	0.10369E-13	0.20119E-13
213.000	698.818	625.00	0.11640E-04	0.11487E-10	0.96791E-14	0.18780E-13
214.000	702.099	625.00	0.10865E-04	0.10723E-10	0.90350E-14	0.17530E-13
215.000	705.380	625.00	0.10142E-04	0.10010E-10	0.84341E-14	0.16364E-13

TABLE F-1 (concl)

VENUS MODEL ATMOSPHERE NO MNC-LOWER DATE 11 SEPT 1969
MEAN MOLECULAR MASS = 43.21 GRAMS/MOLE
INITIAL PRESSURE =0.500000E 07 DYNES/SQCM AT 6088.50 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE KM	ALTITUDE KFT	TEMP KELVIN	PRESSURE DYNE/CM2	PRESSURE ATM	MASS DENSITY G/CM3	MASS DENSITY SLUG/FT3
216.000	708.661	625.00	0.94683E-05	0.93445E-11	0.78732E-14	0.15276E-13
217.000	711.942	625.00	0.88389E-05	0.87233E-11	0.73498E-14	0.14261E-13
218.000	715.223	625.00	0.82515E-05	0.81436E-11	0.68614E-14	0.13313E-13
219.000	718.503	625.00	0.77033E-05	0.76026E-11	0.64055E-14	0.12428E-13
220.000	721.784	625.00	0.71917E-05	0.70976E-11	0.59801E-14	0.11603E-13
221.000	725.065	625.00	0.67142E-05	0.66264E-11	0.55830E-14	0.10832E-13
222.000	728.346	625.00	0.62685E-05	0.61865E-11	0.52125E-14	0.10113E-13
223.000	731.627	625.00	0.58526E-05	0.57760E-11	0.48666E-14	0.94428E-14
224.000	734.908	625.00	0.54643E-05	0.53929E-11	0.45438E-14	0.88164E-14
225.000	738.188	625.00	0.51020E-05	0.50353E-11	0.42424E-14	0.82318E-14
226.000	741.469	625.00	0.47638E-05	0.47015E-11	0.39612E-14	0.76860E-14
227.000	744.750	625.00	0.44480E-05	0.43899E-11	0.36987E-14	0.71767E-14
228.000	748.031	625.00	0.41533E-05	0.40990E-11	0.34538E-14	0.67012E-14
229.000	751.312	625.00	0.38783E-05	0.38275E-11	0.32249E-14	0.62574E-14
230.000	754.593	625.00	0.36215E-05	0.35741E-11	0.30114E-14	0.58430E-14
231.000	757.874	625.00	0.33818E-05	0.33375E-11	0.28120E-14	0.54563E-14
232.000	761.154	625.00	0.31580E-05	0.31167E-11	0.26260E-14	0.50952E-14
233.000	764.435	625.00	0.29491E-05	0.29105E-11	0.24522E-14	0.47582E-14
234.000	767.716	625.00	0.27540E-05	0.27180E-11	0.22901E-14	0.44435E-14
235.000	770.997	625.00	0.25720E-05	0.25383E-11	0.21387E-14	0.41498E-14
236.000	774.278	625.00	0.24020E-05	0.23706E-11	0.19973E-14	0.38755E-14
237.000	777.559	625.00	0.22433E-05	0.22140E-11	0.18654E-14	0.36194E-14
238.000	780.839	625.00	0.20951E-05	0.20677E-11	0.17422E-14	0.33804E-14
239.000	784.120	625.00	0.19568E-05	0.19312E-11	0.16271E-14	0.31572E-14
240.000	787.401	625.00	0.18276E-05	0.18037E-11	0.15197E-14	0.29488E-14
241.000	790.682	625.00	0.17070E-05	0.16847E-11	0.14194E-14	0.27542E-14
242.000	793.963	625.00	0.15944E-05	0.15735E-11	0.13258E-14	0.25725E-14
243.000	797.244	625.00	0.14892E-05	0.14698E-11	0.12383E-14	0.24028E-14
244.000	800.524	625.00	0.13911E-05	0.13729E-11	0.11567E-14	0.22444E-14
245.000	803.805	625.00	0.12994E-05	0.12824E-11	0.10805E-14	0.20965E-14
246.000	807.086	625.00	0.12138E-05	0.11979E-11	0.10093E-14	0.19584E-14
247.000	810.367	625.00	0.11338E-05	0.11190E-11	0.94284E-15	0.18294E-14
248.000	813.648	625.00	0.10592E-05	0.10453E-11	0.88076E-15	0.17089E-14
249.000	816.929	625.00	0.98948E-06	0.97654E-12	0.82278E-15	0.15964E-14
250.000	820.209	625.00	0.92436E-06	0.91228E-12	0.76864E-15	0.14914E-14

TABLE F-2

VENUS MODEL ATMOSPHERE NO SP8011/V5. DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
0.000	0.000	755.32	0.15007E 09	0.14811E 03	0.10132E 00	0.19660E 00
1.000	3.280	747.98	0.14131E 09	0.13946E 03	0.96343E-01	0.18693E 00
2.000	6.561	740.64	0.13297E 09	0.13123E 03	0.91560E-01	0.17765E 00
3.000	9.842	733.30	0.12506E 09	0.12342E 03	0.86973E-01	0.16875E 00
3.000	9.842	733.30	0.12506E 09	0.12342E 03	0.86973E-01	0.16875E 00
4.000	13.123	725.96	0.11754E 09	0.11601E 03	0.82574E-01	0.16022E 00
5.000	16.404	718.62	0.11041E 09	0.10897E 03	0.78358E-01	0.15203E 00
6.000	19.685	711.28	0.10365E 09	0.10230E 03	0.74318E-01	0.14420E 00
7.000	22.965	703.94	0.97247E 08	0.95975E 02	0.70450E-01	0.13669E 00
8.000	26.246	696.60	0.91175E 08	0.89983E 02	0.66747E-01	0.12951E 00
8.000	26.246	696.60	0.91175E 08	0.89983E 02	0.66747E-01	0.12951E 00
9.000	29.527	689.28	0.85426E 08	0.84308E 02	0.63202E-01	0.12263E 00
10.000	32.808	681.96	0.79985E 08	0.78939E 02	0.59812E-01	0.11605E 00
11.000	36.089	674.64	0.74839E 08	0.73860E 02	0.56571E-01	0.10976E 00
12.000	39.370	667.32	0.69975E 08	0.69060E 02	0.53475E-01	0.10375E 00
13.000	42.650	660.00	0.65380E 08	0.64525E 02	0.50517E-01	0.98020E-01
13.000	42.650	660.00	0.65380E 08	0.64525E 02	0.50517E-01	0.98020E-01
14.000	45.931	651.98	0.61040E 08	0.60242E 02	0.47744E-01	0.92639E-01
15.000	49.212	643.96	0.56941E 08	0.56196E 02	0.45092E-01	0.87494E-01
16.000	52.493	635.94	0.53072E 08	0.52378E 02	0.42558E-01	0.82577E-01
17.000	55.774	627.92	0.49423E 08	0.48776E 02	0.40135E-01	0.77882E-01
18.000	59.055	619.90	0.45983E 08	0.45382E 02	0.37828E-01	0.73400E-01
18.000	59.055	619.90	0.45983E 08	0.45382E 02	0.37828E-01	0.73400E-01
19.000	62.335	611.90	0.42744E 08	0.42185E 02	0.35624E-01	0.69122E-01
20.000	65.616	603.90	0.39696E 08	0.39177E 02	0.33522E-01	0.65043E-01
21.000	68.897	595.90	0.36830E 08	0.36349E 02	0.31519E-01	0.61157E-01
22.000	72.178	587.90	0.34137E 08	0.33691E 02	0.29612E-01	0.57457E-01
23.000	75.459	579.90	0.31609E 08	0.31196E 02	0.27797E-01	0.53935E-01
23.000	75.459	579.90	0.31609E 08	0.31196E 02	0.27797E-01	0.53935E-01
24.000	78.740	571.92	0.29238E 08	0.28855E 02	0.26070E-01	0.50585E-01
25.000	82.020	563.94	0.27015E 08	0.26662E 02	0.24430E-01	0.47402E-01
26.000	85.301	555.96	0.24934E 08	0.24608E 02	0.22871E-01	0.44378E-01
27.000	88.582	547.98	0.22988E 08	0.22687E 02	0.21393E-01	0.41509E-01
28.000	91.863	540.00	0.21168E 08	0.20891E 02	0.19991E-01	0.38789E-01
28.000	91.863	540.00	0.21168E 08	0.20891E 02	0.19991E-01	0.38789E-01
29.000	95.144	530.82	0.19468E 08	0.19213E 02	0.18703E-01	0.36290E-01
30.000	98.425	521.64	0.17878E 08	0.17644E 02	0.17478E-01	0.33913E-01
31.000	101.706	512.46	0.16394E 08	0.16179E 02	0.16314E-01	0.31655E-01
32.000	104.986	503.28	0.15010E 08	0.14813E 02	0.15209E-01	0.29511E-01
33.000	108.267	494.10	0.13721E 08	0.13541E 02	0.14161E-01	0.27478E-01
33.000	108.267	494.10	0.13721E 08	0.13541E 02	0.14161E-01	0.27478E-01
34.000	111.548	484.94	0.12522E 08	0.12358E 02	0.13168E-01	0.25550E-01
35.000	114.829	475.78	0.11408E 08	0.11259E 02	0.12227E-01	0.23725E-01
36.000	118.110	466.62	0.10374E 08	0.10239E 02	0.11338E-01	0.22000E-01
37.000	121.391	457.46	0.94177E 07	0.92946E 01	0.10498E-01	0.20370E-01
38.000	124.671	448.30	0.85325E 07	0.84209E 01	0.97061E-02	0.18833E-01

TABLE F-2 (cont)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
38.000	124.671	448.30	0.85325E 07	0.84209E 01	0.97061E-02	0.18833E-01
39.000	127.952	439.16	0.77149E 07	0.76141E 01	0.89588E-02	0.17383E-01
40.000	131.233	430.02	0.69612E 07	0.68702E 01	0.82554E-02	0.16018E-01
41.000	134.514	420.88	0.62675E 07	0.61855E 01	0.75941E-02	0.14735E-01
42.000	137.795	411.74	0.56301E 07	0.55565E 01	0.69732E-02	0.13530E-01
43.000	141.076	402.60	0.50455E 07	0.49796E 01	0.63911E-02	0.12400E-01
43.000	141.076	402.60	0.50455E 07	0.49796E 01	0.63911E-02	0.12400E-01
44.000	144.356	393.48	0.45105E 07	0.44515E 01	0.58458E-02	0.11342E-01
45.000	147.637	384.36	0.40218E 07	0.39692E 01	0.53360E-02	0.10353E-01
46.000	150.918	375.24	0.35762E 07	0.35295E 01	0.48603E-02	0.94305E-02
47.000	154.199	366.12	0.31710E 07	0.31296E 01	0.44169E-02	0.85703E-02
48.000	157.480	357.00	0.28033E 07	0.27667E 01	0.40045E-02	0.77701E-02
48.000	157.480	357.00	0.28033E 07	0.27667E 01	0.40045E-02	0.77701E-02
49.000	160.761	347.88	0.24705E 07	0.24382E 01	0.36216E-02	0.70270E-02
50.000	164.041	338.76	0.21699E 07	0.21416E 01	0.32666E-02	0.63383E-02
51.000	167.322	329.64	0.18993E 07	0.18745E 01	0.29383E-02	0.57013E-02
52.000	170.603	320.52	0.16563E 07	0.16346E 01	0.26353E-02	0.51134E-02
53.000	173.884	311.40	0.14388E 07	0.14199E 01	0.23562E-02	0.45718E-02
53.000	173.884	311.40	0.14388E 07	0.14199E 01	0.23562E-02	0.45718E-02
54.000	177.165	303.78	0.12451E 07	0.12288E 01	0.20902E-02	0.40556E-02
55.000	180.446	296.16	0.10735E 07	0.10595E 01	0.18486E-02	0.35869E-02
56.000	183.727	288.54	0.92218E 06	0.91012E 00	0.16298E-02	0.31624E-02
57.000	187.007	280.92	0.78894E 06	0.77863E 00	0.14322E-02	0.27789E-02
58.000	190.288	273.30	0.67210E 06	0.66332E 00	0.12541E-02	0.24334E-02
59.000	190.288	273.30	0.67210E 06	0.66332E 00	0.12541E-02	0.24334E-02
59.000	193.569	271.68	0.57105E 06	0.56358E 00	0.10719E-02	0.20798E-02
60.000	196.850	270.06	0.48474E 06	0.47840E 00	0.91536E-03	0.17761E-02
61.000	200.131	268.44	0.41110E 06	0.40572E 00	0.78098E-03	0.15153E-02
62.000	203.412	266.82	0.34831E 06	0.34375E 00	0.66572E-03	0.12917E-02
63.000	206.692	265.20	0.29483E 06	0.29098E 00	0.56695E-03	0.11000E-02
63.000	206.692	265.20	0.29483E 06	0.29098E 00	0.56695E-03	0.11000E-02
64.000	209.973	263.42	0.24931E 06	0.24605E 00	0.48265E-03	0.93650E-03
65.000	213.254	261.64	0.21059E 06	0.20783E 00	0.41046E-03	0.79644E-03
66.000	216.535	259.86	0.17769E 06	0.17536E 00	0.34871E-03	0.67661E-03
67.000	219.816	258.08	0.14976E 06	0.14780E 00	0.29593E-03	0.57419E-03
68.000	223.097	256.30	0.12608E 06	0.12443E 00	0.25086E-03	0.48676E-03
68.000	223.097	256.30	0.12608E 06	0.12443E 00	0.25086E-03	0.48676E-03
69.000	226.377	253.96	0.10600E 06	0.10461E 00	0.21286E-03	0.41301E-03
70.000	229.658	251.62	0.88985E 05	0.87821E-01	0.18034E-03	0.34993E-03
71.000	232.939	249.28	0.74581E 05	0.73606E-01	0.15257E-03	0.29604E-03
72.000	236.220	246.94	0.62408E 05	0.61592E-01	0.12888E-03	0.25007E-03
73.000	239.501	244.60	0.52137E 05	0.51455E-01	0.10870E-03	0.21091E-03
73.000	239.501	244.60	0.52137E 05	0.51455E-01	0.10870E-03	0.21091E-03
74.000	242.782	242.02	0.43479E 05	0.42910E-01	0.91616E-04	0.17776E-03
75.000	246.062	239.44	0.36191E 05	0.35718E-01	0.77081E-04	0.14956E-03
76.000	249.343	236.86	0.30066E 05	0.29673E-01	0.64734E-04	0.12560E-03

TABLE F-2 (cont)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
77.000	252.624	234.28	0.24929E 05	0.24603E-01	0.54264E-04	0.10529E-03
78.000	255.905	231.70	0.20628E 05	0.20358E-01	0.45402E-04	0.88095E-04
78.000	255.905	231.70	0.20628E 05	0.20358E-01	0.45402E-04	0.88095E-04
79.000	259.186	229.28	0.17035E 05	0.16812E-01	0.37890E-04	0.73519E-04
80.000	262.467	226.86	0.14040E 05	0.13857E-01	0.31562E-04	0.61241E-04
81.000	265.748	224.44	0.11549E 05	0.11398E-01	0.26241E-04	0.50916E-04
82.000	269.028	222.02	0.94802E 04	0.93562E-02	0.21775E-04	0.42251E-04
83.000	272.309	219.60	0.77656E 04	0.76640E-02	0.18033E-04	0.34991E-04
83.000	272.309	219.60	0.77656E 04	0.76640E-02	0.18033E-04	0.34991E-04
84.000	275.590	217.46	0.63483E 04	0.62652E-02	0.14887E-04	0.28886E-04
85.000	278.871	215.32	0.51796E 04	0.51119E-02	0.12267E-04	0.23803E-04
86.000	282.152	213.18	0.42178E 04	0.41627E-02	0.10089E-04	0.19577E-04
87.000	285.433	211.04	0.34278E 04	0.33829E-02	0.82830E-05	0.16071E-04
88.000	288.713	208.90	0.27800E 04	0.27436E-02	0.67866E-05	0.13168E-04
88.000	288.713	208.90	0.27800E 04	0.27436E-02	0.67866E-05	0.13168E-04
89.000	291.994	206.70	0.22499E 04	0.22204E-02	0.55508E-05	0.10770E-04
90.000	295.275	204.50	0.18168E 04	0.17931E-02	0.45307E-05	0.87911E-05
91.000	298.556	202.30	0.14638E 04	0.14447E-02	0.36902E-05	0.71602E-05
92.000	301.837	200.10	0.11767E 04	0.11614E-02	0.29991E-05	0.58192E-05
93.000	305.118	197.90	0.94379E 03	0.93144E-03	0.24320E-05	0.47189E-05
93.000	305.118	197.90	0.94379E 03	0.93144E-03	0.24320E-05	0.47189E-05
94.000	308.398	195.72	0.75511E 03	0.74524E-03	0.19675E-05	0.38176E-05
95.000	311.679	193.54	0.60270E 03	0.59482E-03	0.15880E-05	0.30813E-05
96.000	314.960	191.36	0.47985E 03	0.47358E-03	0.12787E-05	0.24812E-05
97.000	318.241	189.18	0.38108E 03	0.37610E-03	0.10272E-05	0.19932E-05
98.000	321.522	187.00	0.30185E 03	0.29790E-03	0.82318E-06	0.15972E-05
98.000	321.522	187.00	0.30185E 03	0.29790E-03	0.82318E-06	0.15972E-05
99.000	324.803	185.55	0.23857E 03	0.23545E-03	0.65570E-06	0.12722E-05
100.000	328.083	184.10	0.18823E 03	0.18576E-03	0.52140E-06	0.10116E-05
101.000	331.364	182.65	0.14824E 03	0.14630E-03	0.41389E-06	0.80309E-06
102.000	334.645	181.20	0.11653E 03	0.11501E-03	0.32797E-06	0.63637E-06
103.000	337.926	179.75	0.91440E 02	0.90245E-04	0.25942E-06	0.50336E-06
104.000	341.207	178.30	0.71614E 02	0.70678E-04	0.20482E-06	0.39743E-06
105.000	344.488	176.85	0.55980E 02	0.55248E-04	0.16142E-06	0.31321E-06
106.000	347.769	175.40	0.43673E 02	0.43102E-04	0.12697E-06	0.24638E-06
107.000	351.049	173.95	0.34005E 02	0.33560E-04	0.99692E-07	0.19343E-06
108.000	354.330	172.50	0.26424E 02	0.26078E-04	0.78118E-07	0.15157E-06
108.000	354.330	172.50	0.26424E 02	0.26078E-04	0.78118E-07	0.15157E-06
109.000	357.611	175.55	0.20558E 02	0.20289E-04	0.59721E-07	0.11587E-06
110.000	360.893	178.60	0.16065E 02	0.15855E-04	0.45872E-07	0.89006E-07
111.000	364.173	181.65	0.12607E 02	0.12442E-04	0.35395E-07	0.68678E-07
112.000	367.454	184.70	0.99351E 01	0.98052E-05	0.27431E-07	0.53225E-07
113.000	370.734	187.75	0.78602E 01	0.77575E-05	0.21350E-07	0.41425E-07
114.000	374.015	190.80	0.62427E 01	0.61610E-05	0.16685E-07	0.32374E-07
115.000	377.296	193.85	0.49765E 01	0.49114E-05	0.13091E-07	0.25402E-07
116.000	380.577	196.90	0.39815E 01	0.39294E-05	0.10312E-07	0.20008E-07

TABLE F-2 (cont)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
117.000	383.858	199.95	0.31966E 01	0.31548E-05	0.81528E-08	0.15819E-07
118.000	387.139	203.00	0.25751E 01	0.25415E-05	0.64692E-08	0.12552E-07
118.000	387.139	203.00	0.25751E 01	0.25415E-05	0.64692E-08	0.12552E-07
119.000	390.419	204.37	0.20795E 01	0.20523E-05	0.51891E-08	0.10068E-07
120.000	393.700	205.74	0.16818E 01	0.16598E-05	0.41688E-08	0.80886E-08
121.000	396.981	207.11	0.13622E 01	0.13444E-05	0.33542E-08	0.65082E-08
122.000	400.262	208.48	0.11049E 01	0.10905E-05	0.27028E-08	0.52443E-08
123.000	403.543	209.85	0.89755E 00	0.88581E-06	0.21811E-08	0.42321E-08
124.000	406.824	211.22	0.73011E 00	0.72056E-06	0.17627E-08	0.34203E-08
125.000	410.104	212.59	0.59474E 00	0.58696E-06	0.14266E-08	0.27682E-08
126.000	413.385	213.96	0.48514E 00	0.47880E-06	0.11563E-08	0.22436E-08
127.000	416.666	215.33	0.39628E 00	0.39110E-06	0.93852E-09	0.18210E-08
128.000	419.947	216.70	0.32413E 00	0.31989E-06	0.76280E-09	0.14800E-08
128.000	419.947	216.70	0.32413E 00	0.31989E-06	0.76280E-09	0.14800E-08
129.000	423.228	222.26	0.26598E 00	0.26250E-06	0.61028E-09	0.11841E-08
130.000	426.509	227.82	0.21934E 00	0.21647E-06	0.49098E-09	0.95267E-09
131.000	429.790	233.37	0.18173E 00	0.17935E-06	0.39711E-09	0.77052E-09
132.000	433.070	238.94	0.15125E 00	0.14927E-06	0.32281E-09	0.62636E-09
133.000	436.351	244.50	0.12642E 00	0.12477E-06	0.26368E-09	0.51163E-09
134.000	439.632	250.06	0.10610E 00	0.10471E-06	0.21638E-09	0.41985E-09
135.000	442.913	255.62	0.89398E-01	0.88229E-07	0.17835E-09	0.34605E-09
136.000	446.194	261.18	0.75605E-01	0.74616E-07	0.14762E-09	0.28643E-09
137.000	449.475	266.74	0.64169E-01	0.63330E-07	0.12268E-09	0.23804E-09
138.000	452.755	272.30	0.54651E-01	0.53936E-07	0.10235E-09	0.19859E-09
138.000	452.755	272.30	0.54651E-01	0.53936E-07	0.10235E-09	0.19859E-09
139.000	456.036	285.00	0.46791E-01	0.46179E-07	0.83726E-10	0.16245E-09
140.000	459.317	297.70	0.40336E-01	0.39809E-07	0.69097E-10	0.13407E-09
141.000	462.598	310.40	0.34989E-01	0.34532E-07	0.57485E-10	0.11154E-09
142.000	465.879	323.10	0.30526E-01	0.30127E-07	0.48181E-10	0.93486E-10
143.000	469.160	335.80	0.26774E-01	0.26424E-07	0.40661E-10	0.78895E-10
144.000	472.440	348.50	0.23599E-01	0.23290E-07	0.34532E-10	0.67004E-10
145.000	475.721	361.20	0.20895E-01	0.20622E-07	0.29501E-10	0.57242E-10
146.000	479.002	373.90	0.18580E-01	0.18337E-07	0.25341E-10	0.49170E-10
147.000	482.283	386.60	0.16586E-01	0.16369E-07	0.21879E-10	0.42453E-10
148.000	485.564	399.30	0.14862E-01	0.14668E-07	0.18981E-10	0.36830E-10
148.000	485.564	399.30	0.14862E-01	0.14668E-07	0.18981E-10	0.36830E-10
149.000	488.845	414.95	0.13368E-01	0.13193E-07	0.16429E-10	0.31879E-10
150.000	492.125	430.60	0.12072E-01	0.11914E-07	0.14297E-10	0.27742E-10
151.000	495.406	446.25	0.10942E-01	0.10799E-07	0.12504E-10	0.24263E-10
152.000	498.687	461.90	0.99520E-02	0.98218E-08	0.10987E-10	0.21319E-10
153.000	501.968	477.55	0.90801E-02	0.89614E-08	0.96964E-11	0.18814E-10
154.000	505.249	493.20	0.83094E-02	0.82007E-08	0.85918E-11	0.16670E-10
155.000	508.530	508.85	0.76254E-02	0.75257E-08	0.76421E-11	0.14828E-10
156.000	511.811	524.50	0.70161E-02	0.69244E-08	0.68217E-11	0.13236E-10
157.000	515.091	540.15	0.64715E-02	0.63869E-08	0.61099E-11	0.11855E-10
158.000	518.372	555.80	0.59831E-02	0.59049E-08	0.54897E-11	0.10651E-10

TABLE F-2 (cont)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
158.000	518.372	555.80	0.59831E-02	0.59049E-08	0.54897E-11	0.10651E-10
159.000	521.653	567.75	0.55428E-02	0.54703E-08	0.49701E-11	0.96436E-11
160.000	524.934	579.71	0.51438E-02	0.50766E-08	0.45098E-11	0.87505E-11
161.000	528.215	591.68	0.47816E-02	0.47190E-08	0.41010E-11	0.79573E-11
162.000	531.496	603.64	0.44519E-02	0.43936E-08	0.37370E-11	0.72510E-11
163.000	534.776	615.59	0.41512E-02	0.40970E-08	0.34120E-11	0.66205E-11
164.000	538.057	627.56	0.38766E-02	0.38259E-08	0.31212E-11	0.60563E-11
165.000	541.338	639.51	0.36252E-02	0.35778E-08	0.28604E-11	0.55502E-11
166.000	544.619	651.48	0.33947E-02	0.33503E-08	0.26260E-11	0.50954E-11
167.000	547.900	663.44	0.31830E-02	0.31413E-08	0.24149E-11	0.46857E-11
168.000	551.181	675.40	0.29882E-02	0.29491E-08	0.22243E-11	0.43159E-11
168.000	551.181	675.40	0.29882E-02	0.29491E-08	0.22243E-11	0.43159E-11
169.000	554.461	683.86	0.28082E-02	0.27715E-08	0.20628E-11	0.40026E-11
170.000	557.742	692.32	0.26412E-02	0.26067E-08	0.19150E-11	0.37157E-11
171.000	561.023	700.78	0.24862E-02	0.24537E-08	0.17795E-11	0.34528E-11
172.000	564.304	709.24	0.23422E-02	0.23116E-08	0.16551E-11	0.32115E-11
173.000	567.585	717.70	0.22082E-02	0.21793E-08	0.15409E-11	0.29899E-11
174.000	570.866	726.16	0.20834E-02	0.20561E-08	0.14359E-11	0.27861E-11
175.000	574.146	734.62	0.19671E-02	0.19414E-08	0.13392E-11	0.25985E-11
176.000	577.427	743.08	0.18586E-02	0.18343E-08	0.12501E-11	0.24256E-11
177.000	580.708	751.54	0.17574E-02	0.17344E-08	0.11679E-11	0.22662E-11
178.000	583.989	760.00	0.16628E-02	0.16410E-08	0.10920E-11	0.21189E-11
178.000	583.989	760.00	0.16628E-02	0.16410E-08	0.10920E-11	0.21189E-11
179.000	587.270	766.60	0.15742E-02	0.15536E-08	0.10234E-11	0.19857E-11
180.000	590.551	773.20	0.14912E-02	0.14717E-08	0.95969E-12	0.18621E-11
181.000	593.832	779.80	0.14134E-02	0.13950E-08	0.90055E-12	0.17473E-11
182.000	597.112	786.40	0.13404E-02	0.13229E-08	0.84560E-12	0.16407E-11
183.000	600.393	793.00	0.12719E-02	0.12552E-08	0.79451E-12	0.15416E-11
184.000	603.674	799.60	0.12075E-02	0.11917E-08	0.74697E-12	0.14493E-11
185.000	606.955	806.20	0.11469E-02	0.11319E-08	0.70270E-12	0.13634E-11
186.000	610.236	812.80	0.10899E-02	0.10757E-08	0.66146E-12	0.12834E-11
187.000	613.517	819.40	0.10363E-02	0.10227E-08	0.62300E-12	0.12088E-11
188.000	616.797	826.00	0.98584E-03	0.97295E-09	0.58711E-12	0.11391E-11
188.000	616.797	826.00	0.98584E-03	0.97295E-09	0.58711E-12	0.11391E-11
189.000	620.078	829.63	0.93817E-03	0.92590E-09	0.55542E-12	0.10777E-11
190.000	623.359	833.26	0.89308E-03	0.88140E-09	0.52562E-12	0.10198E-11
191.000	626.640	836.89	0.85041E-03	0.83929E-09	0.49758E-12	0.96547E-12
192.000	629.921	840.51	0.81003E-03	0.79944E-09	0.47120E-12	0.91428E-12
193.000	633.202	844.15	0.77180E-03	0.76170E-09	0.44636E-12	0.86609E-12
194.000	636.482	847.78	0.73558E-03	0.72596E-09	0.42297E-12	0.82071E-12
195.000	639.763	851.40	0.70127E-03	0.69210E-09	0.40094E-12	0.77796E-12
196.000	643.044	855.04	0.66875E-03	0.66000E-09	0.38018E-12	0.73767E-12
197.000	646.325	858.67	0.63792E-03	0.62958E-09	0.36060E-12	0.69969E-12
198.000	649.606	862.30	0.60868E-03	0.60072E-09	0.34214E-12	0.66387E-12
198.000	649.606	862.30	0.60868E-03	0.60072E-09	0.34214E-12	0.66387E-12
199.000	652.887	865.09	0.58094E-03	0.57334E-09	0.32490E-12	0.63042E-12

TABLE F-2 (cont)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
200.000	656.167	867.88	0.55460E-03	0.54734E-09	0.30862E-12	0.59882E-12
201.000	659.448	870.67	0.52958E-03	0.52265E-09	0.29323E-12	0.56896E-12
202.000	662.729	873.46	0.50581E-03	0.49920E-09	0.27868E-12	0.54073E-12
203.000	666.010	876.25	0.48323E-03	0.47691E-09	0.26492E-12	0.51404E-12
204.000	669.291	879.04	0.46177E-03	0.45573E-09	0.25191E-12	0.48880E-12
205.000	672.572	881.82	0.44137E-03	0.43559E-09	0.23961E-12	0.46492E-12
206.000	675.853	884.62	0.42196E-03	0.41644E-09	0.22796E-12	0.44232E-12
207.000	679.133	887.40	0.40350E-03	0.39823E-09	0.21693E-12	0.42092E-12
208.000	682.414	890.20	0.38594E-03	0.38090E-09	0.20649E-12	0.40066E-12
208.000	682.414	890.20	0.38594E-03	0.38090E-09	0.20649E-12	0.40066E-12
209.000	685.695	891.76	0.36922E-03	0.36439E-09	0.19684E-12	0.38193E-12
210.000	688.976	893.34	0.35328E-03	0.34866E-09	0.18767E-12	0.36414E-12
211.000	692.257	894.90	0.33809E-03	0.33367E-09	0.17896E-12	0.34724E-12
212.000	695.538	896.48	0.32361E-03	0.31938E-09	0.17069E-12	0.33119E-12
213.000	698.818	898.05	0.30980E-03	0.30575E-09	0.16282E-12	0.31594E-12
214.000	702.099	899.62	0.29663E-03	0.29275E-09	0.15535E-12	0.30144E-12
215.000	705.380	901.19	0.28406E-03	0.28035E-09	0.14825E-12	0.28766E-12
216.000	708.661	902.75	0.27208E-03	0.26852E-09	0.14150E-12	0.27456E-12
217.000	711.942	904.32	0.26064E-03	0.25723E-09	0.13508E-12	0.26210E-12
218.000	715.223	905.90	0.24972E-03	0.24646E-09	0.12897E-12	0.25025E-12
218.000	715.223	905.90	0.24972E-03	0.24646E-09	0.12897E-12	0.25025E-12
219.000	718.503	906.98	0.23930E-03	0.23617E-09	0.12315E-12	0.23895E-12
220.000	721.784	908.06	0.22935E-03	0.22635E-09	0.11761E-12	0.22820E-12
221.000	725.065	909.14	0.21986E-03	0.21698E-09	0.11234E-12	0.21797E-12
222.000	728.346	910.21	0.21079E-03	0.20803E-09	0.10732E-12	0.20824E-12
223.000	731.627	911.30	0.20212E-03	0.19948E-09	0.10255E-12	0.19898E-12
224.000	734.908	912.38	0.19385E-03	0.19131E-09	0.98008E-13	0.19016E-12
225.000	738.188	913.46	0.18594E-03	0.18351E-09	0.93681E-13	0.18177E-12
226.000	741.469	914.54	0.17838E-03	0.17605E-09	0.89560E-13	0.17377E-12
227.000	744.750	915.62	0.17116E-03	0.16892E-09	0.85635E-13	0.16616E-12
228.000	748.031	916.70	0.16426E-03	0.16211E-09	0.81897E-13	0.15890E-12
228.000	748.031	916.70	0.16426E-03	0.16211E-09	0.81897E-13	0.15890E-12
229.000	751.312	917.31	0.15765E-03	0.15559E-09	0.78361E-13	0.15204E-12
230.000	754.593	917.92	0.15134E-03	0.14936E-09	0.74990E-13	0.14550E-12
231.000	757.874	918.53	0.14530E-03	0.14340E-09	0.71774E-13	0.13926E-12
232.000	761.154	919.14	0.13951E-03	0.13769E-09	0.68706E-13	0.13331E-12
233.000	764.435	919.75	0.13398E-03	0.13223E-09	0.65779E-13	0.12763E-12
234.000	767.716	920.36	0.12868E-03	0.12700E-09	0.62986E-13	0.12221E-12
235.000	770.997	920.96	0.12361E-03	0.12200E-09	0.60321E-13	0.11704E-12
236.000	774.278	921.57	0.11876E-03	0.11721E-09	0.57776E-13	0.11210E-12
237.000	777.559	922.19	0.11411E-03	0.11262E-09	0.55347E-13	0.10739E-12
238.000	780.839	922.80	0.10966E-03	0.10822E-09	0.53027E-13	0.10289E-12
238.000	780.839	922.80	0.10966E-03	0.10822E-09	0.53027E-13	0.10289E-12
239.000	784.120	923.20	0.10539E-03	0.10402E-09	0.50788E-13	0.98545E-13
240.000	787.401	923.59	0.10131E-03	0.99992E-10	0.48651E-13	0.94398E-13
241.000	790.682	924.00	0.97407E-04	0.96133E-10	0.46611E-13	0.90441E-13

TABLE F-2 (concl)

VENUS MODEL ATMOSPHERE NO SP8011/V5 DATE 04 AUG 1969
MEAN MOLECULAR MASS = 42.40 GRAMS/MOLE
INITIAL PRESSURE =0.169000E 09 DYNES/SQCM AT 6048.00 KM RADIUS
PRINT INTERVAL = 1.00 KM

ALTITUDE IS ABOVE 6050.0 KM RADIUS

ALTITUDE		TEMP	PRESSURE		MASS DENSITY	
KM	KFT	KELVIN	DYNE/CM2	ATM	G/CM3	SLUG/FT3
242.000	793.963	924.40	0.93662E-04	0.92437E-10	0.44664E-13	0.86664E-13
243.000	797.244	924.80	0.90075E-04	0.88897E-10	0.42806E-13	0.83057E-13
244.000	800.524	925.20	0.86637E-04	0.85504E-10	0.41031E-13	0.79613E-13
245.000	803.805	925.59	0.83343E-04	0.82253E-10	0.39336E-13	0.76324E-13
246.000	807.086	926.00	0.80185E-04	0.79137E-10	0.37717E-13	0.73183E-13
247.000	810.367	926.40	0.77159E-04	0.76150E-10	0.36170E-13	0.70181E-13
248.000	813.648	926.80	0.74257E-04	0.73286E-10	0.34692E-13	0.67313E-13
248.000	813.648	926.80	0.74257E-04	0.73286E-10	0.34692E-13	0.67313E-13
249.000	816.929	927.00	0.71474E-04	0.70540E-10	0.33279E-13	0.64572E-13
250.000	820.209	927.21	0.68806E-04	0.67906E-10	0.31929E-13	0.61952E-13
251.000	823.490	927.43	0.66246E-04	0.65380E-10	0.30638E-13	0.59447E-13
252.000	826.771	927.64	0.63790E-04	0.62956E-10	0.29403E-13	0.57053E-13
253.000	830.052	927.84	0.61434E-04	0.60631E-10	0.28223E-13	0.54762E-13
254.000	833.333	928.06	0.59173E-04	0.58399E-10	0.27094E-13	0.52572E-13
255.000	836.614	928.26	0.57003E-04	0.56258E-10	0.26014E-13	0.50476E-13
256.000	839.895	928.48	0.54920E-04	0.54202E-10	0.24981E-13	0.48472E-13
257.000	843.175	928.69	0.52920E-04	0.52228E-10	0.23992E-13	0.46553E-13
258.000	846.456	928.90	0.51000E-04	0.50333E-10	0.23046E-13	0.44717E-13

I. TRIAL MISSION SUMMARY

A. PURPOSE OF TRIAL MISSION

The trial mission system was configured as an effective method of early problem identification, although a high percentage of design data and techniques developed were applied directly to the subsequent baseline mission studies. It is important to recognize that the trial mission was a means to an end and not a recommended configuration. Its identification and discussion here is to illustrate its usefulness as a mission design tool.

B. TRIAL MISSION DESCRIPTION

1. General Discussion

The trial mission is composed of eight separate entry probes, which are mounted on the modified Mariner spacecraft (Configuration 20a) by means of a common capsule adapter. The eight probes include three basic types of probes: ballistic descent probes; high cloud probes; and balloon probes. These probes are supplemented by upper-atmospheric instruments mounted on the impacting spacecraft. The ballistic probes are identified as "large" or "small" due to varied instrument complements. Table G-1 summarizes the trial mission probes and target zones selected.

The instrument complements selected for the trial mission probes are identified in Table G-2.

Table G-1 Trial Mission Probes and Target Zones

Probe Type	Objectives	Target Sites
Large Ballistic	Clouds, Atmospheric Structure, Atmosphere Dynamics	Light-Side Morning Terminator
Small Ballistic	Provides Distribution of Above	One Each: Subsolar, Antisolar, Pole
High Cloud	High Cloud Composition	One Each: Subsolar, Light-Side Morning Terminator
Balloon	General Circulation	Two Each: Subearth
Impacting Spacecraft	Upper Atmosphere	Light-Side Morning Terminator

Table G-2 Trial Mission Instrumentation

Large Ballistic Probes Pressure Temperature Radar Altimeter (70 km) Mass Spectrometer Solar Radiometer Thermal Radiometer Nephelometer Cloud Particle Number, Density, Size Evaporimeter/Condensimeter Cloud Composition Accelerometer Transponder UV Photometer	**High-Cloud Probes** Pressure Temperature Nephelometer Solar Radiometer Cloud Composition
	Balloon Probes Pressure Temperature Solar Radiometer Transponder
Small Ballistic Probes Pressure Temperature Acceleration Solar Radiometer Thermal Radiometer Transponder	**Impacting Spacecraft** Neutral Particle Mass Spectrometer Ion Mass Spectrometer Electron Temperature and Density Television Microwave Imager Dayglow Photometer and Spectrometer

2. Ballistic Probe Description

The large and small ballistic descent probes are similar in design and operation, but differ primarily in the instruments they carry, which affects their overall size. Both contain a pressure vessel designed to withstand the thermal and pressure environments all the way to the planet's surface. The science instruments and supporting subsystems are housed within this pressure vessel. A conic skirt is added to the pressure vessel to provide aerodynamic stability during subsonic descent. All the items are contained in a blunt cone aeroshell/heat shield for entry, and are extracted by parachutes. Figure G-1 presents the major configuration characteristics of the trial mission ballistic probes.

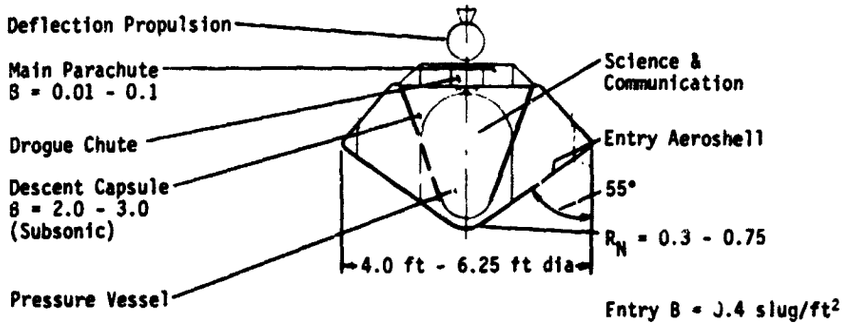


Fig. G-1 Trial Mission Ballistic Probe Characteristics

3. High-Cloud Probe Description

In the instrument selection process for each target site, the first ballistic probe was found to require a large instrument complement, which, in turn, defined a rather large probe. Some of the instruments, however, required deployment at a very high altitude (i.e., a radius of 6130 km) to be effective, and required a slow descent rate at these high altitudes to be compatible with sample-acquisition and processing times. Providing the necessary

deployment altitude and descent velocity to the large probe would have required large supersonic decelerators, and extremely large parachutes would have been needed to produce the required subsonic ballistic coefficients (in the range of 0.005 slug/ft^2). Since relatively few instruments required those conditions (operation above a radius of 6120 km), and since these instruments would be of less value at lower altitudes, it was determined that they should be placed in an extremely light probe designed to operate only above a radius of 6100 km. This would allow the use of supersonic decelerators similar to those already tested, and the size of the main parachute could be reduced to an acceptable percentage of entry weight. Hence, the high-cloud probe was configured to contain the high-cloud instruments, no protection was provided against the pressure and temperature environments to be encountered at lower altitudes, and the probe's mission was to be considered complete at the 6100-km radius level. At this time it could be switched to a noncoherent data link to avoid interference with the other probes, and it could be monitored until its destruction by the environment. See Fig. G-2 for the characteristics of the high-cloud probe.

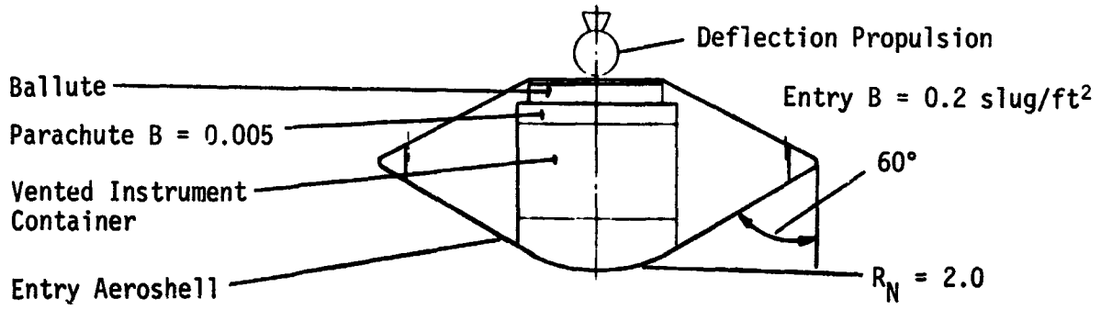


Fig. G-2 Trial Mission High-Cloud Probe Characteristics

4. Balloon Probe Description

The balloon probes are instrumented gondolas supported by hydrogen-filled balloons. They are contained within an aeroshell for entry in the same fashion as the ballistic and high-cloud probes. However, their deployment altitude is not as critical since they will return to the density altitude for which they were designed. Their float altitudes are the 50- and 500-mb pressure zones, and their primary data are via the transponders and ranging used to track their positions. The general configuration of the balloon probe is depicted in Fig. G-3.

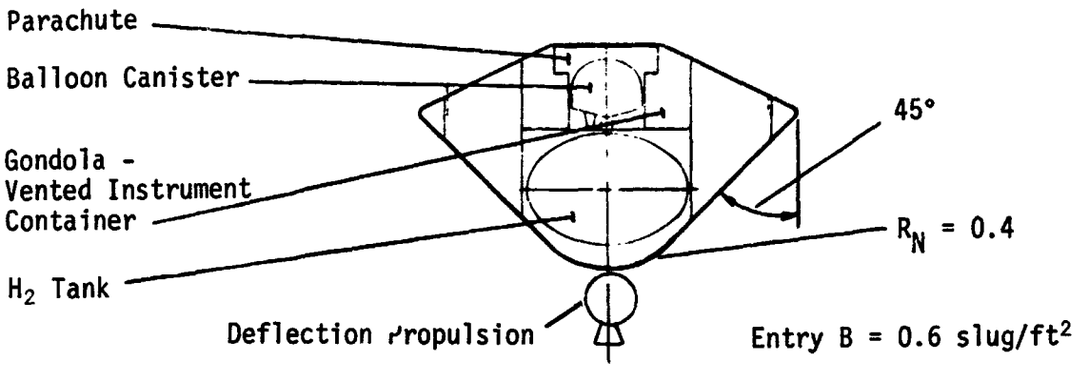


Fig. G-3 Trial Mission Balloon Probe Characteristics

5. Planetary Vehicle Configuration

The Planetary Vehicle is designated as that equipment placed on the interplanetary transfer trajectory. It includes basically the modified Mariner spacecraft, the eight entry probes (including their deflection propulsion systems and biological canisters), and the common capsule adapter. The capsule adapter is configured to provide a clean interface between the probes and the Mariner spacecraft and combines all common signals, requirements, and support-function interfaces. It includes the structure that adapts the probes to the spacecraft, and carries electronic equipment

such as separation sequencers, power-conditioning equipment, batteries, and separation mechanisms. Figure G-4 shows the general arrangement of the Planetary Vehicle within the outline of the payload fairing.

A weight summary for the trial mission is shown in Table G-3.

Table G-3 Trial Mission Weight Summary

Probe Type	Target	ΔV (m/sec)	Probe Weight Breakdown (lb)					Entry Weight (lb)	Deflection Propulsion Weight (lb)	Probes Installed on Planetary Vehicle (lb)
			Science	Communications	Descent Capsule	Decelerator(s)	Aeroshell			
Large	LSMT	5	75	55	275	15	198	488	4	552
High Cloud	LSMT/SS	5/35	25	30	70	94	116	281	3/10	343/350
Small	P/SS/AS	17/41/50	11	41	114	34	81	229	10/8/10	3 @ 285
Balloon	50 mb LSMT 500 mb	5	10	50	217 183	13 11	123	353 317	3	405 368
Probe Total										2873
Modified Mariner (plus Probe Adapter Structure)										1171
Grand Total										4044
Mission Margin										+106

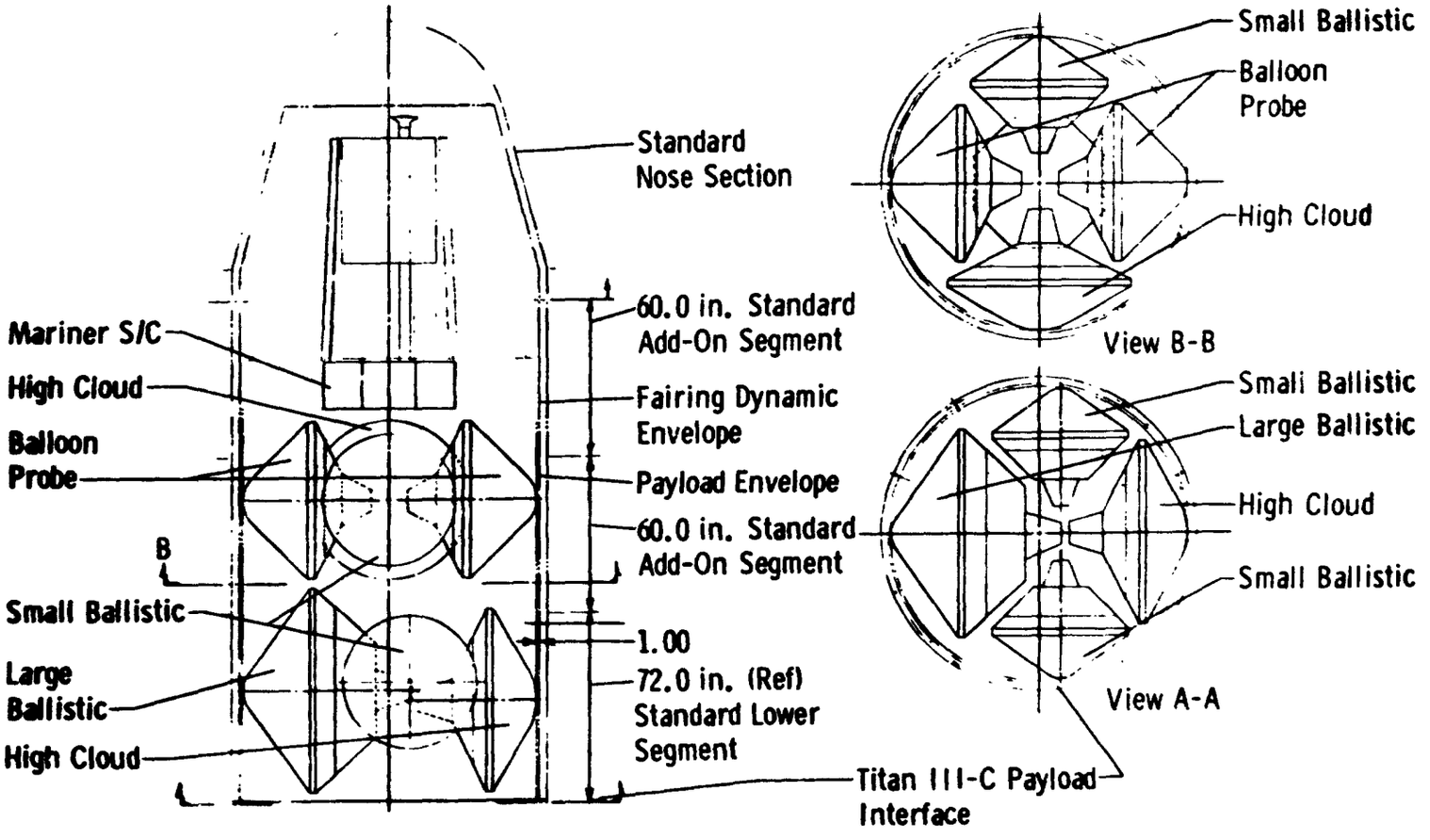


Fig. G-4 Trial Mission Planetary Vehicle

C. TRIAL MISSION OPERATION

The trial mission utilizes a Type II trajectory to Venus and an arrival date of 10/31/75. A 10-day launch period is considered from 5/25/75 to 6/4/75. The maximum value of C_3 for this mission is 6.0 km^2/sec^2 and the maximum V_{HE} is 3.6 km/sec. The Titan IIIC's payload capability for the mission is 4150 lb. The communication range is 95 x 10^6 km, and the maximum mission time is 159 days. All launch and midcourse maneuvers were considered to be accomplished in the normal fashion for the designated systems so that the study effort could be concentrated upon the deflection, approach, and entry portions of the mission.

Since the parametric flight mechanics studies (discussed in detail under the baseline mission summary) and the methodology are applicable to both the trial and the baseline missions, only the resulting parameters for each mission phase will be included here.

The deflection and entry parameters for an impacting spacecraft mission are defined in Table G-4. The impacting spacecraft is targeted near the light side of the morning terminator site (LSMT). The periapsis radius is 3200 km. The activity sequence is shown in Fig. G-5.

Table G-4 Deflection and Entry Parameters for an Impacting Spacecraft Mission*

Entry Altitude = 815,000 ft (6300 km); Entry Velocity = 35,367 fps (10.78 km/sec);			Deflection Radius = 4 x 10^6 km; Deflection Angle = 20° (160° for balloons).	
Targets	Subsolar	Polar	Antisolar	LSMT
Latitude (deg)	0	-60	0	-30
Longitude (deg)	25/12.5	55	157	66
Entry Flight Path Angle, γ_E (deg)	50/45	25	35	45
Entry Angle of Attack, α_E (deg)	34/38	51	45	34/27
Deflection Velocity (m/sec)	35/40	17	60	5 fwd/12 retro
Time from Deflection to Entry (hr)	296.8/ 296.5	298.3	295.0	299.6/ 301.2
Maximum Entry Load Factor (g)	393/352	196	275	x/337/ 341/352
Probe Types	Small/ Cloud	Small	Small	S/C/Large/ Balloon/ Cloud

*Subearth point is at 3.3° latitude and 93.97° longitude.

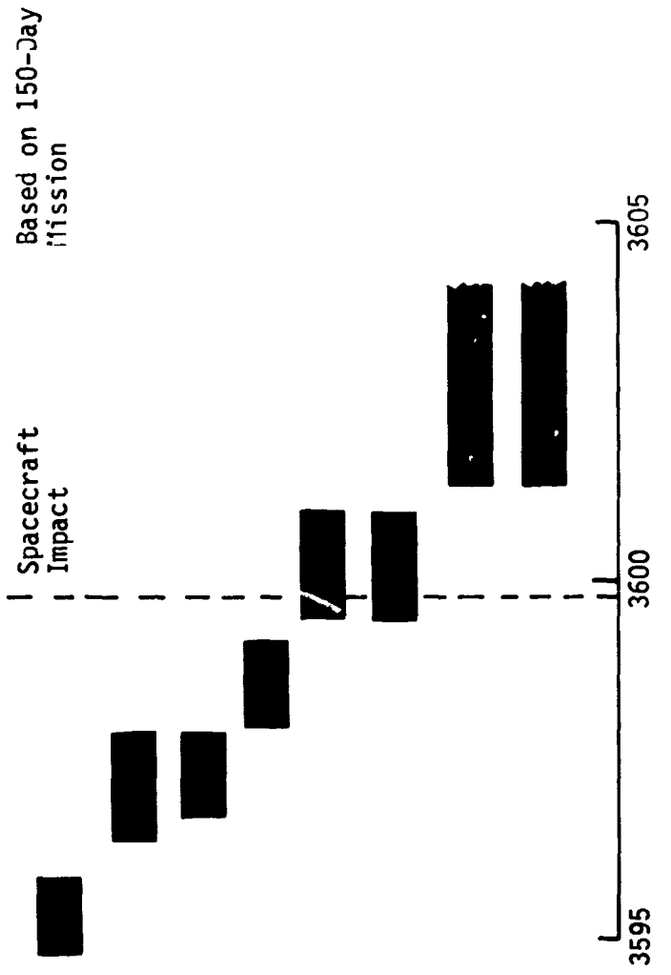


Fig. G-5 Trial Mission Activity Sequence

D. TRIAL MISSION CONCLUSIONS

The trial mission study effort resulted in a mission definition that would produce a good, but not an optimum, science data return. The trial mission utilizes essentially all the Titan IIIC's payload capability. The number of probes to be entered leads to complicated, but not unfeasible, separation and activity sequences.

The trial mission has brought out the need for the high cloud probe, and the desire for balloon/transponder probes. It has shown that, by properly applying the deflection velocity increment, coherent communications may be maintained with all entry probes within the capability of the deep space communications net.

The most significant contributions of the trial mission definition are that no insoluble problems were discovered, and that the solutions developed for the trial mission can be applied with confidence to the baseline mission studies.

II. TRIAL MISSION STUDIES

A. REQUIREMENTS

A mission that encompassed all likely probe-type candidates and operating modes was identified in the early weeks of the study to aid in identifying potential items which would require more study. The mission that was selected was purposely complicated; it contained eight separate probes, and used an impacting spacecraft. The science objectives were obtained directly from the 18 science questions in Appendix D. This effort was limited to defining the gross configuration of all probes and the packaging on the planetary vehicle, selecting the science instruments, and determining the flight-mechanics parameters.

B. ENTRY PROBE STUDIES

1. Trial Mission Science Capabilities

In retrospect, the trial mission is both reasonably feasible and reasonably adequate for the accomplishment of the scientific objectives; it is not, however, an optimum mission and, in some cases, the accomplishment of the desired objectives is superfluous, while in others, it is less than ideal. For this reason, it has proved useful as a base from which redundancy can be removed and on which improvements can be made. The specific trial-mission probe configurations have also provided bases for investigating mechanized instrument sampling and data handling during descent. Finally, the particular problems encountered have led to a reexamination both of the science mission requirements defined earlier

in the study and of the methods selected to meet those requirements (e.g., probe types, instrument mechanization concepts, data handling, etc). This, in turn, has led to the identification of tradeoff studies which were not obvious at the beginning of this work.

The arrival date selected for the trial mission is a result of the requirement to investigate variations between the subsolar, polar, and antisolar regions and the requirement for a direct-earth communication link. As shown in Fig. G-6, all three regions are within view of Earth for this arrival date. Earlier arrival dates give poor viewing of the most interesting region on the planet -- the subsolar region -- while later arrival dates increase both the communication range to Earth and the entry flight path angle at the subsolar region (steep entry flight path angles are undesirable since deployment above the clouds is extremely difficult). Fortuitously, the selected arrival date also provides the maximum payload capability.

The trial mission targeting is also summarized in Fig. G-6. The large probe, which contains all of the proposed instruments, is targeted to the lightside of the morning terminator, well within view of Earth, at the point labeled 2. This was done since it was not certain at the time whether the high data rates could be reasonably achieved near the surface at the limb (subsolar). The two (500- and 50-mb) balloon transponder probes were also targeted there due to the uncertainty in the wind pattern. The impacting spacecraft was also targeted to the same general vicinity since that required the least ΔV. The small probes were targeted to the subsolar, polar, and antisolar regions to obtain information in the variations in atmospheric and cloud structure between these points. The high-cloud probes were targeted to the subsolar region and to the light side of the morning terminator to complement the information from the small and large descent probes at those points.

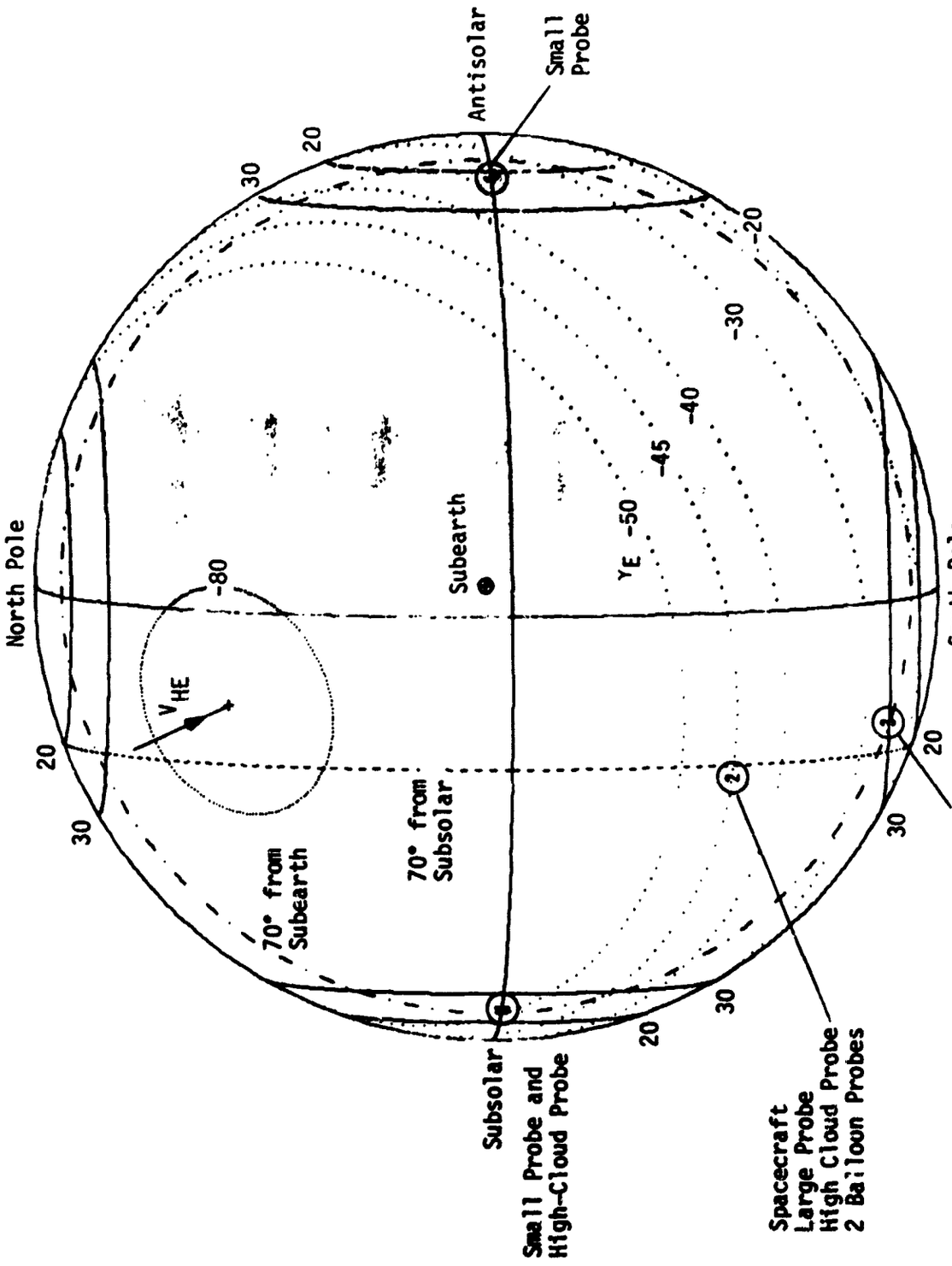


Fig. G-6 Venus As Seen From Earth On 10/30/75, Type II Trajectory, 5/30 Launch Date

The three general types of probes selected for the trial mission are a direct result of the requirements to observe the atmosphere and clouds from above the cloud tops to the surface and of the penalties forced on the design of a single system to meet these requirements over the extreme range of environmental conditions between the cloud tops and the surface of Venus.

The particular terminal-descent (postentry) ballistic coefficients for the trial mission probes and the staging (parachute-release) altitudes were selected to meet the requirements of the cloud objectives in the region of the cloud tops, to complement one another in altitude coverage, and to make the descent times compatible with reasonable thermal-control and power systems. The selections were made without the luxury of complete parametric data. The resulting descent profiles and coverage are shown in Fig. G-7 and G-8.

The instrument complements for the various probe configurations of the trial mission are summarized in Tables G-5 thru G-8, which list the sample time intervals selected for each instrument to meet the specified altitude sampling intervals. The minimum sample time for the cloud composition experiment (300 sec) was the controlling factor in selecting B = 0.005 slug/ft^2 for the high-cloud probe. The analysis was based on the MMC Lower Density Model Atmosphere, since this represents the worst case, in this instance.

2. Trial Mission Probes

The probe configurations evolved for the trial mission are shown in Fig. G-9 and G-10. A summary of probe weights is given in Table G-9. These types of probes evolved into the final versions used for the baseline mission and are described in detail in Vol II, Chapter III, Sections B thru F.

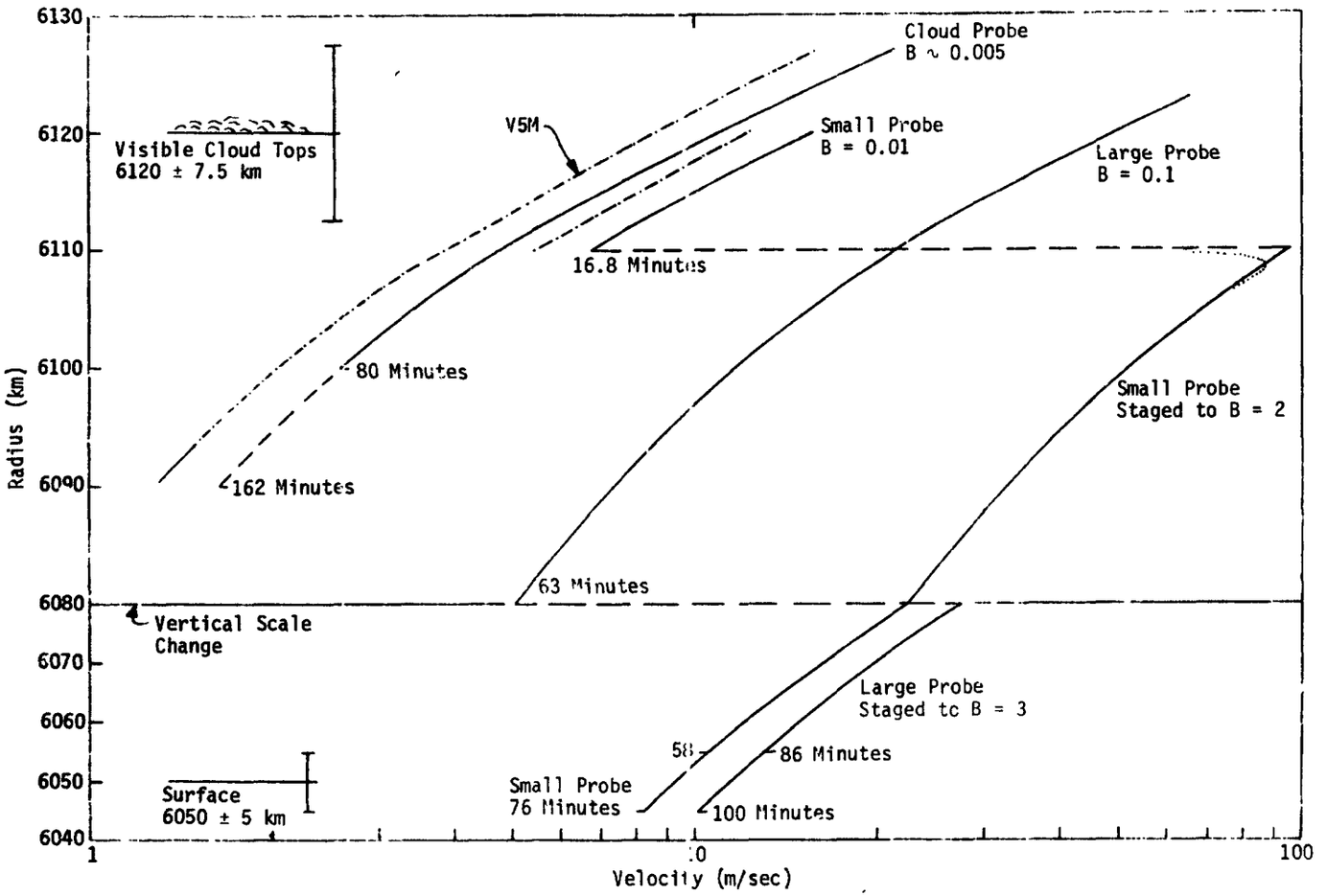


Fig. G-7 Trial Mission Velocity Profiles in MMC-Lower Model Atmosphere

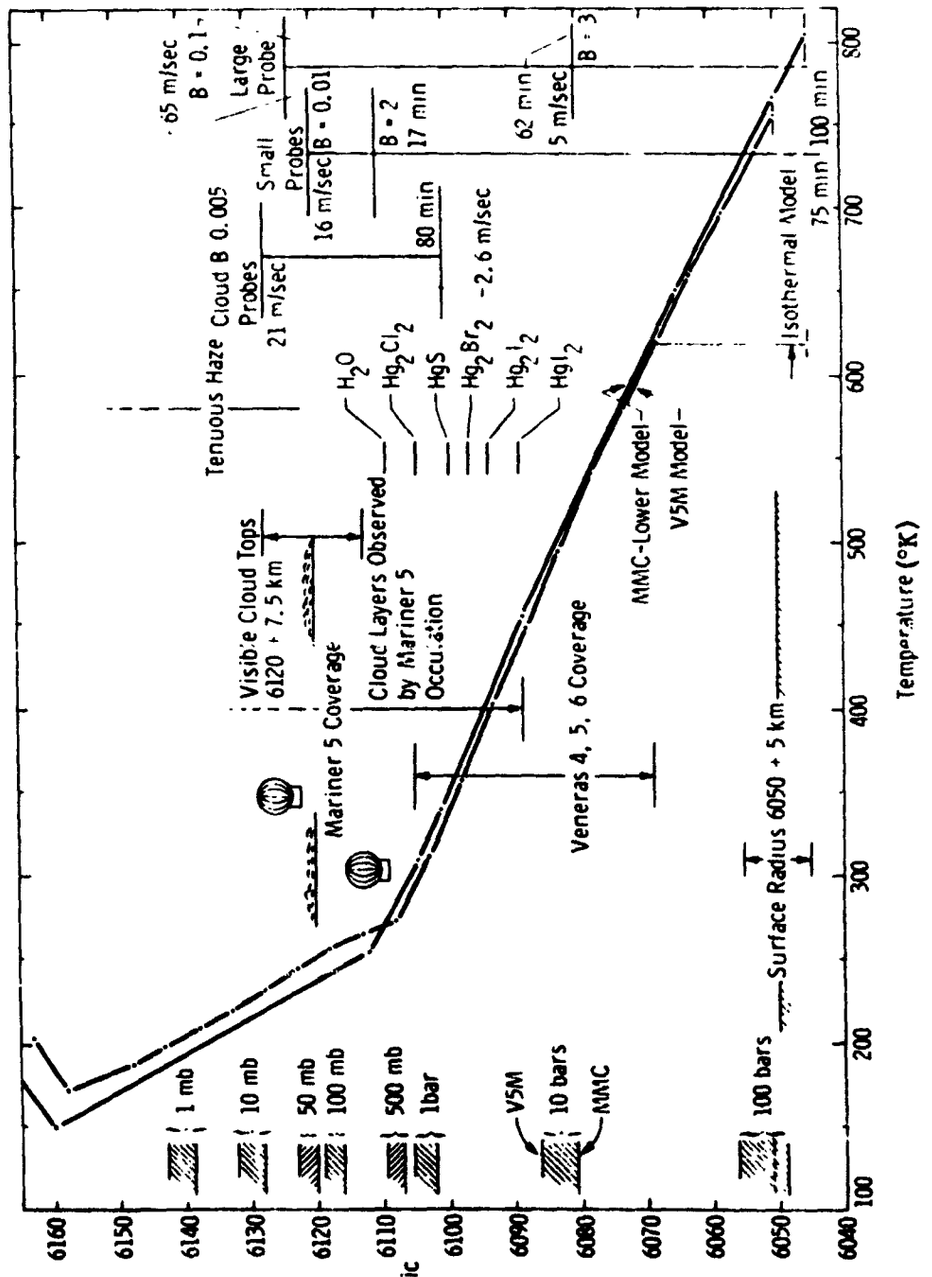


Fig. G-8 Vertical Targeting

Table G-5 Trial Mission Large Probe Instruments

Instrument	Sampling Time Interval (sec)	Bits/Sample	Average Bit Rate (bps)
Pressure	10	8	0.8
Temperature	10	8	0.8
Solar Radiometer	30	480	16
Thermal Radiometer	10	14	1.4
Mass Spectrometer	30	600	20
Nephelometer	10	16	1.6
Cloud Particle No.	10	80	8
Cloud Composition	300	1600	5.333
Evap/Condensimeter	30	456	15.2
Radar Altimeter	30	56	1.866
Transponder			
			71. bps total
Accelerometer	Stored During Entry	20000	
UV Photometer		3200	

Table G-6 Trial Mission Small Probe Instruments

Instrument	Sampling Time Interval (sec)	Bits/Sample	Average Bit Rate (bps)
Pressure	10	8	0.8
Temperature	10	8	0.8
Solar Radiometer	60	1200	20
Thermal Radiometer	10	14	1.4
Transponder	-	-	-
Accelerometer	Stored during entry	20000	23 bps total

Table G-7 Trial Mission Cloud Probe Instruments

Instrument	Sampling Time Interval (sec)	Bits/Sample	Average Bit Rate (bps)
Pressure	10		0.8
Temperature	10		0.8
Solar Radiometer	60	480	8
Nephelometer	10	16	1.6
Cloud Composition	300	1600	5.333
			16.533 bps total

Table G-8 Trial Mission Balloon Probe Instruments

Instrument	Sampling Time Interval (sec)	Bits/Sample	Average Bit Rate (bps)
Pressure	600	8	Into Storage
Temperature	600	8	
Solar Radiometer	600	120	

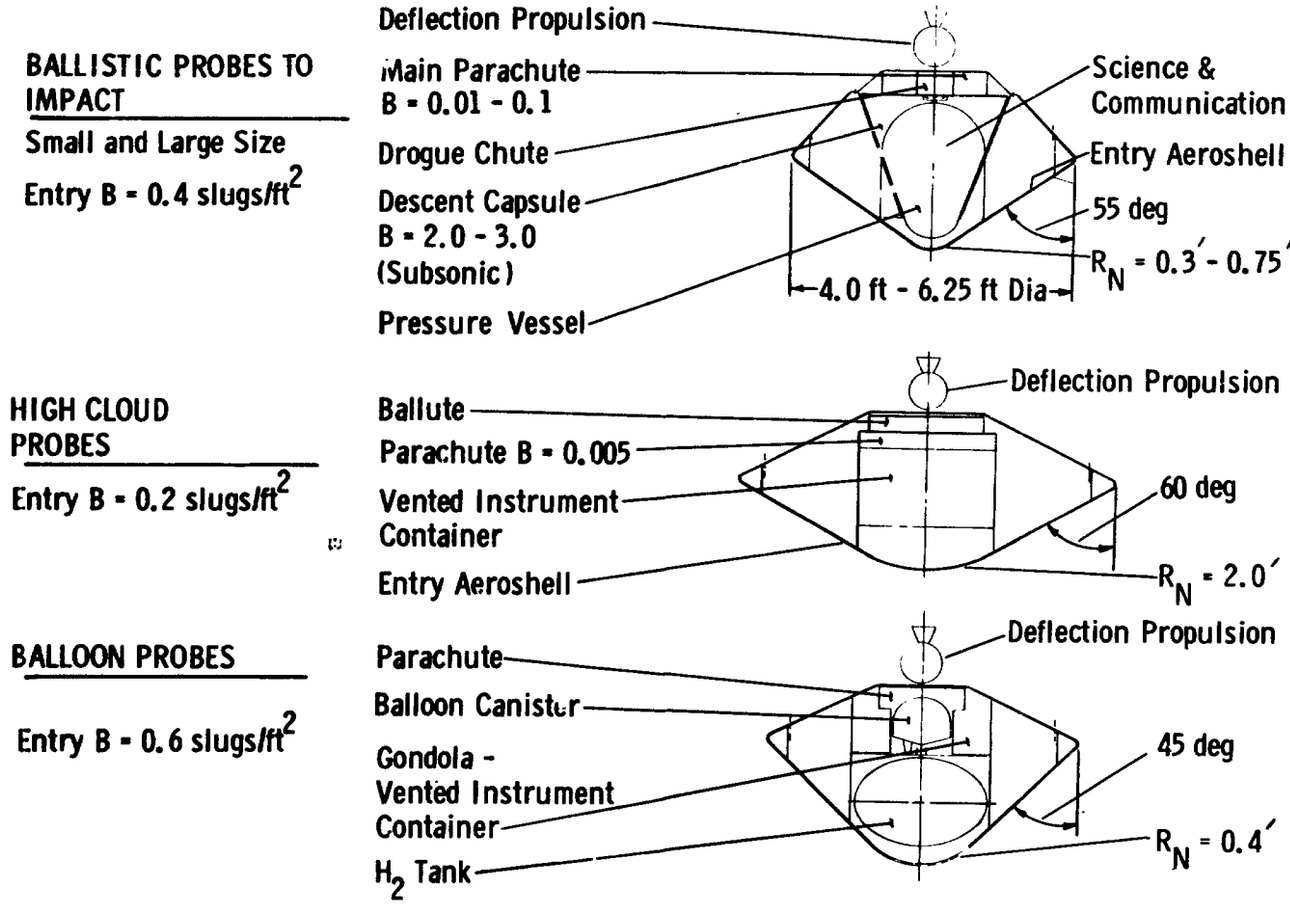


Fig. G-9 Probe Configuration Summary

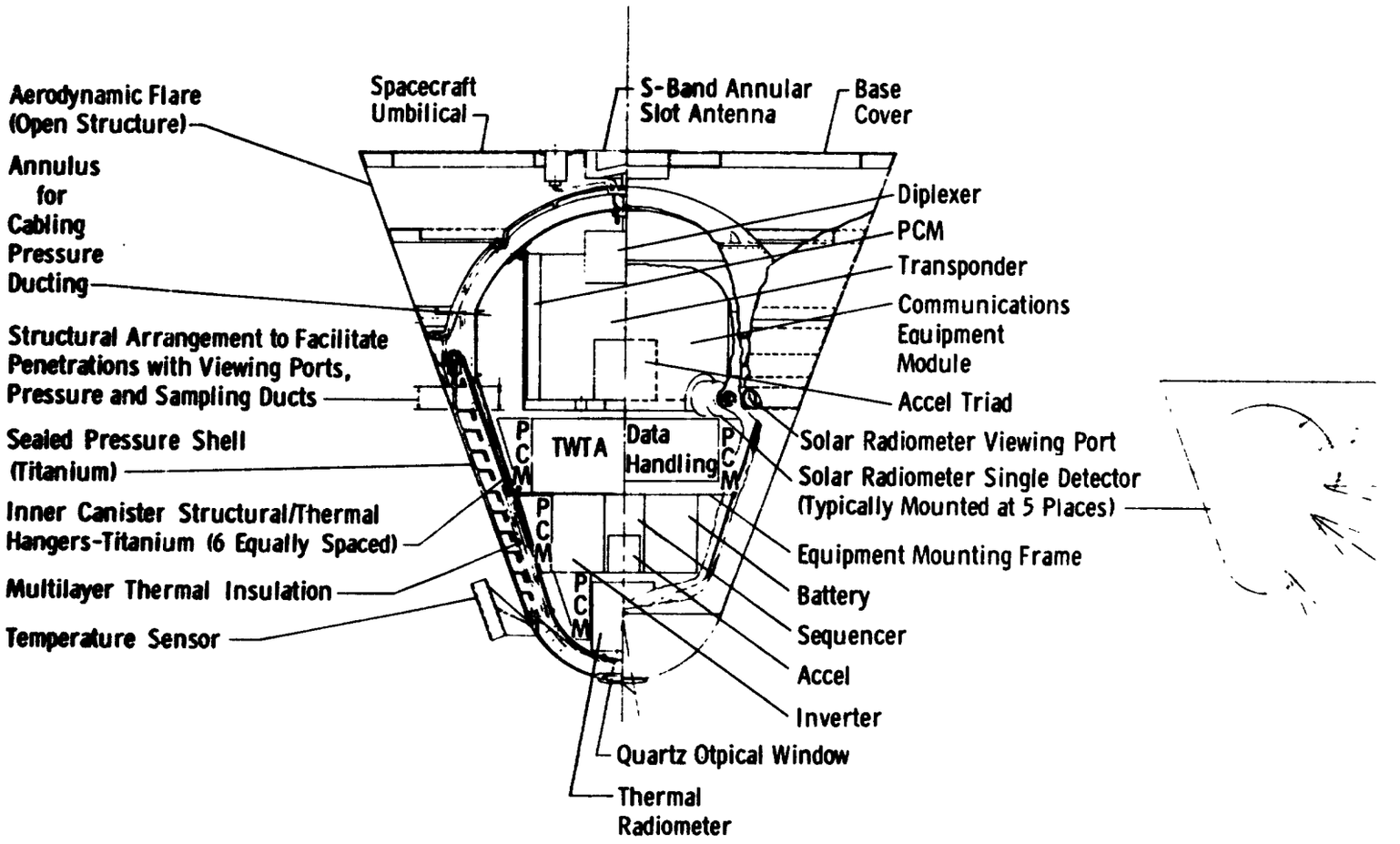


Fig. G-10 Small Probe Internal Arrangement - Trial Case

Table G-9 Probe Weight Summary - Trial Case

Probe Type	Target	Δ_V (m/sec)	γ_E (-deg)	Probe Weight Breakdown (lb)					Entry Weight (lb)	Deflection Propulsion Weight (lb)	Probes Deflection Installed Propulsion on Planetary Vehicle (lb)
				Science	Commun-ications	Descent Capsule	Decel-erator(s)	Aero-shell			
Large	LSMT	5	45	75	55	275	15	198	488	4	552
High Cloud	LSMT/SS	5/35	45	25	30	70	94	116	281	3/10	343/350
Small	P/SS/AS	17/41/50	25/50/35	11	41	114	34	81	229	10/8/10	3 @ 285
Balloon	50 mb LSMT 5000 mb	5	45	10	50	217 183	13 11	123	353 317	3	405 368
Probe Total											2873
Modified Mariner (plus Probe Adaptor Structure)											1171
Grand Total Mission Margin											4044 +106

3. Trial Mission Probe Deflection, Entry, and Descent

The deflection and entry parameters for the trial mission are shown in Table G-10. The spacecraft is on an impacting path and is targeted near the light side of the morning terminator. The spacecraft's periapsis is 3200 km, and its entry characteristics are similar to those shown in Table G-10 under the LSMT target. Except for the balloon probes all of the probes are deflected forward at an angle of 20° from the spacecraft's velocity vector. The balloon probes are deflected backward to achieve the desired staggered entry times.

The entry times and active experiment durations are noted in Fig. G-11. The times are based on a 150-day mission. The probe operating times are staggered so that no more than two probes are working at one time and so that these two probes are at the same target area. The deflection impulse occurs near 3300 hr.

Descent profiles for each type of probe and target are presented in Fig. G-12 thru G-19.

Table G-10 Deflection and Entry Parameters for the Trial Mission*

Entry Altitude = 815,000 ft (6300 km); Deflection Radius = 4 x 10^6 km;
Entry Velocity = 35,367 fps (10.78 km/sec); Deflection Angle = 20° (160° for balloons)

Target	Subsolar	Polar	Antisolar	LSMT
Latitude (deg)	0	-60	0	-30
Longitude (deg)	25/12.5	55	157	66
Entry Flight Path Angle, γ_E (deg)	-50/45	-25	-35	-45
Entry Angle of Attack, α_E (deg)	34/38	51	45	34/27
Deflection Velocity (m/sec)	35/40	17	60	5 fwd/12 retro
Time from Deflection to Entry (hr)	296.8/ 296.5	298.3	295.0	299.6/ 301.2
Maximum Entry Load Factor (g)	393/352	196	275	x/337/ 341/352
Probe Types	Small/ Cloud	Small	Small	S/C/Large/ Balloon/ Cloud

*Subearth point is at 3.3° latitude and 93.97° longitude.

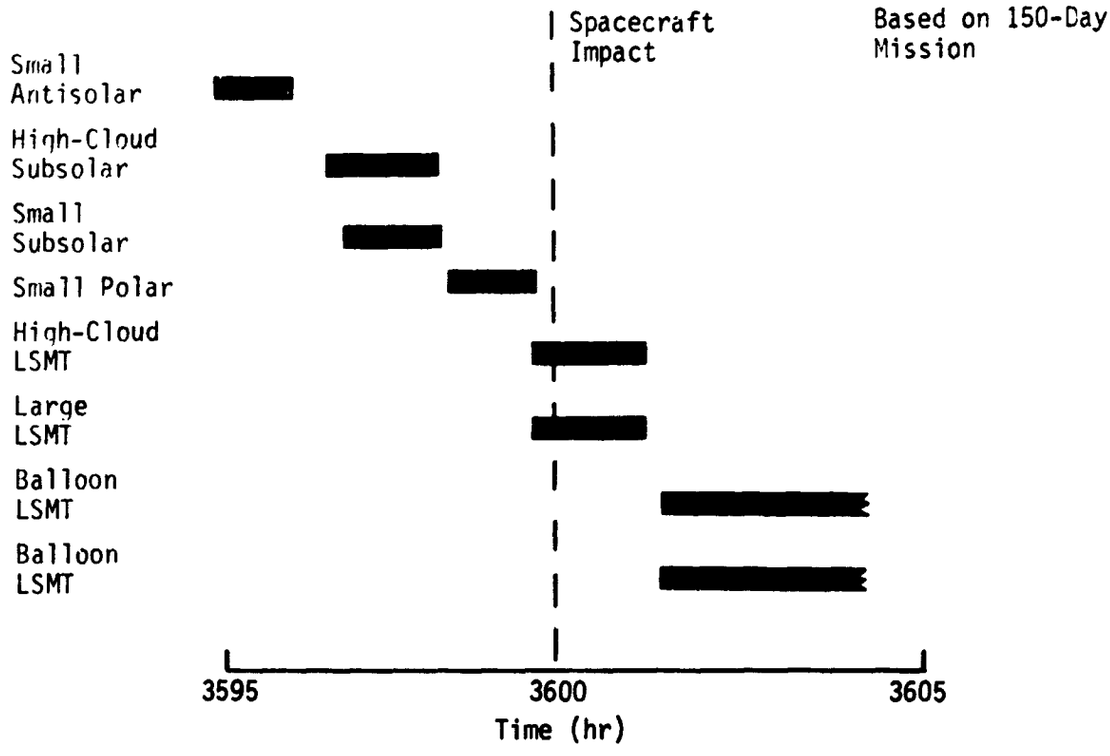


Fig. G-11 Activity Sequence - Trial Mission

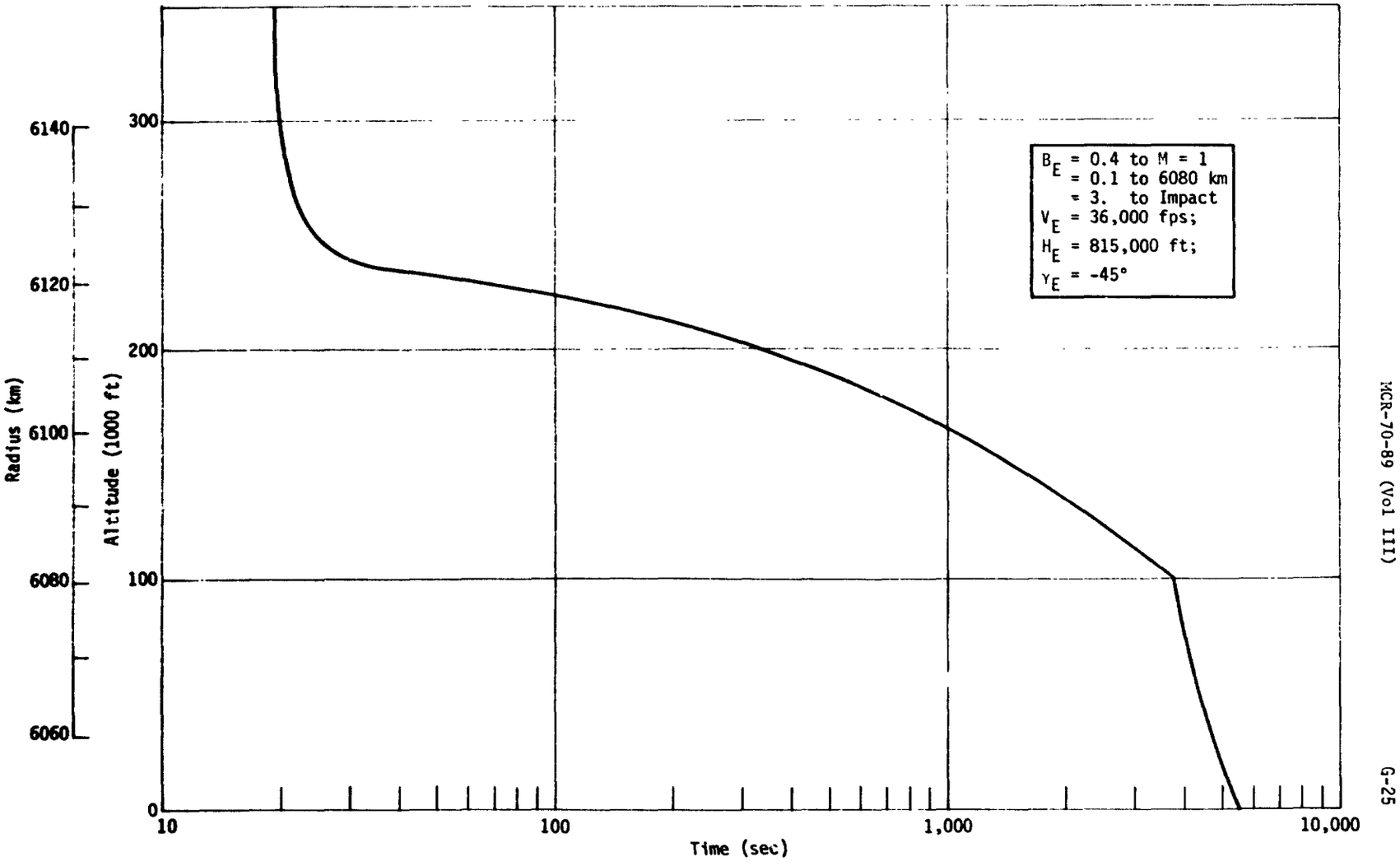


Fig. G-12 Venus Descent Profile, Altitude vs Time, Large Probe

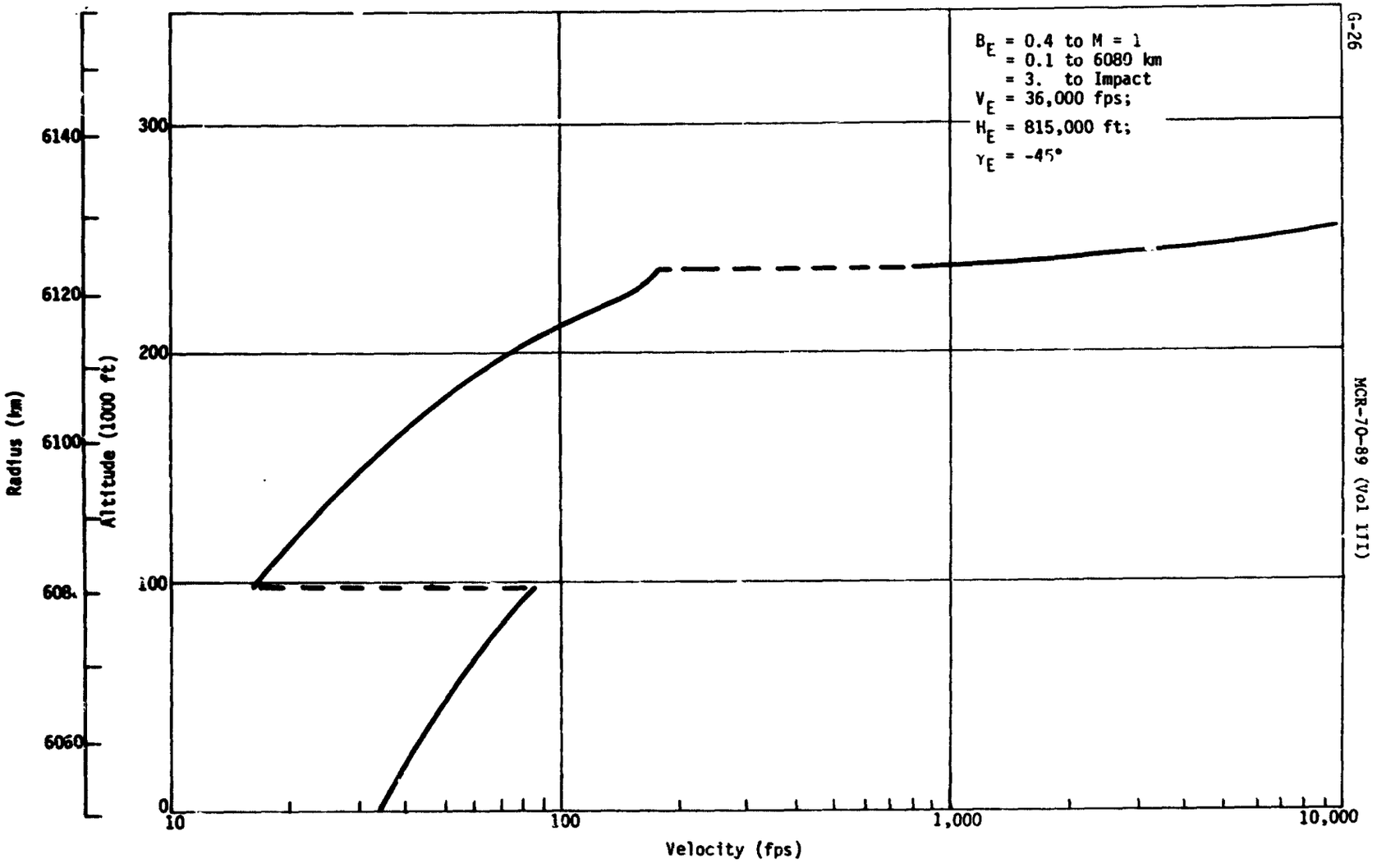


Fig. G -13 Venus Descent Profile, Altitude vs Velocity, Large Probe

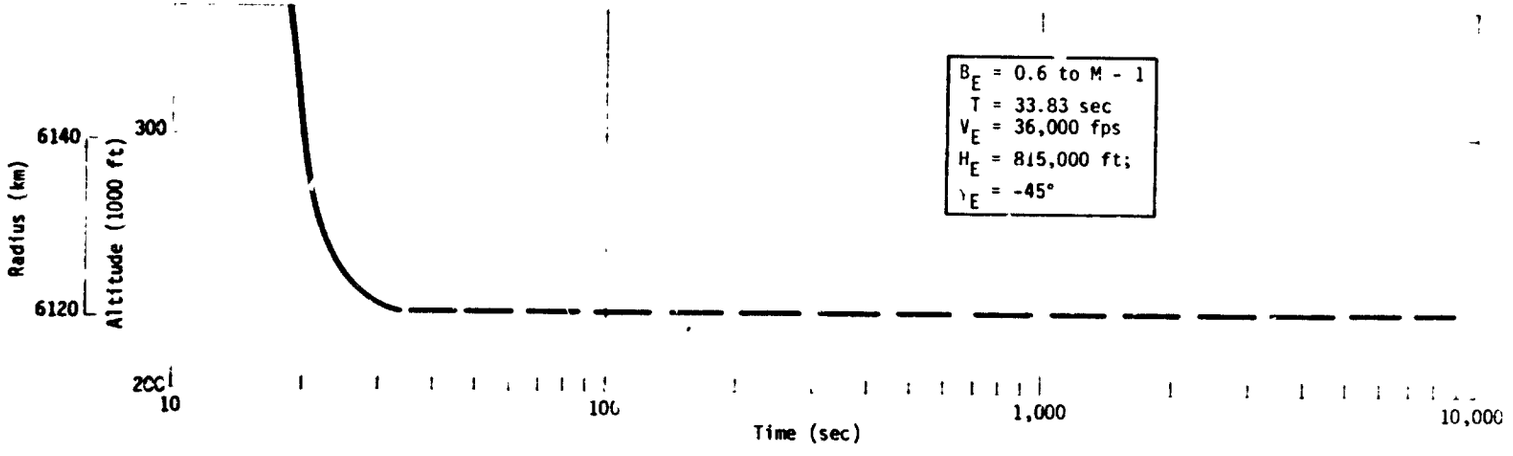


Fig. G-14 Venus Descent Profile, Altitude vs Time, Balloon Probe

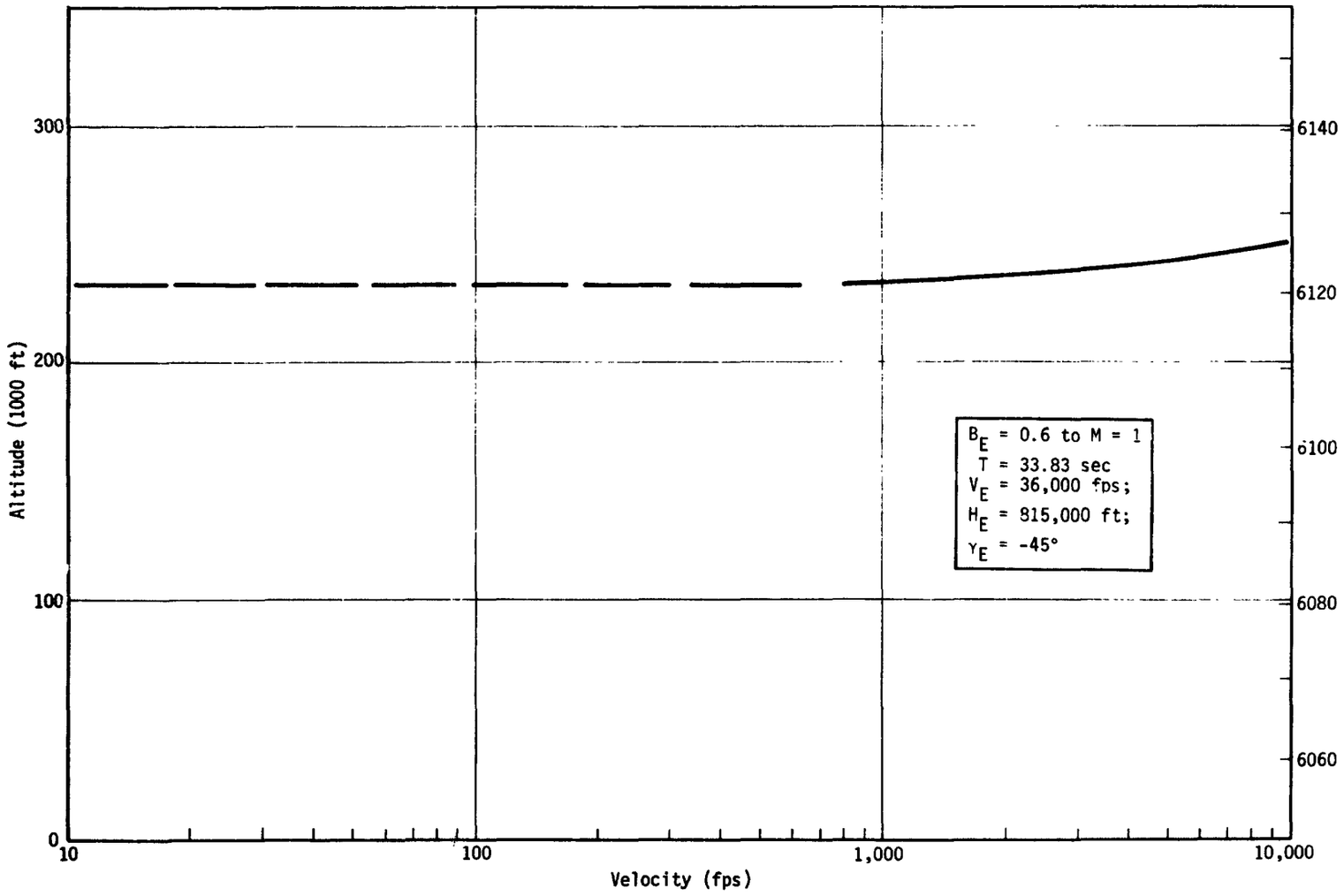


Fig. G-15 Venus Descent Profile, Altitude vs Velocity, Balloon Probe

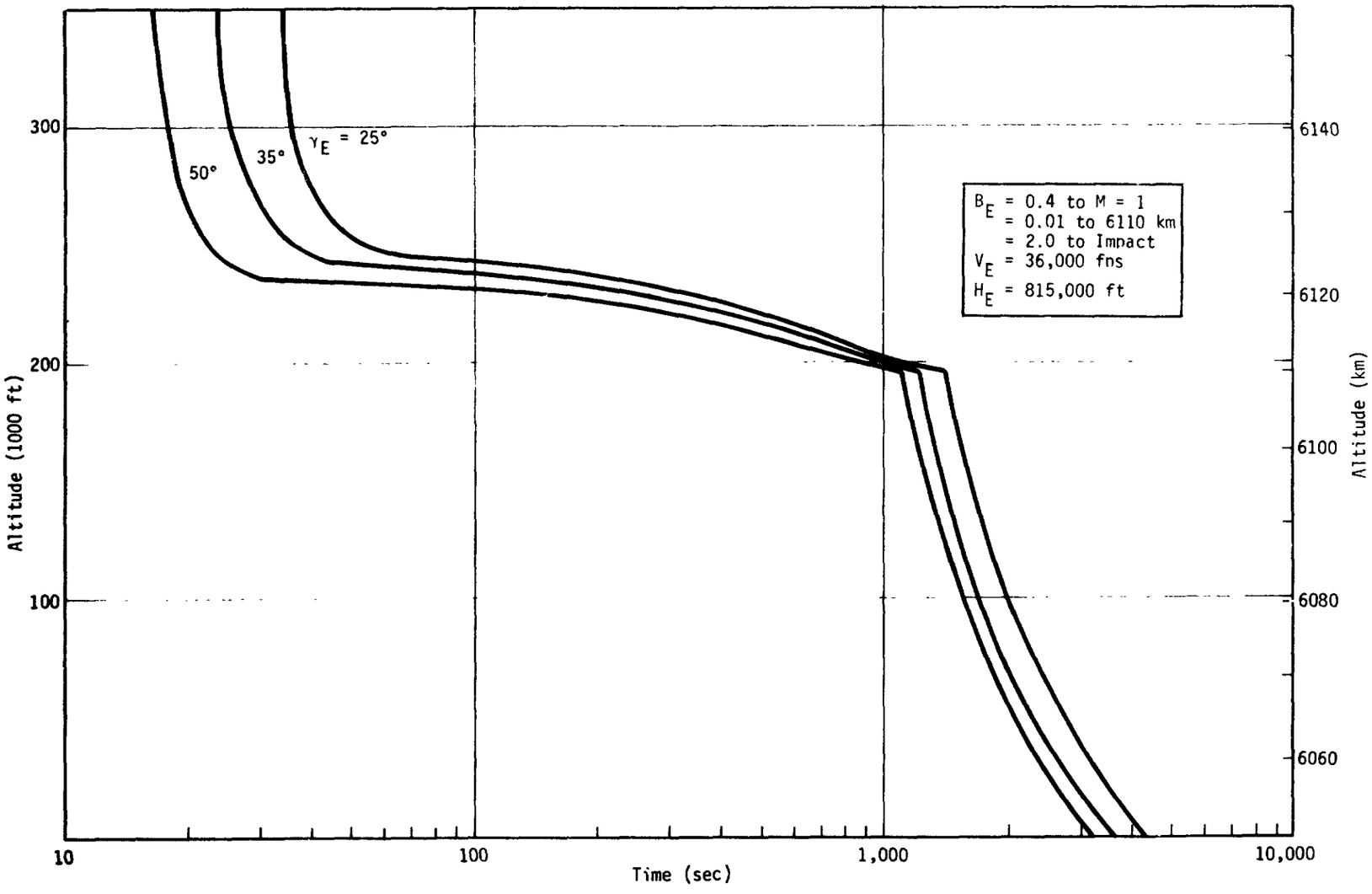


Fig. G-16 Venus Descent Profile, Altitude vs Time, Small Probe

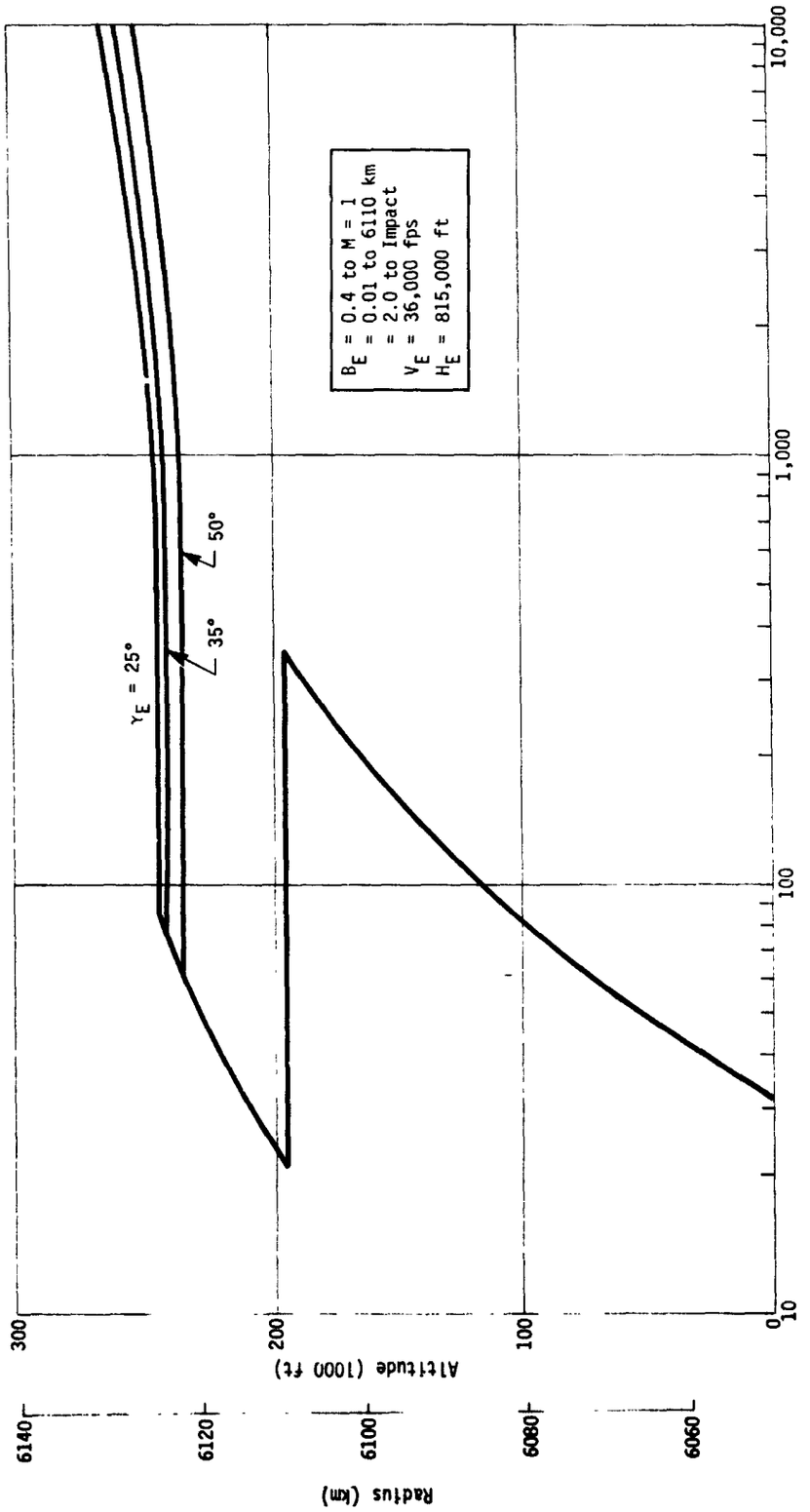


Fig. G-17 Venus Descent Profile, Altitude vs Velocity, Small Probe

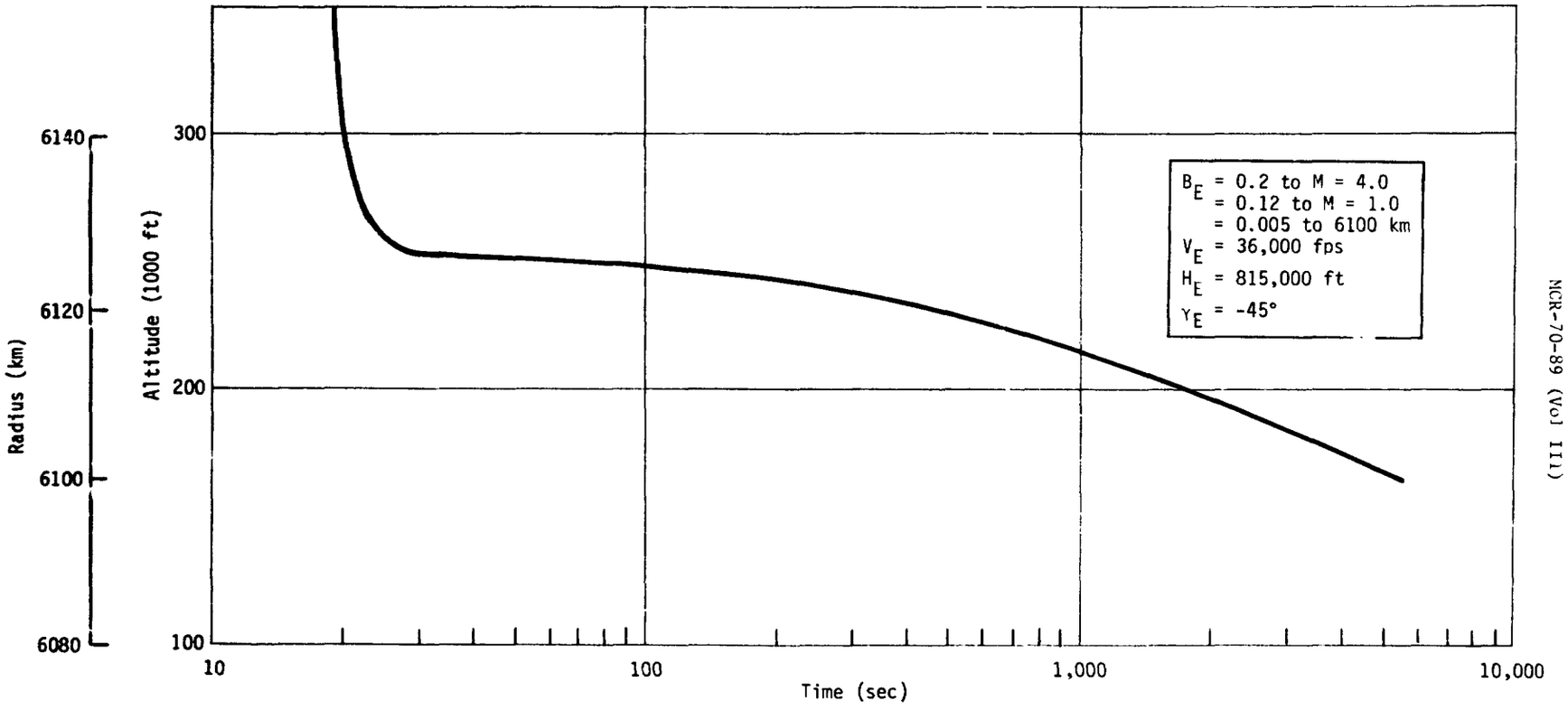


Fig. G-18 Venus Descent Profile, Altitude vs Time, Cloud Probe

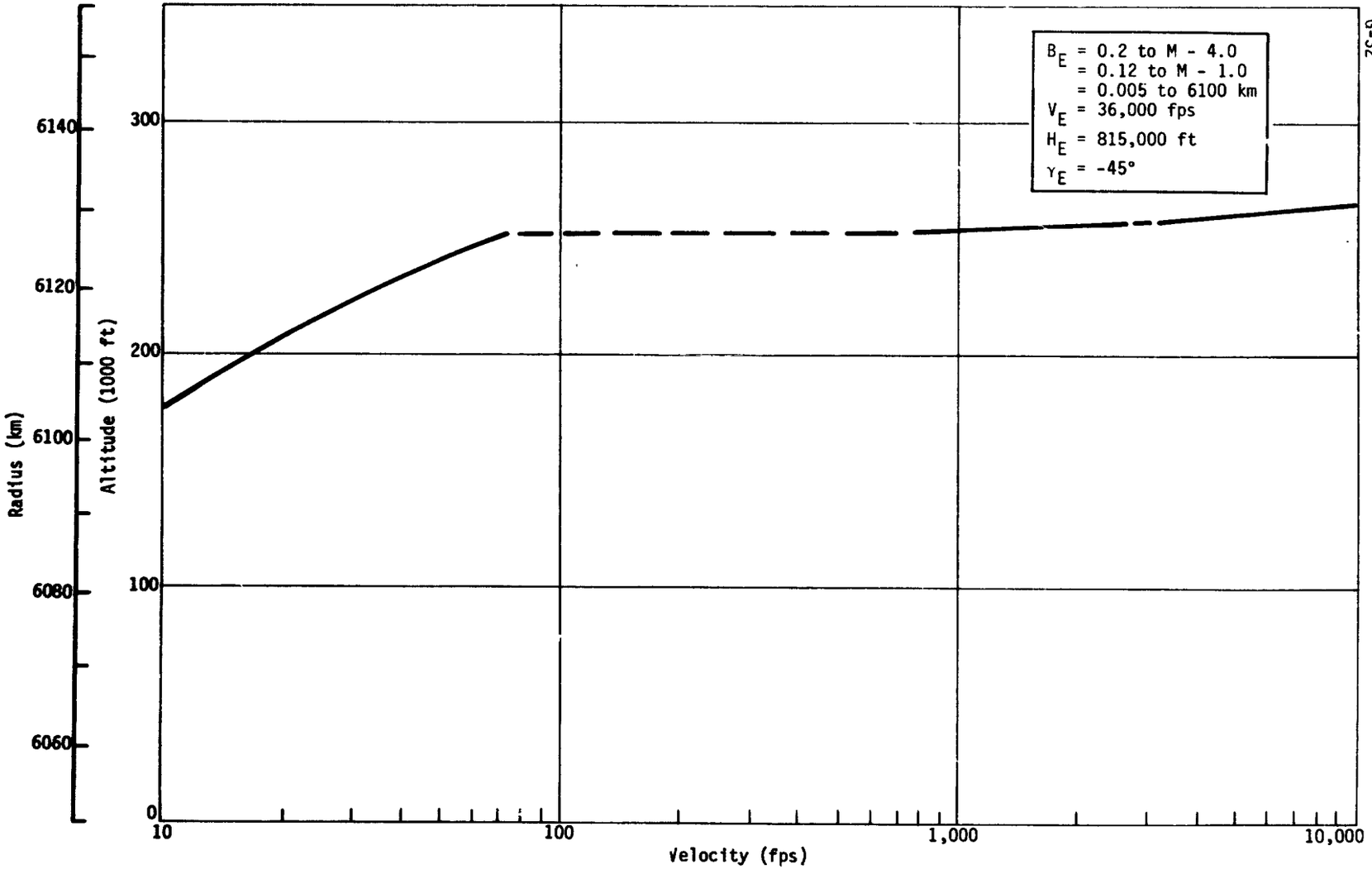


Fig. G-19 Venus Descent Profile, Altitude vs Velocity, Cloud Probe

4. Trial Mission Telecommunications Systems

The telecommunication systems on the four probe types included in the trial mission do not differ greatly from those on the final baseline and optional missions. These systems will be described briefly below, with emphasis on the differences between them and the ones on the final missions.

a. Large Probe Telecommunication System - The large probe was targeted closer to the subearth point on the trial mission. The communication angle, ϕ, was 40°. A 1.2-λ annular slot antenna was used to match this targeting; its radiation pattern is shown in Vol II, Chapter VII, Section E. A 25-W TWT transmitter was used. The data rate was set at 83 1/3 bps. This was not switched to a lower rate for the lower atmosphere because the atmospheric losses at ϕ = 40° are much lower than those at 70°. Preentry communications for the flyby spacecraft option was not considered on the trial mission. Aside from these differences, the system is essentially the same as that described in Vol II, Chapter III, Section B for the final mission.

b. Small Probe Telecommunications System - The small probe studies in the trial mission is smaller and has fewer instruments than the small probe in the final mission. A bit rate of 33 1/3 bits was selected. A 10-W TWT transmitter provided enough margin to allow this data rate to be carried all the way to the surface. Aside from these differences, the system is essentially the same as that described in Vol II, Chapter III, Section B for the final mission.

c. High-Cloud Probe Telecommunication System - The high-cloud probe on the trial mission had the same instrument complement as in the final mission, but a lower bit rate, 25 bps, was assumed. At that time, the 2-way Doppler requirement was not applied to the high-cloud probe, so noncoherent signalling was assumed. The transmitter was sized at 5 W, and a solid-state amplifier was assumed.

d. Balloon Probes Telecommunication System - The principal difference between the balloon probes on the trial and final mission is that the former stores data between contacts while the latter does not. Therefore, the transmission time at each contact was 11 minutes rather than 6½ minutes. The same ranging-polarization position fix is used on both missions. However, at that time we were proposing a "recorded burst" technique for ranging. This consisted of the transmission of a short burst of ranging having insufficient duration for a real-time lock-on, but (theoretically) sufficient duration if repeated processing of the data were done using a recording of the received burst. It was later determined* that this technique is not within the present or projected capability of the DSN, so this approach was dropped in favor of the conventional real-time approach used in the final mission.

5. Trial Mission Data Systems

Typical telemetry data formats and functional block diagrams of the data system were prepared for each of the four types of probes considered in the trial mission for the purpose of testing the data sampling concept and estimating requirements for hardware.

The instrumentation complements, bit rates and storage requirements vary from probe to probe to the extent that the data system for each is described separately.

a. Large Probe Data System - The large probe data system is the most complex of all of the probes due to the large number of higher data acquisition rate instruments. Three analog multiplexers and A/D converters are shown in Fig. G-20 to accommodate the various data sources.

*J. R. Hall, personal communication.

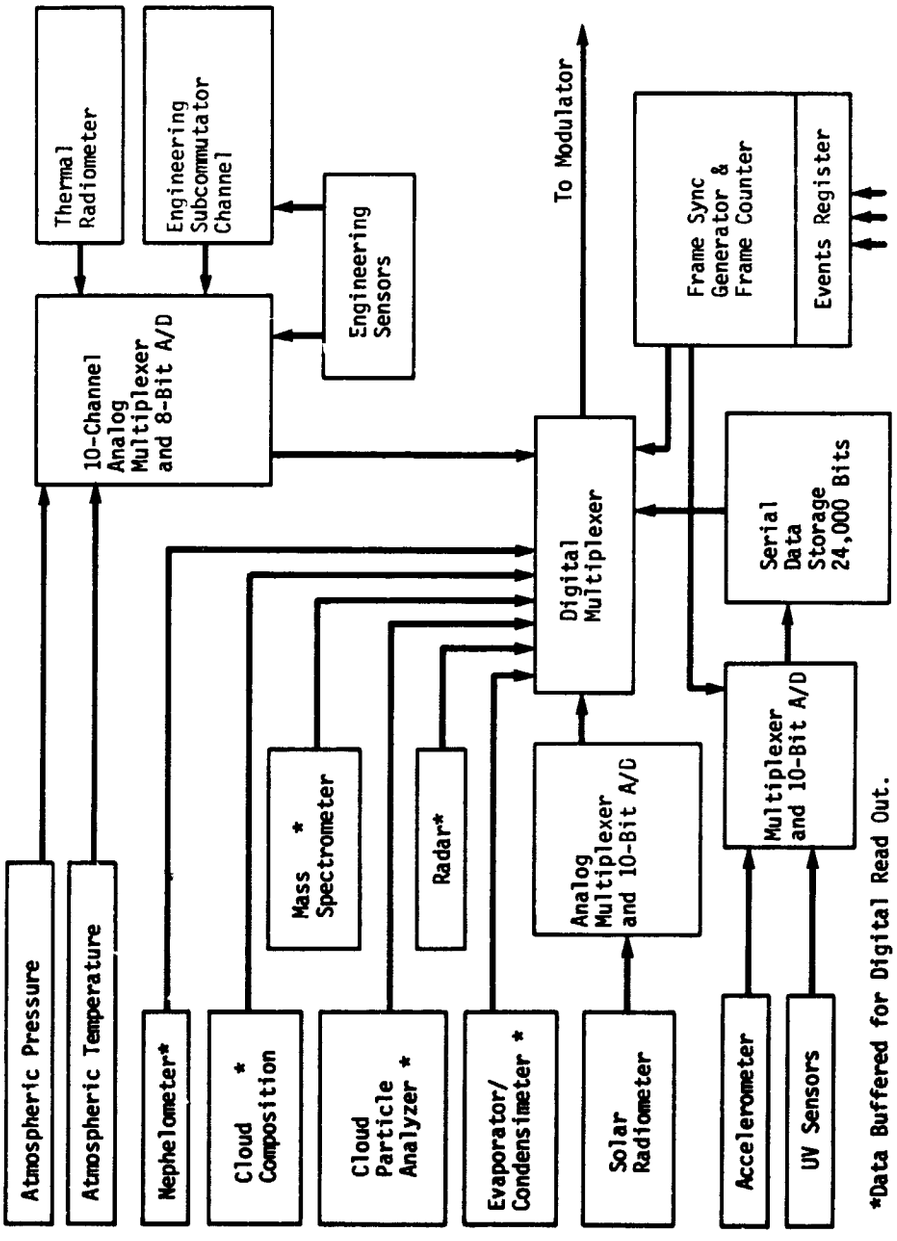


Fig. G-20 Data Handling System Large Probe (Trial Mission)

Data processing blocks that are integral to the instruments marked with an asterisk (*) are not shown in detail. These in general require their own commutator, analog-to-digital converters and buffer storage. The main digital commutator accepts 1/3 of the total bits per sample from these instruments each time through the ∿10 sec cycle period except for the mass spectrometer, which requires 30 cycles of the main commutator to output a full complement of mass spectrometer data.

The accelerometer and UV data are acquired during ΔV deflection burn and during initial entry before real-time data transmission. Consequently, these data are handled separately from the rest of the instrumentation and require a data storage capacity of approximately 24,000 bits.

Readout is accomplished by taking 60 bits from storage each main commutator cycle (∿10 sec) resulting in an average readout rate of 6 bps.

Detailed data formats for the large probe are shown in Fig. G-21 and are essentially self explanatory. Note that the subcommutated data channel format and the stored data format are shown below the main frame format. The transmission bit rate is 83 1/3 bps.

b. Small Probe Data System - The small probe data system for the trial mission is considerably simplified by exclusion of the more complex instrumentation (mass spectrometer, cloud composition, etc).

The data handling system block diagram and data format details are shown in Fig. G-22 and G-23, respectively.

Real-Time Telemetry Frame 832 bits/10 sec for 83 1/3 bps TM Rate

Sync 21	TD 4	Frame Count 10	Sub-frame Count 5	Sub-comm 8	ATM Temp 8	ATMO Press 8	Thermal Rad 16	Prob Temp 8	Prob Press 8	SPE 8	Xmit Pwr Out 8	SCI Temp 8	Stored Entry 60	(cont)
				↑ See below									↑ See below	

* Radar 20	* Evap Condens 21	* Solar Rad 120	§ Cloud Part 30	Cloud Comp 60	* Mass Spect 200	Neph-elom-eter 16	Events 4

1 Frame/10 sec
*3 Frames to Complete
§30 Frames to complete

Subcommutated Data

80 bits/100 sec
8 bits Transmitted per Real-Time TM Frame

Sync 8	Exciter Pwr Out 8	Xponder VCO 8	Batt Volt 8	Batt Temp 8	Clock Temp 8	Probe Temp 8	Main Batt Current 8	Batt Charge Current 8	Probe Press 8

Stored Entry Data Format

960 bits/4 sec into Storage;
60 bits Transmitted Each Real-Time TM Frame

Sync 21	Mode ID 4	Frame Count 10	Sub-frame Count 5	UV 8	Event 2	UV 8	Event 2	UV 8	Event 2	Accel No. 1 10	Accel No. 2 10	Accel No. 3 10	Accel No. 4 10	Accelerometer 1 thru 4 4×40 = 160 bits
				← Repeat for Total of 4 Cycles Per 4 Sec Frame →										

Fig. G-21 Data Formats, Large Probe (Trial Mission)

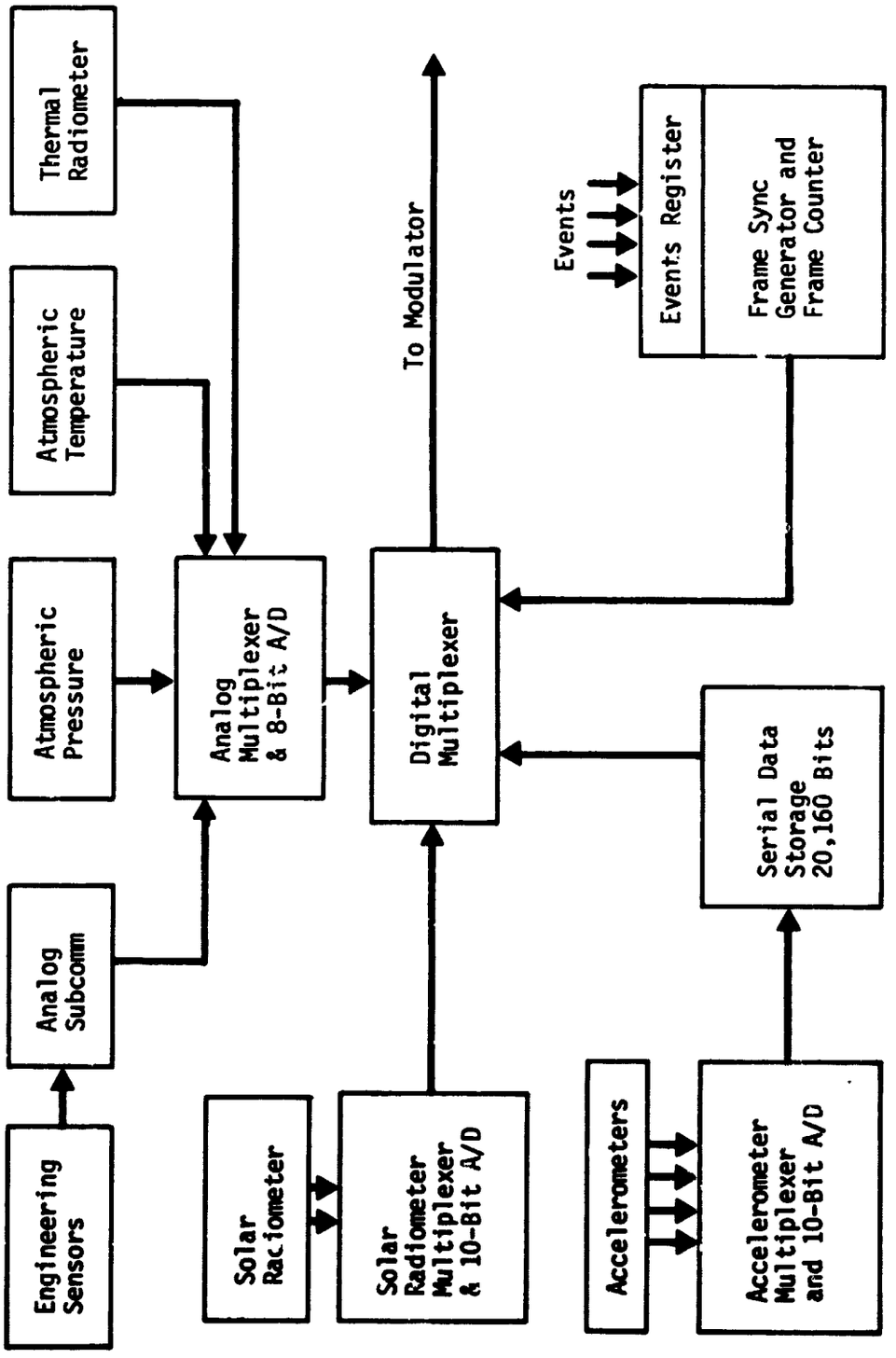
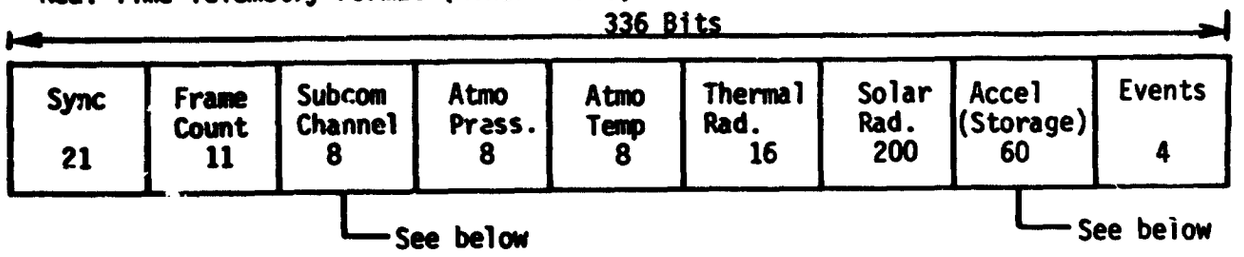


Fig. G-22 Data Handling System, Small Probe (Trial Mission)

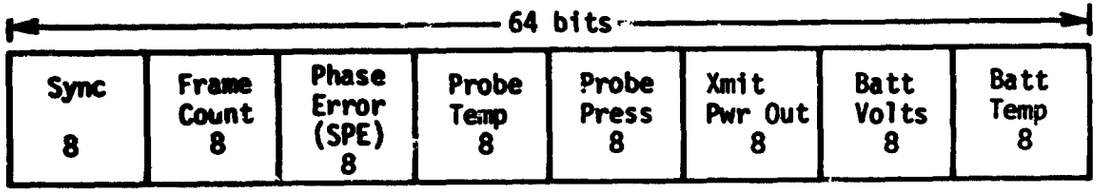
Real-Time Telemetry Format (Minor Frame)



1 Frame/10.1 sec at 33 1/3 bps

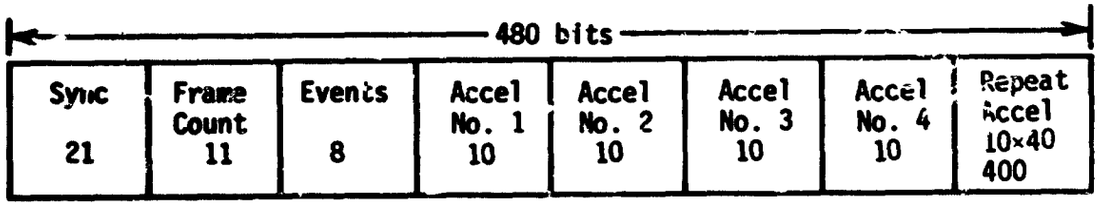
8 Minor Frames per Major Frame

Subcommutated Real-Time Channel (Rate 1/8)



1 Frame per 8 Minor Frames (Above)

Stored Data Format (Accelerometer Time & Events)



Stored at 200 bps

1 Frame Readout for Each 8 Minor Frames Transmitted

Fig. G-23 Data Formats, Small Probe (Trial Mission)

Separate analog multiplexer analog-to-digital converters are shown for the solar radiometer and accelerometers. However, it is noted that sharing of a single multiplexer/converter by the two types of instruments could be accomplished by switching both inputs and output to accommodate the solar radiometer after completion of the accelerometer data acquisition mode (for the trial mission no real-time accelerometer data are transmitted).

Both a subcommutated and stored data format are shown, as well as the main stream data format. The main stream data frame cycles approximately one every 10 sec to give a bit rate of 33 1/3 bps. Memory readout is similar to the large probe 60 bits every main frame cycle. Other characteristics are detailed in the figure.

c. High-Cloud Probe Data System - The cloud probe data system block diagram and data format are shown in Fig. G-24 and G-25. Note the absence of accelerometers and a central data storage.

A single data format is used for this probe with the atmospheric pressure and temperature supercommutated to give 2 samples per data frame for each. The frame rate is one per ∿15 sec, resulting in a bit rate of 25 bps.

d. Balloon Probe Data System - The data system for the balloon probe departs somewhat from the data systems for the other trial mission probes in that the atmospheric data and the solar radiometer data are stored during the balloon flotation period and read out at 8-hr intervals. For this reason these instruments share the same analog commutator and analog-to-digital converter as shown in Fig. G-26.

The subcommutator for engineering data is operated as an extension of the analog multiplexer during postdeploy operations to reduce the number of commutation cycles required to obtain a full data sample.

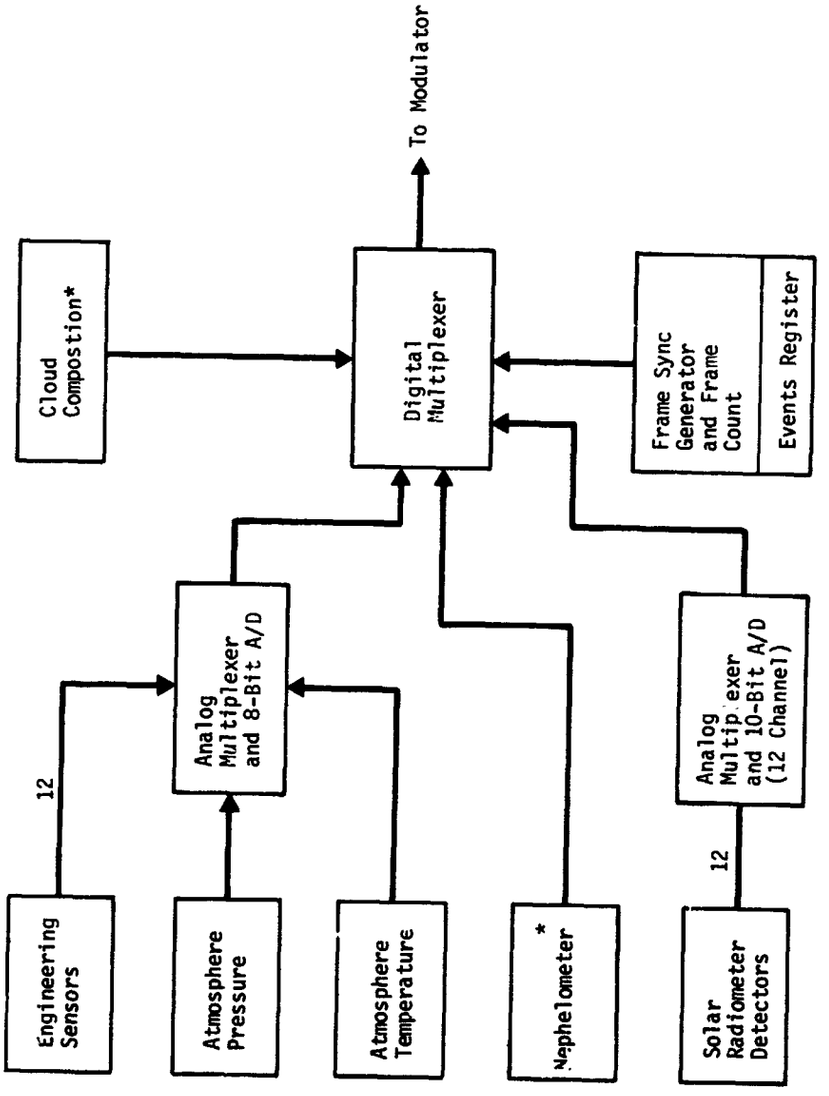


Fig. G-24 Data Handling System, Cloud Probe (Trial Mission)

Sync	ID	Frame Count	Subframe Count	Events	Solar Rad	Nephelometer	Atm Pressure	Atm Temp	Cloud Composition	(cont)
21	4	10	5	8	120	16	8	8	80	

(cont)	Xmit Osc Temp	Probe Temp	Probe Press	RF Power	Batt Volt	Batt Current	Batt Temp	Inst Temp	Clock Temp	Reg Volt	Atm Pressure	Atm Temp
	8	8	8	8	8	8	8	8	8	8	8	8

Frame Length - 376 bits (20 Frames to Obtain Cloud Composition)

Frame Period - 376/25 15 sec

Output Bit Rate - 25 bps

Fig. G-25 Format, Cloud Probe (Trial Mission)

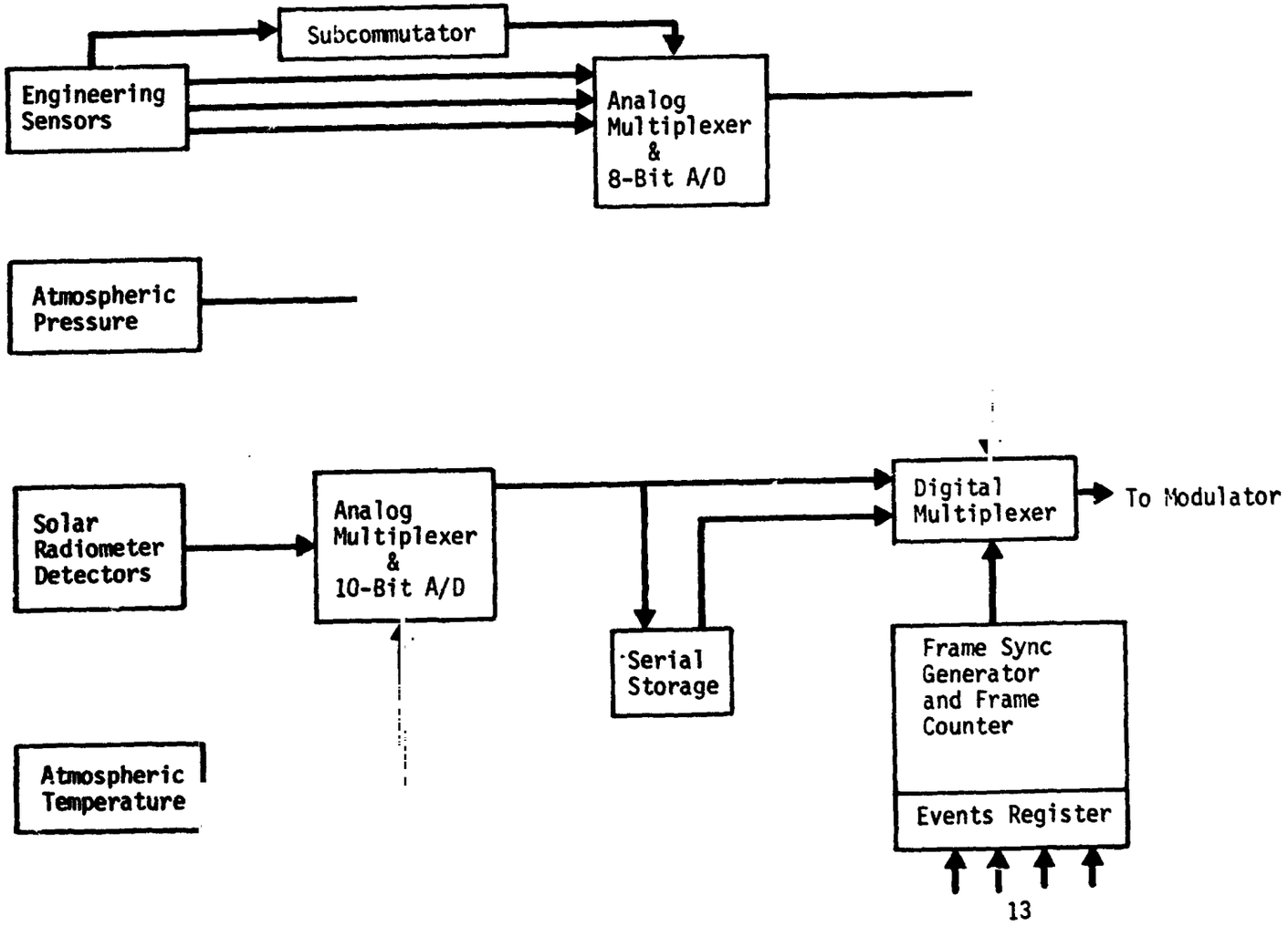


Fig. G-26 Data Handling System, Balloon Probe (Trial Mission)

The bit storage is of the serial first in, first out, type and must accommodate 6898 bits (8-hr data input) plus margin for variations in time.

Three data formats are provided for the balloon probe as shown in Fig. C-27. During entry and balloon deployment the real-time format is used with one channel subcommutated. Both science and engineering data, including 13 bits for events, are accommodated.

After the flotation phase is entered (∿30 minutes later) the probe enters a data acquisition mode in which atmospheric temperature, atmospheric pressure and solar radiometer measurements are made once every 10 minutes and placed in storage. Once every hour sync and frame count data are included to make up a frame 856 bits long.

Every 8 hr stored data are transmitted to earth followed by a few real-time data frames. During this period, the subcommutator is run completely through the eight channels and each minor frame extends the frame length by 7 eight-bit words.

For spacecraft cruise monitoring functions the subcommutator may be used as for the other probes.

6. Trial Mission Probe Power Systems

The battery sizing computations were less sophisticated (and more optimistic) on the trial mission than on the final mission. A capacity of 30 W-hr/lb was simply assumed without any derating.

Solar panels were not included on the balloon probes. Batteries were sized for a 7-day lifetime. No provisions were made for heating of the 50 mb balloon.

Entry and Deploy

Real-Time Telementry Format Entry - 256 bits/15.3 sec = 16 2/3 bps

Sync	ID	Frame Count	Events	SPE	Batt Current	Balloon Press	Balloon Temp 1, 2 & 3	Xmtr Power	Exciter Power	Sub Comm	Atm Press	Atm Press	Solar Rad
21	4	10	13	8	8	8	24	8	8	8	8	8	120

Subcommutated Data (on Entry and Deploy)

Sync	Pwr Amp Temp	Internal Temp No. 1 & 2	Batt Temp	Xtal Temp	Batt Volt	Reg. Bus Volt
8	8	16	8	8	8	8

Postdeploy

Real-Time Data for Post Deploy

Same as Above Except Bit Rate of 25 bps and
Run Subcommutator Completely through on Each Frame

Stored Data Format

Sync	ID	Frame Count	Events	Atm Press	Atm Temp	Solar Rad	Repeat Meas 5 Times
21	4	10	5	8	8	120	5 × 136 = 680

One Sample (10 min of 136 bits)
One 40-bit Framing Word Every 6 Sample (Every Hour)

Fig. G-27 Data Format, Balloon Probe (Trial Mission)

Weight estimates for RF components in the trial mission were made before receiving the Motorola inputs given in Chapter III, Section B (Vol II), so these weights are different on the trial mission. TWT amplifiers were assumed for the large and small probes instead of the solid-state amplifiers assumed in the final mission.

Weight and power estimates for the four probe types are given in Tables G-11 thru G-14.

7. Trial Mission Sequencers

Work done on sequencers in the trial mission was limited to making first-cut estimates of their weight and power consumption. These data are shown in Tables G-11 thru G-14.

C. TRIAL MISSION PLANETARY VEHICLE

1. Engineering Mechanics

The arrangement of the probes on the Planetary Vehicle is shown in Fig. G-28 and the weight summary in Table G-9. Although the seven probes fit within the two added segments, the arrangement is not conducive to minimizing probe ejection tip-off impulse. A better arrangement has since been developed for the baseline mission and options; Option 2 also has seven probes. These are discussed in Chapter IV, Vol II.

2. Mission Analysis

The trial mission launch, interplanetary, and encounter parameters are noted in Table G-15. The arrival geometry is shown in Fig. G-29 where the spacecraft periapsis is 3200 km and targeted near point 2. The actual spacecraft plane is noted on the figure. The trajectory is a Type II path and is based on a 10-day launch period.

Table G-11 Large Probe Power Summary

	WEIGHT (lb)	POWER (watts)
ANTENNA	3.0	---
DIPLEXER	1.4	---
TRANSPONDER	---	---
Receiver	5.3	2.5
RF Exciter	0.9	1.5
Modulator	0.9	0.5
TWTA, 25 Watts	9.2	61.0
SEQUENCER	4.0	3.0
DATA HANDLING	7.0	7.0
MEMORY	2.2	0.2
INVERTER	4.3	5.0
CABLING	4.2	---
BATTERY	11.8	---
	54.2	80.5
INSTRUMENTS		125.3
		205.8

Table G-12 Small Probe Power Summary

	WEIGHT (lb)	POWER (watts)
ANTENNA	0.8	---
DIPLEXER	1.4	---
TRANSPONDER		
Receiver	5.3	2.5
RF Exciter	0.9	1.5
Modulator	0.9	0.5
TWTA - 10 Watts	7.5	32.0
Sequencer	4.0	3.0
Data Handling	5.0	3.0
Memory	2.2	0.2
Inverter	3.0	5.0
Cabling	4.1	---
Battery	2.5	---
	37.6	47.7
instrumentation	10.5	6.3
	48.1	54.0

Table G-13 High-Cloud Probe Power Summary

	WEIGHT (lb)	POWER (watts)
ANTENNA	1.5	---
RF EXCITER	0.9	1.5
MODULATOR	0.9	0.5
AMPLIFIER, 5 WATT	2.0	17.0
SEQUENCER	4.0	3.0
DATA HANDLING	5.0	3.0
INVERTER	3.0	5.0
CABLING	4.4	---
BATTERY	8.3	---
	30.0	30.0
INSTRUMENTATION		61.3
		91.3

Table G-14 Balloon Probe Power Summary

	WEIGHT (lb)	POWER (watts) (Transmit Mode)	POWER (watts) (Data Collection Mode)
ANTENNA			
Circular	0.8	---	
Linear	0.7	---	
Switch	1.4	---	
TRANSPONDER			
RF Exciter	0.9	1.5	
Modulator	0.9	0.5	
Receiver	5.3	2.5	
Ranging Unit	1.6	1.0	
AMPLIFIER - 5 Watt	2.0	17.0	
SEQUENCER	5.0	0.1	0.1
DATA HANDLING	3.0	3.0	1.0
MEMORY	2.2	0.2	0.1
INVERTOR	3.0	5.1	0.5
CABLING	5.2	---	---
BATTERY+	20.0	---	
	52.0	30.9	
INSTRUMENTATION		2.0	0.5
		32.9	2.2‡

*Mechanical.
+7-day mission, data readout three times a day.
‡Based on 25% duty cycle.

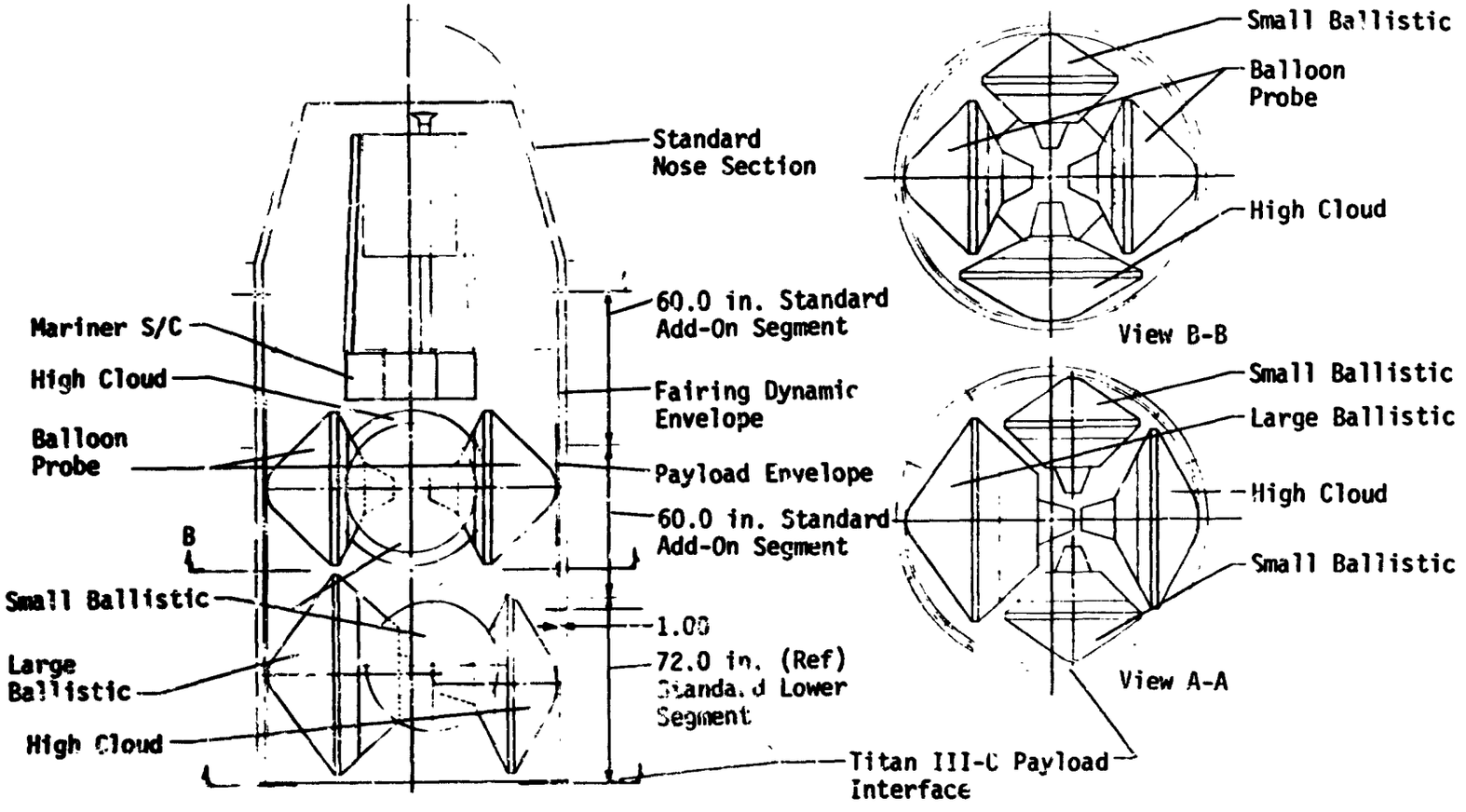
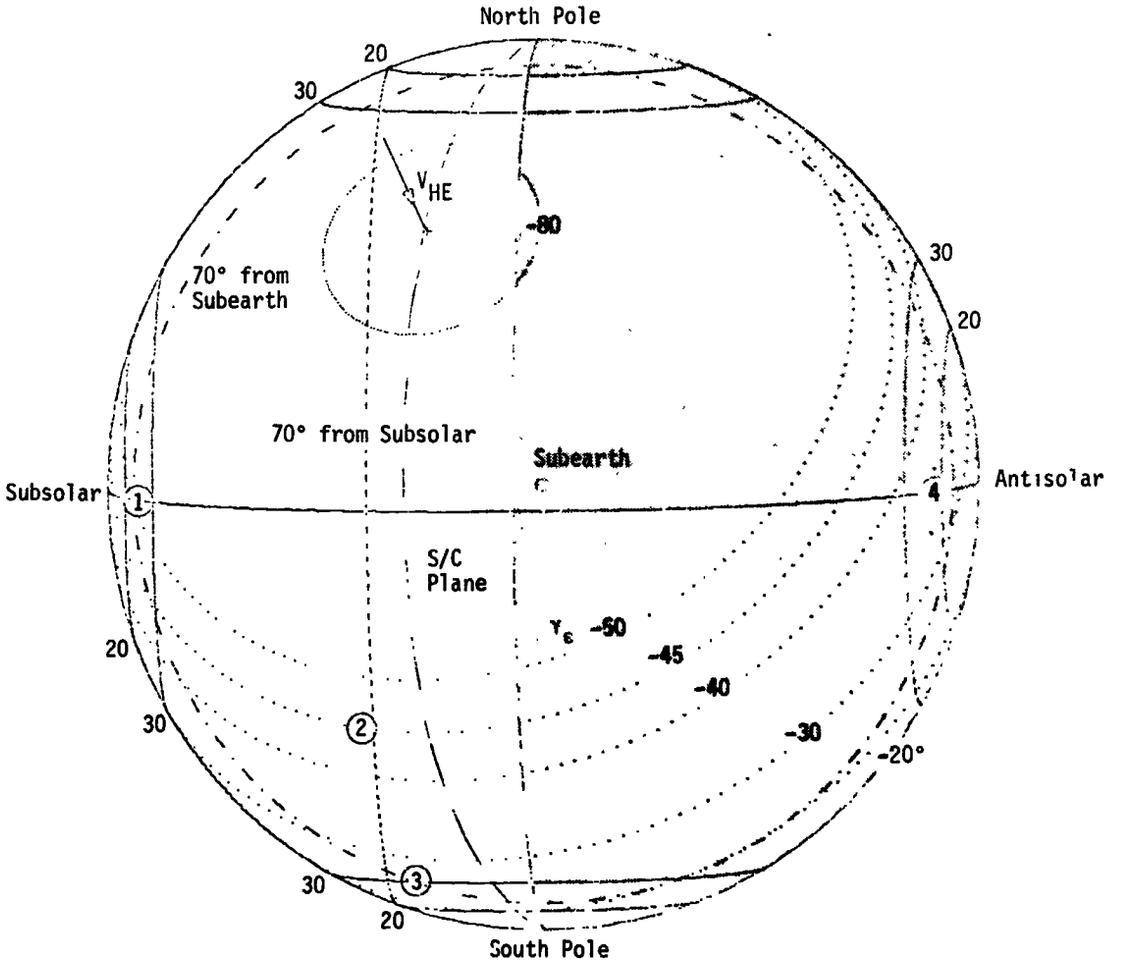


Fig. G-28 Spacecraft/Probe/Launch Vehicle Integration

Table G-15 Trial Mission Parameters

Launch Parameters	Units
Launch Period	5/25/75 to 6/4/75
Arrival Date	10/31/75
Maximum C_3	6.0 km^2/sec^2
Maximum V_{HE}	3.6 km/sec
Declination of Launch Asymptote	6.9 to 8.7 deg
True Anomaly	173 to 180 deg (approx)
Right Ascension	163 to 140 deg (approx)
Launch Vehicle	Titan IIIC
Injection Altitude	100 n mi
Launch Azimuth (nominal)	114 deg
Payload (incl Spacecraft and Adapter)	4150 lb
Heliocentric Trajectory Parameters	
Time of Flight	159/149 days
Perihelion Radius	107.8 x 10^6 km
Eccentricity	0.170
Inclination to Ecliptic	0.5 to 4.0 (approx)
Central Angle of Travel	193 to 184 deg (approx)
Communication Range	95 x 10^6 km



Venus as seen from Earth on 10/31/75, Type II 5/30 LD

Fig. G-29 Trial Mission Targeting

APPENDIX H

PARAMETRIC ENTRY DATA

This appendix presents parametric trajectory profiles entering the atmosphere of Venus. The objective of these entries is to achieve deceleration to velocities above the cloud tops that are suitable for science experiment operation. The data are presented in plots taken directly from the digital computer tapes.

The data of this report were generated using the Martin Marietta Corporation UD208 (Ref H-1) point mass simulation model on the CDC 6400 digital computer. Angles of attack are not considered. The atmosphere models for Venus are defined in Ref H-2 and Appendix F. The Martin Marietta lower density model and the V5M appear to bracket the conditions providing upper and lower boundries. The two models are essentially the same during entry but are separated by 9,000 to 12,000 ft (3 to 4 km) of altitude as shown in Fig. H-1. Entry is assumed to occur at 815,000 ft (248.4 km) of altitude and an initial velocity of 36,000 fps (10.96 km/sec). The entry profile extends from this point to the conditions of Mach No. = 0.5. The descent from the cloud tops to impact is accomplished at terminal conditions and is presented in Chapter II of Vol II.

The entry velocity and flightpath angle are defined in an inertial coordinate system whose origin is at the center of the planet Venus. The initial latitude and longitude are assumed to be 0°, and the planetary rotation rate is assumed to be zero. The planetary radius is taken as 6050 km and oblateness is neglected. The gravitation constant is 1.1472308×10^{16} ft^3/sec^2 (3.248596×10^5 km^3/sec^2).

The entry ballistic coefficient is defined by the expression

$$B_E = m/C_D A \text{ slug/ft}^2,$$

where m is the mass of the vehicle in slugs and C_D is the local drag coefficient. The drag coefficient is a function of Mach number; the following tabulation presents the values used in this study.

M	C_D	M	C_D
0	1.00	2.0	1.52
0.5	1.02	3.0	1.53
1.0	1.25	5.0	1.51
1.5	1.48	100.0	1.51

The reference area, A, is assumed to be 0.0206 ft^2 and the entry ballistic coefficient range is achieved by varying the entry mass. The drag coefficient variation with Mach number is assumed to be the same for all configurations in this study.

Figures H-2 thru H-91 present the parametric entry data generated for this study. The entry velocity is 36,000 fps (10.96 km/sec) and the entry angles vary from -20 to -90°. The ballistic coefficients vary from 0.1 slug/ft^2 to 0.8 slug/ft^2, and data are presented for both MMC-lower density model atmosphere and the V5M atmosphere. The plots are arranged in the following order.

	MMC-Lower Figures	V5M
Altitude - Velocity	H-2/H-8	H-65/H-67
Altitude - Time	H-9/H-15	H-68/H-70
Velocity - Time	H-16/H-22	H-71/H-73
Altitude - Mach Number	H-23/H-29	H-74/H-76
Altitude - Flightpath Angle	H-30/H-36	H-77/H-79
Altitude - Acceleration	H-37/H-43	H-80/H-82
Time - Acceleration	H-44/H-50	H-83/H-85
Altitude - Dynamic Pressure	H-51/H-57	H-86/H-88
Time - Dynamic Pressure	H-58/H-64	H-89/H-91

These data present the trajectory profile from an altitude of 815,000 ft (248.4 km) to conditions of M = 0.5. The entry parameter symbols used on the figures are explained in the following tabulation.

Parameter	Symbol	Units
Altitude	ALTUDE	ft
Time	TIME	sec
Relative Velocity	VEL(R)	fps
Mach Number	MACHNO	
Relative Flightpath angle	GAM(R)	deg
Dynamic Pressure	DYNPRS	psf
Drag Acceleration	DGACC	Earth g

The entry parameteric data are well behaved and the trends can be predicted readily. The peak values of dynamic pressure and deceleration occur at approximately the same altitude and time. The magnitude of the peak dynamic pressure and deceleration are a function of the sine of the entry angle. The time of occurrence is a function of the inverse of the sine of the entry angle. The altitude of occurrence is only slightly affected by entry angle, varying less than 13,000 ft (4 km) for entry path angles between -30 and -90°. The effect of increasing entry velocity is reflected in a proportional change in maximum values of deceleration and dynamic pressure. The time and altitude of occurrence are reduced, but by a negligible amount. Increasing the ballistic coefficient increases the maximum dynamic pressure directly and slightly reduces the maximum deceleration. The effects on deceleration are generally neglected in simplified analysis of entry paths. The altitude of occurrence is reduced 23,000 ft (7 km) by increasing the value of B_E from 0.3 to 1.0. The variation is nearly linear. The time of occurrence is increased in a linear manner from 21.5 to 23.0 sec for the range of B_E from 0.3 to 1.0

REFERENCES

H-1. W. E. Wagner and W. R. Garner: *Near Planetary Flight Analysis (UD208).* ER1346J. Martin Marietta Corporation, Denver, Colorado, June 1964.

H-2. A. R. Barger: *Venus Planetary Environment Models, Part I, Atmosphere Models for Use in Entry and Descent Studies of a Multiple Probe Mission.* Martin Marietta Corporation, Denver, Colorado, September 1969.

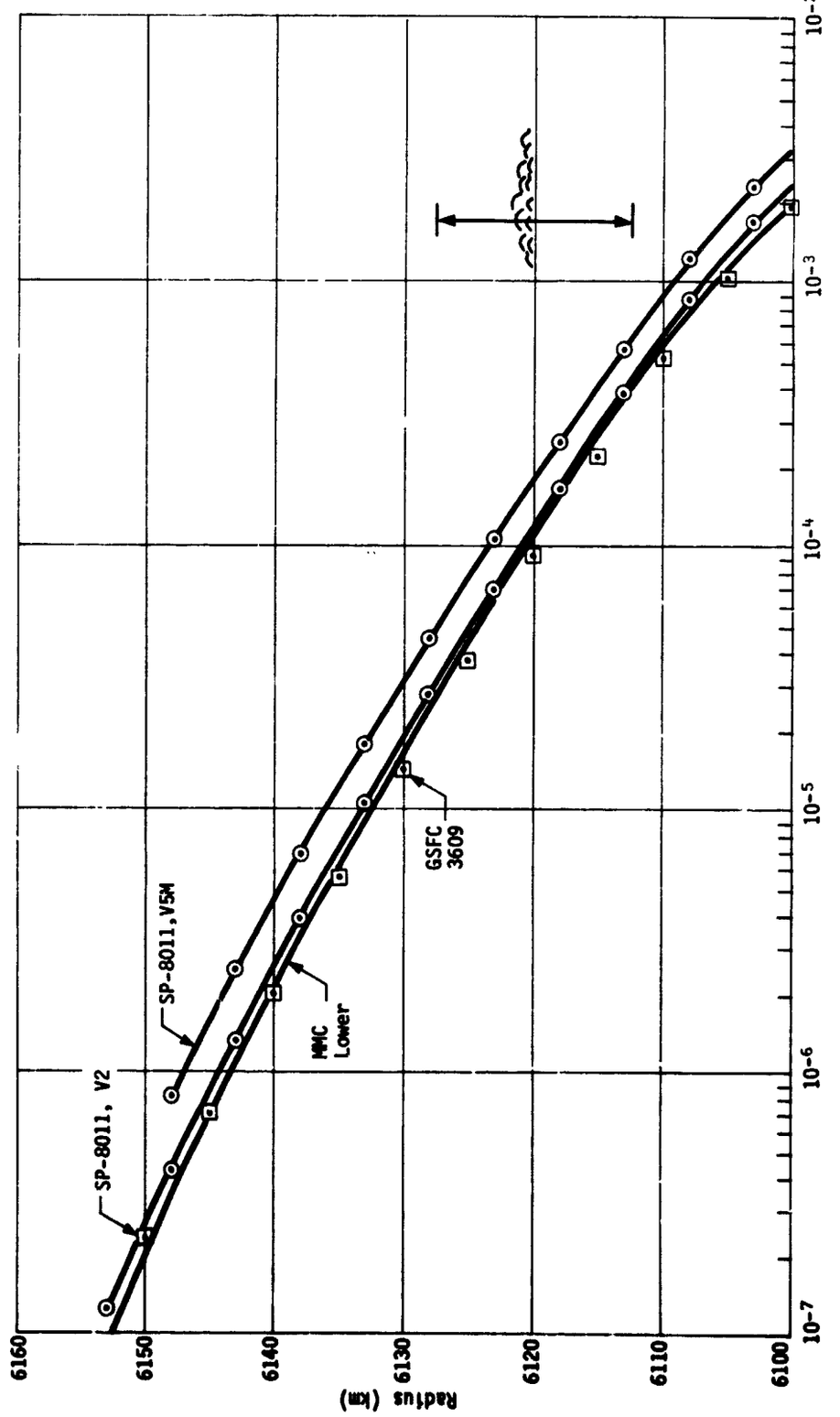


Fig. H-1 Density Profiles above Cloud Tops

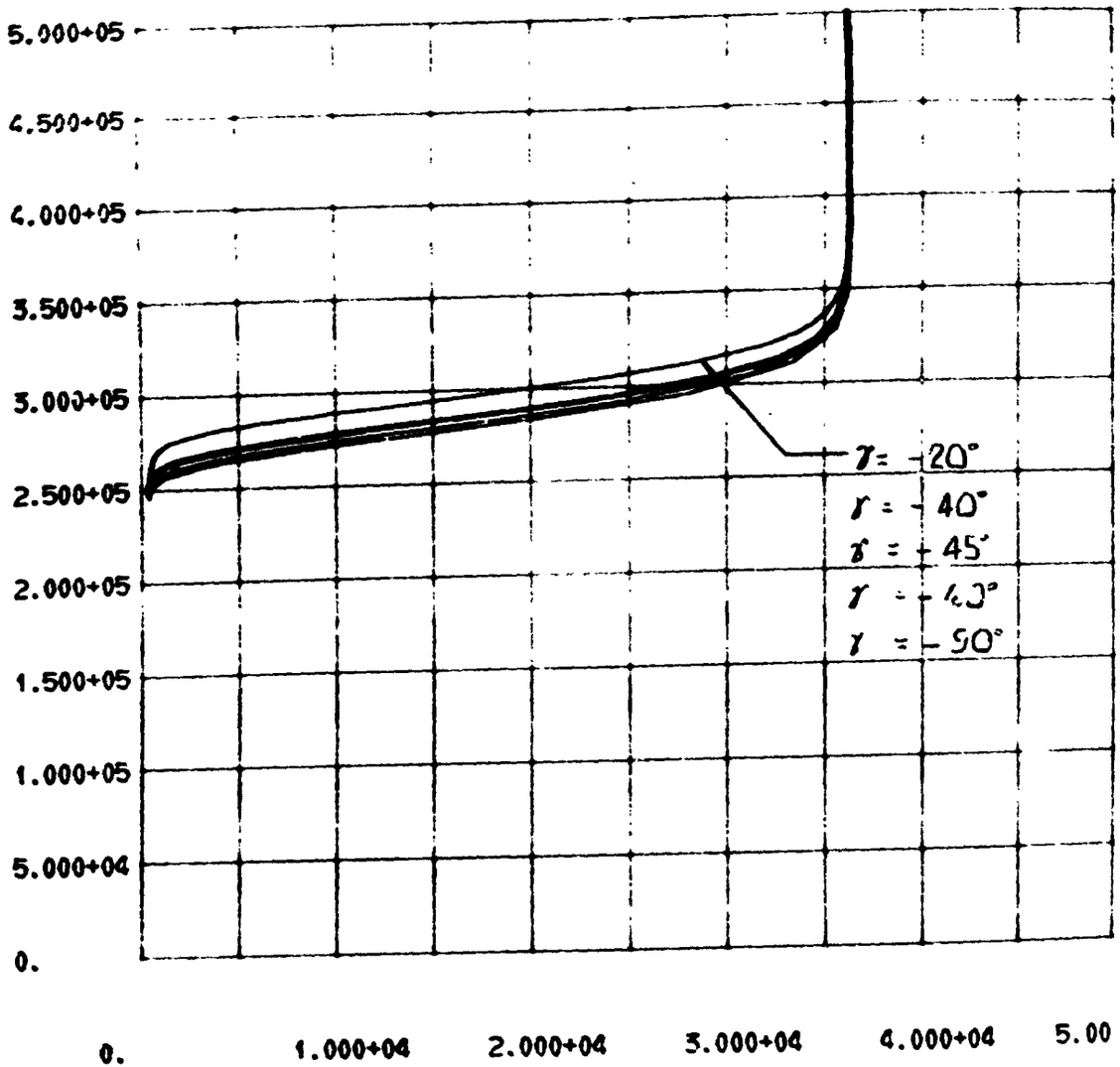


Fig. H-2

1 \ENUS M/P CNCT NMCL BE=.1 \E=36000FPS

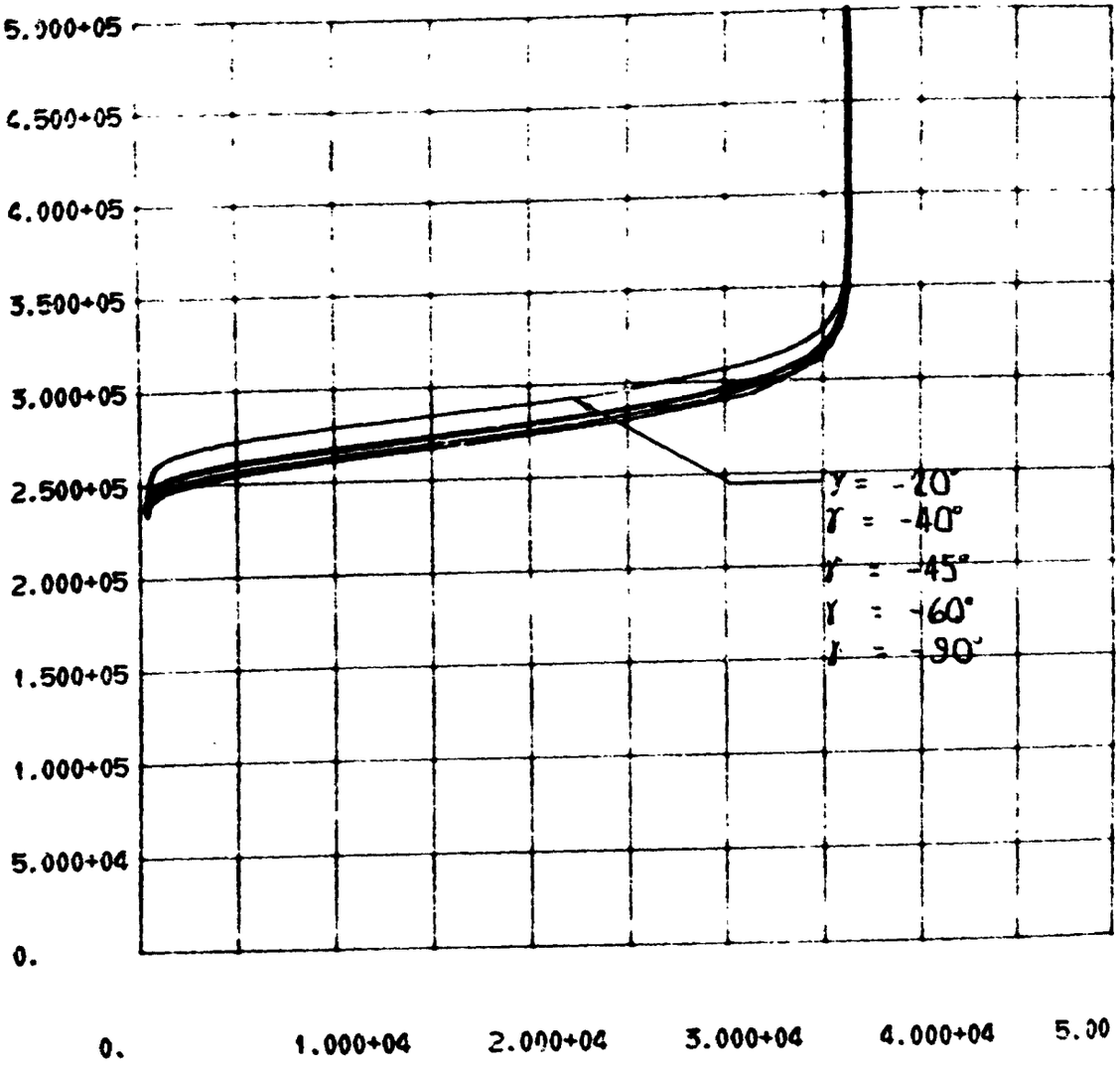


Fig. H-3

1 \ENLS M/P CNCT MMCL BE=.2 \E=36000FPS

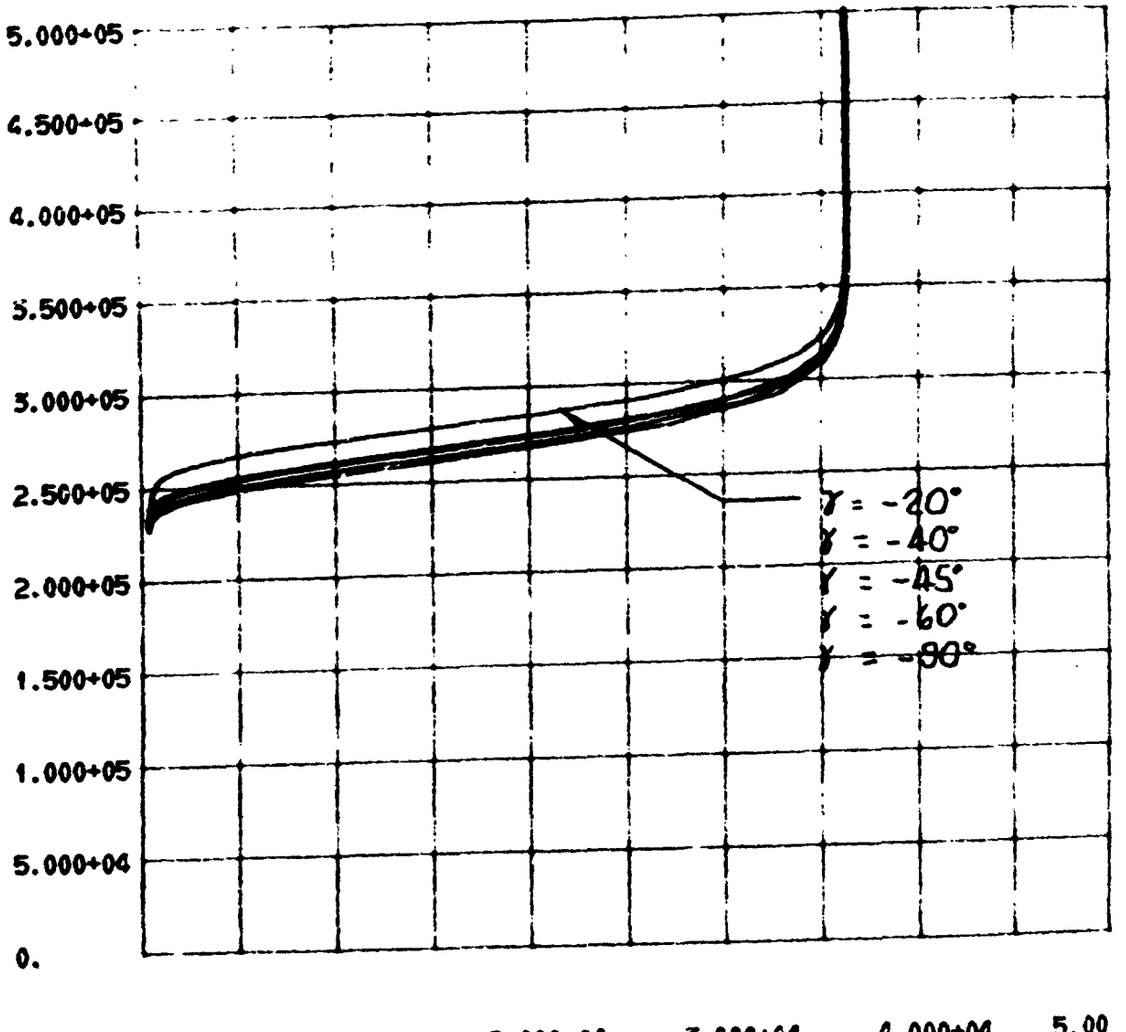


Fig. H-4

1 \ENUS M/P CNCT MMCL BE=.3 VE=36000FPS

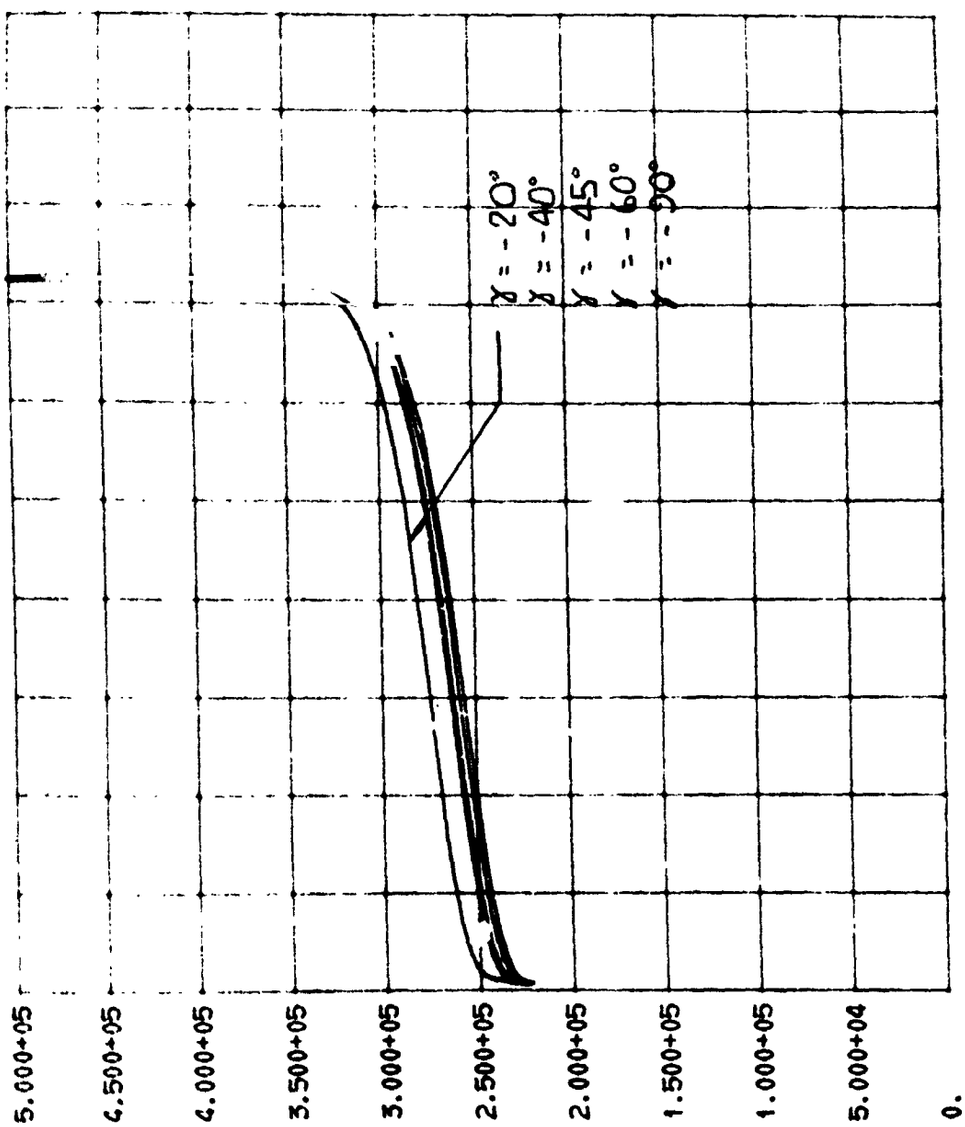


Fig. H-5

VENUS MVP CNCT MNCL BE=.4 VE=36000FPS

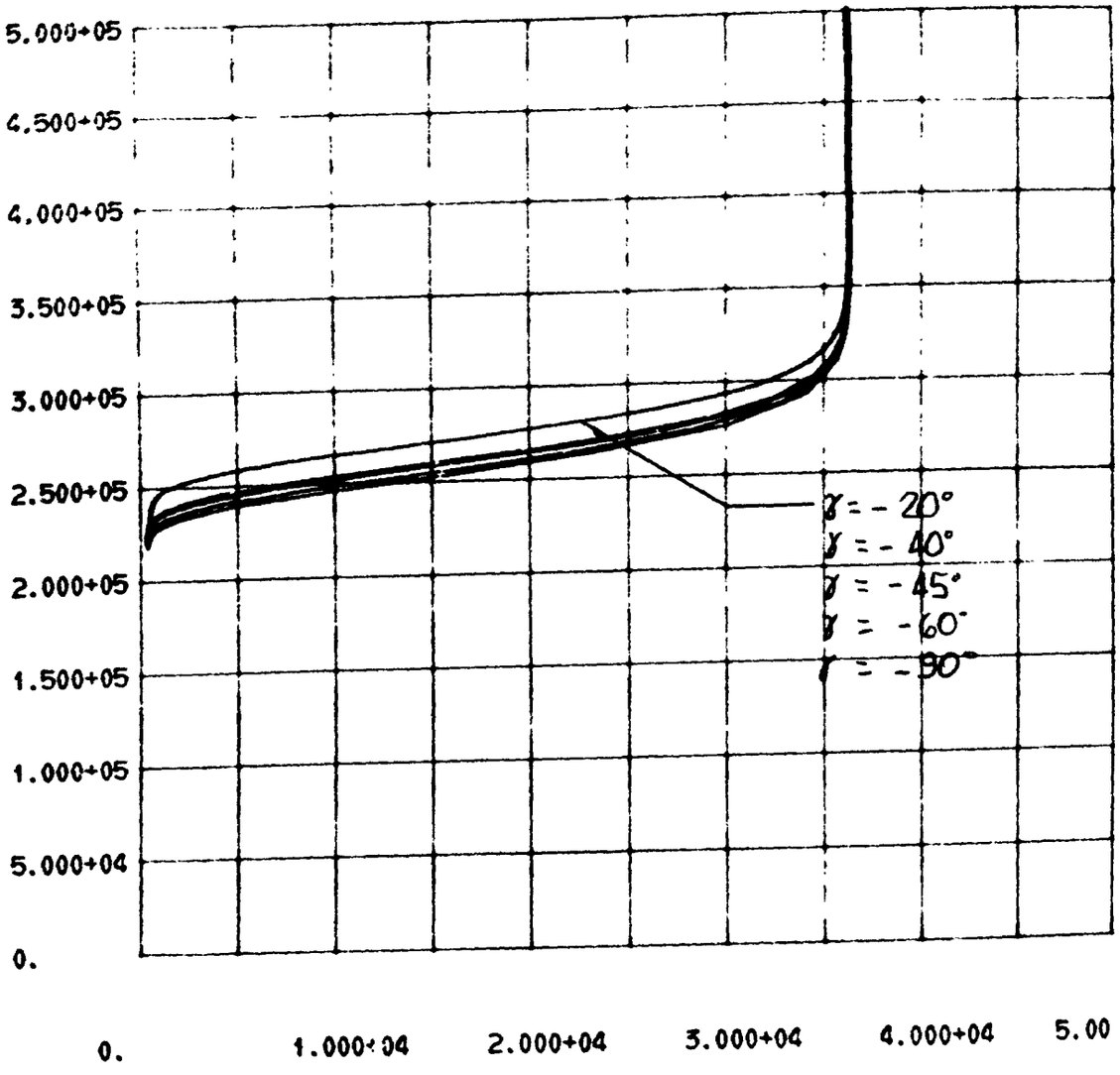


Fig. H-6

1 VENUS M/P CNCT MMCL BE=.5 VE=36000FPS

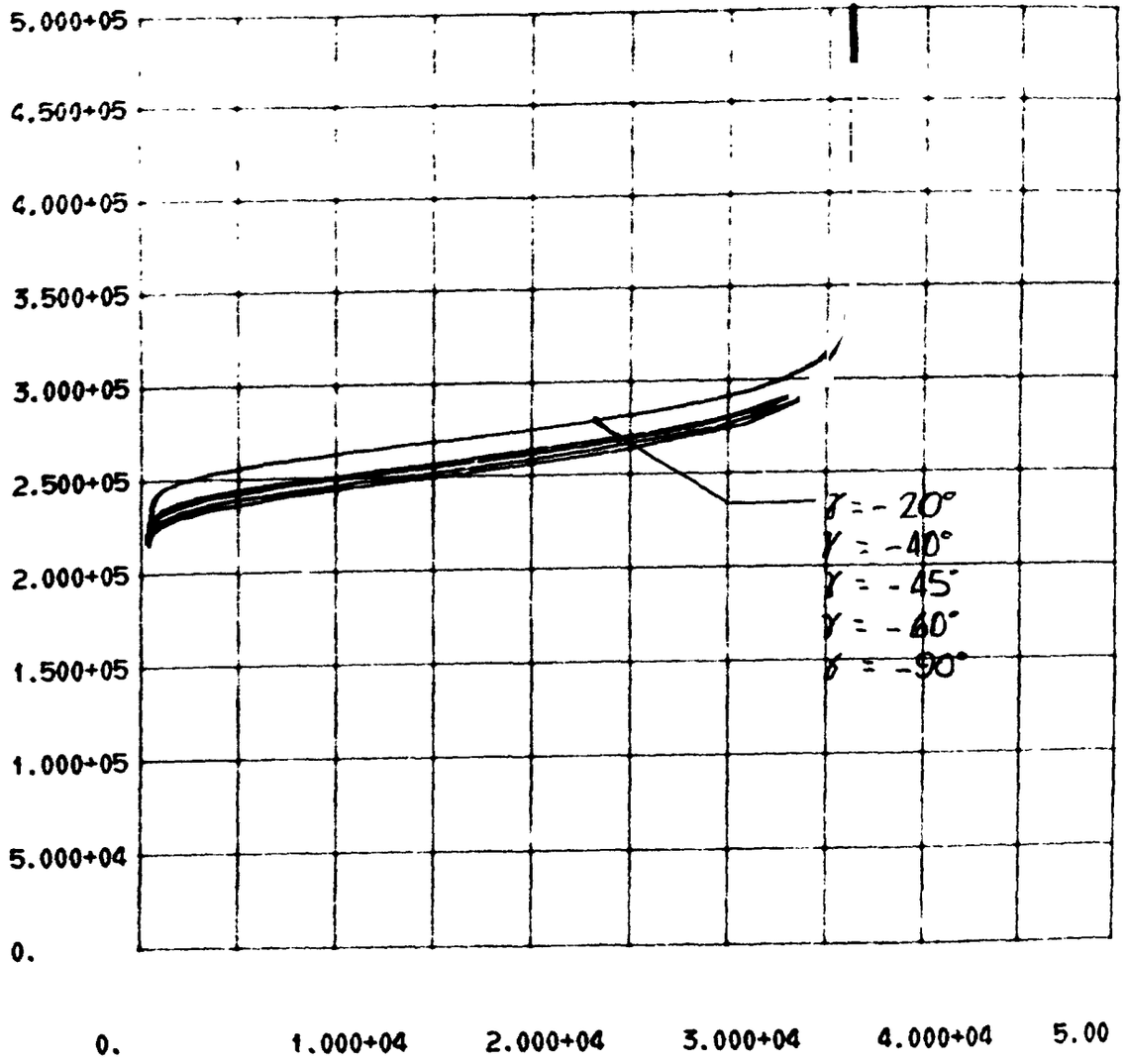


Fig. H-7

1 VENUS M/P CNCT MMCL BE=.6 VE=36000FPS

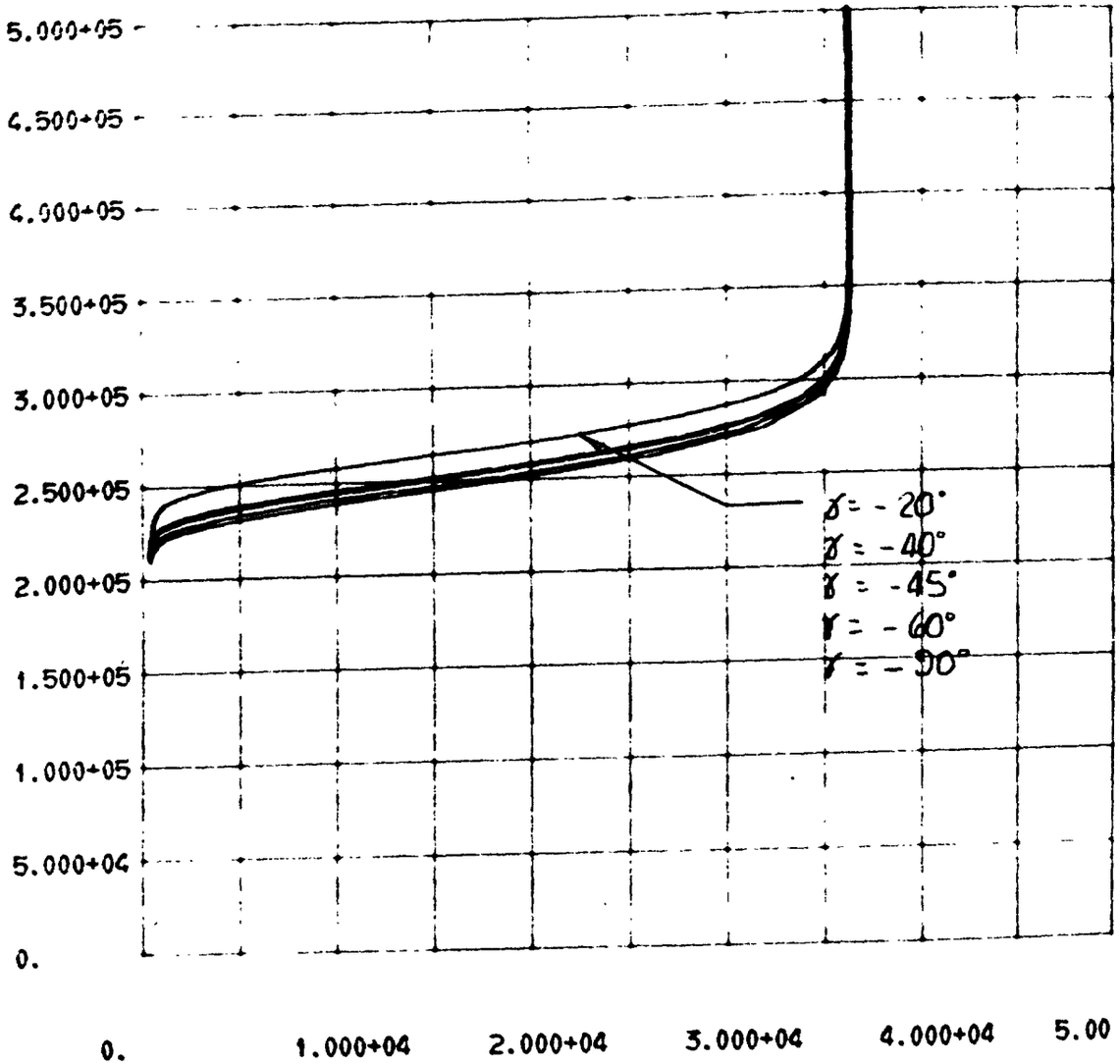


Fig. H-8

1 VENUS MVP CNCT MMCL BE=.8 VE=36000FPS

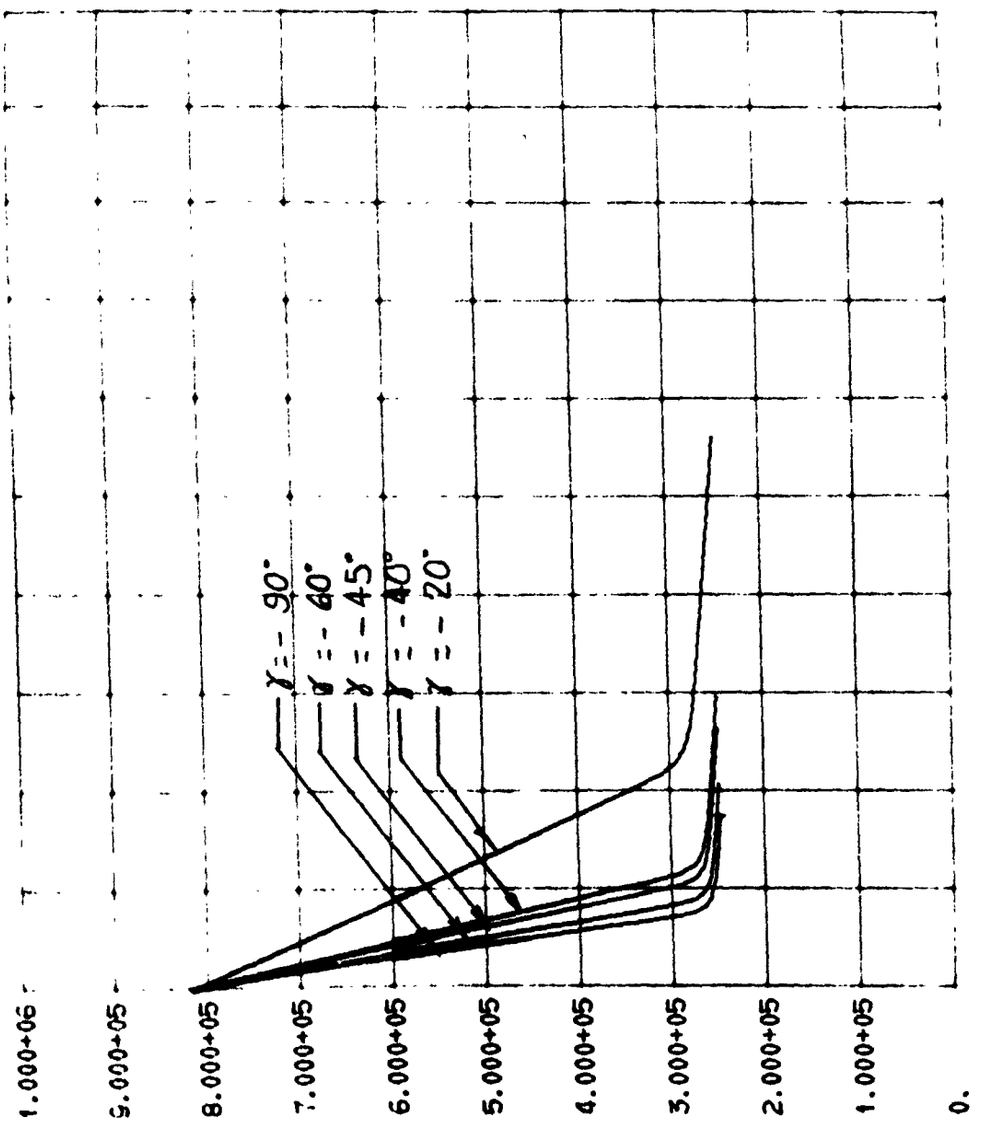

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ = - 90°
γ = - 60°
γ = - 45°
γ = - 40°
γ = - 20°
0.
4.000+01
8.000+01
1.200+02
1.600+02
2.00
ALTUDE
VS
TIME
1
VENUS MAP CNCT MNCL BE=.1 VE=36000FPS

Fig. H-9

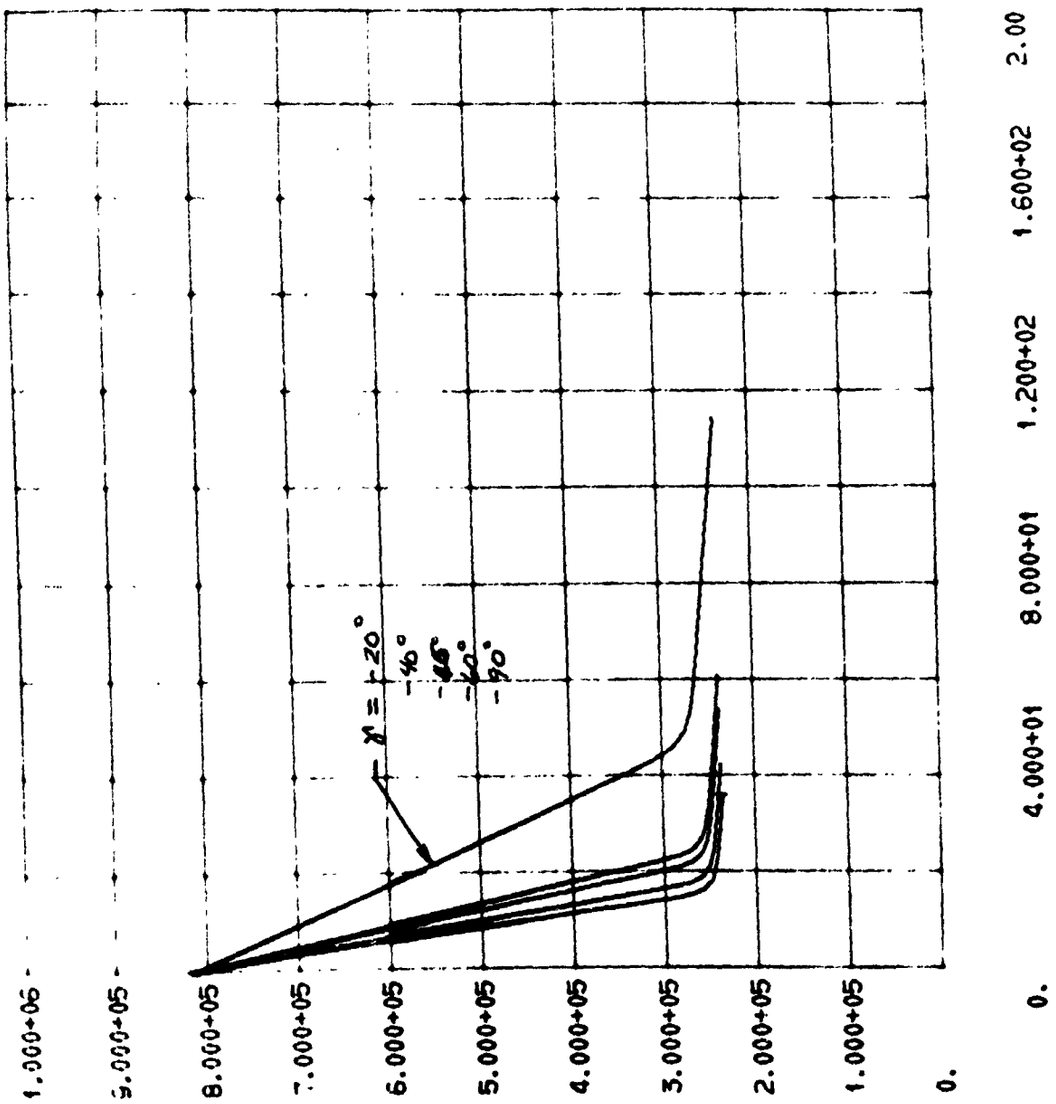

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
ALTUDE
0.
4.000+01
8.000+01
1.200+02
1.600+02
2.00
TIME
1
VENUS M/P CNCT MNCL BE=.2 VE=36000FPS

Fig. H-10

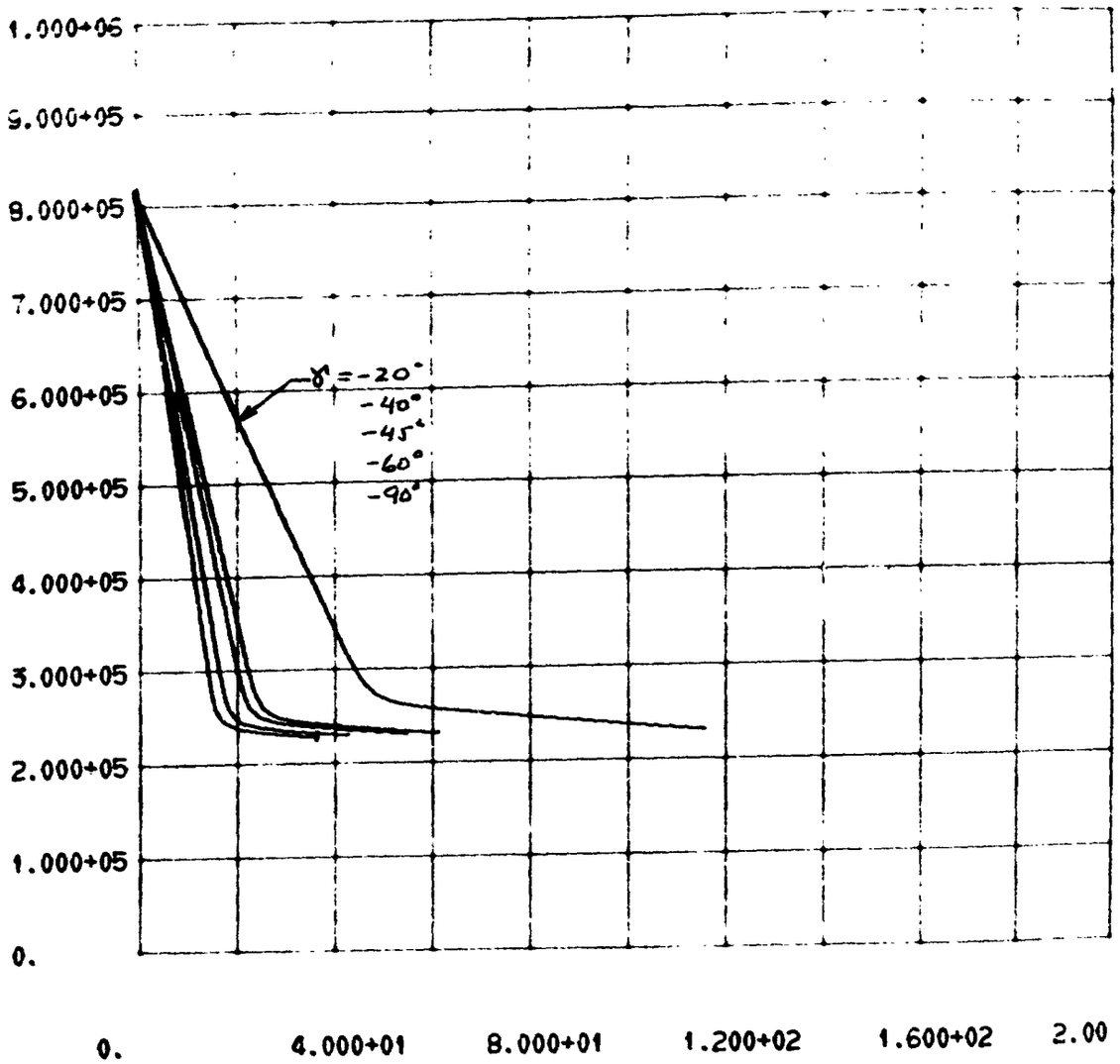


Fig. H-11

1 VENUS M/P CNCT MMCL BE=.3 VE=36000FPS

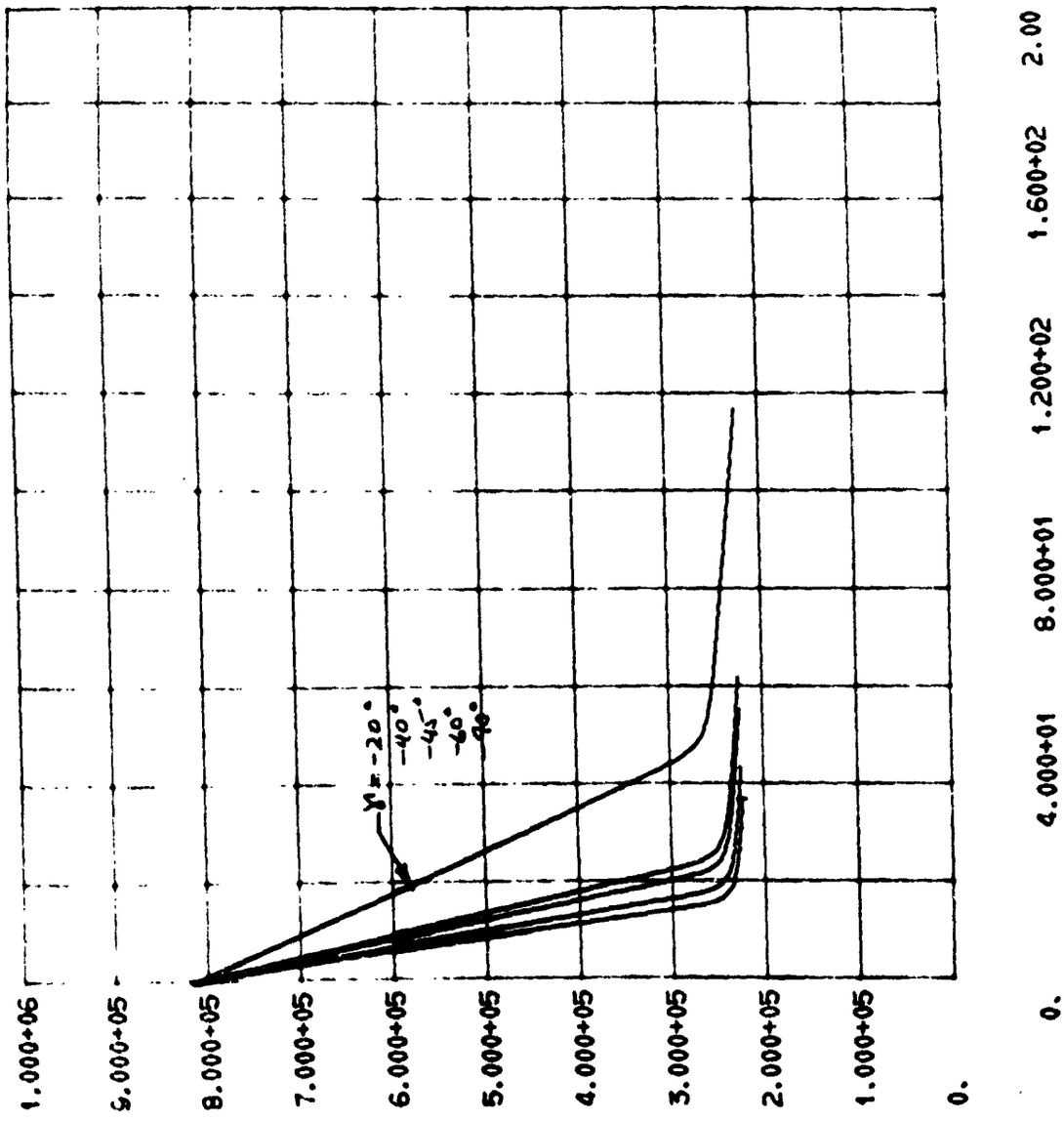

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ = -20°
-40°
-45°
-60°
-90°
0.
4.000+01
8.000+01
1.200+02
1.600+02
2.00
ALTUDE
VS
TIME
1
VENUS MP CNCT MNCL BE=.4 VE=36000FPS

Fig. H-12

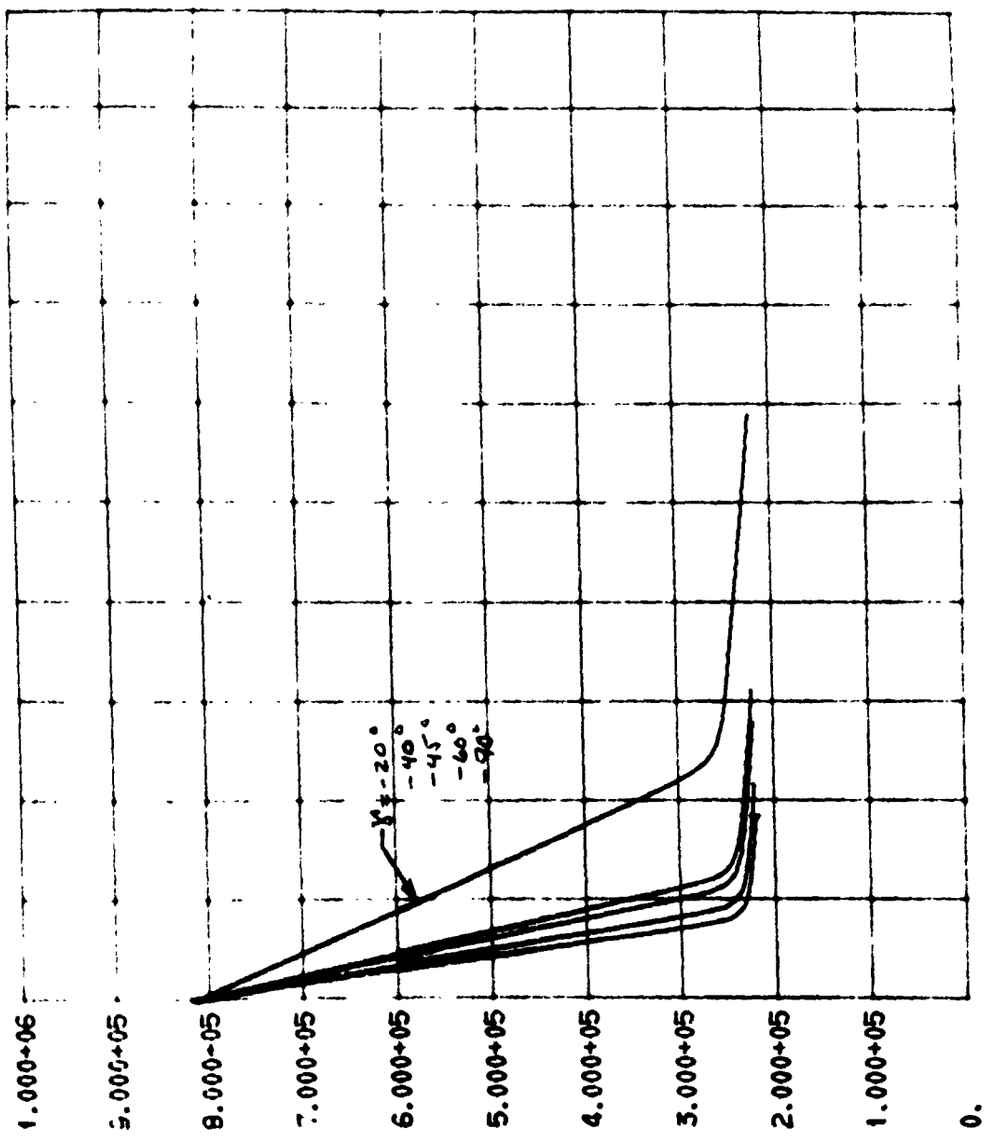


Fig. H-13
VEMLS NVP CNCT MMCL BE=.5 VE=36000FPS

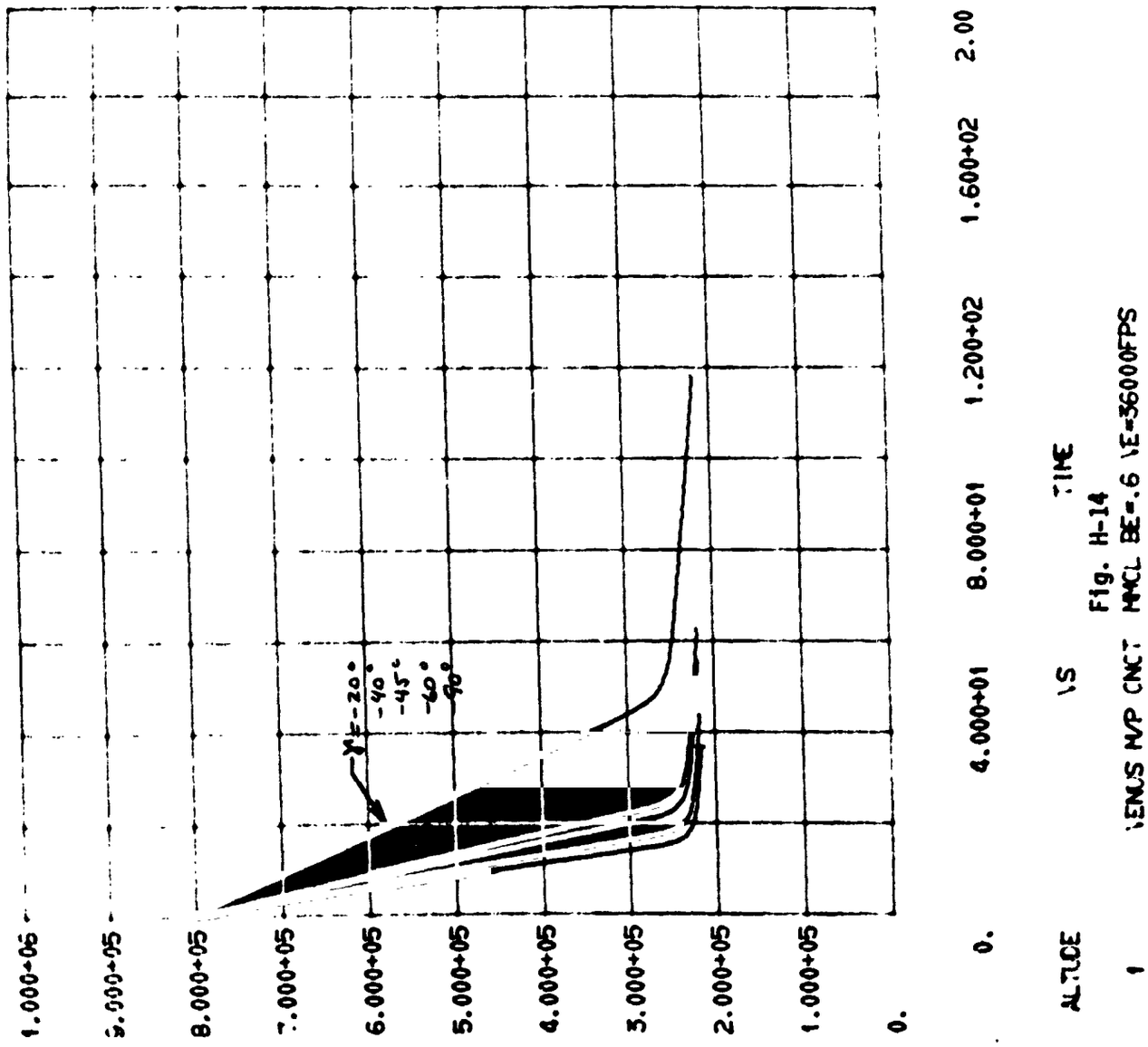


Fig. H-14

\ENUS M/P CNCT MMCL BE=.6 \E=36000FPS

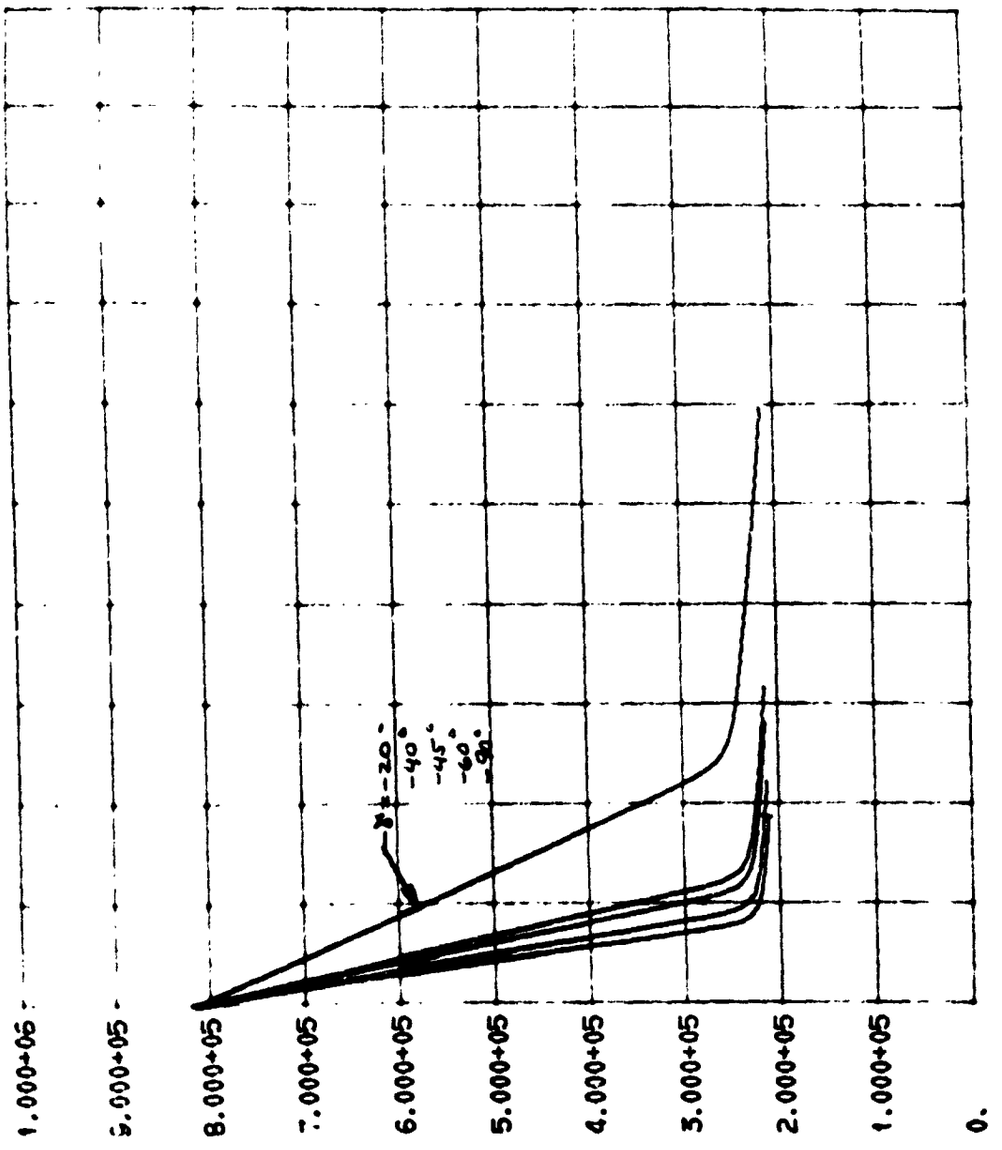


Fig. H-15

VENUS MVP TRJCT MMCL BE=.8 VE=36000FPS

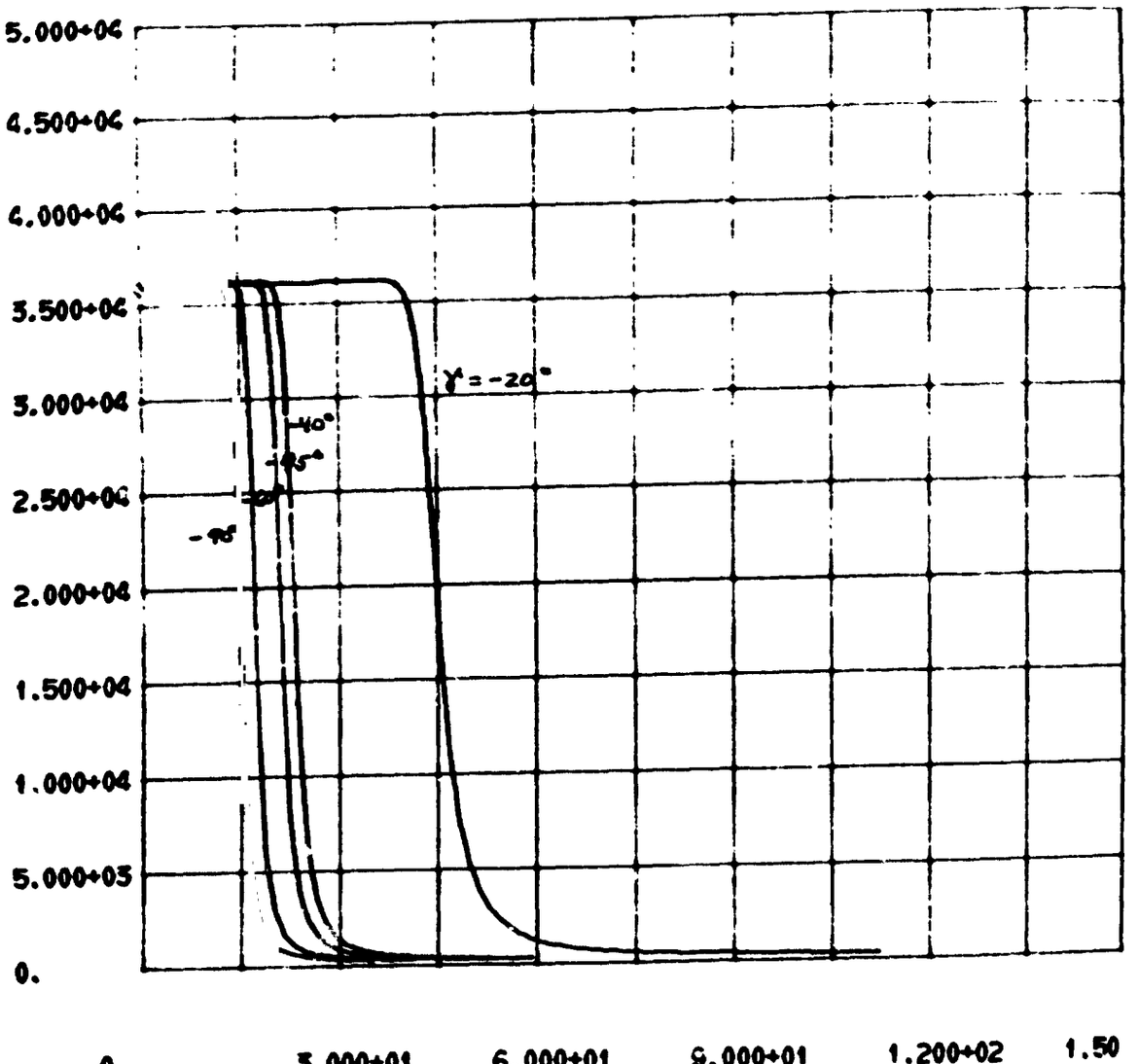

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4.500+06
4.000+06
3.500+06
3.000+06
2.500+06
2.000+06
1.500+06
1.000+06
5.000+05
0.
γ = -20°
-40°
-45°
-90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VEL(R)
VS
TIME
1
VENUS MVP CNCT MMCL BE=.1 VE=36000FPS

Fig. H-16

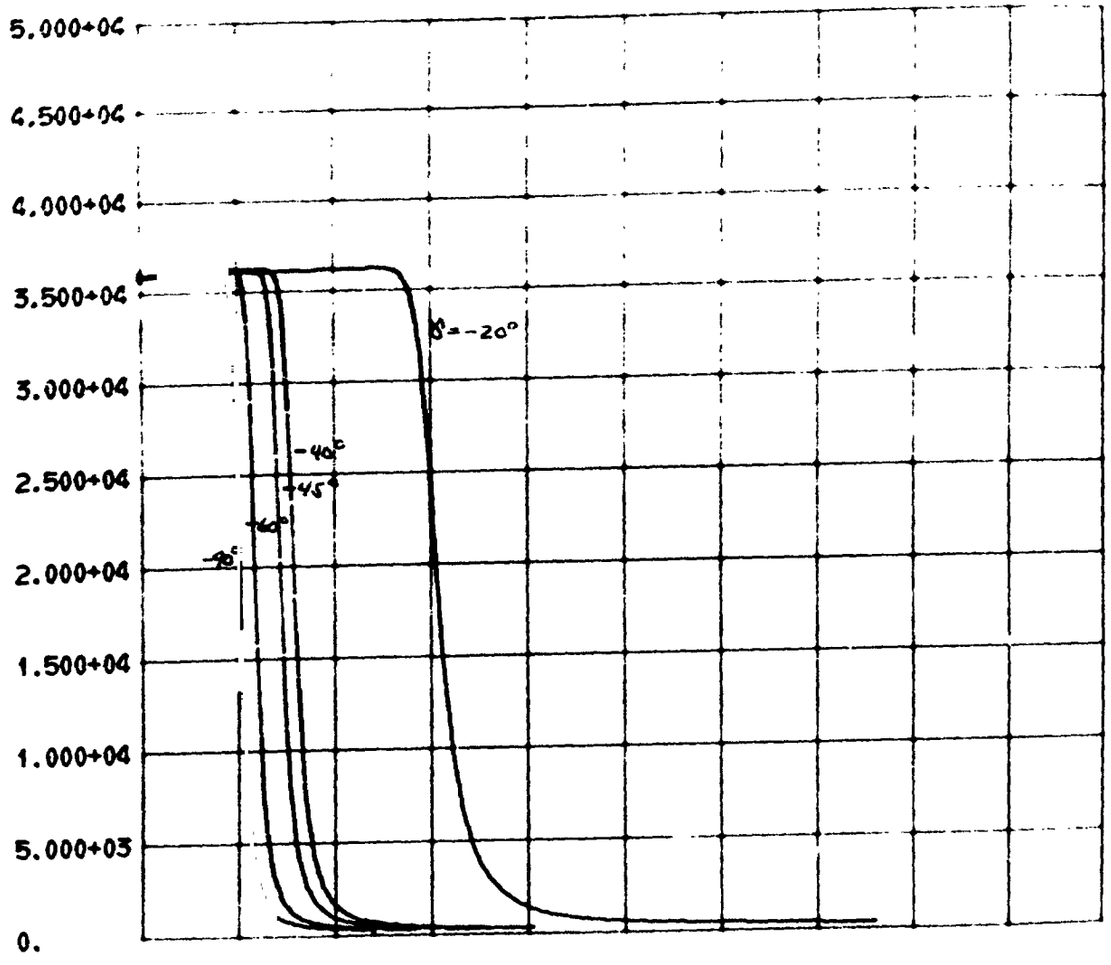

5.000+04
4.500+04
4.000+04
3.500+04
3.000+04
2.500+04
2.000+04
1.500+04
1.000+04
5.000+03
0.
β=-20°
-40°
-45°
-60°
-70°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VEL(R)
VS
TIME
1
VENUS M/P CNCT MMCL BE=.2 VE=36000FPS

Fig. H-17

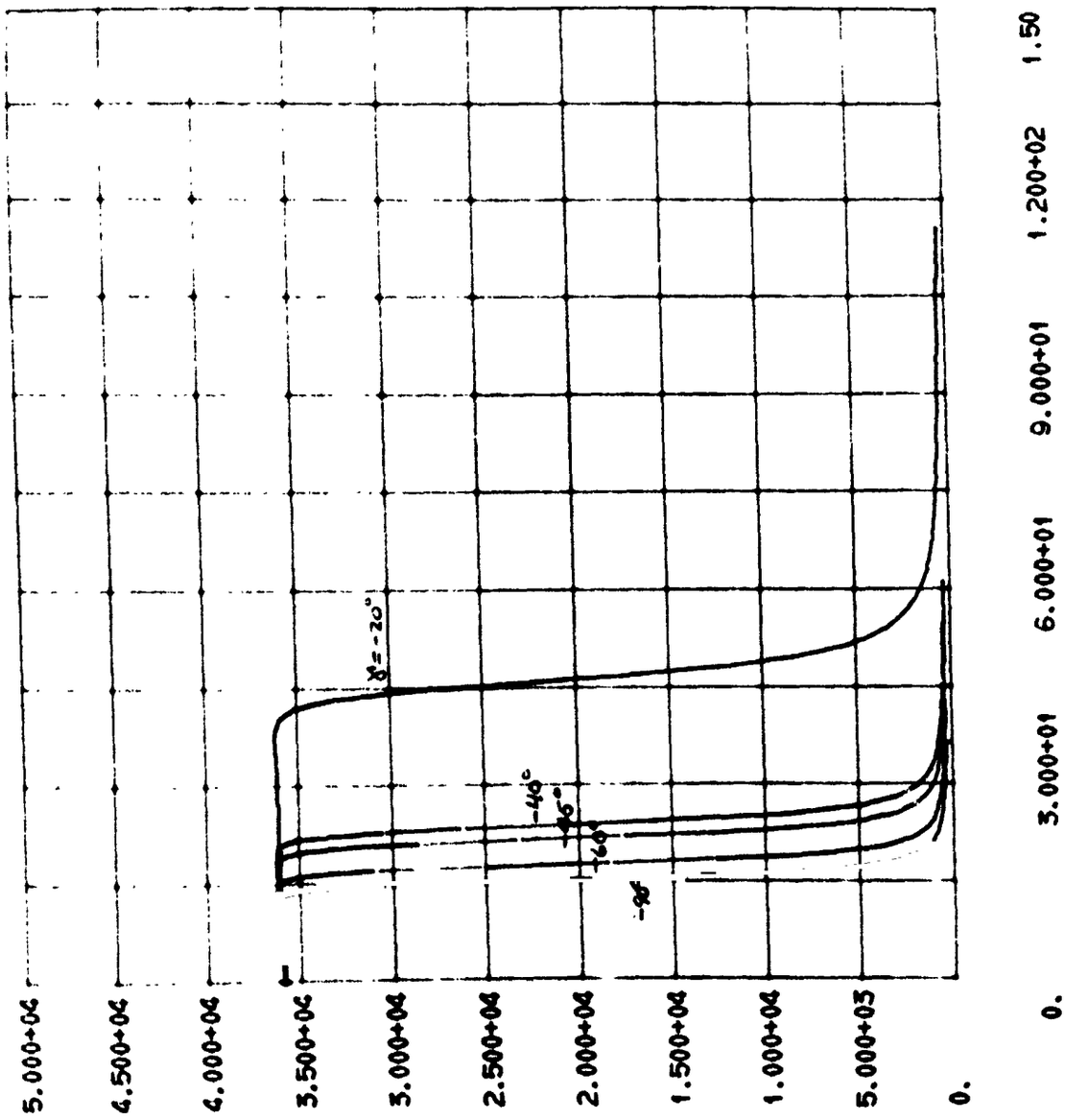


Fig. H-18
VENUS M/P CNCT MNCL BE=.3 VE=36000FPS

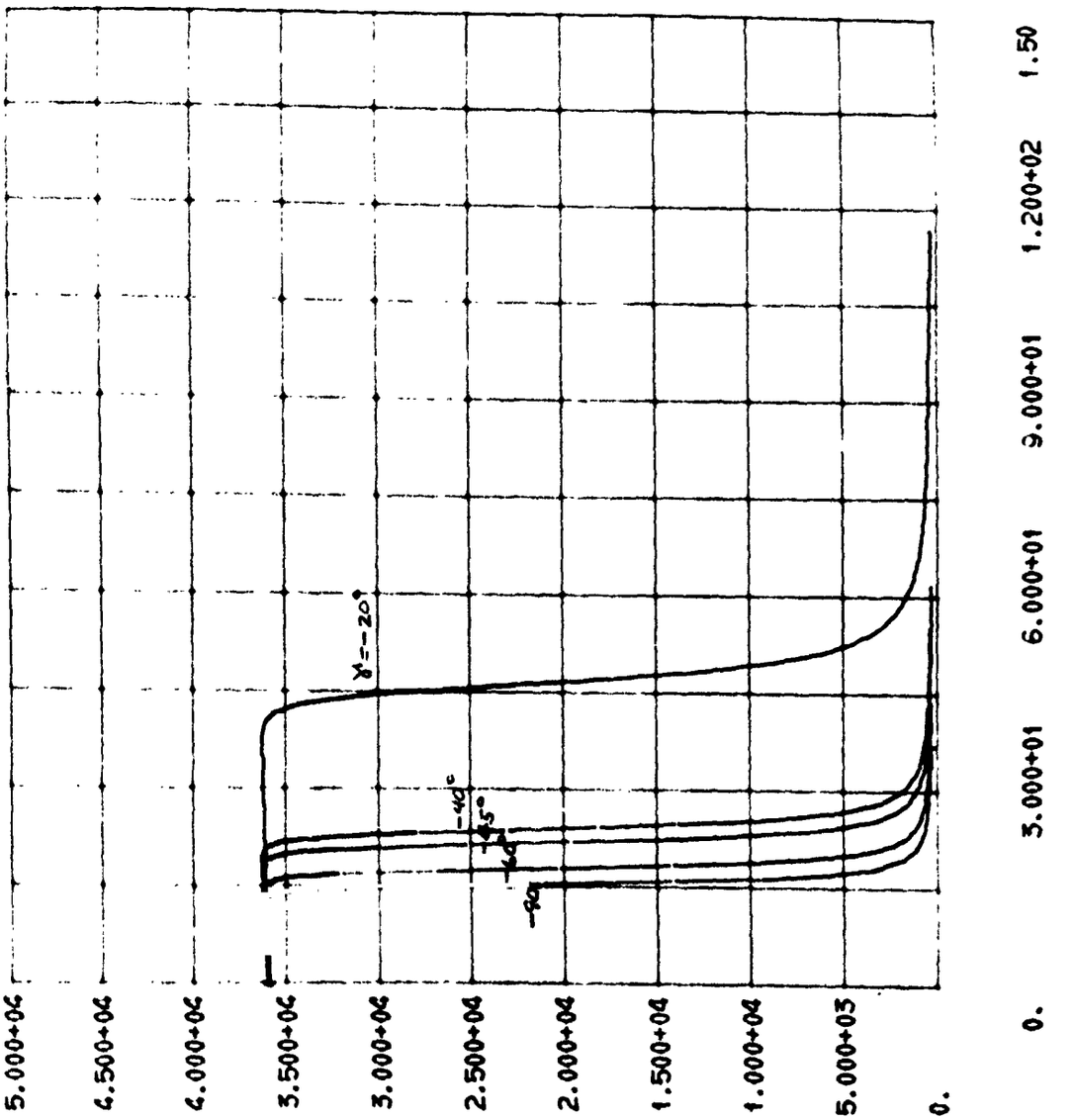

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4.500+04
4.000+04
3.500+04
3.000+04
2.500+04
2.000+04
1.500+04
1.000+04
5.000+03
0.
γ'=-20°
-40°
-45°
-90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VEL(R) VS TIME
1 VENUS MVP CNCT MNCL BE=.4 VE=36000FPS

Fig. H-19

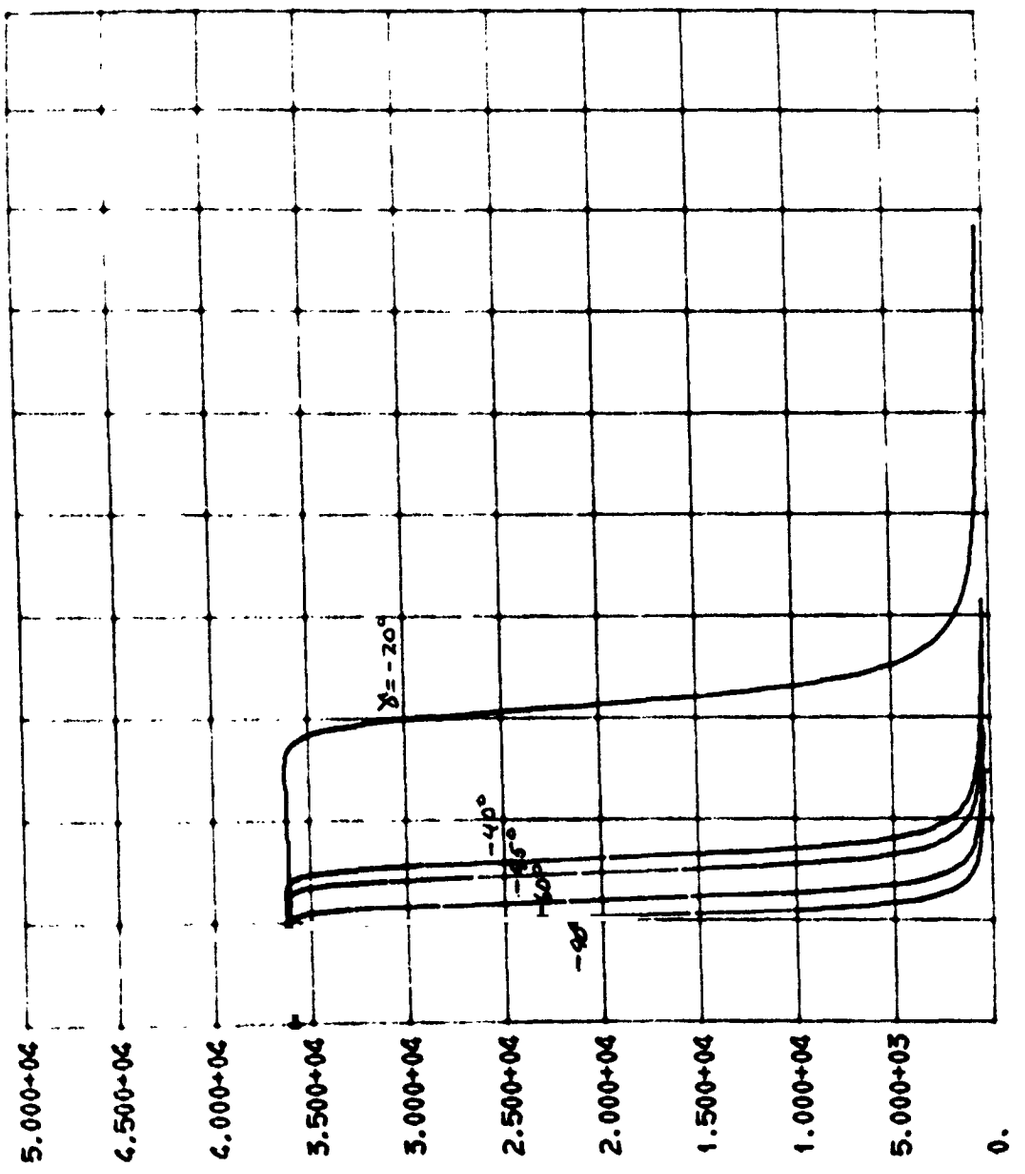

5.000+04
4.500+04
4.000+04
3.500+04
3.000+04
2.500+04
2.000+04
1.500+04
1.000+04
5.000+03
0.
γ= -20°
-40°
-45°
-90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VEL(R) VS TIME
1 VENUS MP CNCT MNCL BE=.5 VE=36000FPS

Fig. H-20

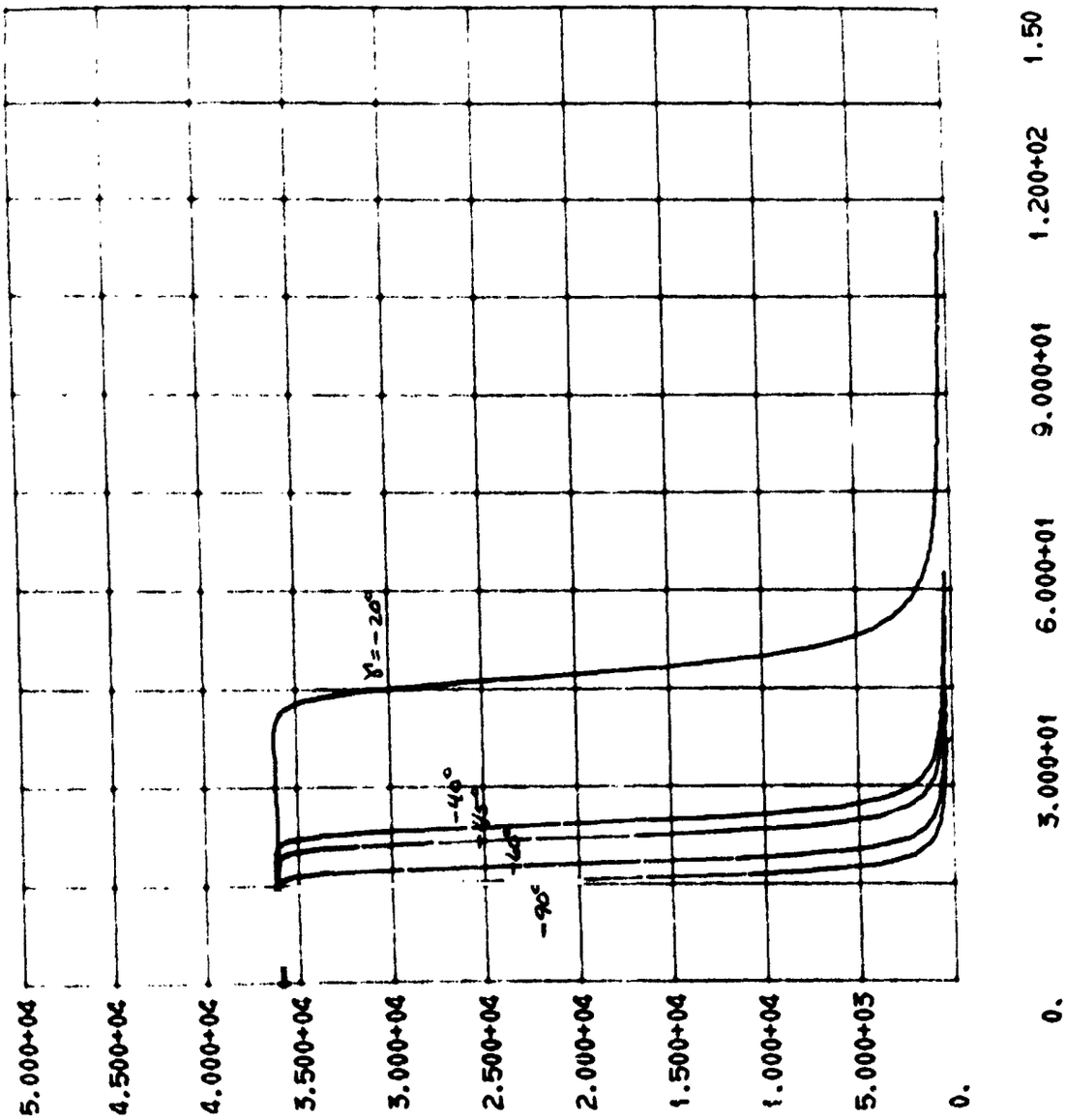


Fig. H-21

VENUS MP CNCT MNCL BE=.6 VE=36000FPS

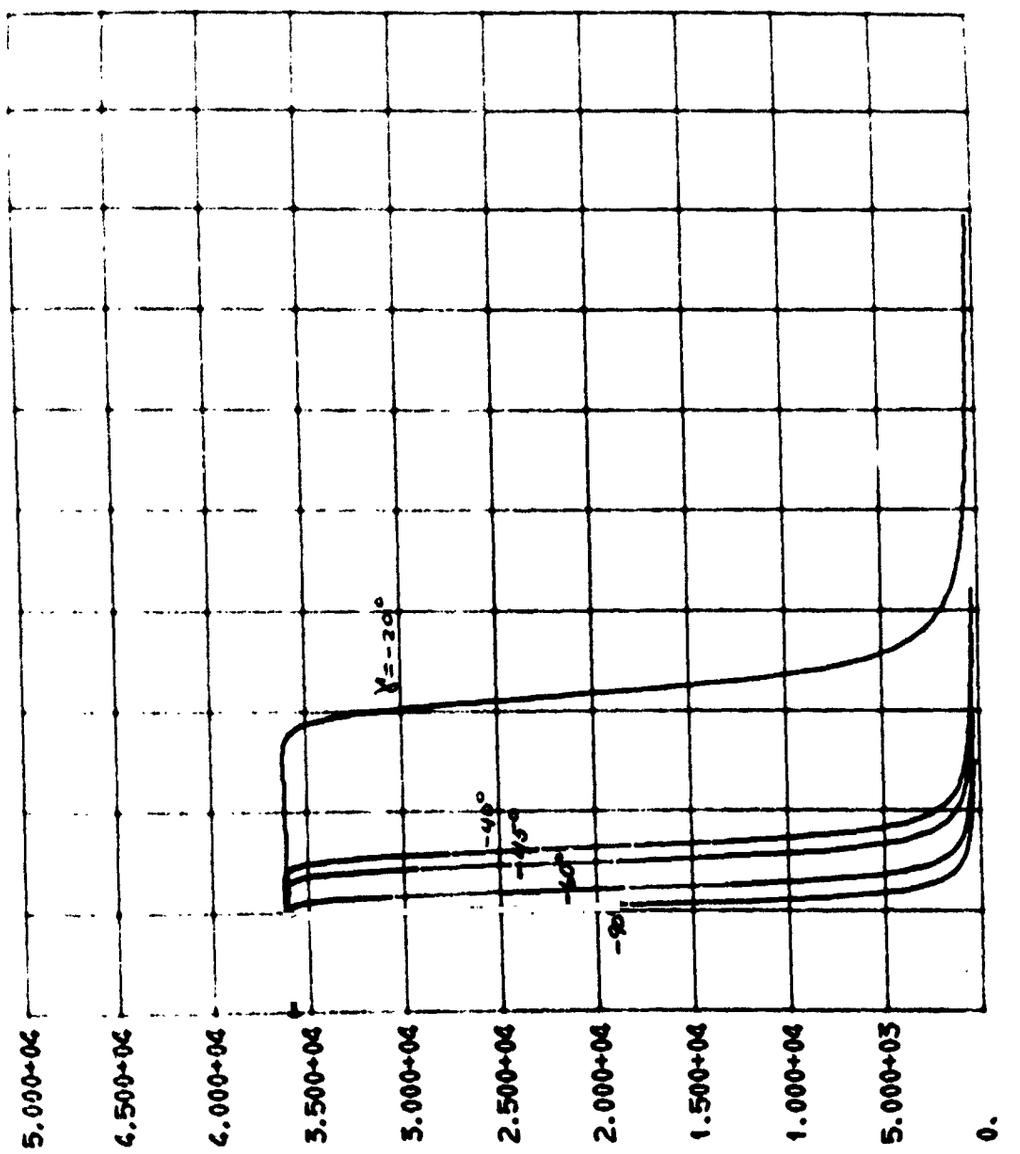


Fig. H-22
VENUS MVP CNCT MNCL BE=.8 VE=36000FPS

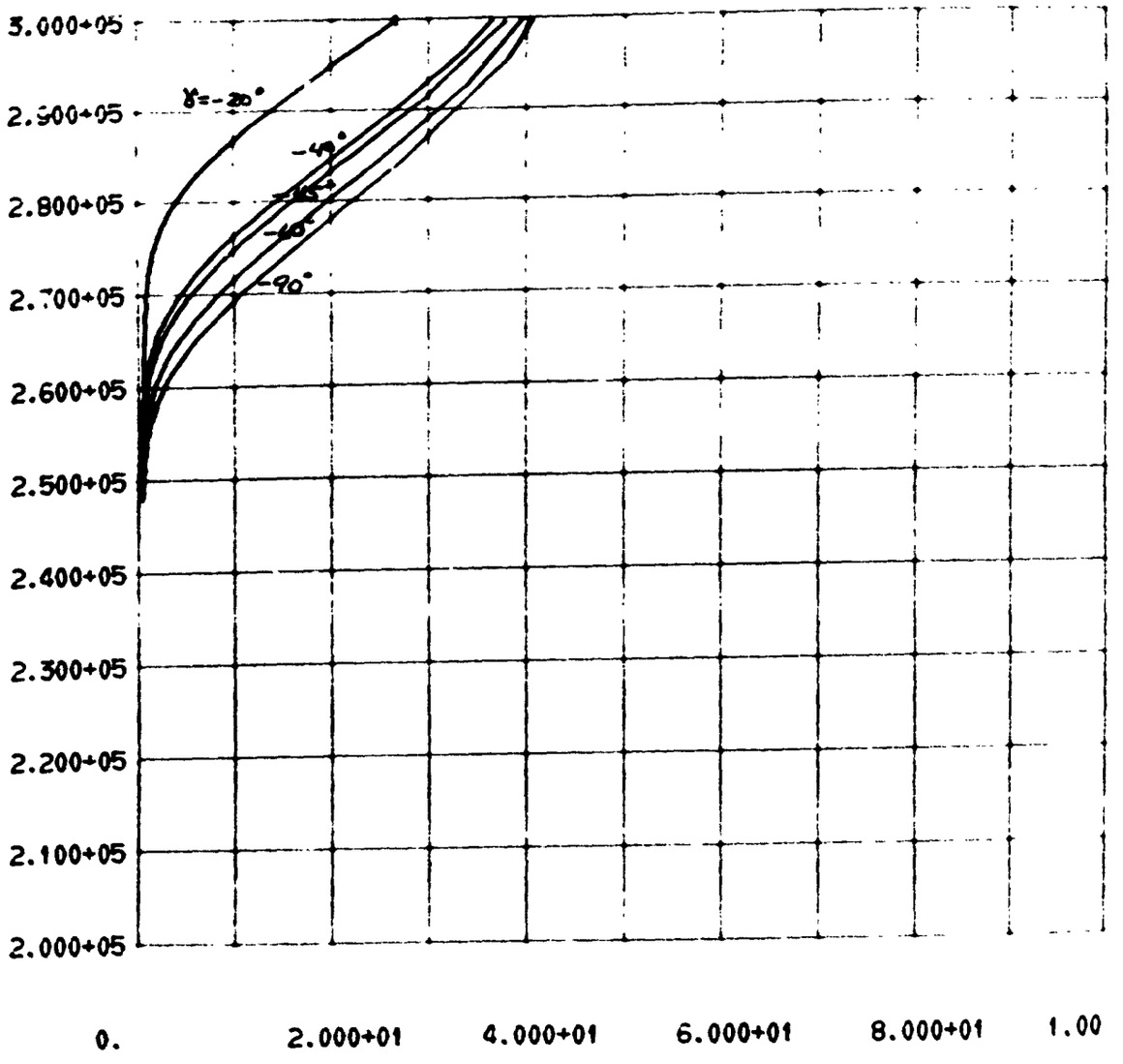


Fig. H-23

1 VENUS M/P CNCT MMCL BE=.8 VE=36000FPS

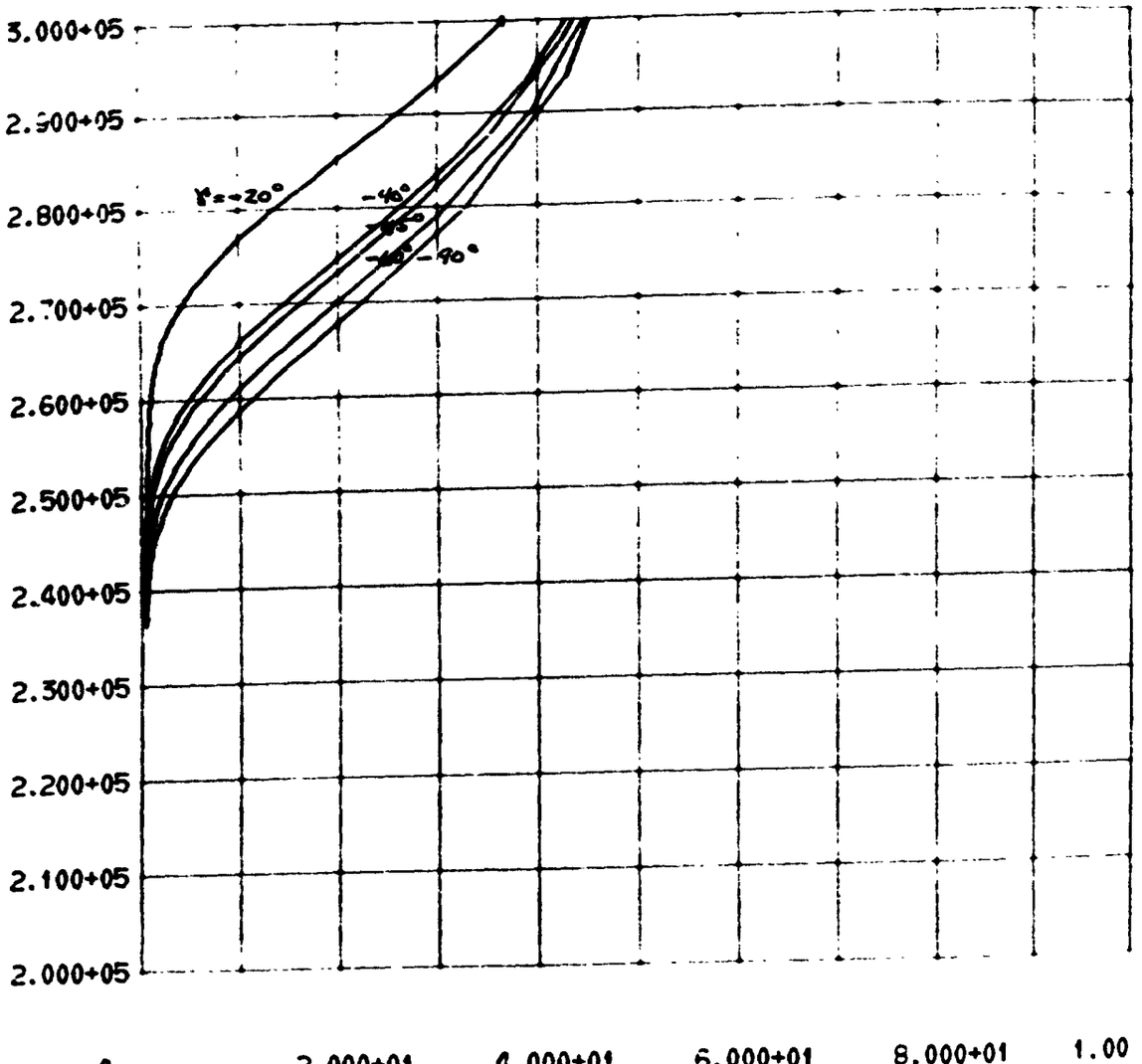

3.000+05
2.900+05
2.800+05
2.700+05
2.600+05
2.500+05
2.400+05
2.300+05
2.200+05
2.100+05
2.000+05
γ=-20°
-40°
-90°
0.
2.000+01
4.000+01
6.000+01
8.000+01
1.00
ALTUDE
VS
MACHNO
1
VENUS M/P CNCT MMCL BE=.2 VE=36000FPS

Fig. H-24

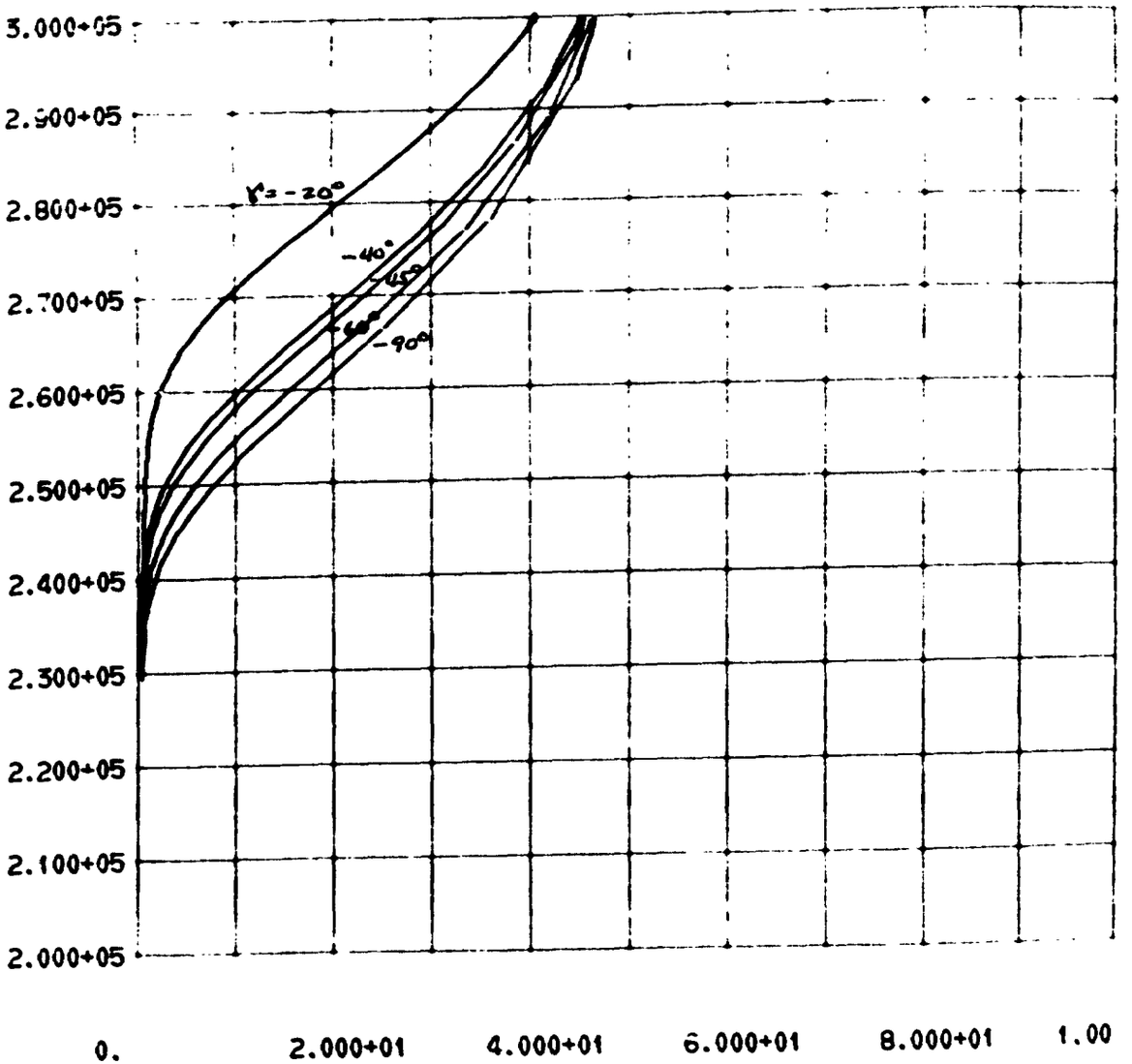
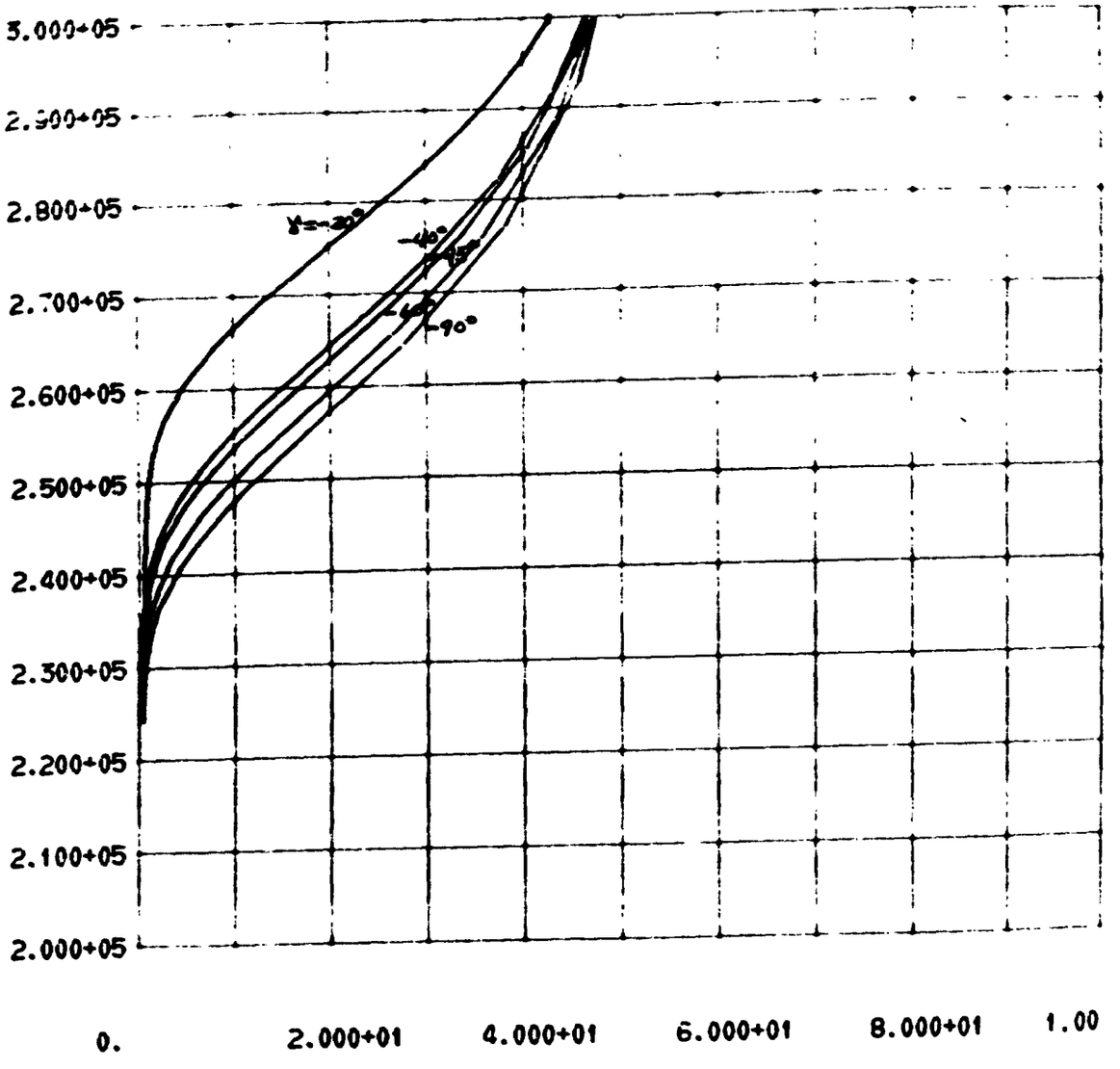


Fig. H-25

1 VENUS M/P CNCT MMCL BE=.3 VE=36000FPS



ALTUDE VS MACHNO

Fig. H-26

1 VENUS M/P CNCT MMCL BE=.4 VE=36000FPS

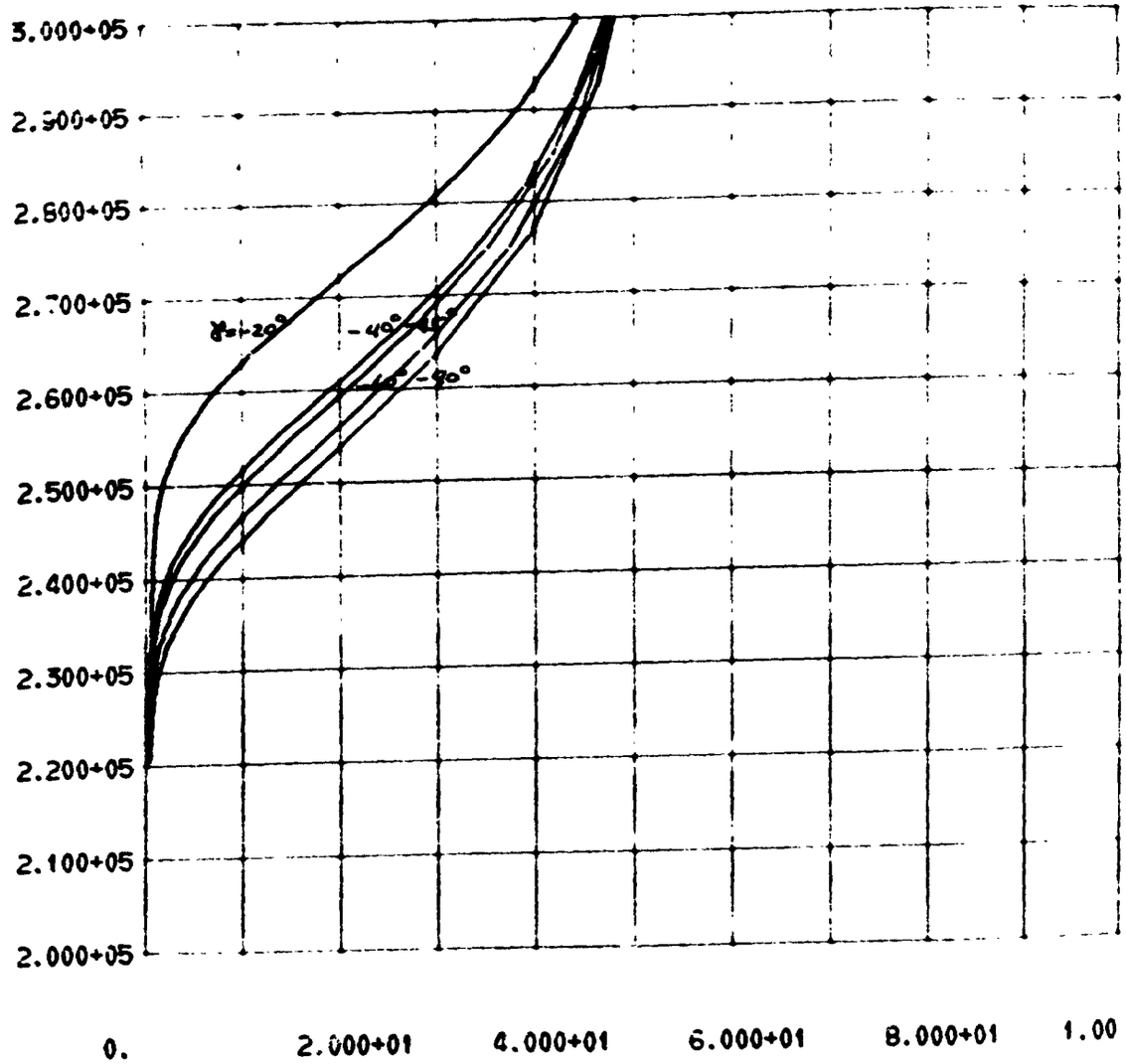


Fig. H-27

1 VENUS M/P CNCT MMCL BE=.5 VE=36000FPS

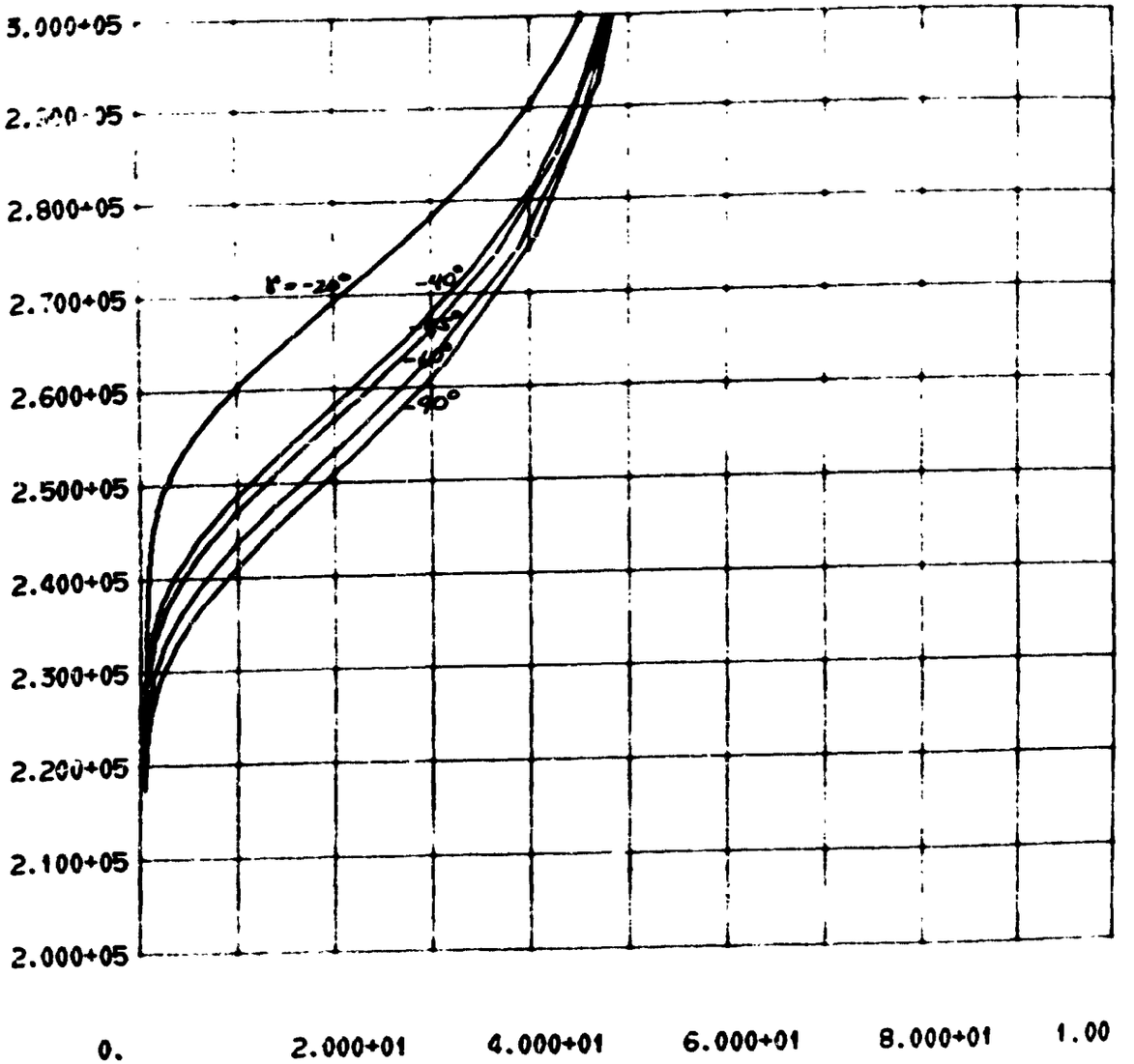

3.000+05
2.900+05
2.800+05
2.700+05
2.600+05
2.500+05
2.400+05
2.300+05
2.200+05
2.100+05
2.000+05
0.
2.000+01
4.000+01
6.000+01
8.000+01
1.00
ALTUDE
VS
MACHNO
1
VENUS M/P CNCT MMCL BE=.6 VE=36000FPS

Fig. H-28

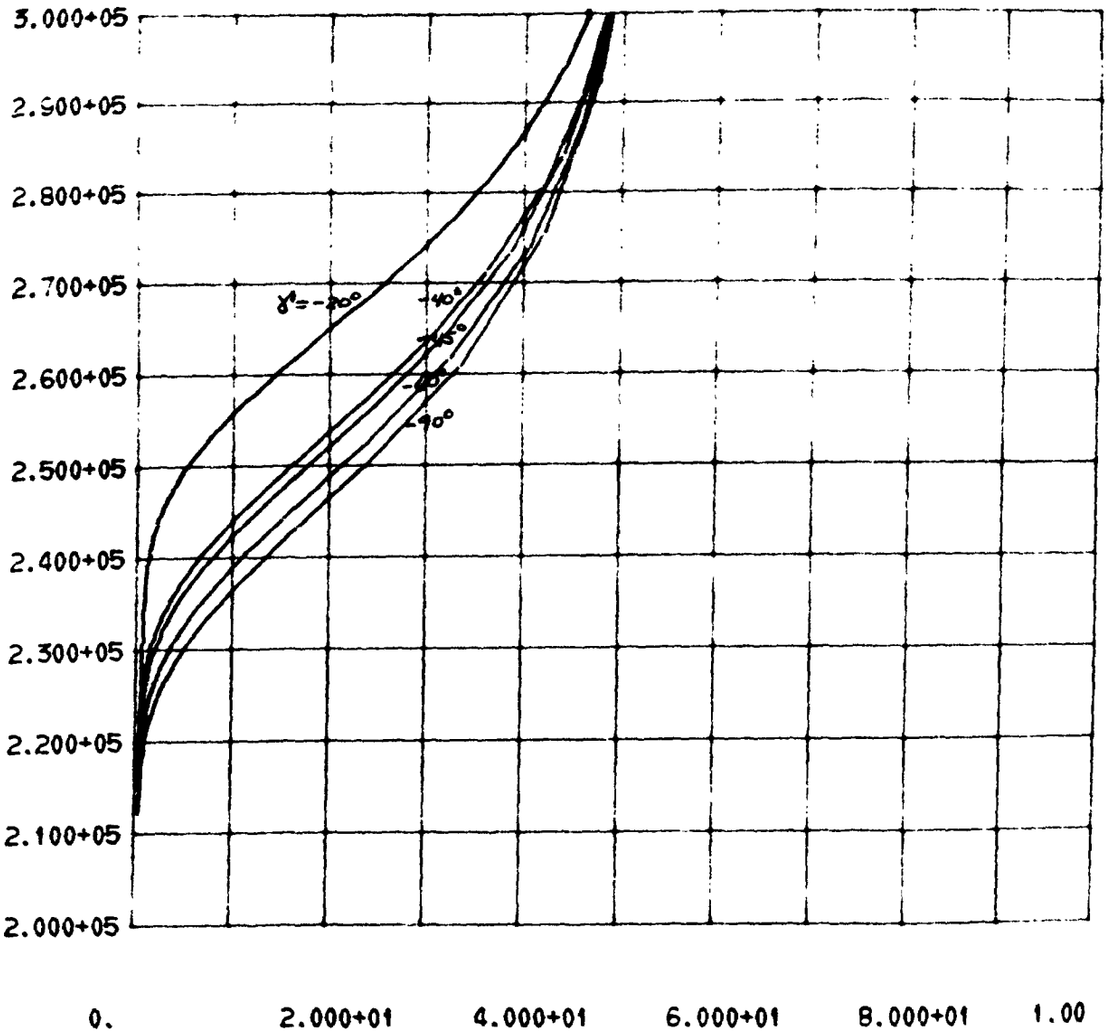


Fig. H-29

1 VENUS M/P CNCT MMCL BE=.8 VE=36000FPS

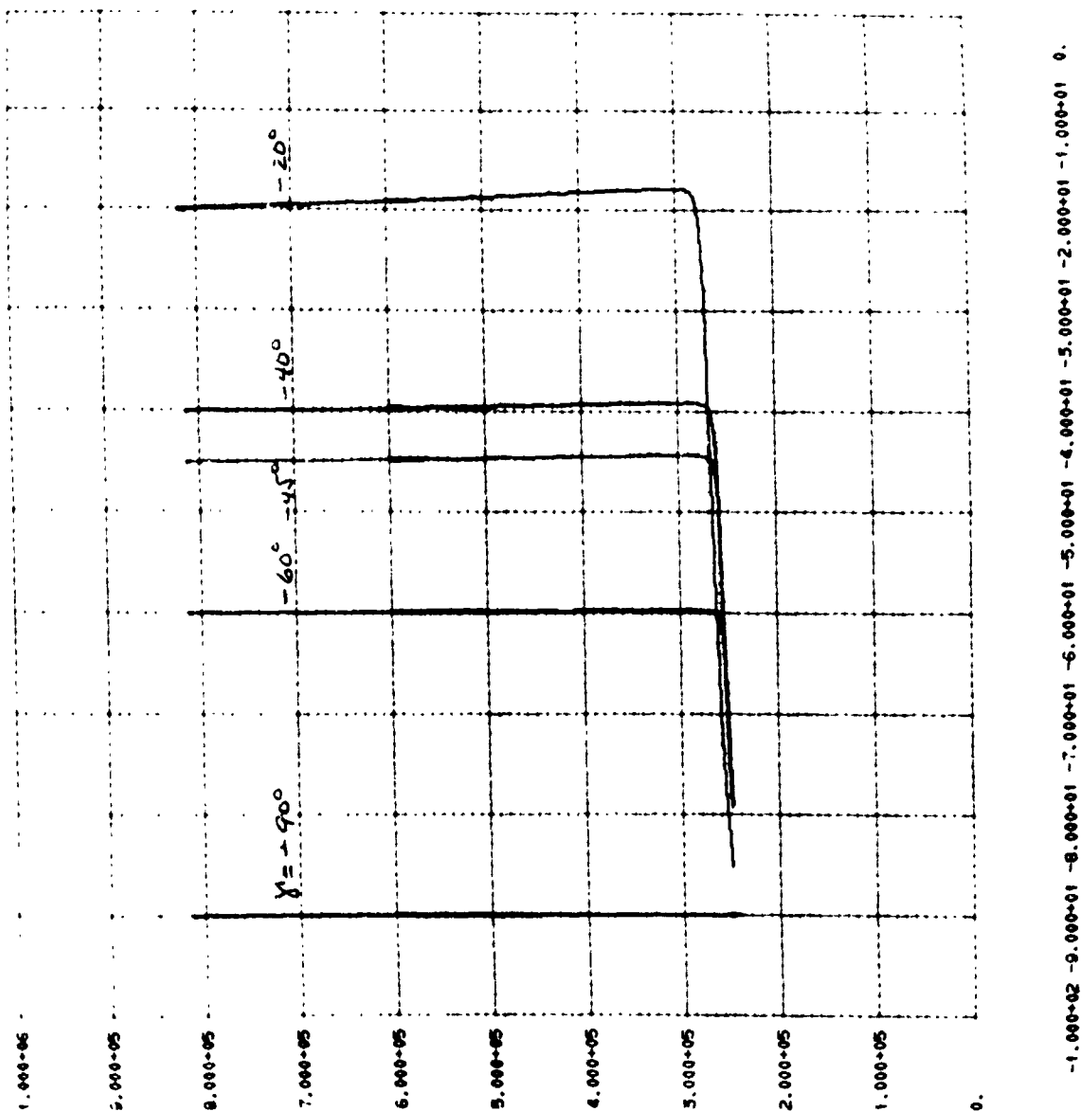

γ = -90°
-60°
-45°
-40°
-20°
1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-1.000+02 -9.000+01 -8.000+01 -7.000+01 -6.000+01 -5.000+01 -4.000+01 -5.000+01 -2.000+01 -1.000+01 0.
ALTUDE
VS
GAM(R)
1
VENUS MAP CNCT MNCL BE=.1 VE=35000FPS

Fig. H-30

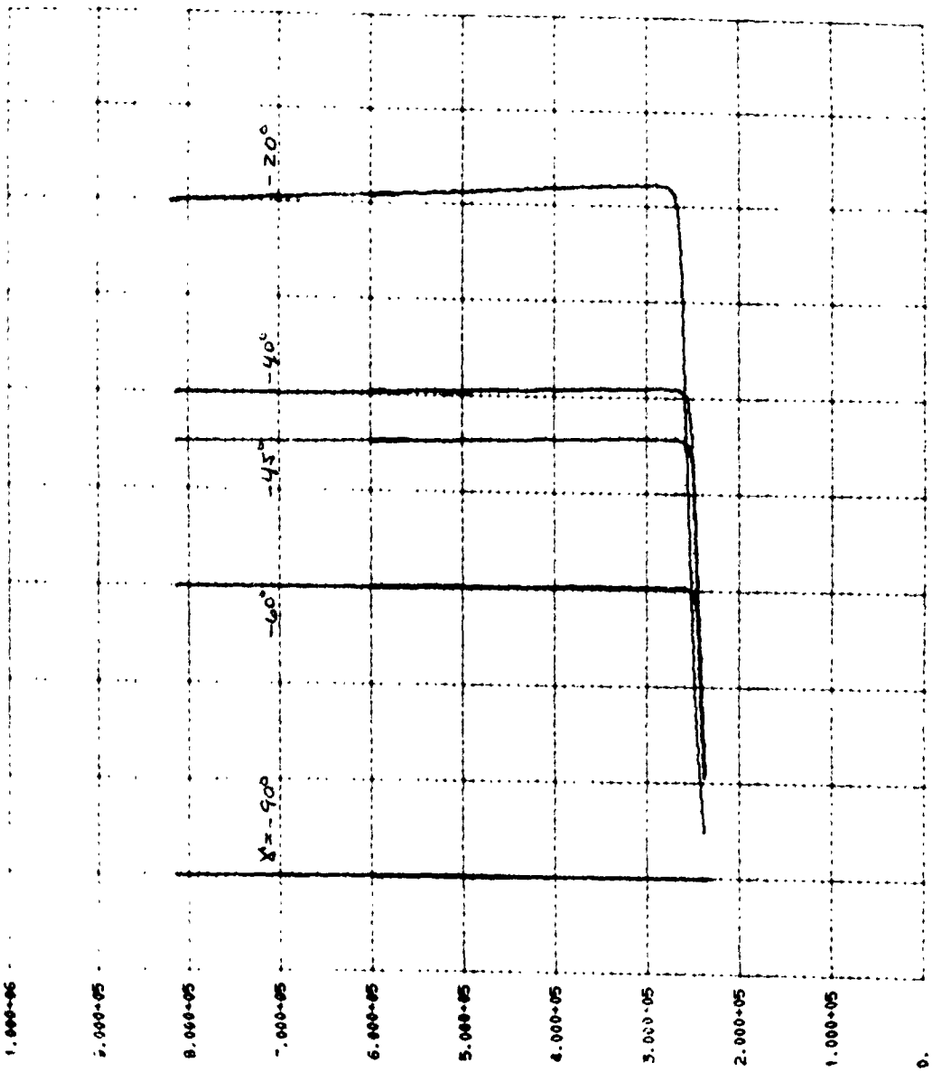


Fig. H-31

VENUS MVP CNCT MNCL BE=.2 VE=36000FPS

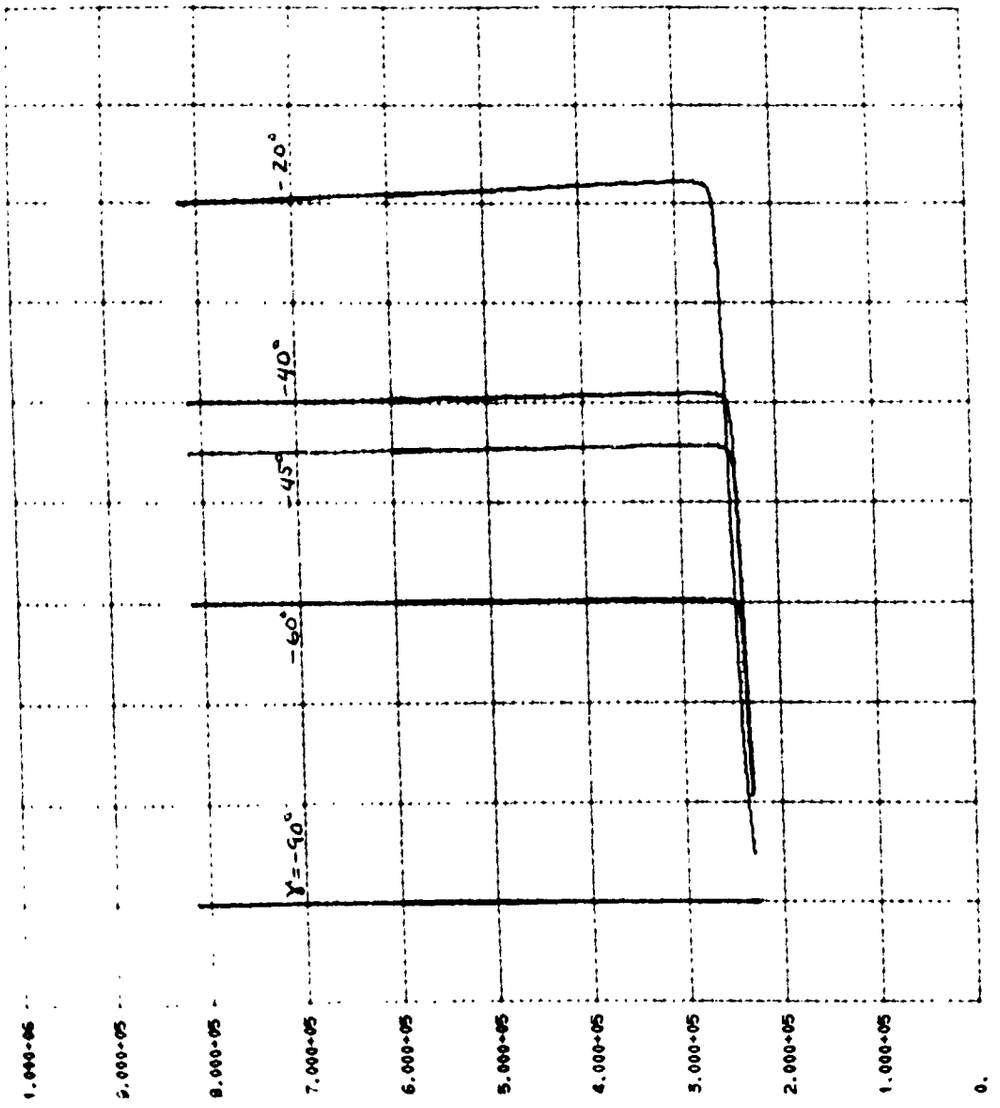

-20°
-40°
-45°
-60°
γ=-90°
1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-1.000+02 -9.000+01 -8.000+01 -7.000+01 -6.000+01 -5.000+01 -4.000+01 -3.000+01 -2.000+01 -1.000+01 0.
GAMMA(R)
VS
ALTUDE
VENUS MVP CNCT MNCL BE-.5 VE-36000FPS

Fig. H-32

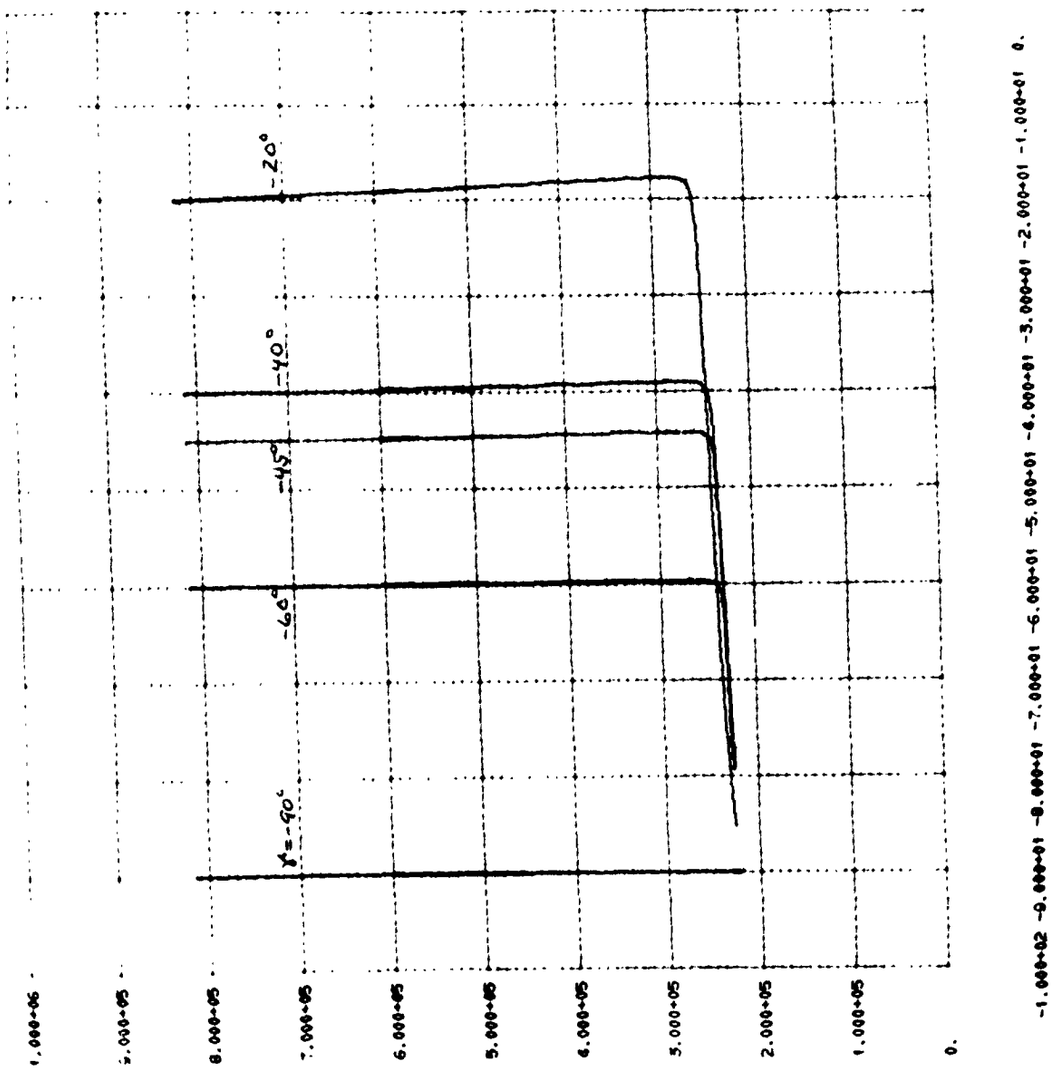


Fig. H-33

VENUS MAP CIRCT MNCL BE-.4 VE-36000FPS

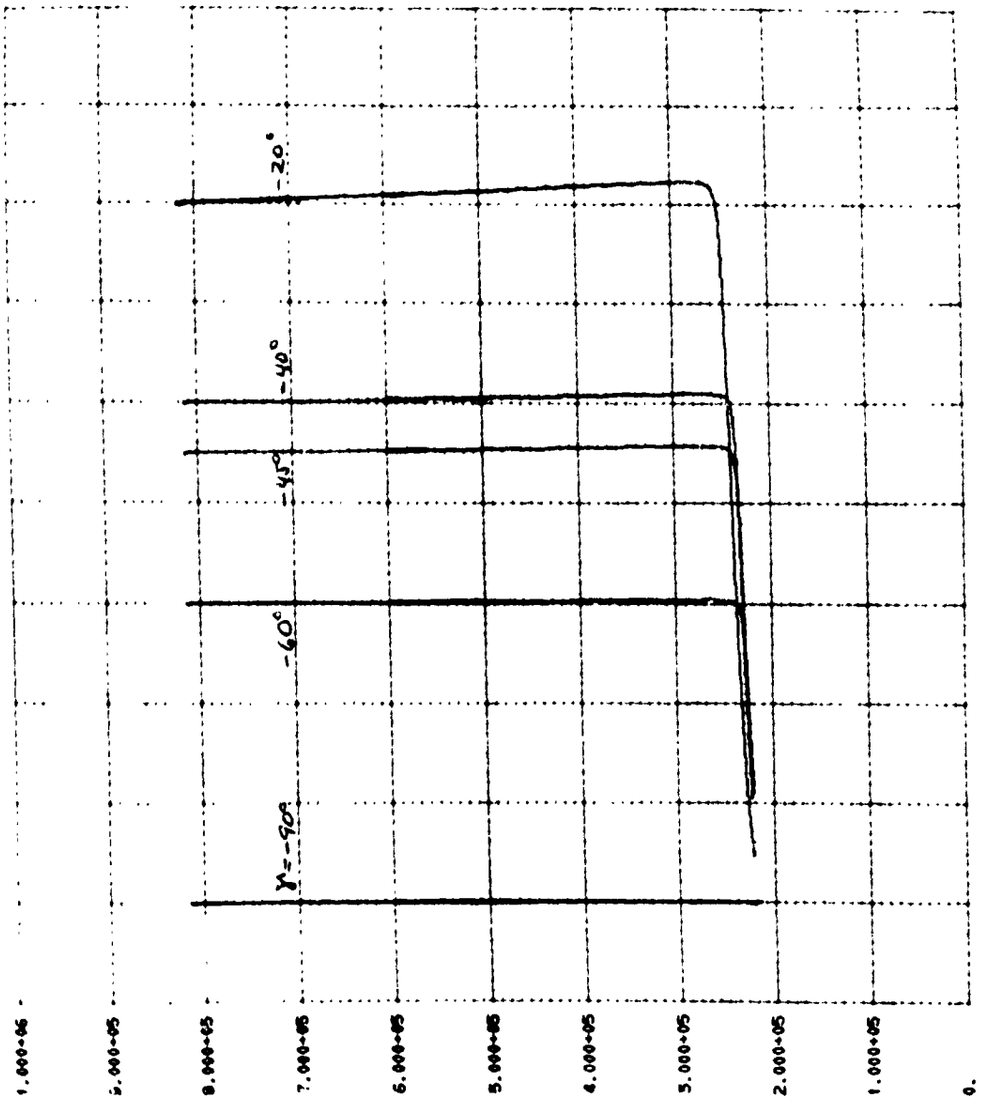

γ=-20°
-40°
-45°
-60°
γ=-90°
1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-1.000+02 -9.000+01 -8.000+01 -7.000+01 -6.000+01 -5.000+01 -4.000+01 -3.000+01 -2.000+01 -1.000+01 0.
ALTUDE
VS
VENUS MVP CNCT ANGL BE=.5 VE=36000FPS

Fig. H-34

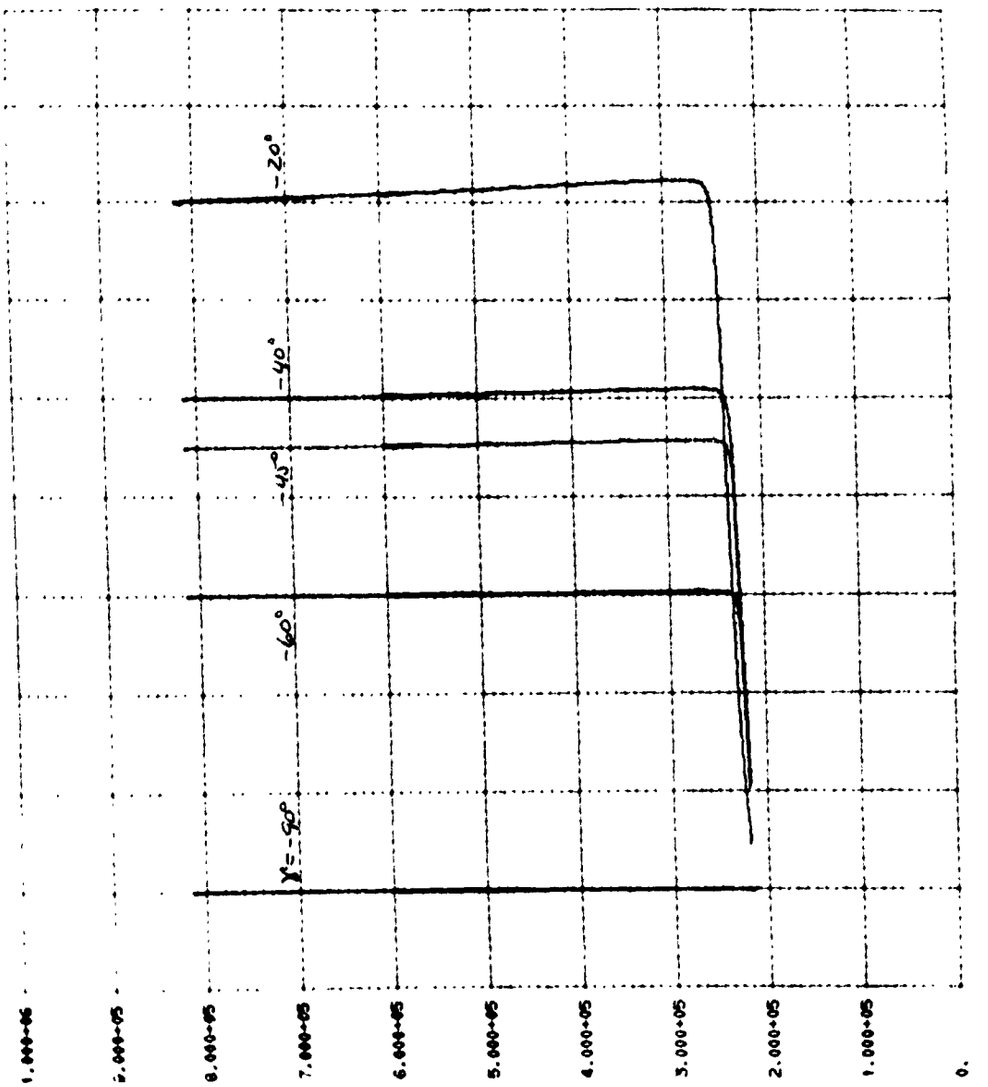


Fig. H-35

VENUS MP CNST MACL BE=.6 VE=36000FPS

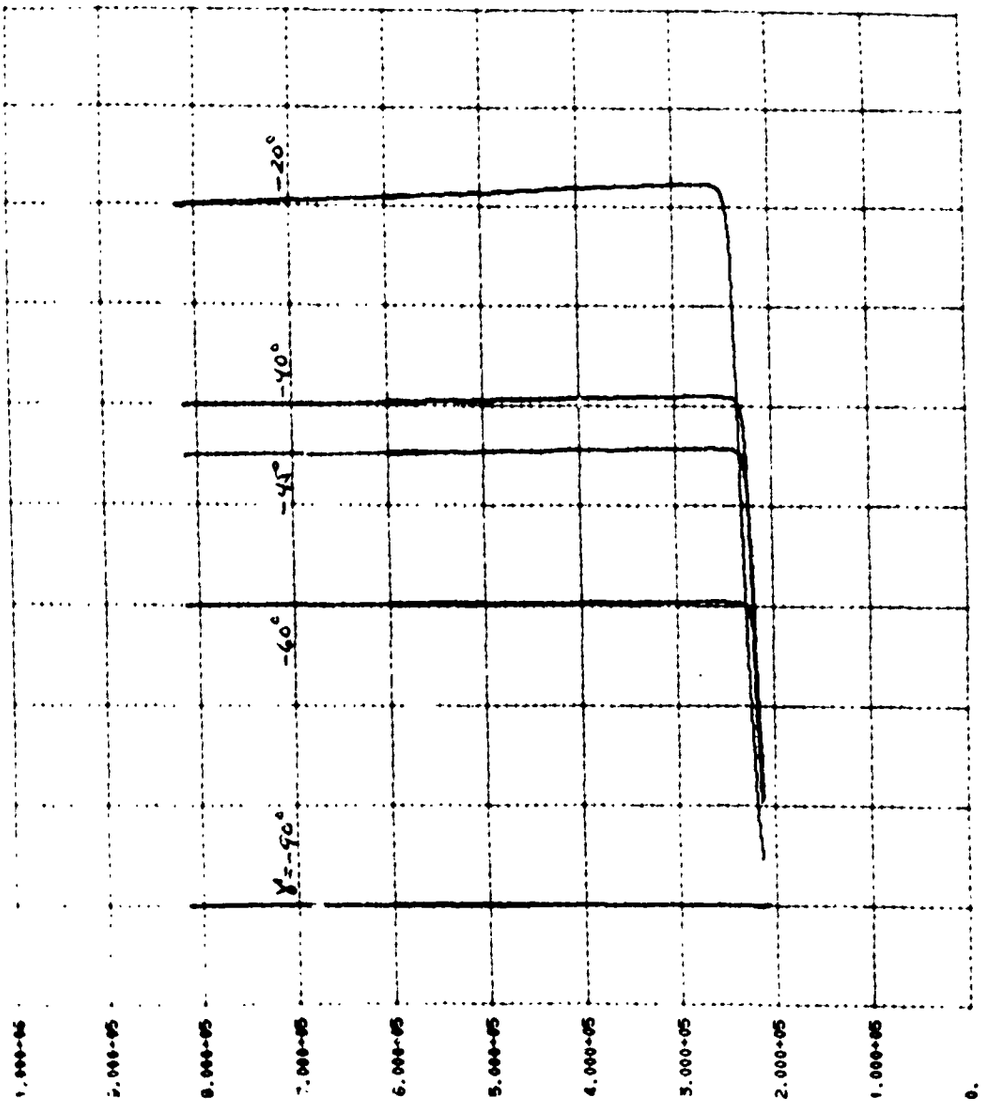


Fig. H-36

VENUS MP CNCT MNCL BE-.8 VE-36000FPS

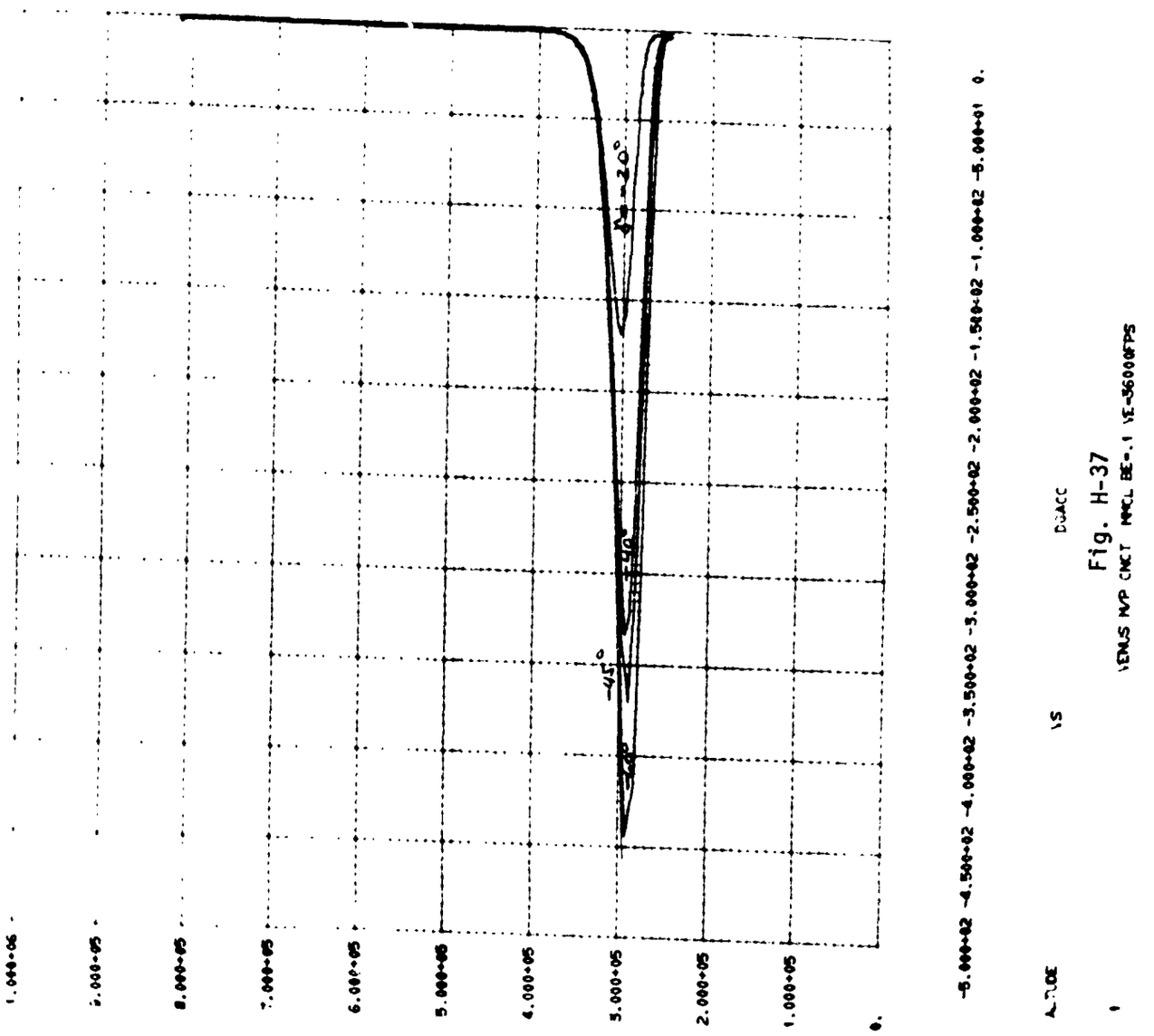


Fig. H-37
VENUS MP CKET MMCL BE-.1 VE-36000FPS

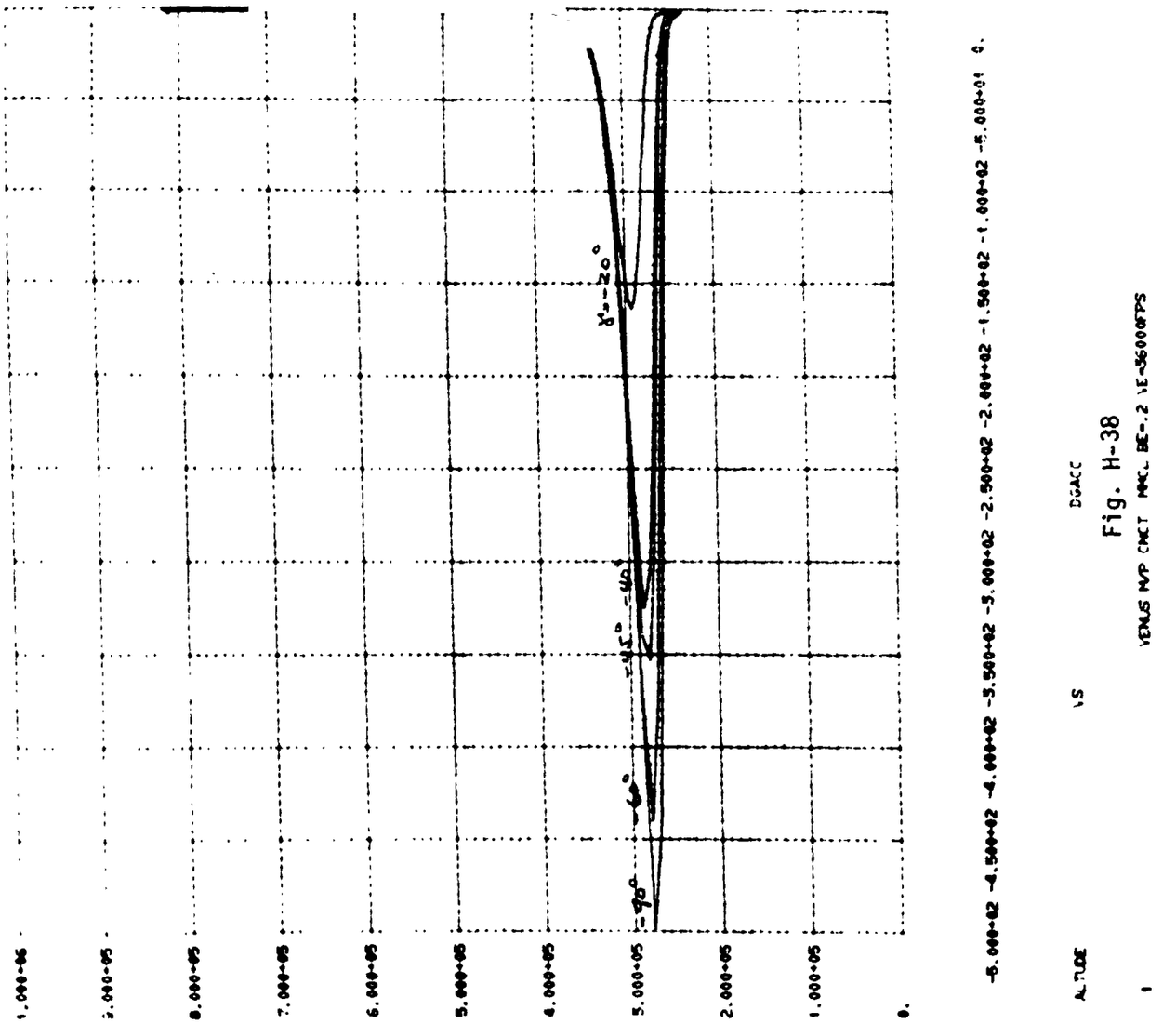

1.000+06
2.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ=-20°
γ=-30°
γ=-40°
γ=-45°
γ=-60°
γ=-90°
-5.000+02 -4.500+02 -4.000+02 -3.500+02 -3.000+02 -2.500+02 -2.000+02 -1.500+02 -1.000+02 -5.000+01 0.
ALTUDE
VS
DGACC
VENUS MAP CKCT MAX. BE-.2 VE-36000FPS

Fig. H-38

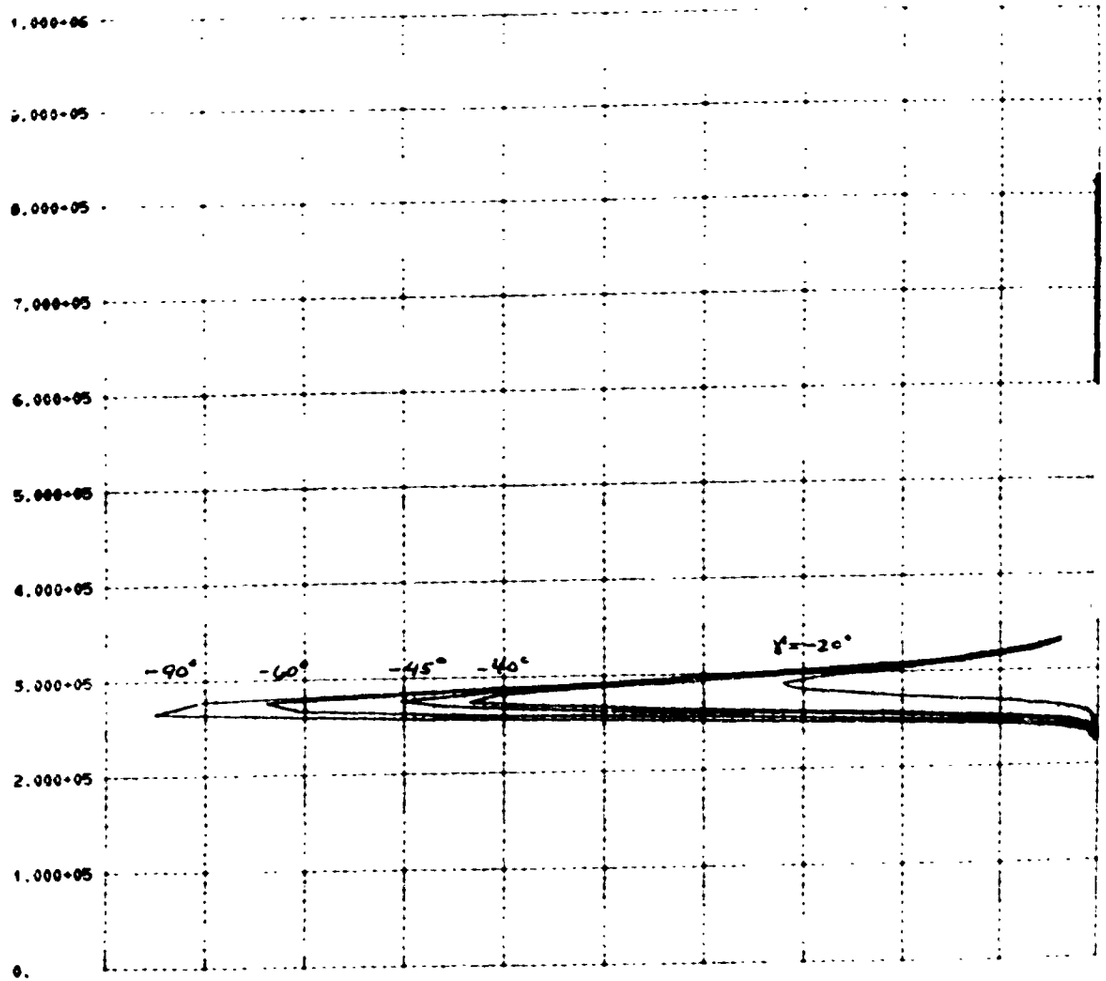

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-90°
-60°
-45°
-40°
γ=-20°
-5.000+02 -4.500+02 -4.000+02 -3.500+02 -3.000+02 -2.500+02 -2.000+02 -1.500+02 -1.000+02 -5.000+01 0.
ALTUDE
VS
DGACC
1
VENUS MVP CNCT MMCL BE=.5 VE=36000FPS

Fig. H-39

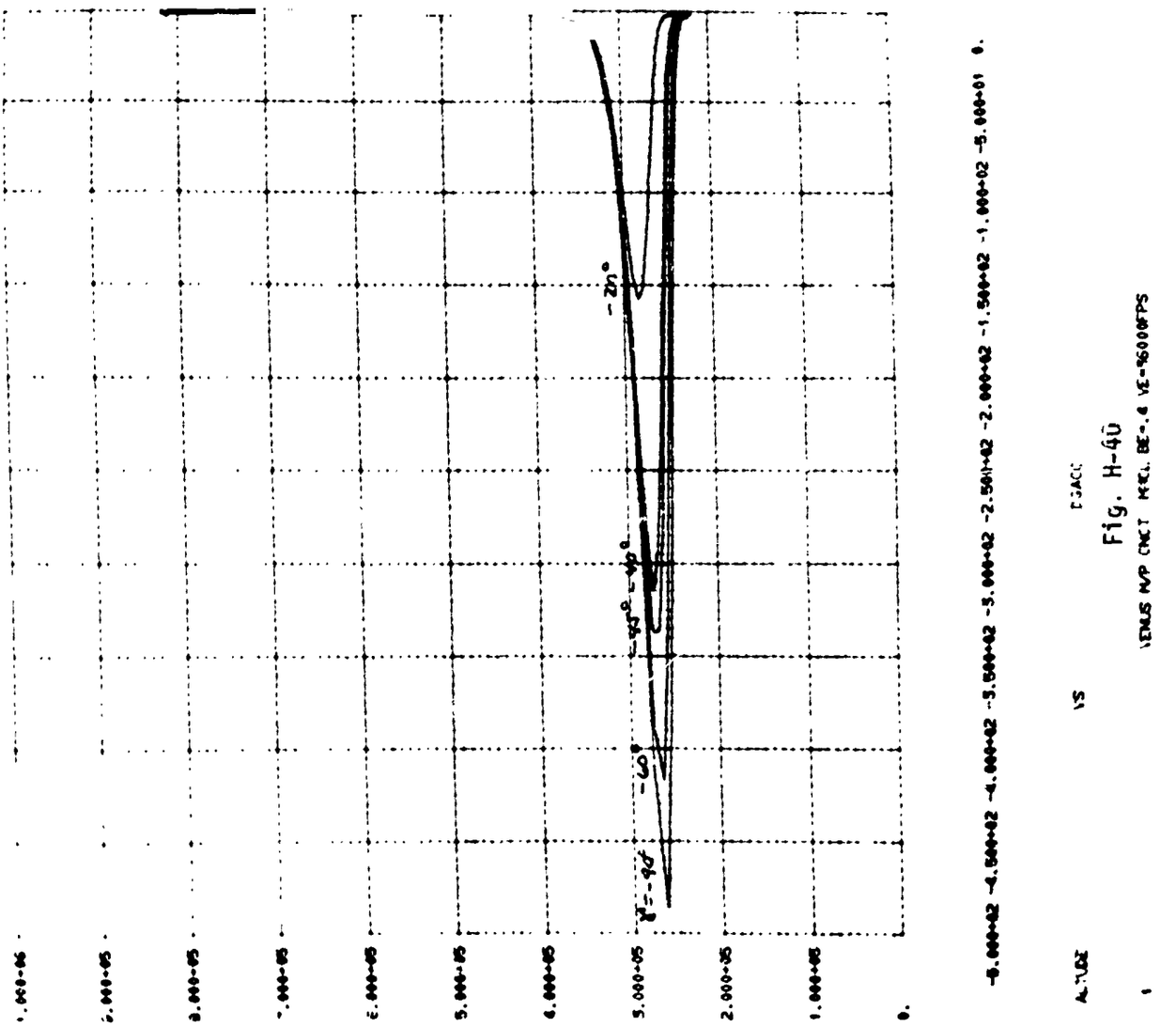


Fig. H-40

VENUS MAP CHCT MCL BE-.4 VE-36000FPS

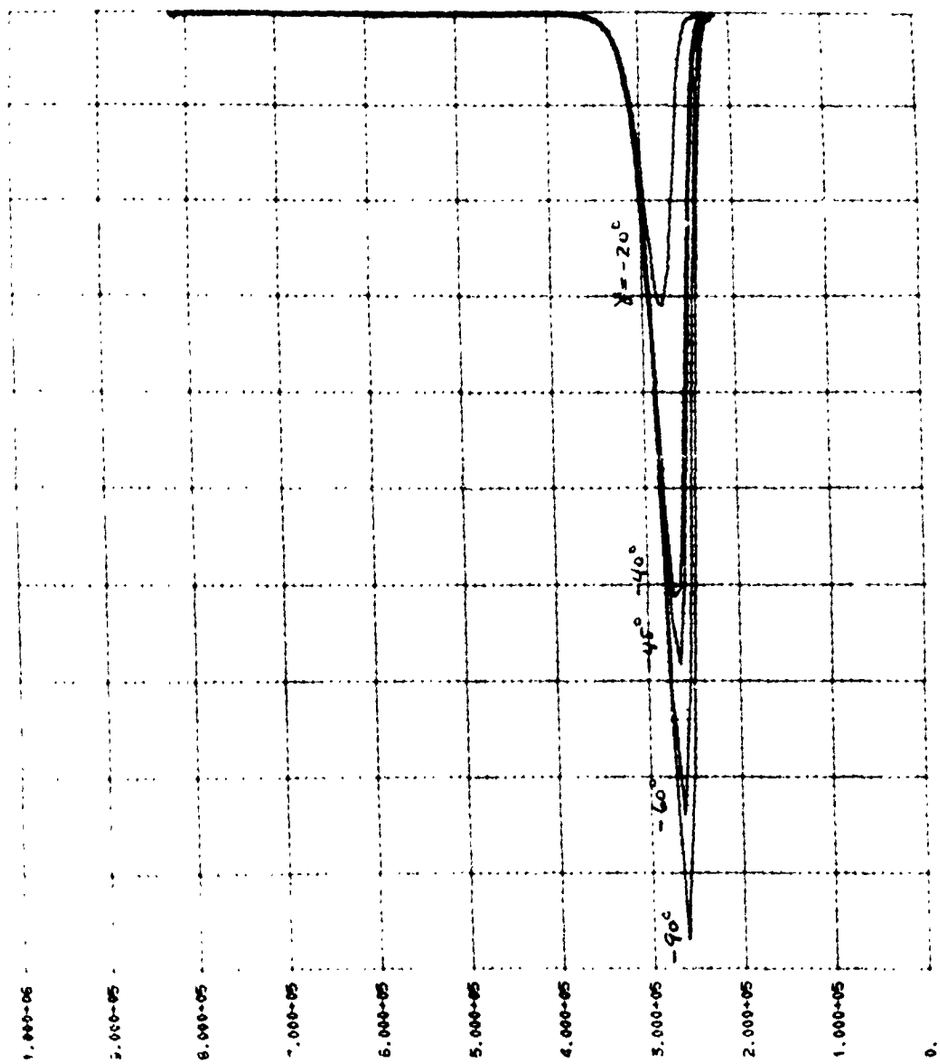


Fig. H-41

VENUS MVP CNCT MNCL BE=.5 VE=36000FPS

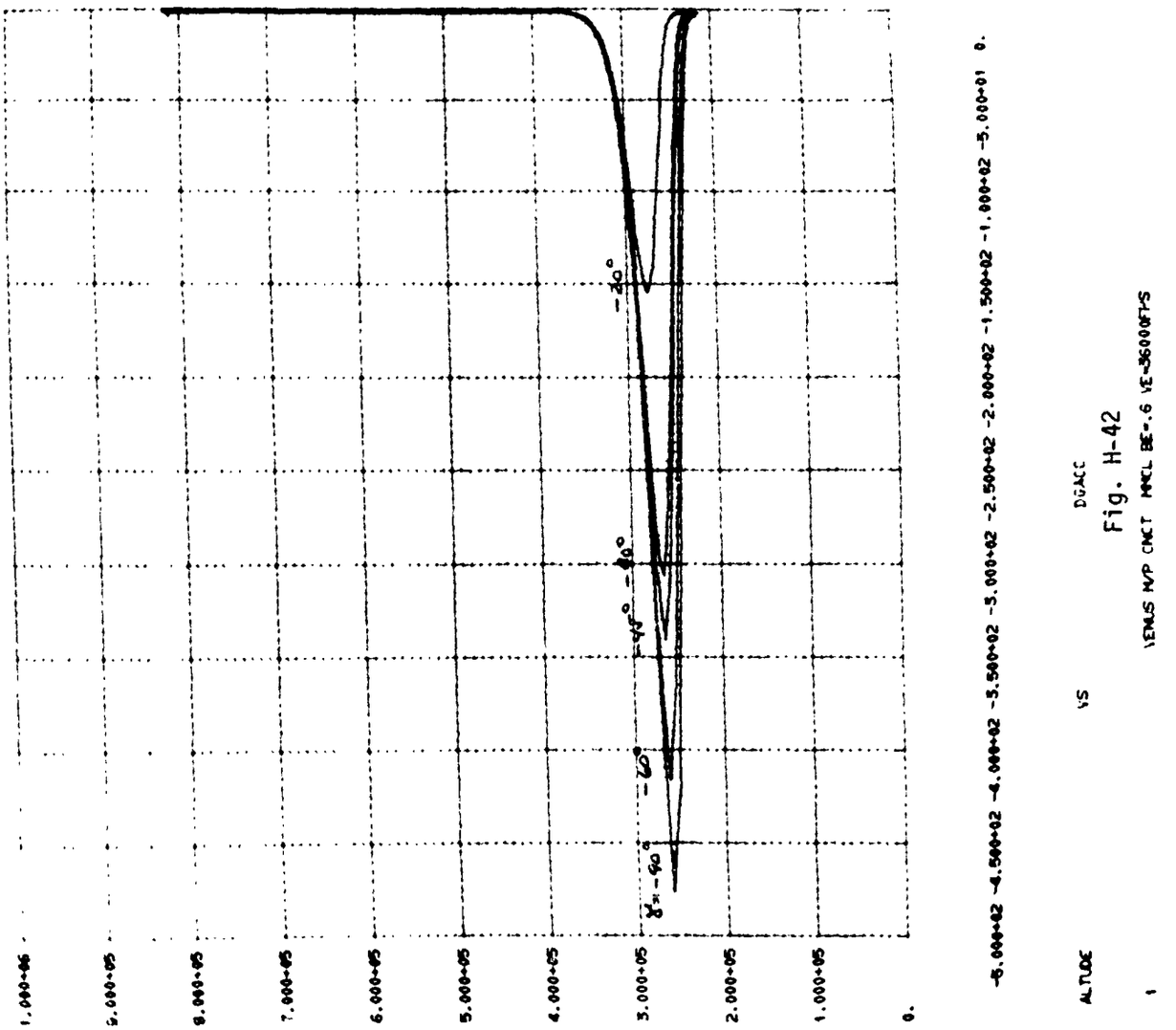


Fig. H-42

VENUS MP CKCT MNCL BE-.6 VE=36000FPS

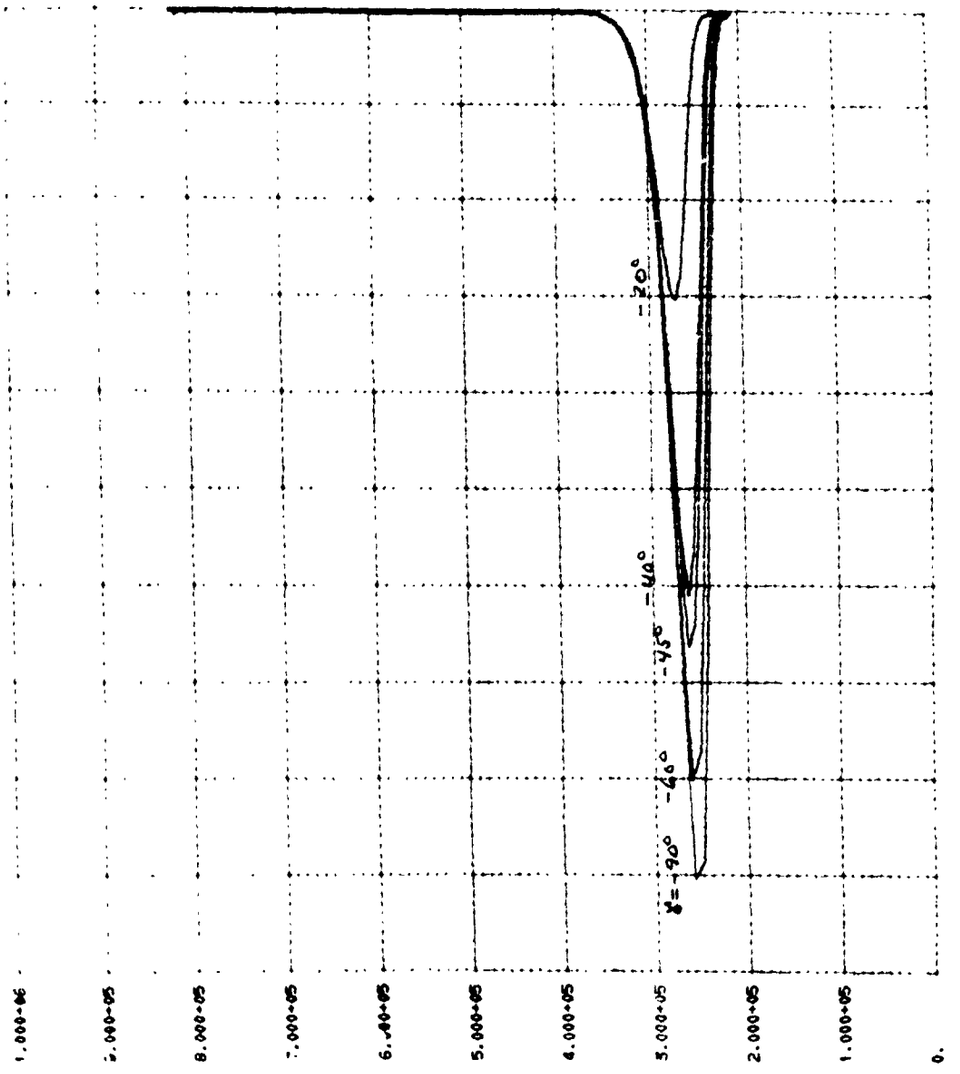


Fig. H-43

VENUS MVP CNCT MNCL BE=.8 VE=36000FPS

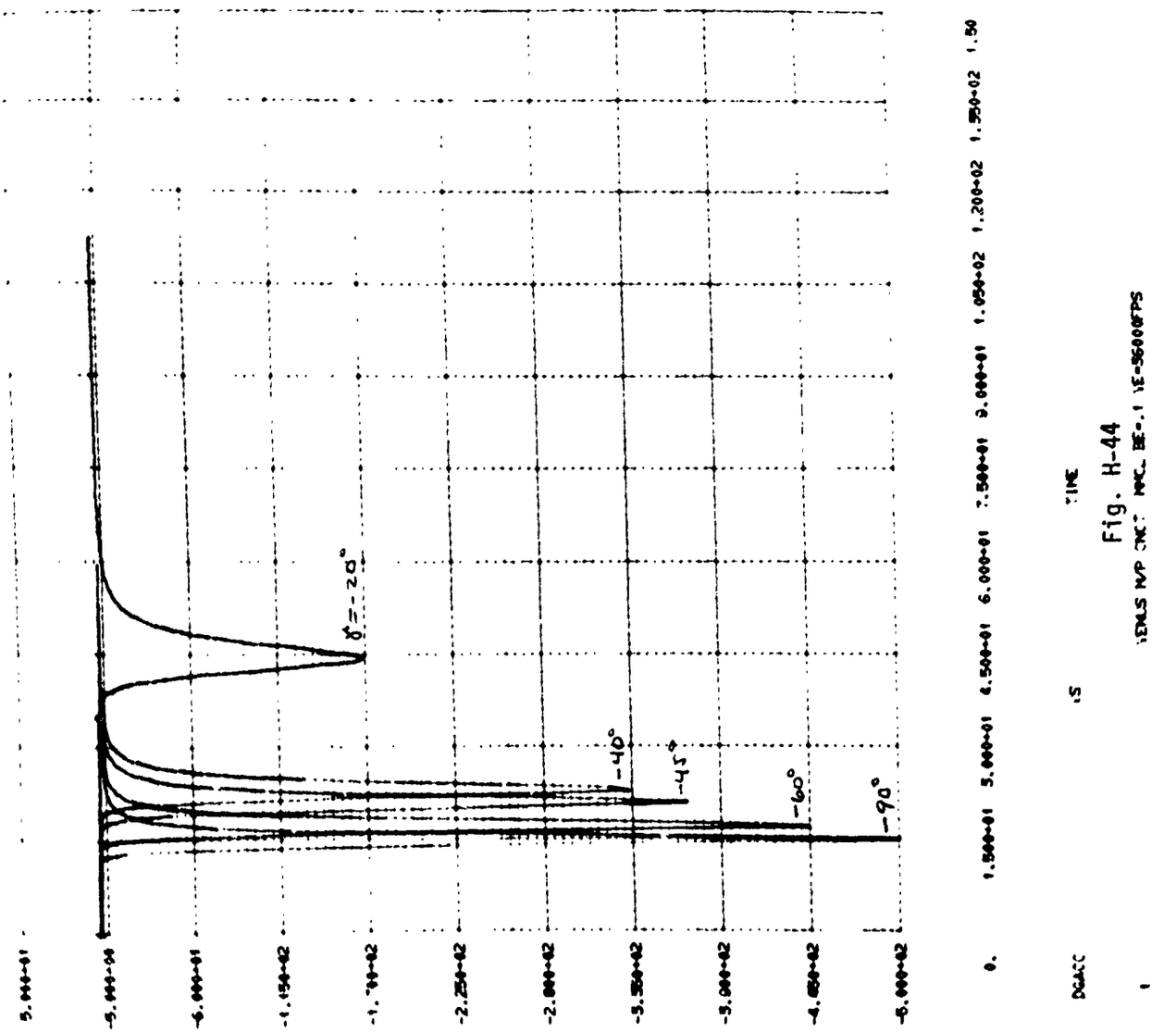


Fig. H-44

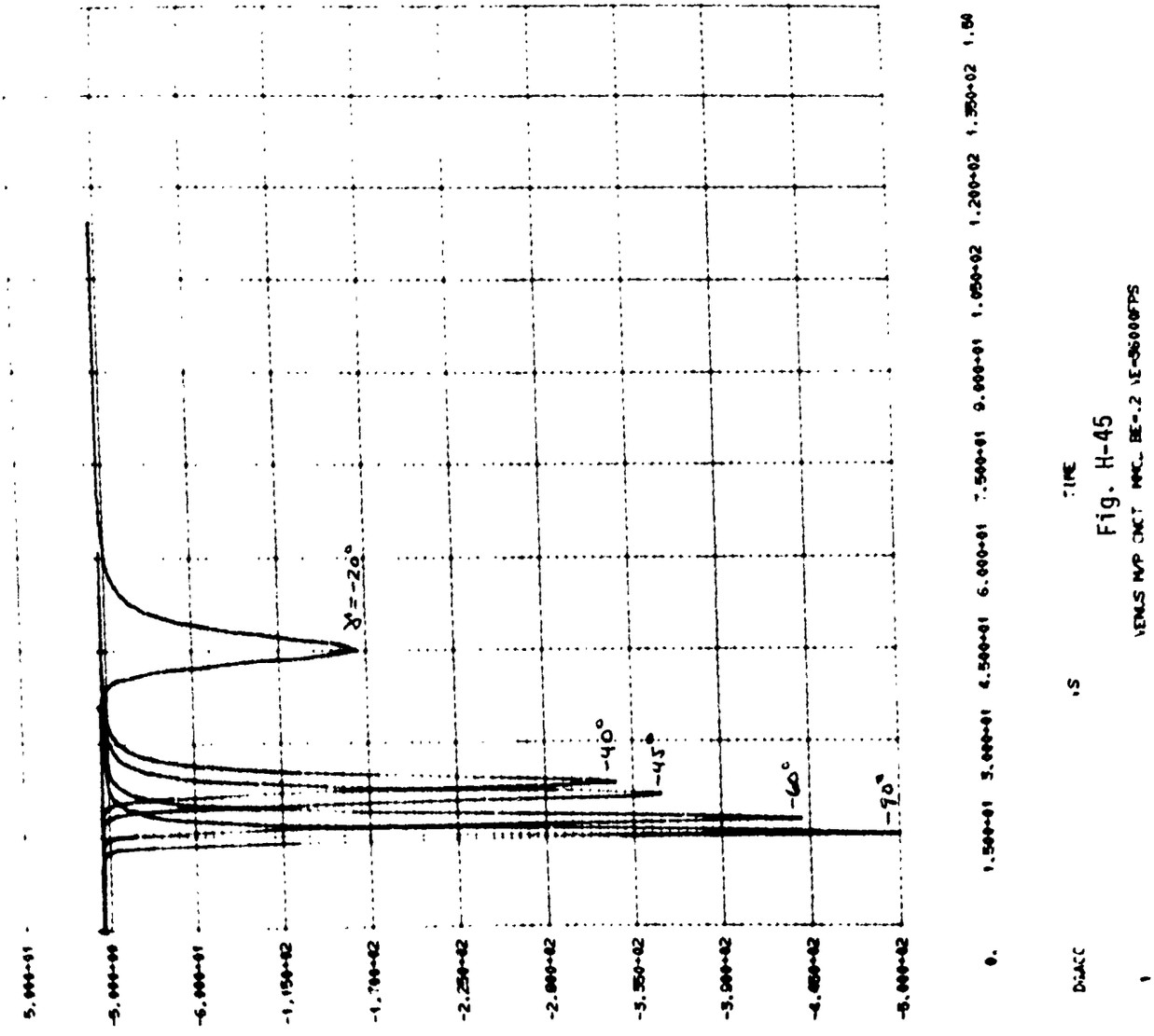

γ'=-20°
-40°
-45°
-60°
-90°
5.000+01
-5.000+00
-6.000+01
-1.150+02
-1.700+02
-2.250+02
-2.800+02
-3.350+02
-3.900+02
-4.450+02
-5.000+02
0.
1.500+01
3.000+01
4.500+01
6.000+01
7.500+01
9.000+01
1.050+02
1.200+02
1.350+02
1.50
TIME
VENUS MAP ORBIT RNG. RE=.2 VE=36000FPS

Fig. H-45

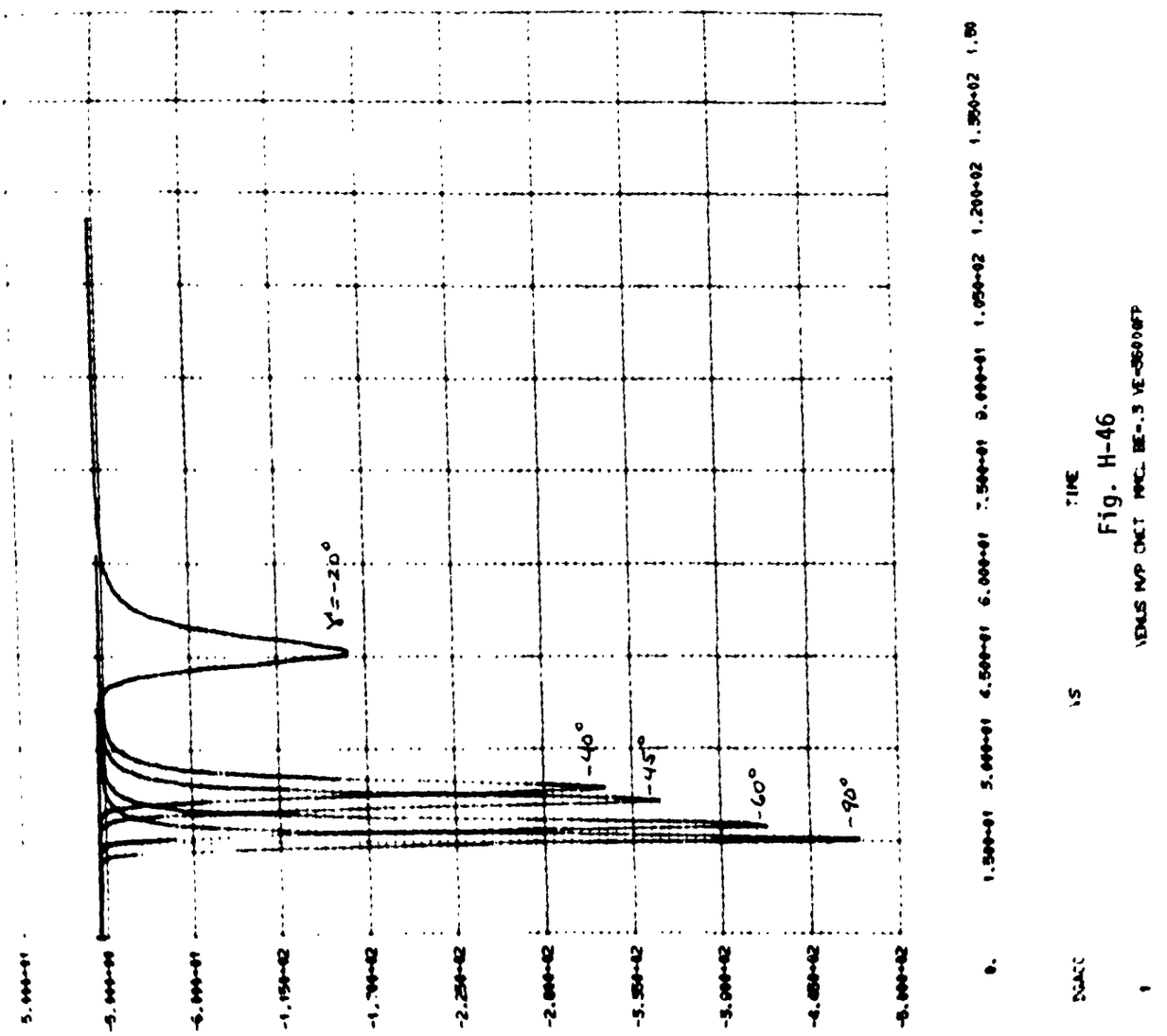


Fig. H-46

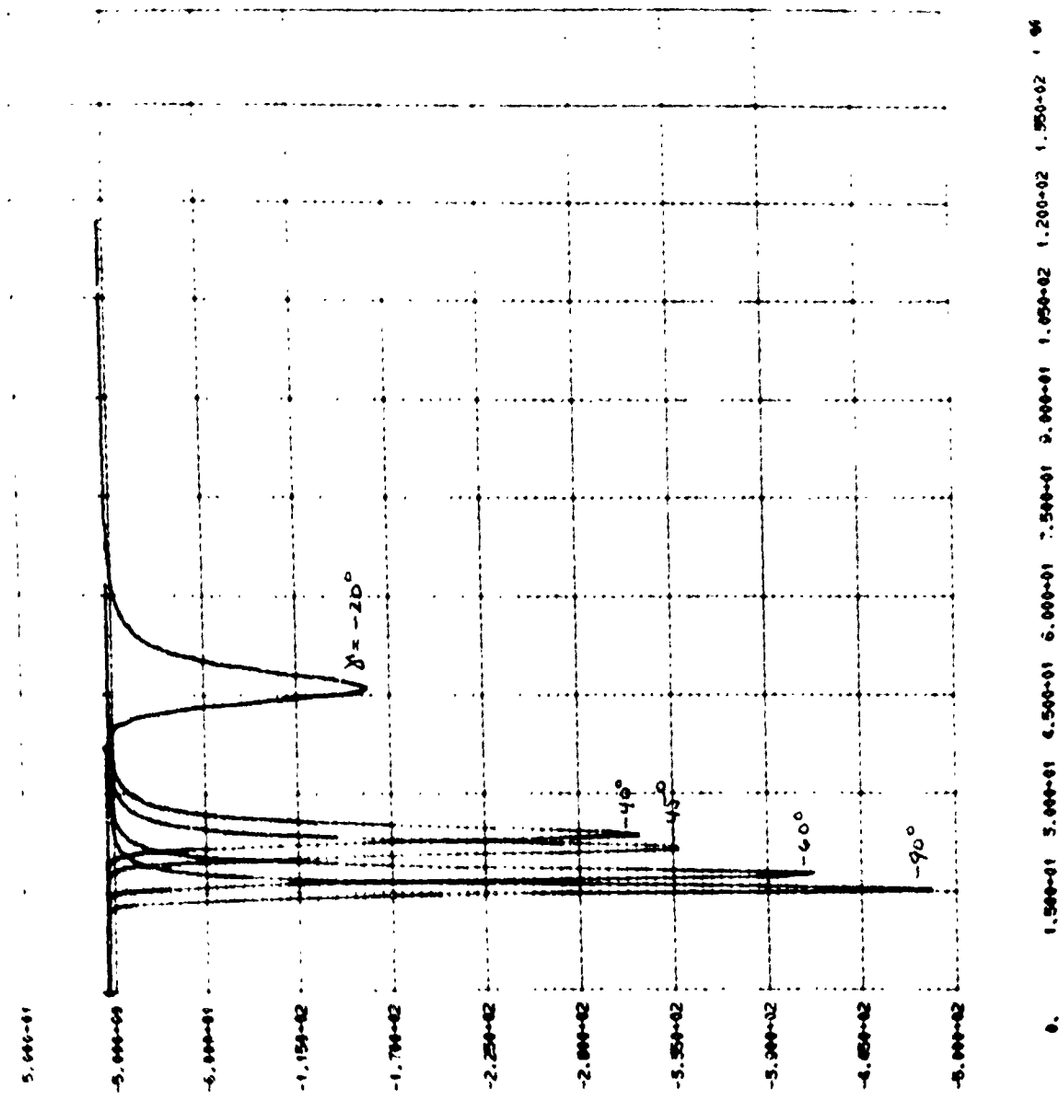


Fig. H-47

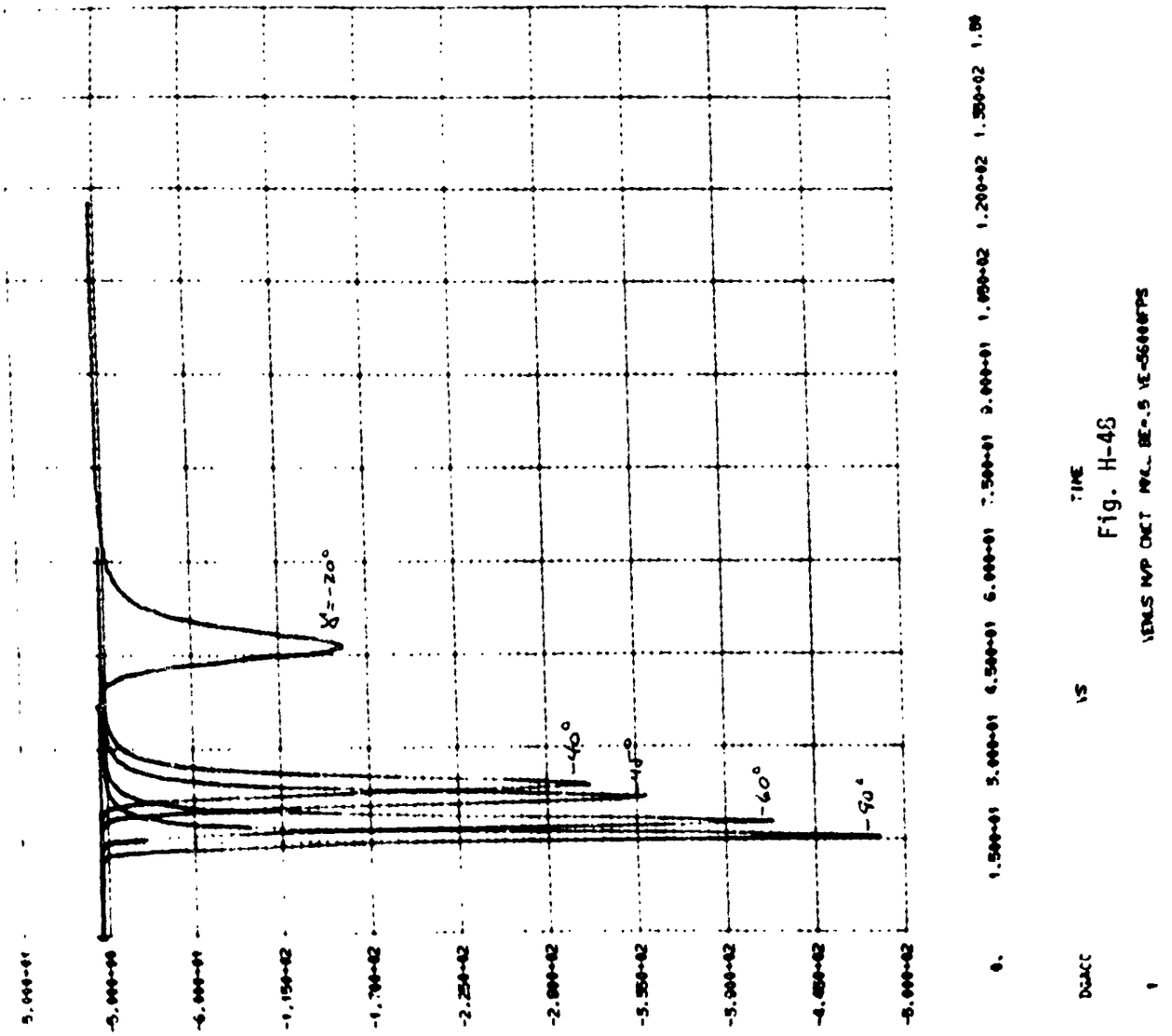


Fig. H-45

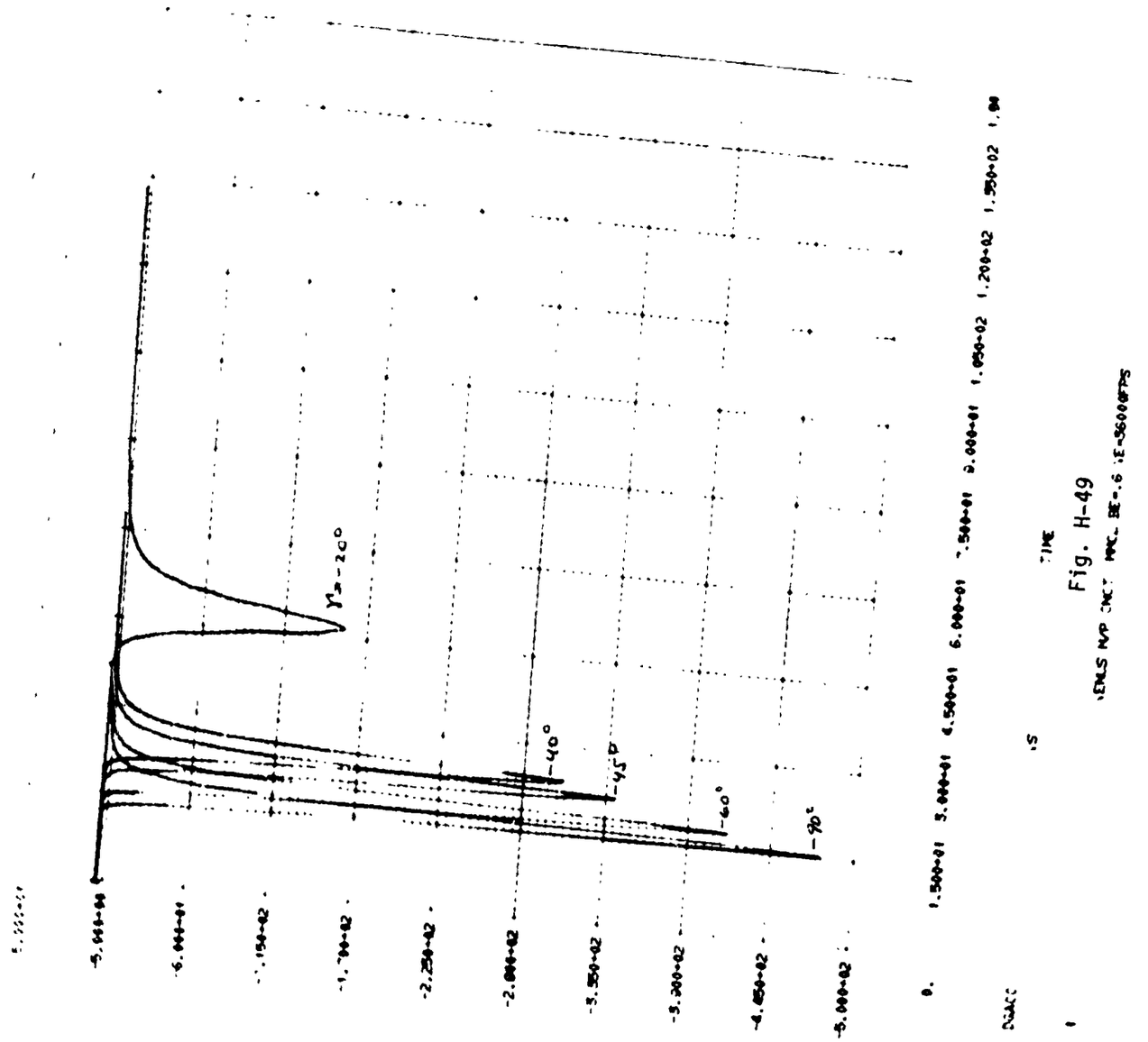

γ = -20°
-40°
-45°
-60°
-90°
-5.000+02
-4.250+02
-3.500+02
-2.750+02
-2.000+02
-1.250+02
-5.000+01
1.500+01
3.000+01
4.500+01
6.000+01
7.500+01
9.000+01
1.050+02
1.200+02
1.350+02

Fig. H-49

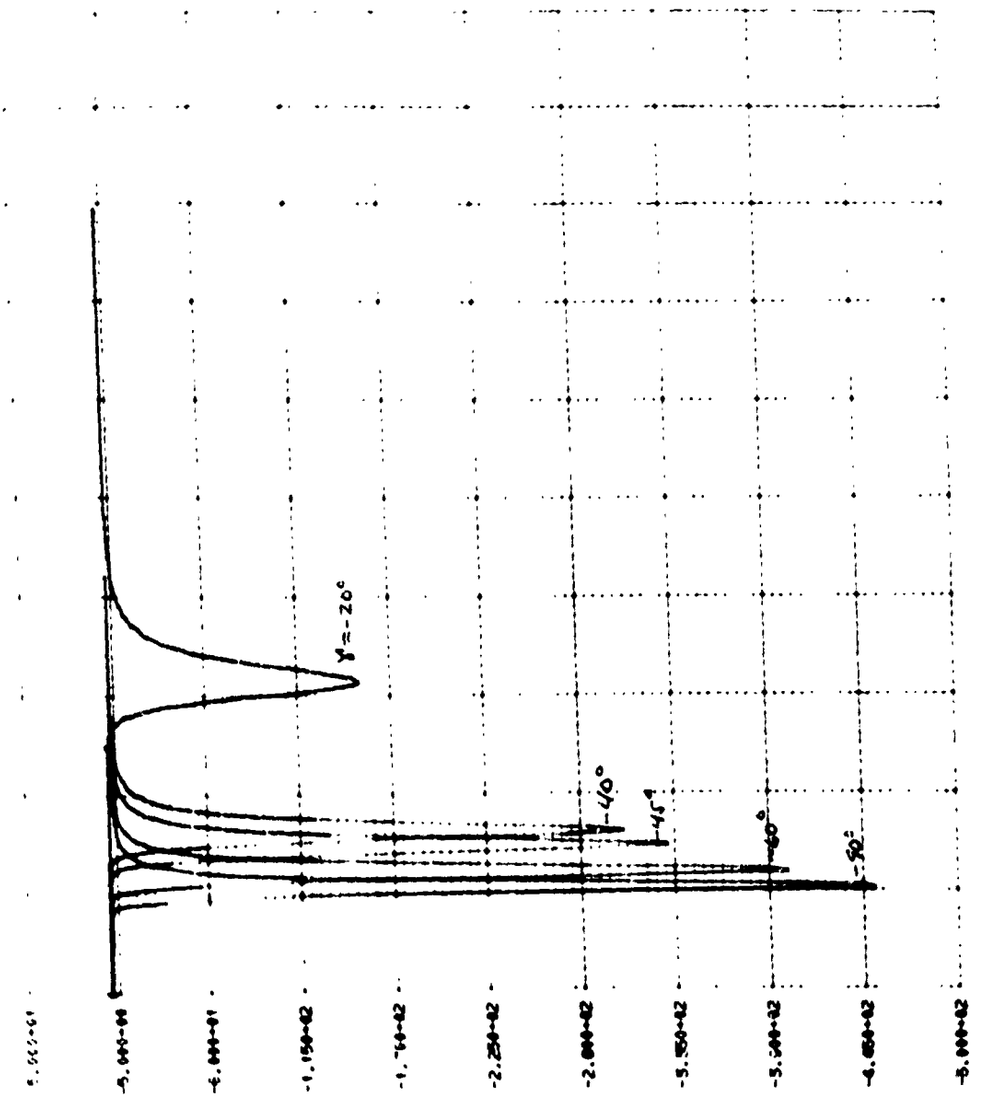

γ=-20°
-40°
-45°
-60°
-90°
-5.000-02
-4.000-01
-1.150-02
-1.700-02
-2.250-02
-2.800-02
-3.350-02
-3.900-02
-4.450-02
-5.000-02
0.
1.500+01
3.000+01
4.500+01
6.000+01
7.500+01
9.000+01
1.050+02
1.200+02
1.350+02
1.50
TIME

Fig. H-50

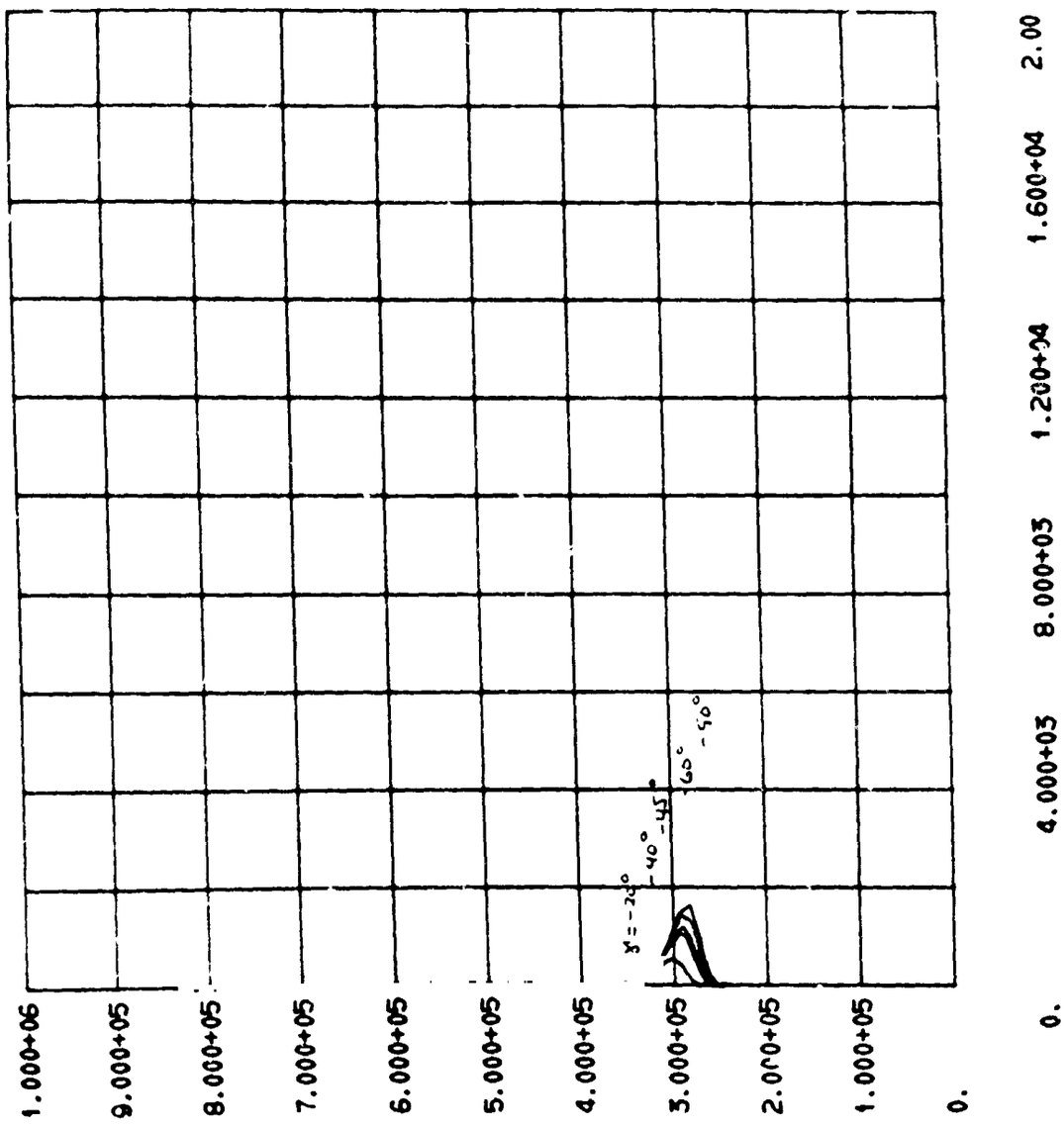

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ = -20°
-40°
-45°
-60°
-90°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNARS
1
VENUS M/P CNCT MNCL BE=.1 VE=36000FPS

Fig. H-51

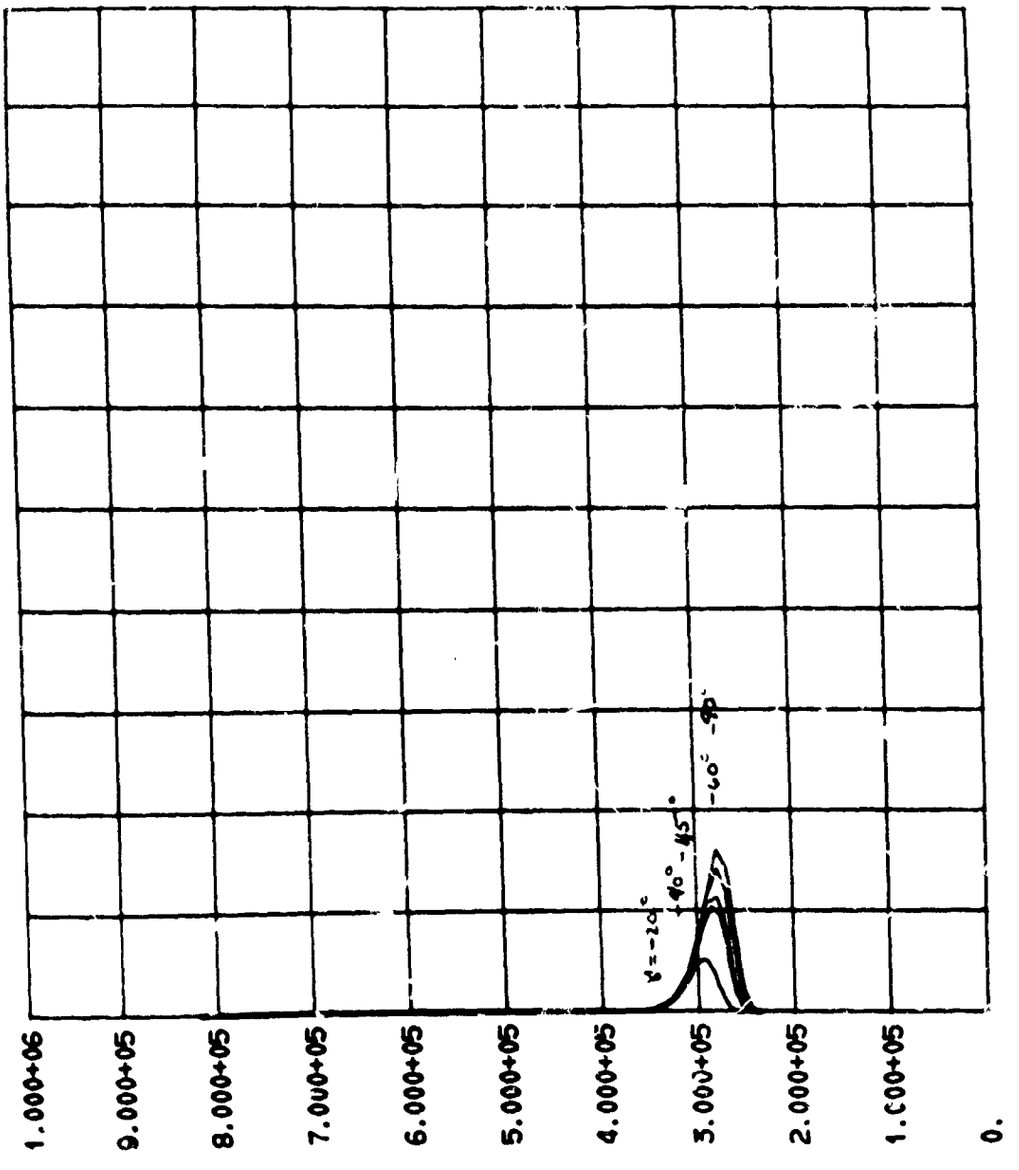


Fig. H-52

VENUS M/P CNCT MNCL BE=.2 VE=36000FPS

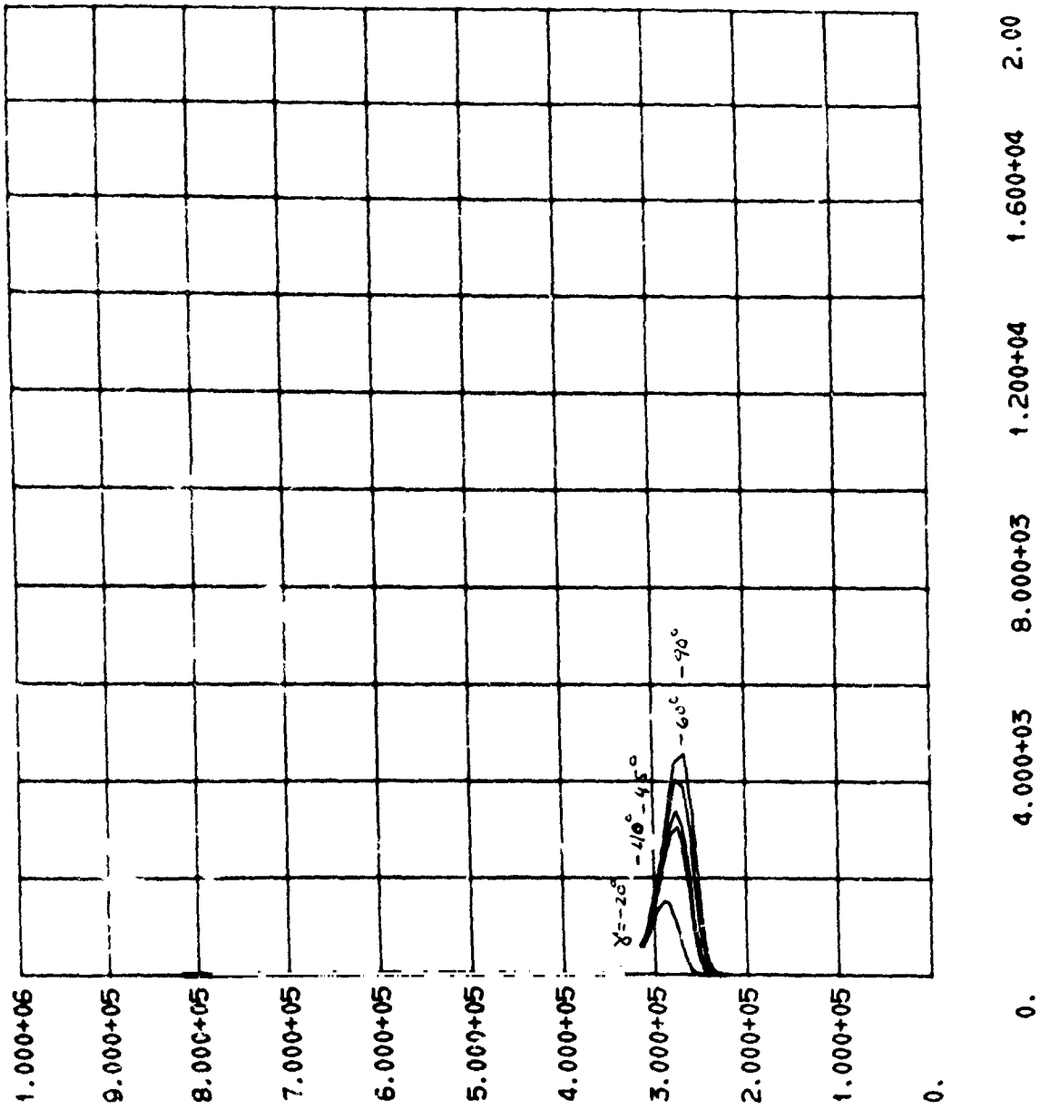

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ=-20°
-40°-45°
-60°
-90°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNPRS
1
VENUS M/P CNCT MMCL BE=.3 VE=36000FPS

Fig. H-53

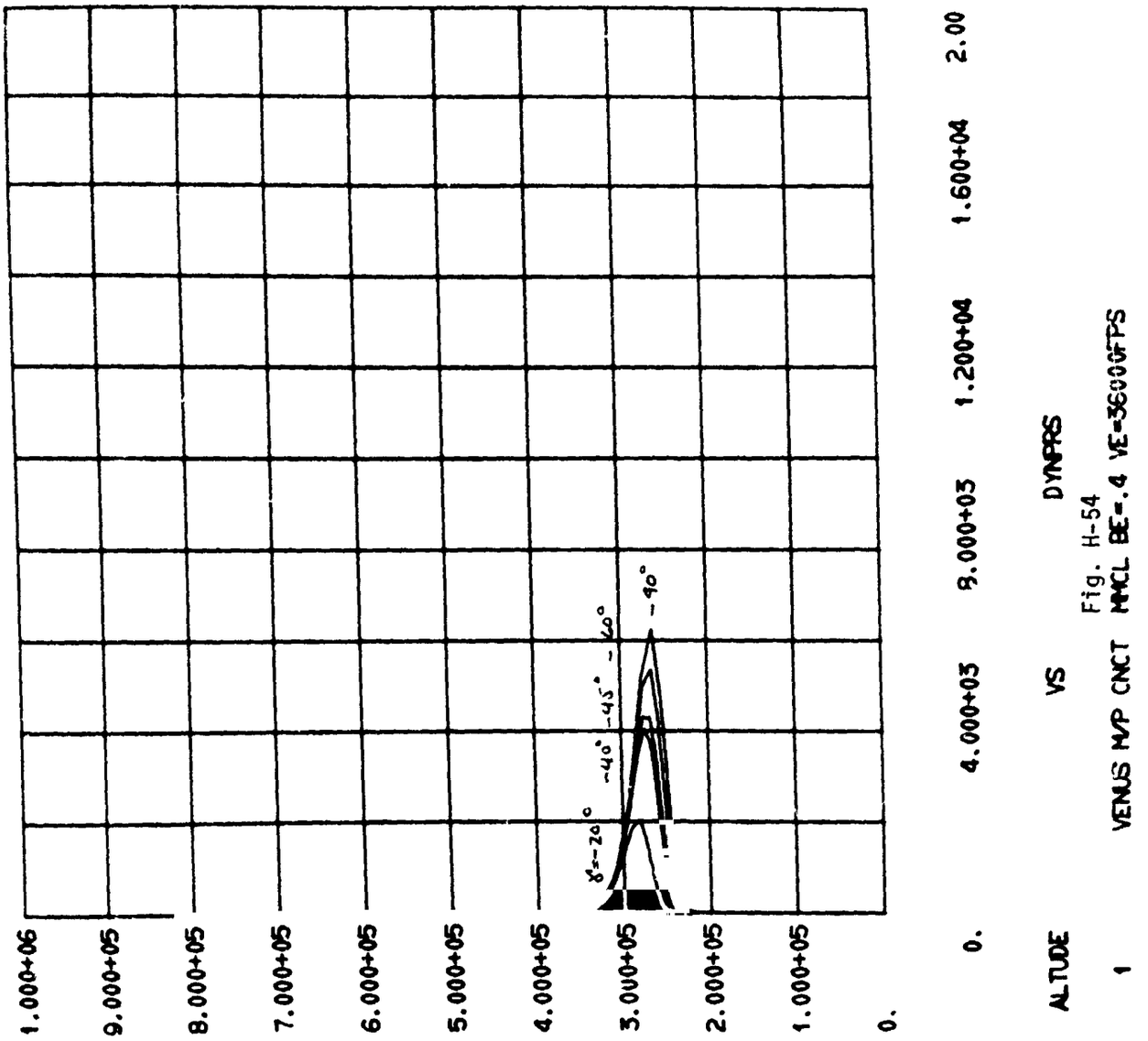

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
δs=-20°
-40°
-45°
-60°
-90°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNPRS
1
VENUS MP CNCT MMCL BE=.4 VE=36000FPS

Fig. H-54

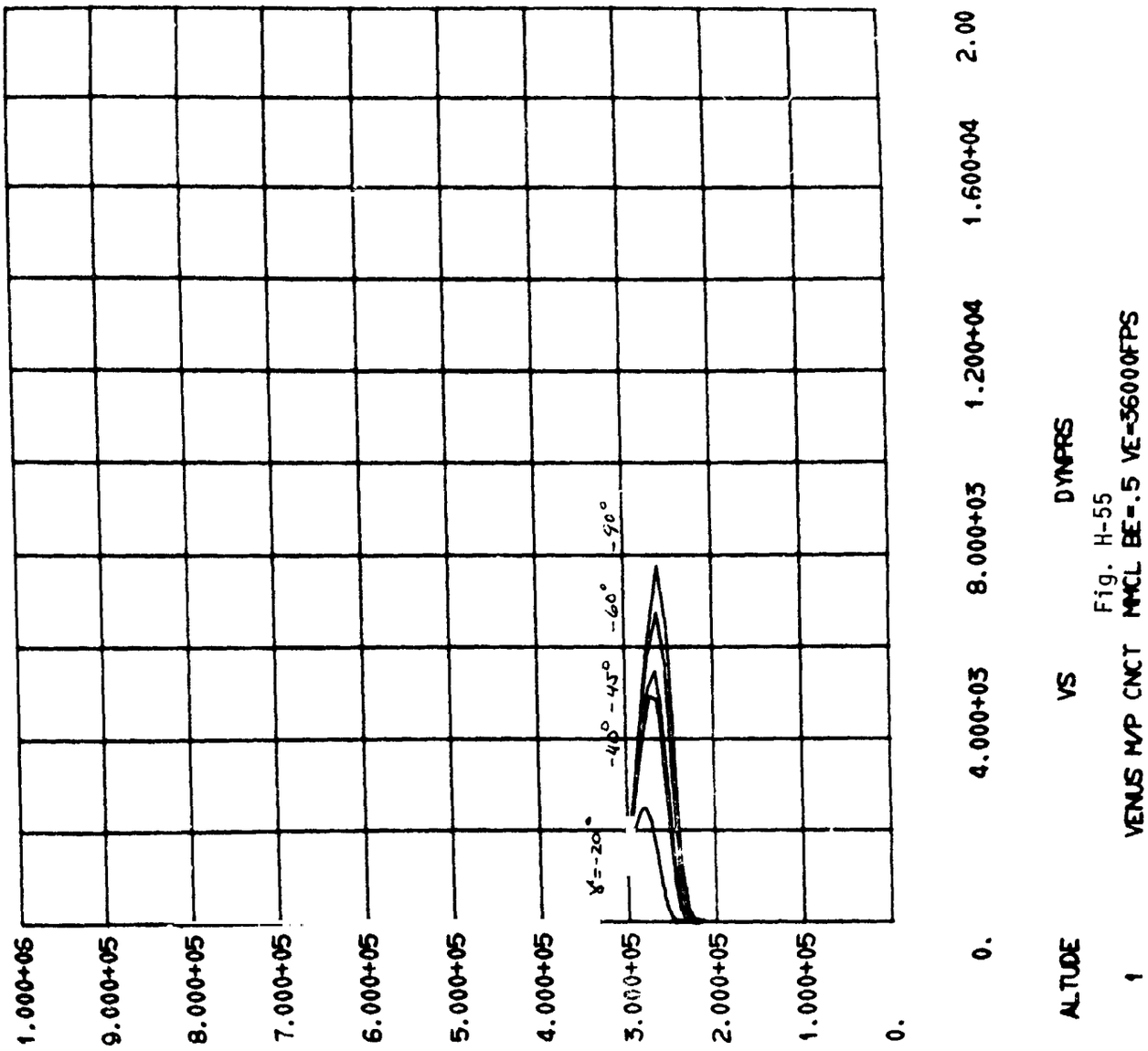

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ=-20°
-40°
-45°
-60°
-90°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNPRS
1
VENUS M/P CNCT MMCL BE=.5 VE=36000FPS

Fig. H-55

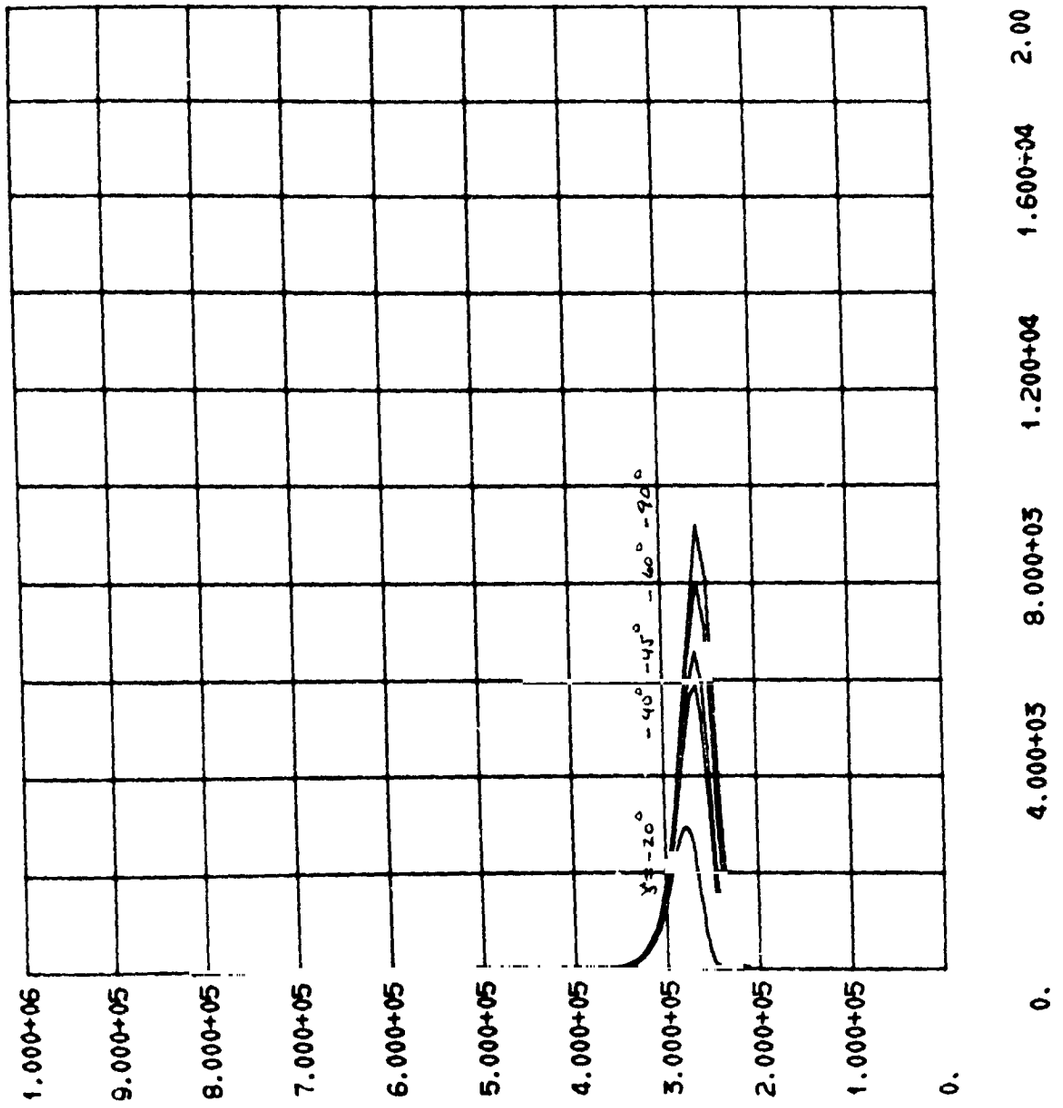

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ=-20°
-40°
-45°
-60°
-90°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNPRS
1
VENUS M/P CNCT MNCL BE=.6 VE=36000FPS

Fig. H-56

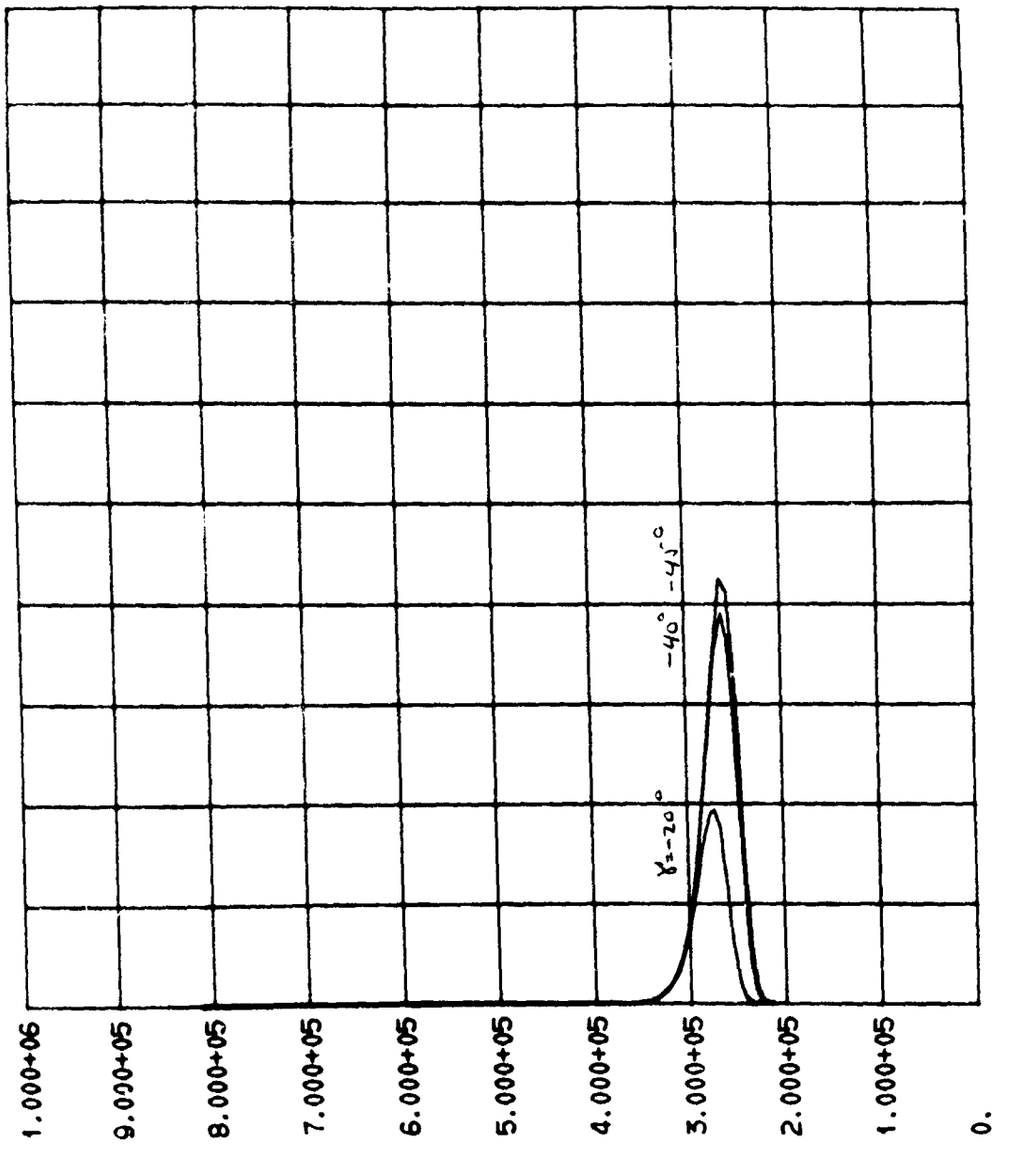

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ_E=-20°
-40°
-43°
0.
4.000+03
8.000+03
1.200+04
1.600+04
2.00
ALTUDE
VS
DYNPRS
1
VENUS MVP CNCT MMCL BE=.8 VE=36000FPS

Fig. H-57

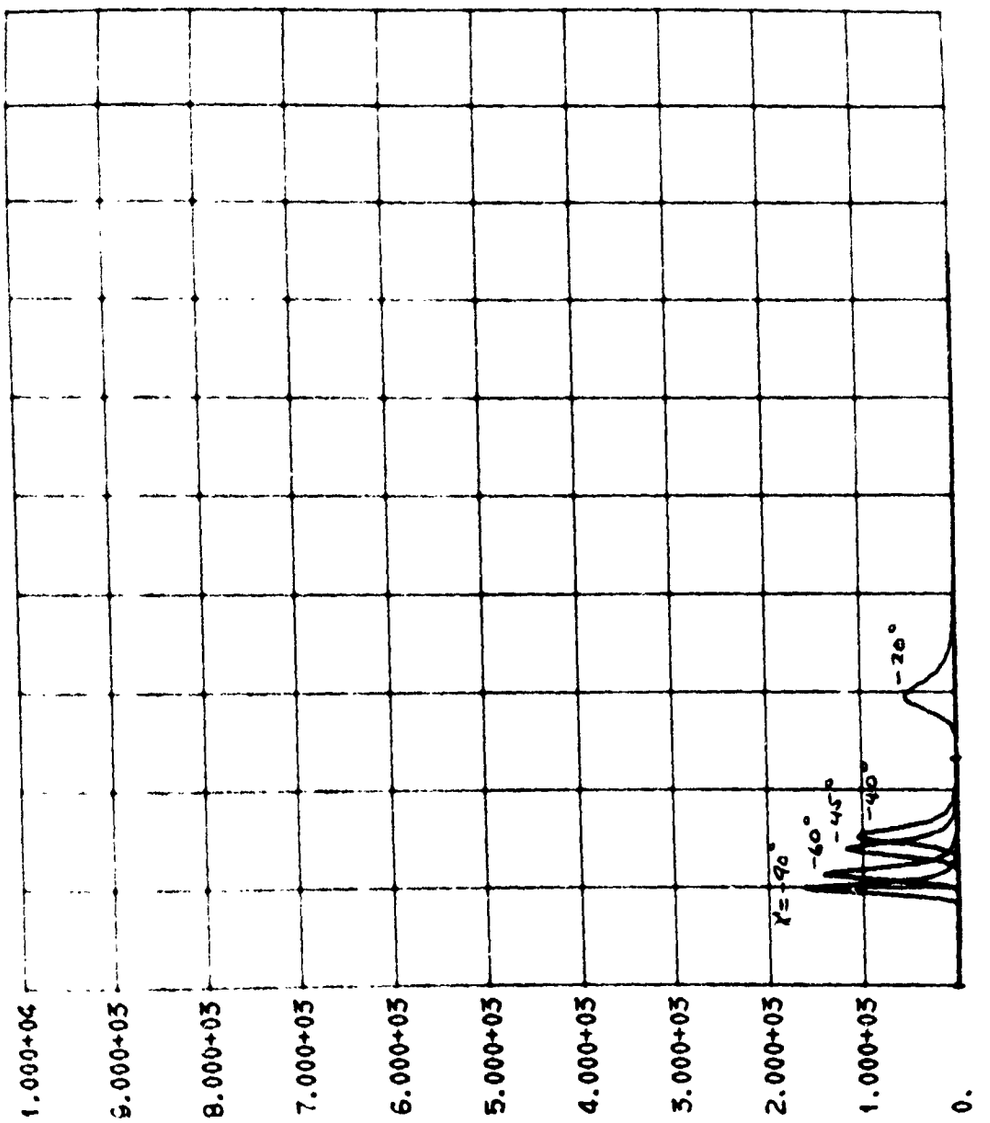

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
γ=-90°
-60°
-45°
-40°
-20°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DYNPRS
VS
TIME
1
VENUS M/P CNCT NNCL BE=.1 VE=36000FPS

Fig. H-58

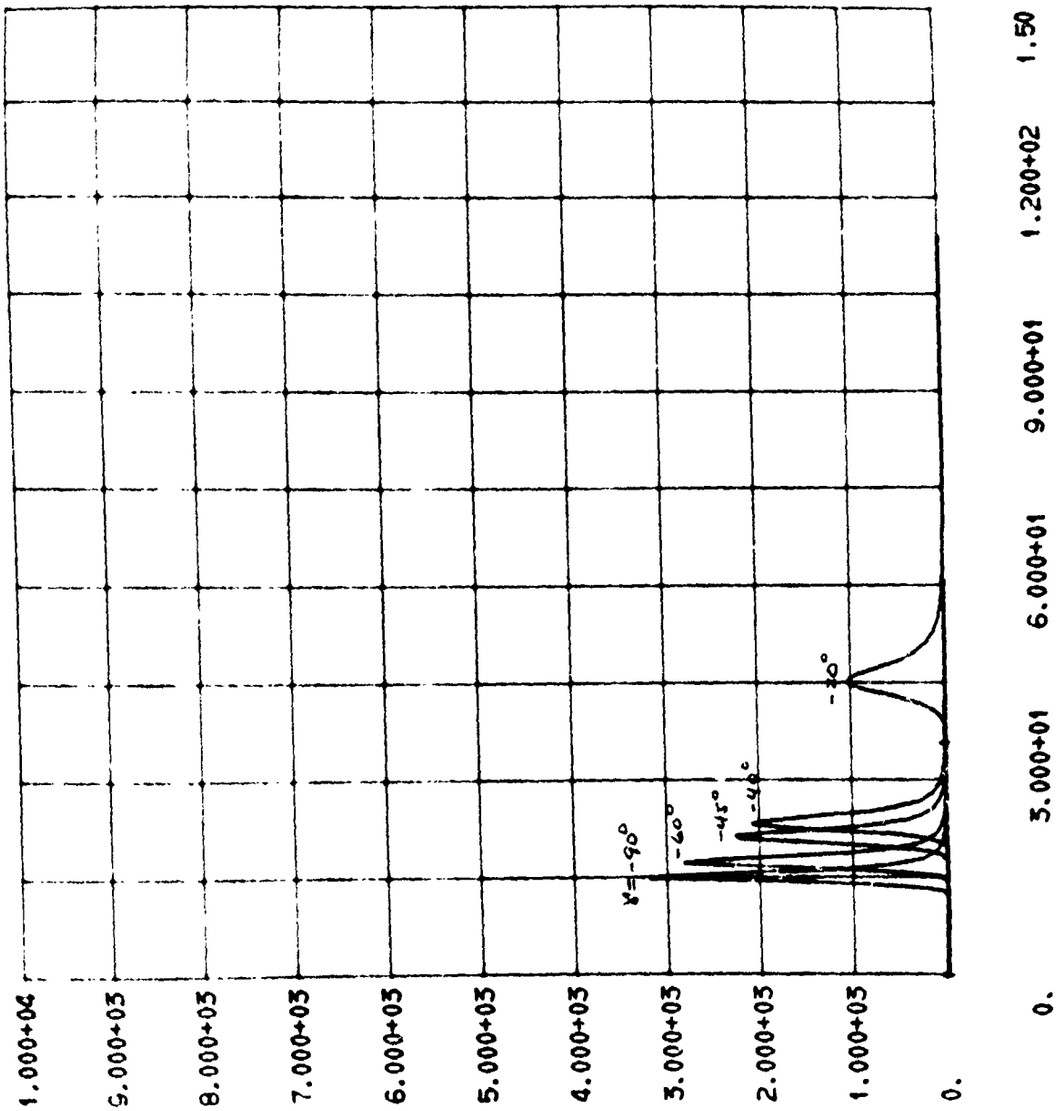

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
γ=-90°
-60°
-45°
-30°
-15°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DYNPRS
VS
TIME
1
VENUS MP CNCT NMCL BE=.2 VE=36000FPS

Fig. H-59

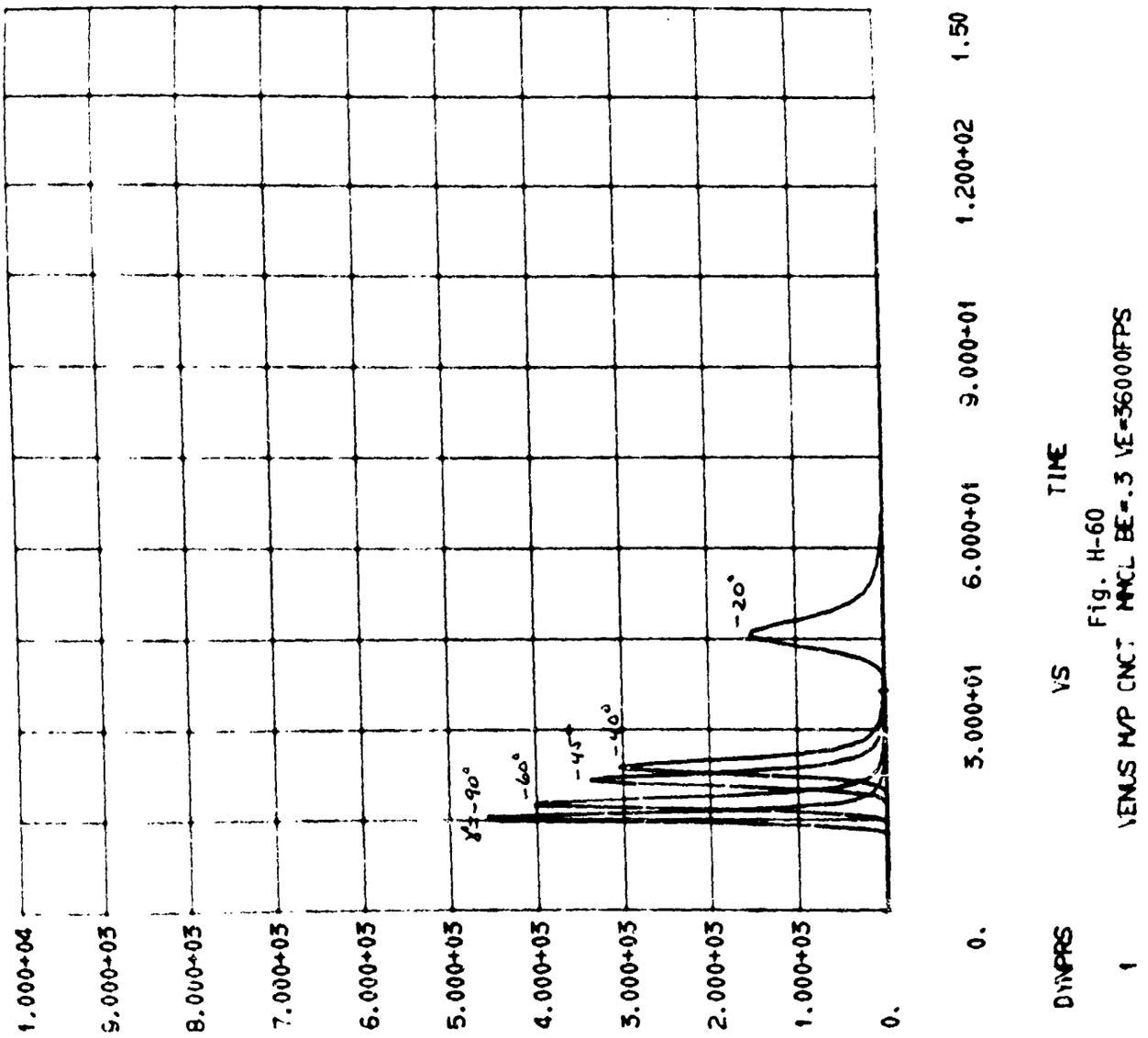

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
-90°
-60°
-45°
-30°
-20°
VS
TIME
DIMENS
1
VENUS M/P CNCT

Fig. H-60

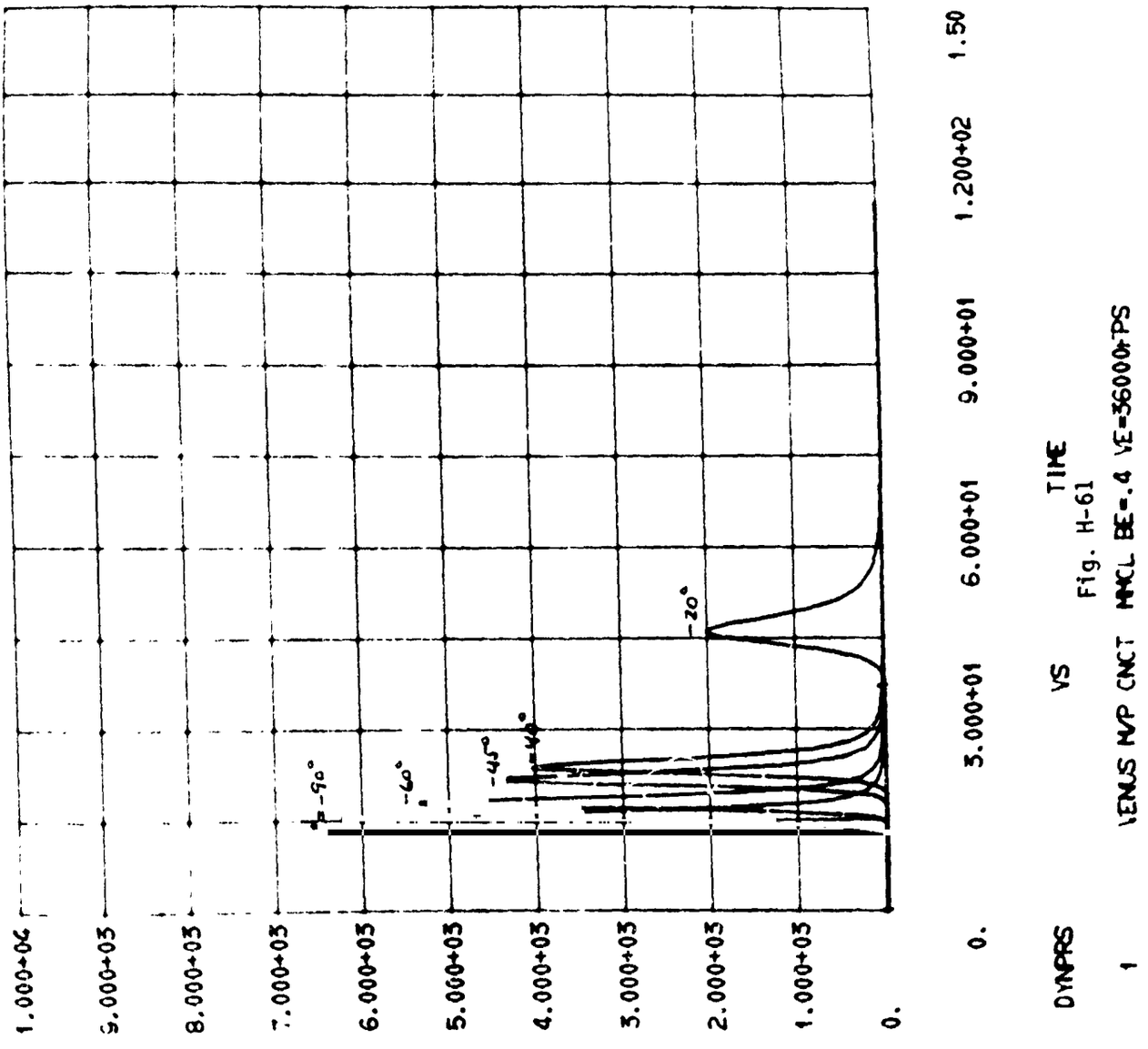

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
-90°
-60°
-45°
-20°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
TIME
VS
DYNPRS
1
VENUS MVP CNCT MNCL BE=.4 VE=36000 PS

Fig. H-61

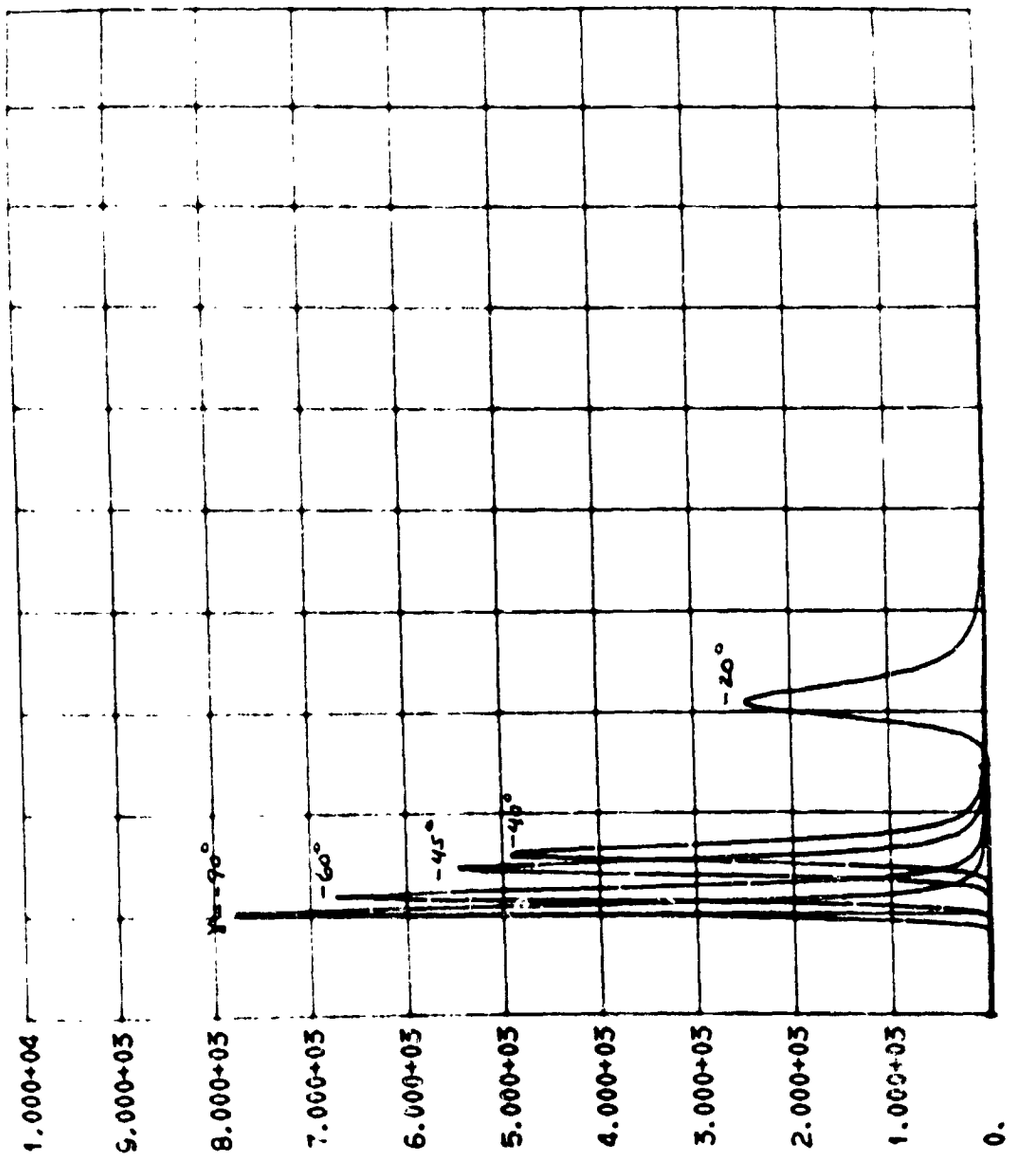


Fig. H-62
VENUS MP CNCT MNCL BE=.5 VE=36000FPS

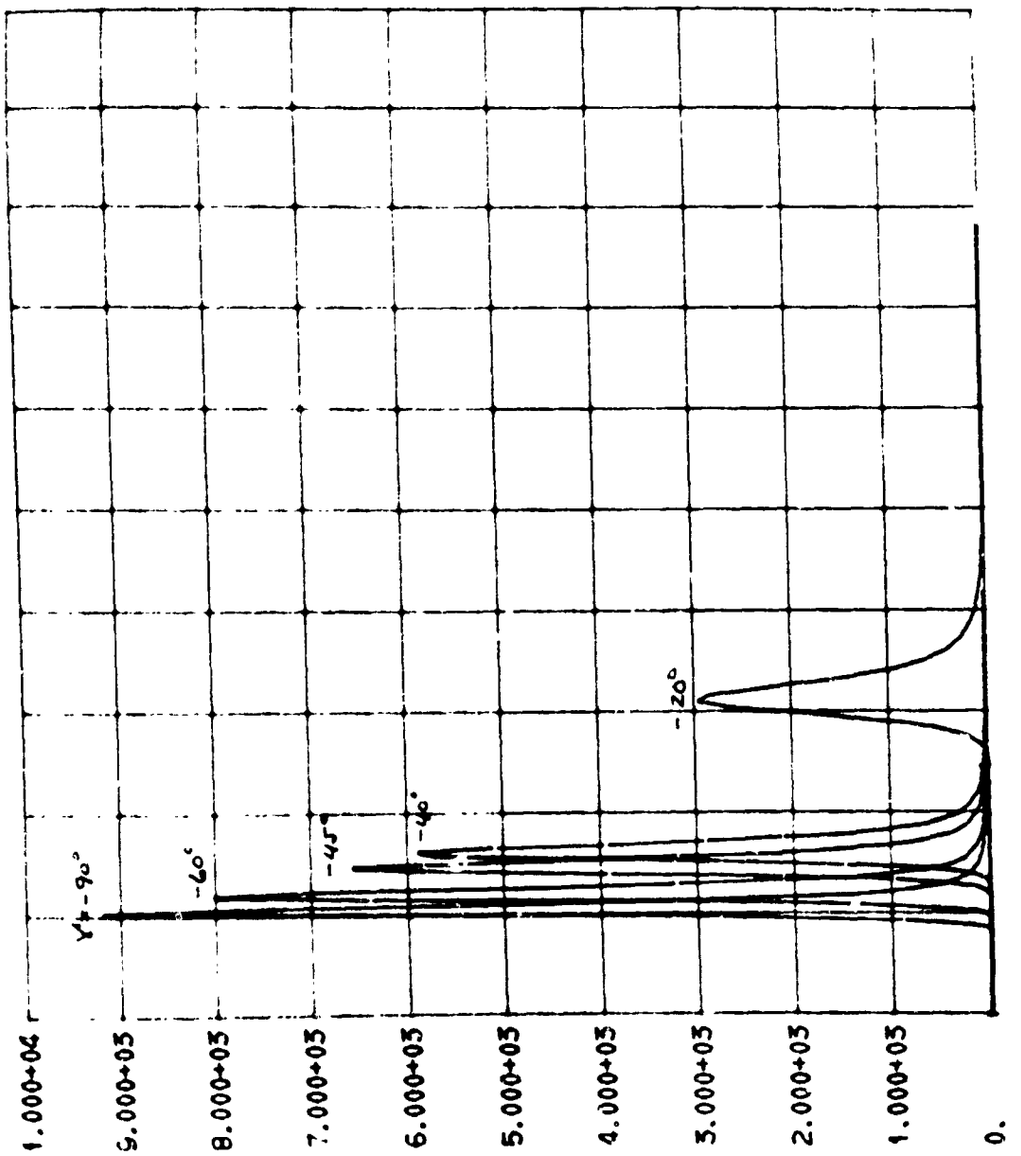

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
-90°
-60°
-45°
-40°
-20°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DYNPRS
VS
TIME
1
VENUS NVP CNCT MMCL BE=.6 VE=36000FPS

Fig. H-63

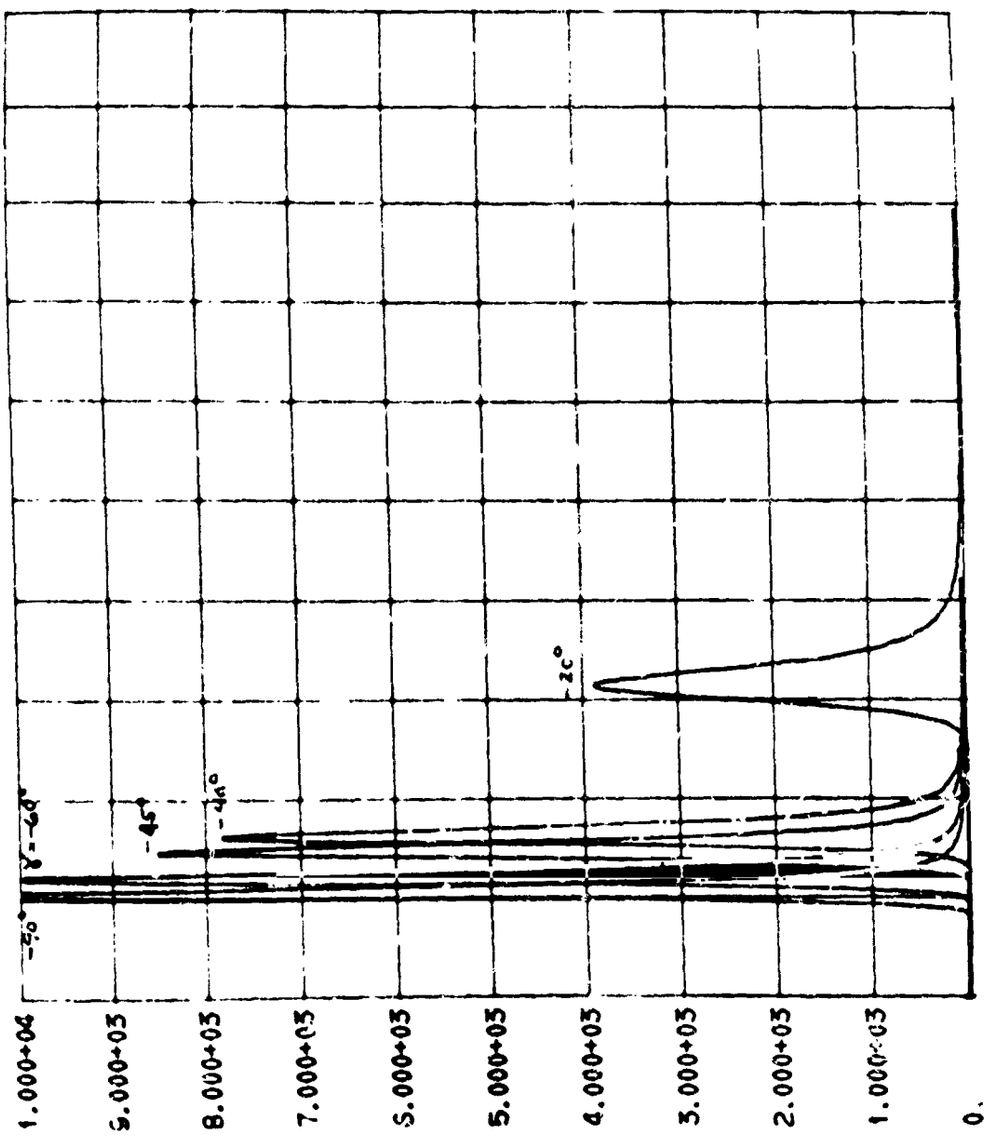

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
-20°
γ=-60°
-45°
-40°
-26°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DYNPRS
VS
TIME
1
VENUS M/P CNCT NMCL BE=.8 VE=36000FPS

Fig. H-64

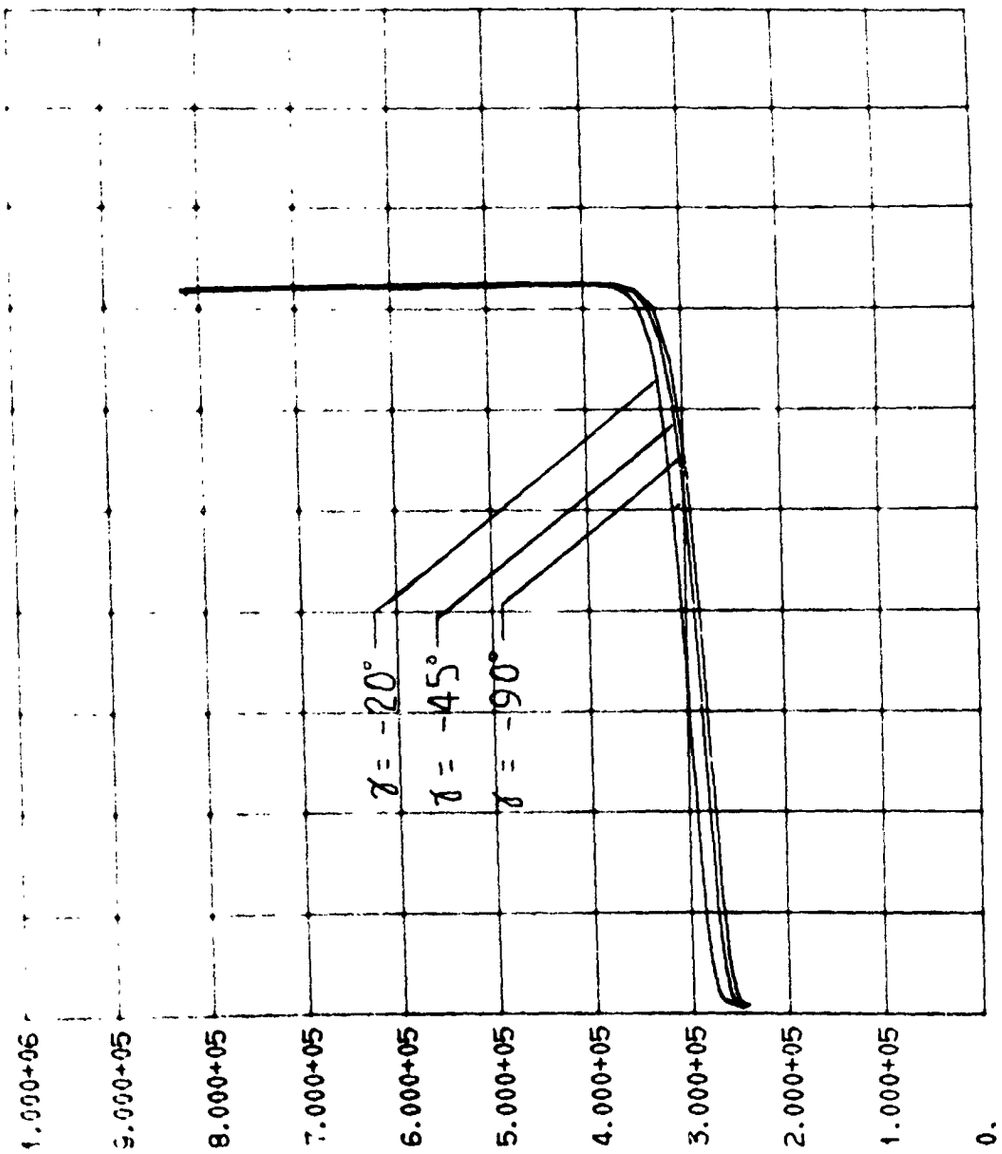


Fig. H-65

VENUS M/P ENCT VE=36000FPS BE=.2 VSM

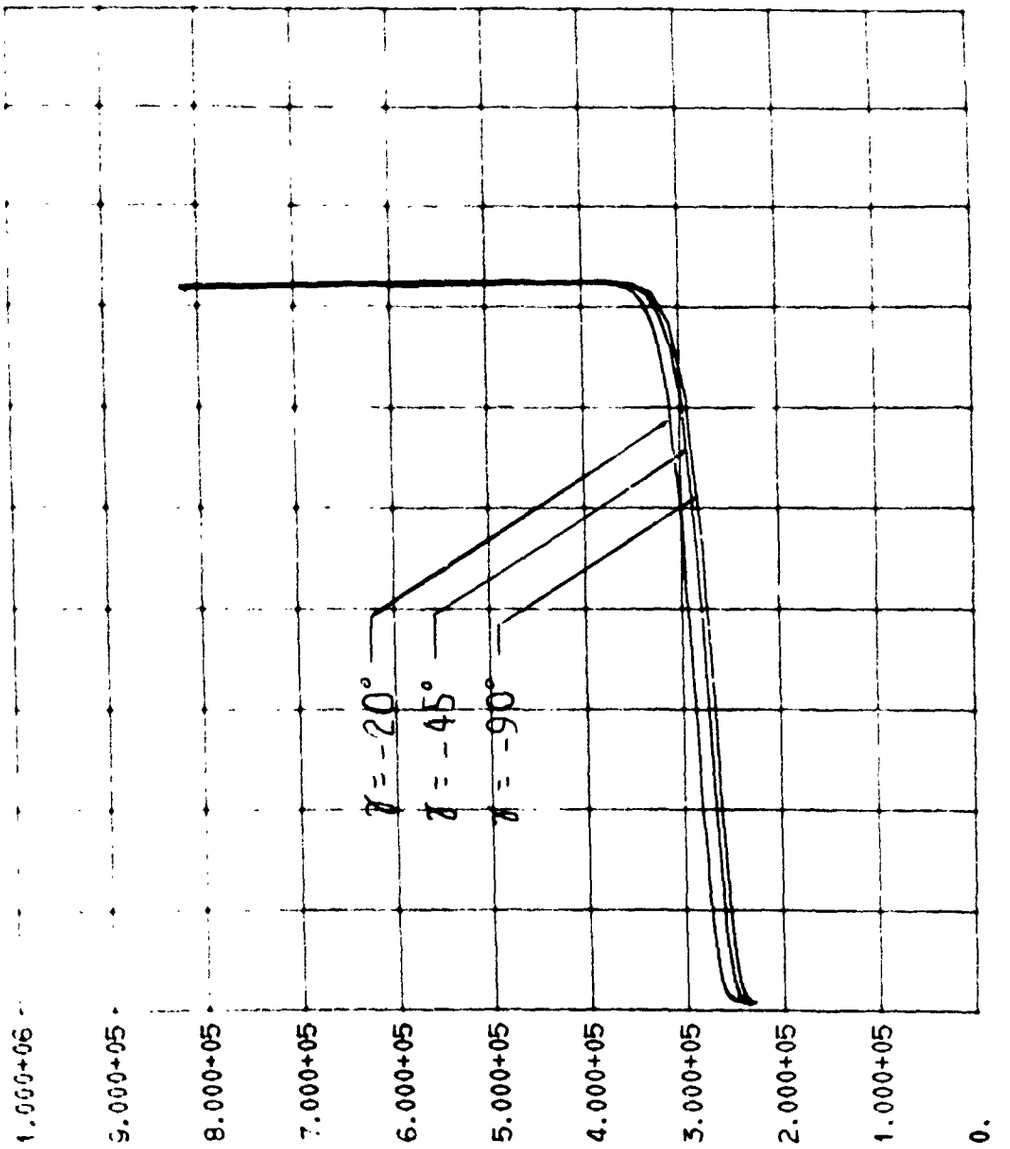


Fig. H-66

VENUS MVP INCT IE=36000FPS BE=.4 ISM

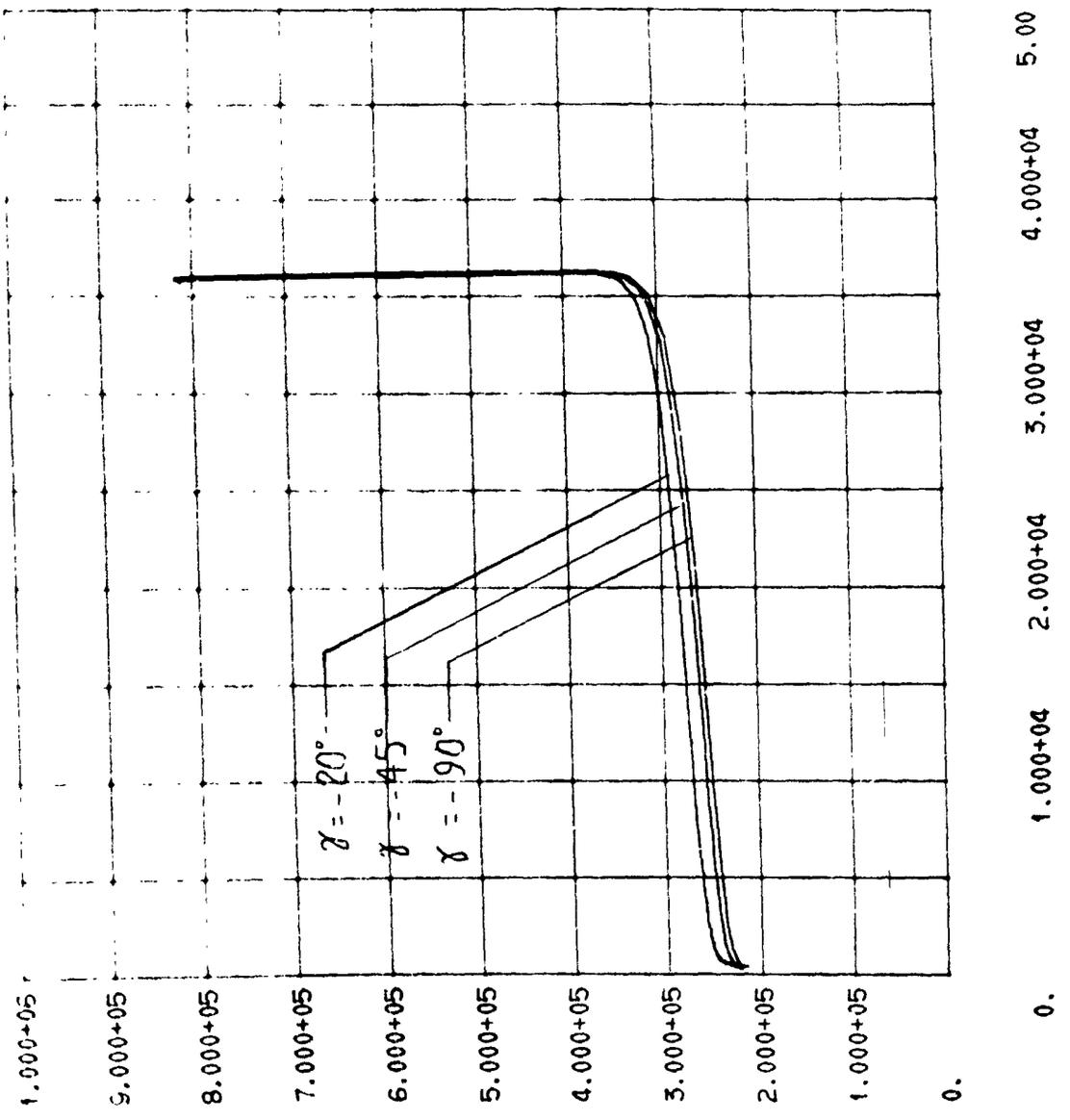


Fig. H-67

VENUS M/P CNCT VE=36000FPS BE=.8 1SM

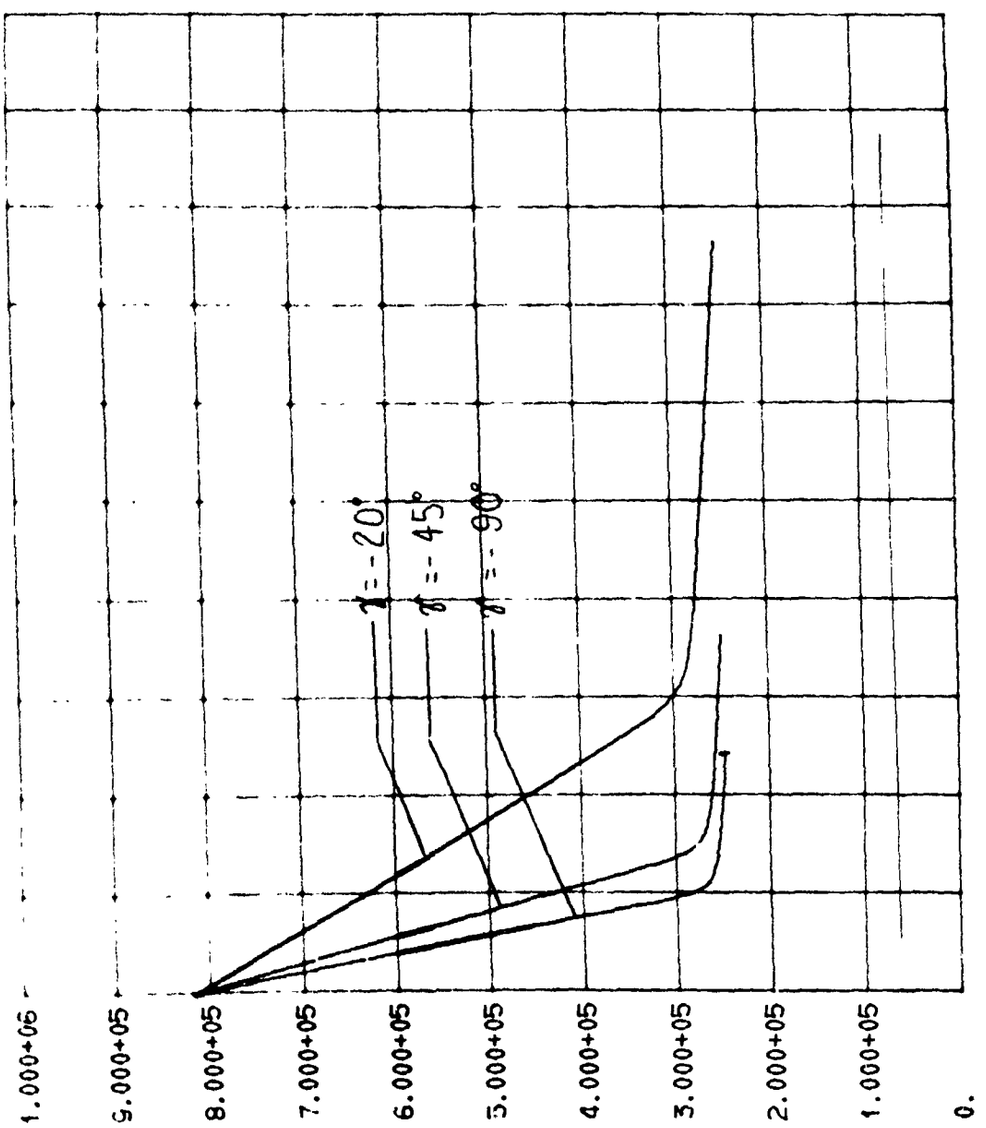

1.000+06
9.000+05
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ = -20°
γ = -45°
γ = -90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
ALTUDE
VS
TIME
1
VENUS M/P CNCT VE=36000FPS BE=.2 VSM

Fig. H-68

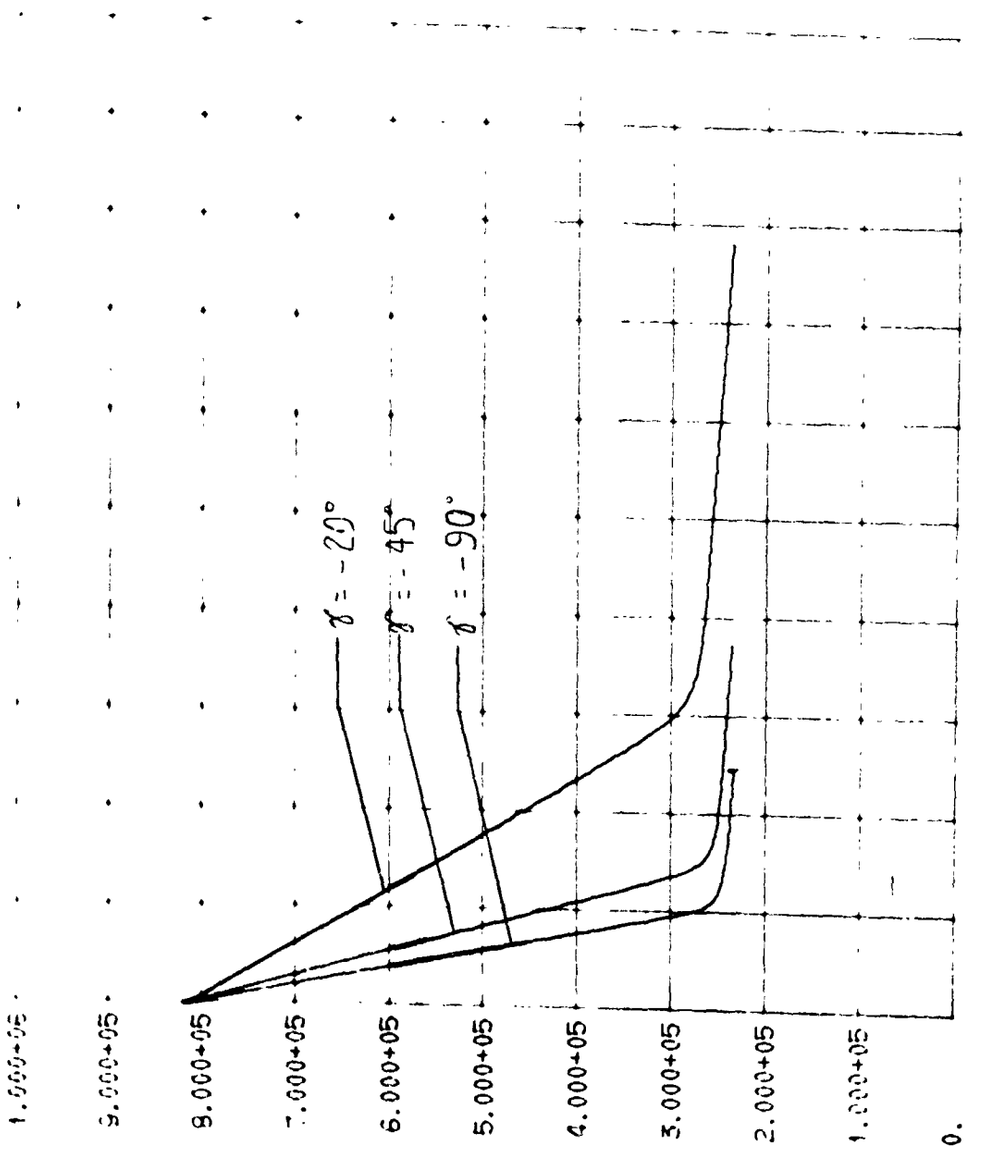

8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
γ = -20°
γ = -45°
γ = -90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50

Fig. H-69

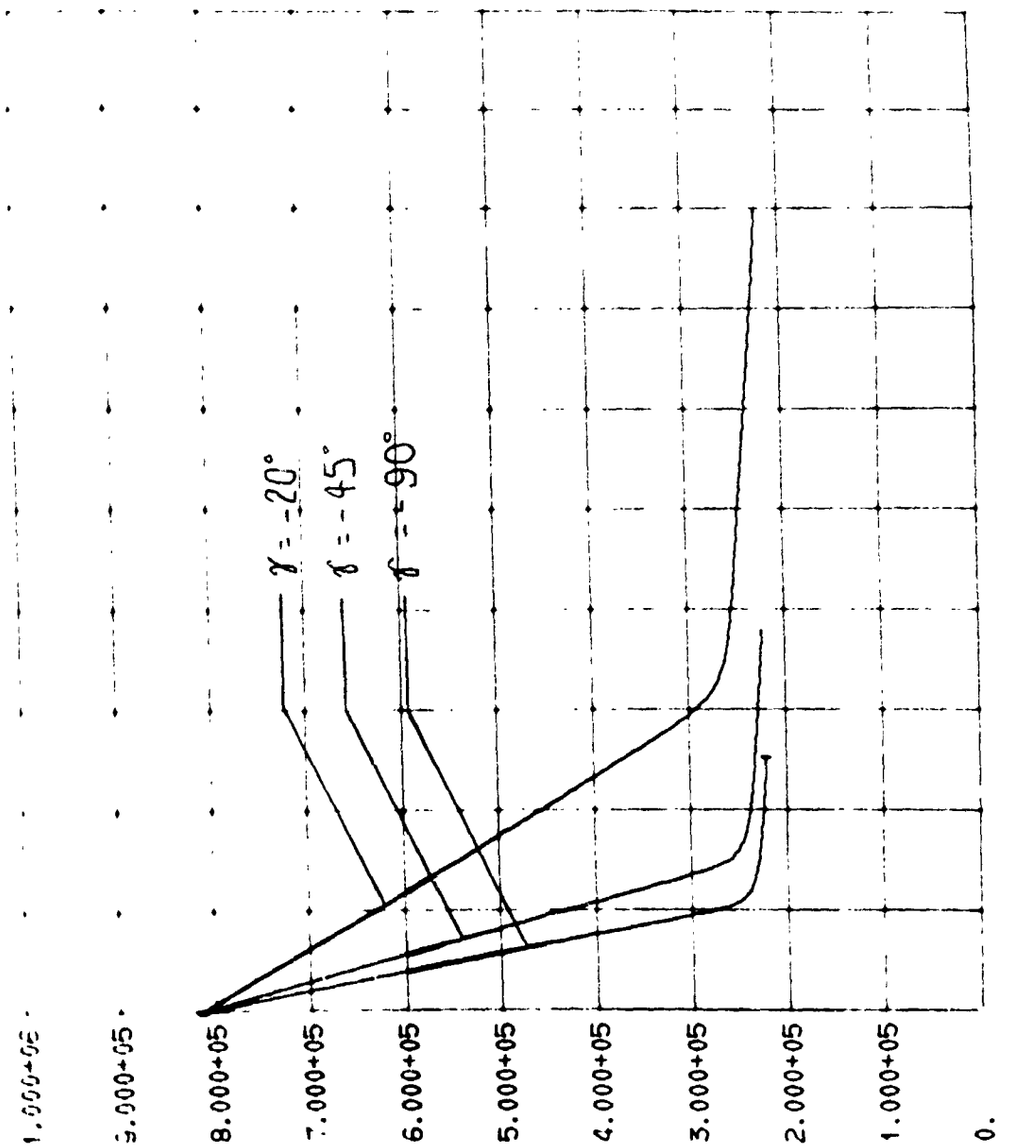

γ = -20°
γ = -45°
γ = -90°
8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
TIME

Fig. H-70

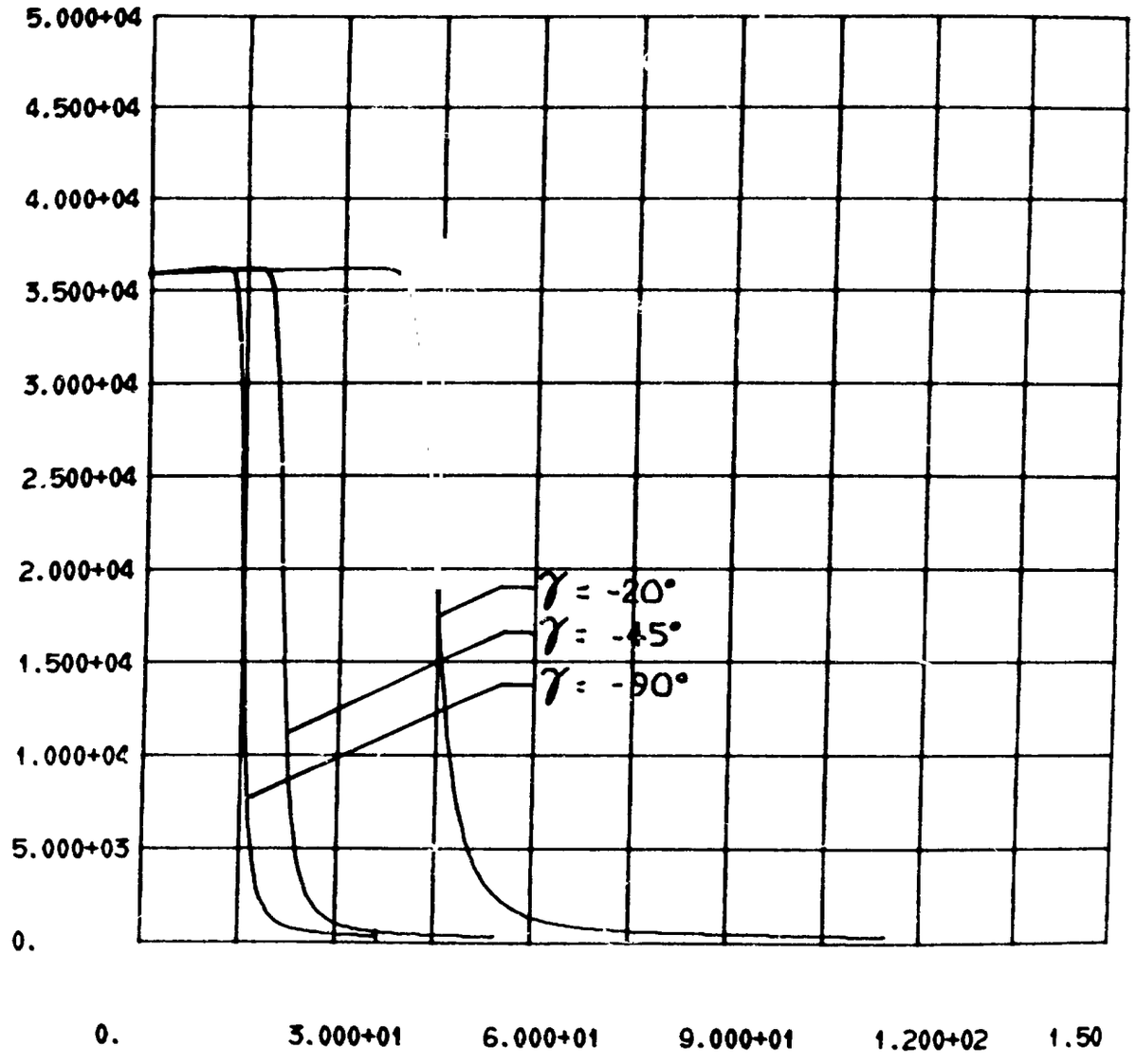

5.000+04
4.500+04
4.000+04
3.500+04
3.000+04
2.500+04
2.000+04
1.500+04
1.000+04
5.000+03
0.
γ = -20°
γ = -45°
γ = -90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VEL(R)
VS
TIME
1
VENUS M/P CNCT VE=36000FPS BE=.2 VSM

Fig. H-71

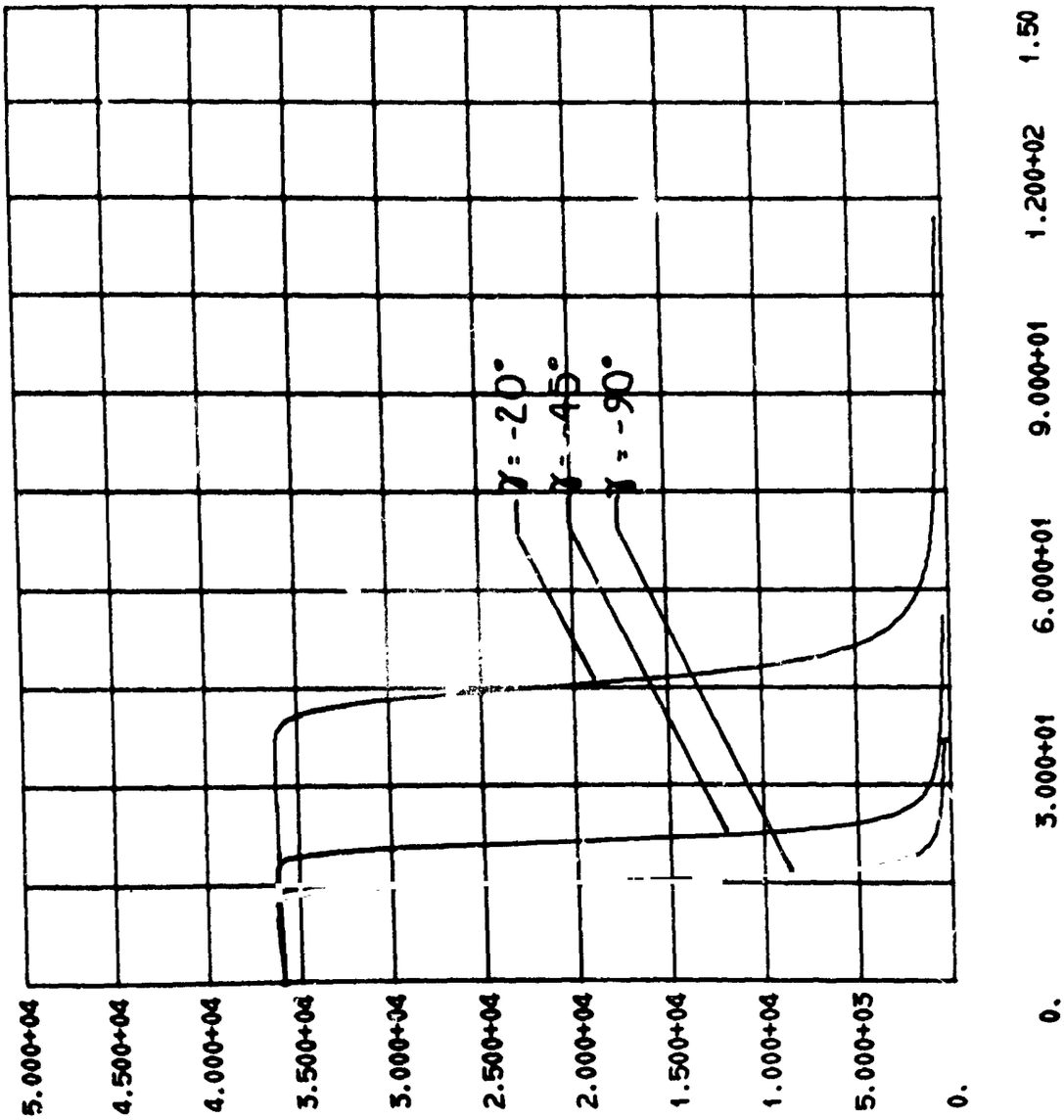


Fig. H-72

VENUS MVP CNCT VE=36000FPS BE=.4 VSN

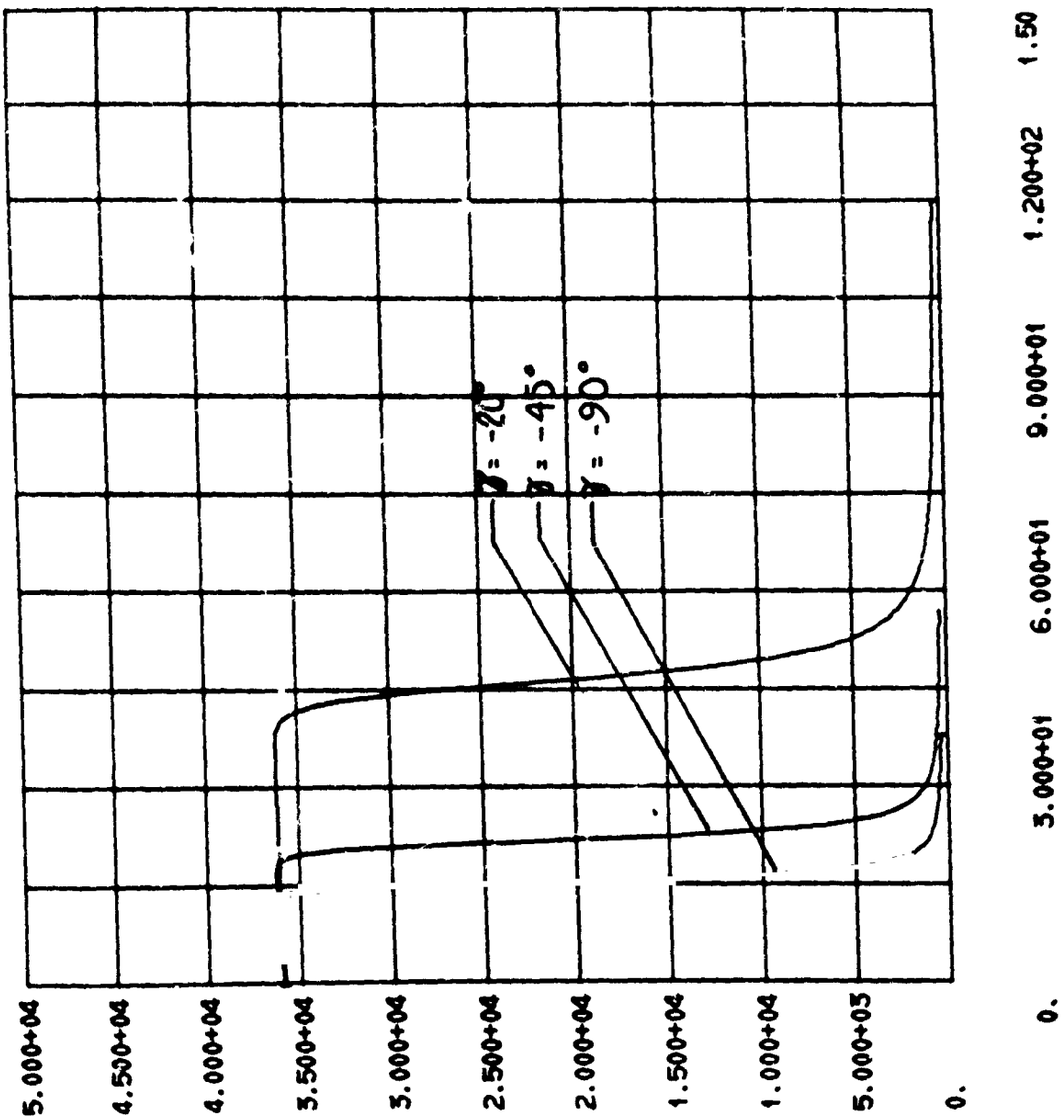


Fig. H-73

VENUS MVP CNCT VE=36000FPS BE=.8 VSH

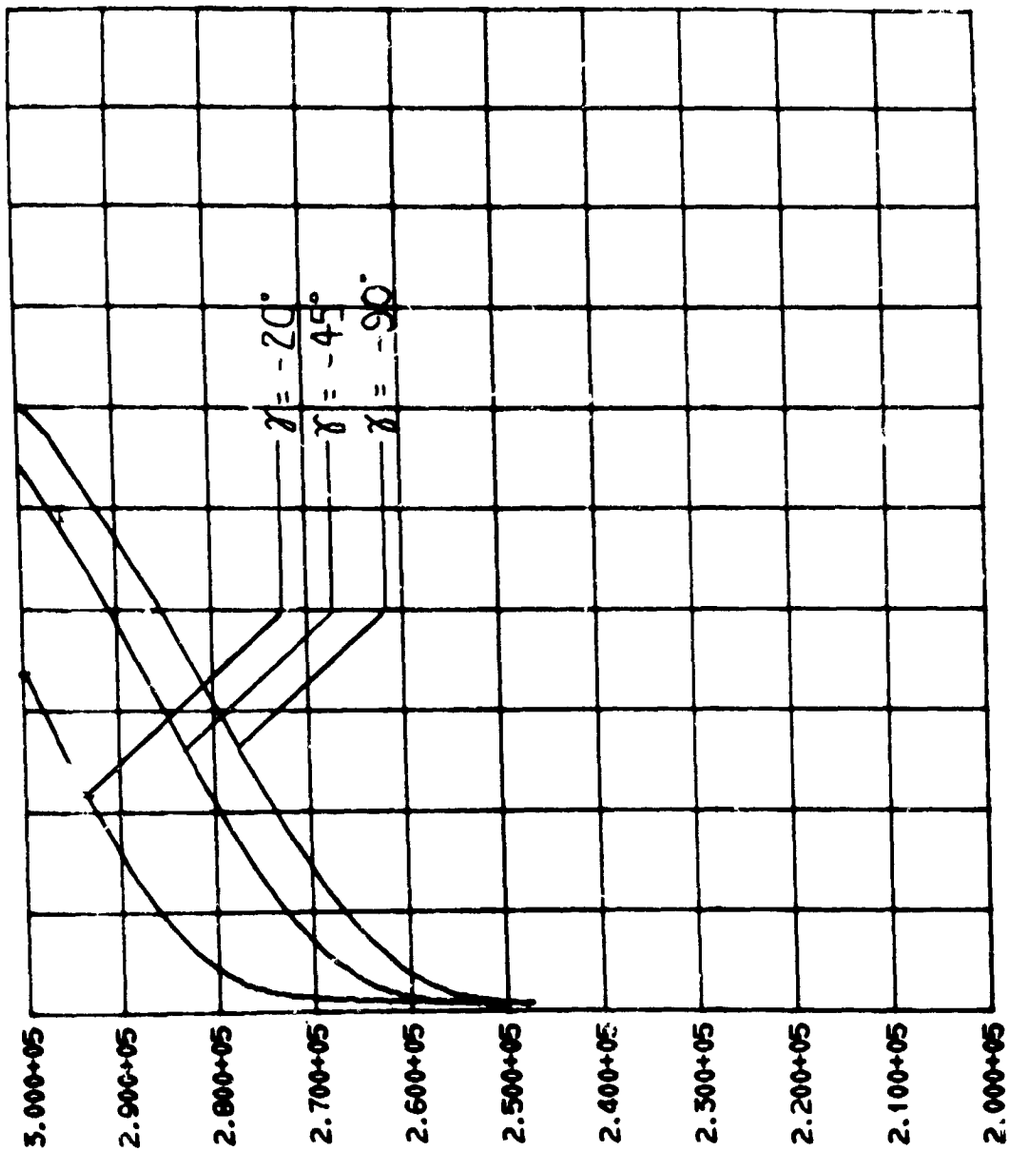


Fig. H-74

VENUS M/P CNCT VE=.6000FPS BE=.2 VSN

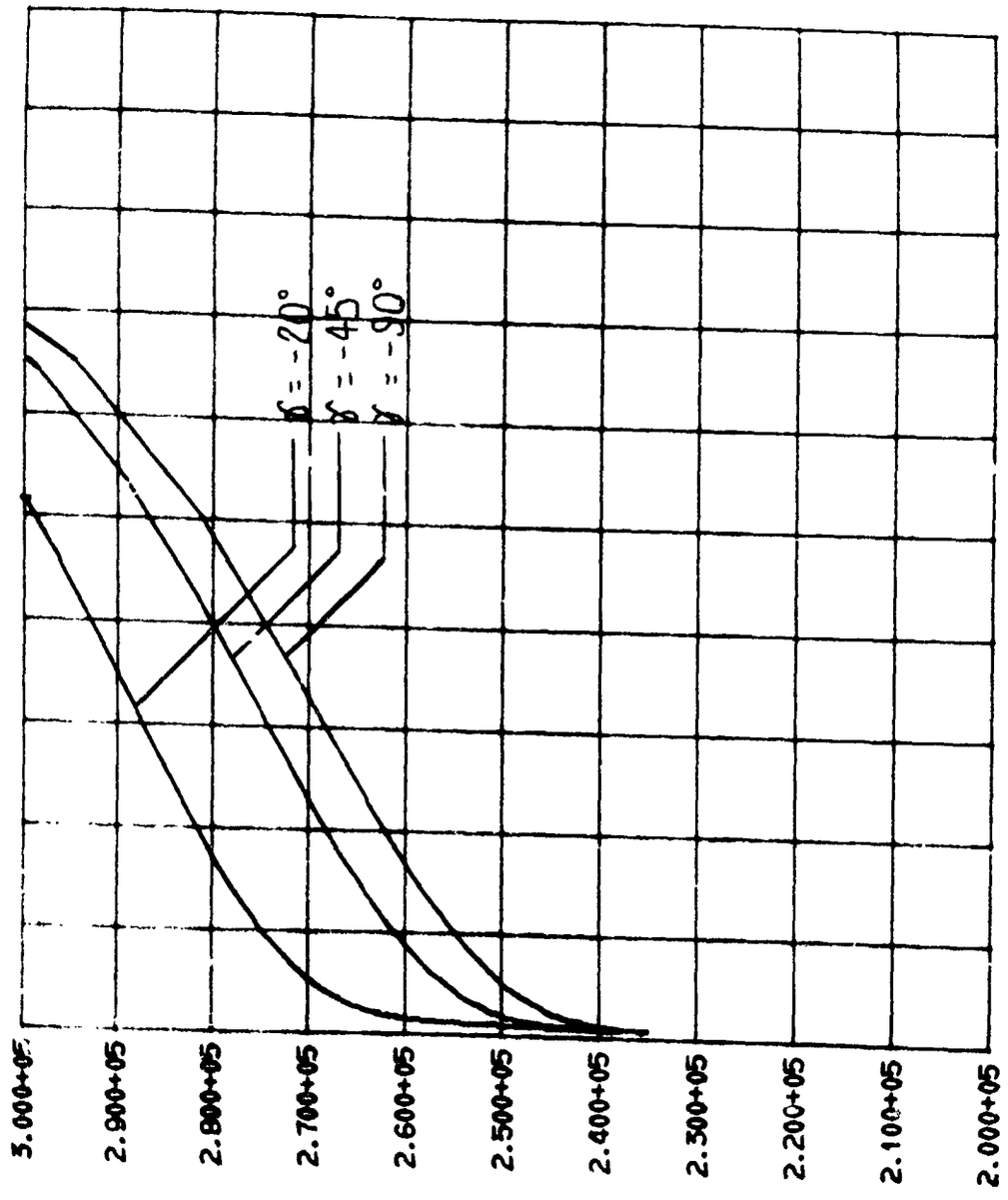


Fig. H-75

VENUS MVP CNCT VE=36000FPS BE=.4 VSH

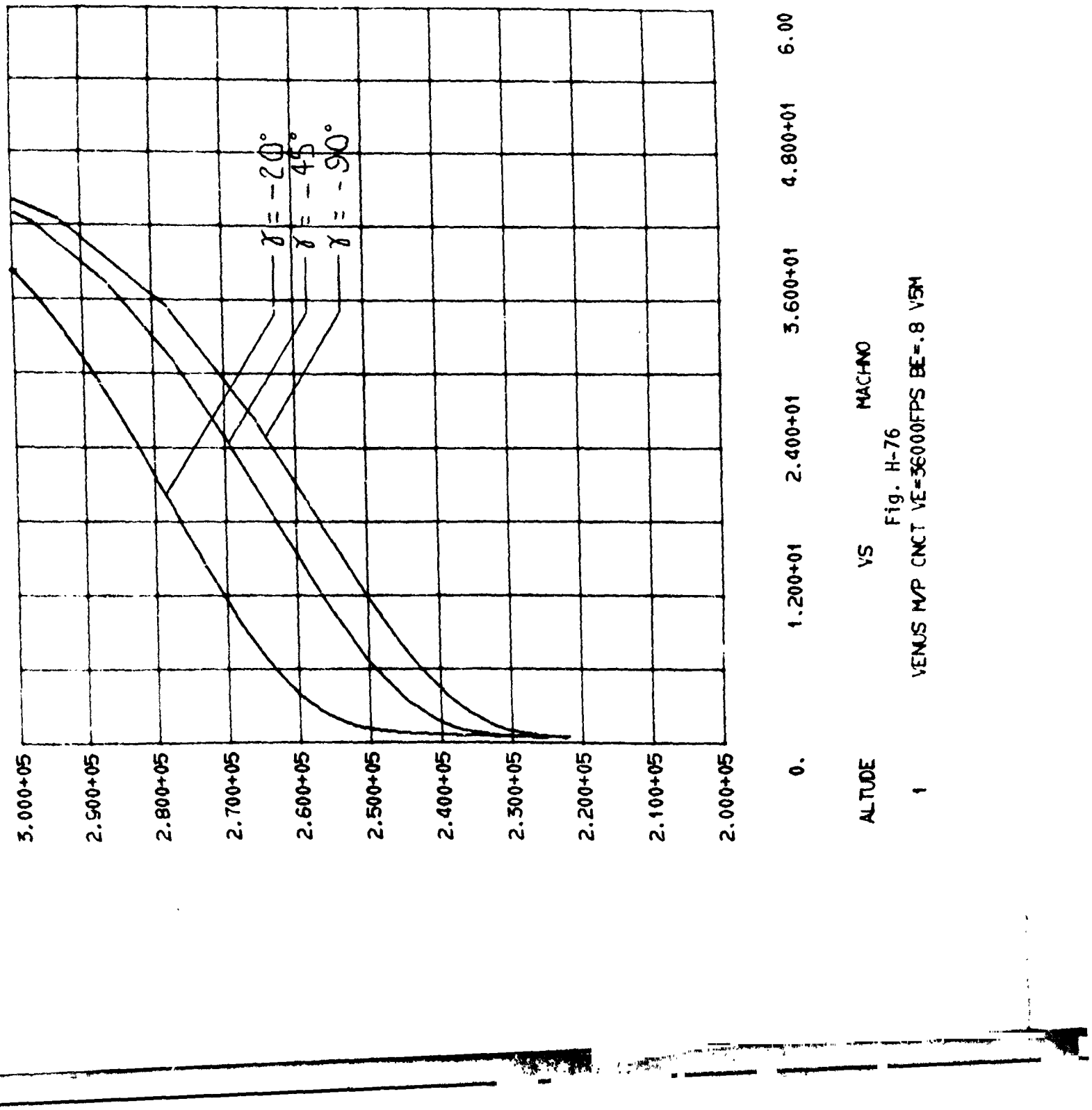


Fig. H-76
VENUS MVP CNCT VE=36000FPS BE=.8 VSM

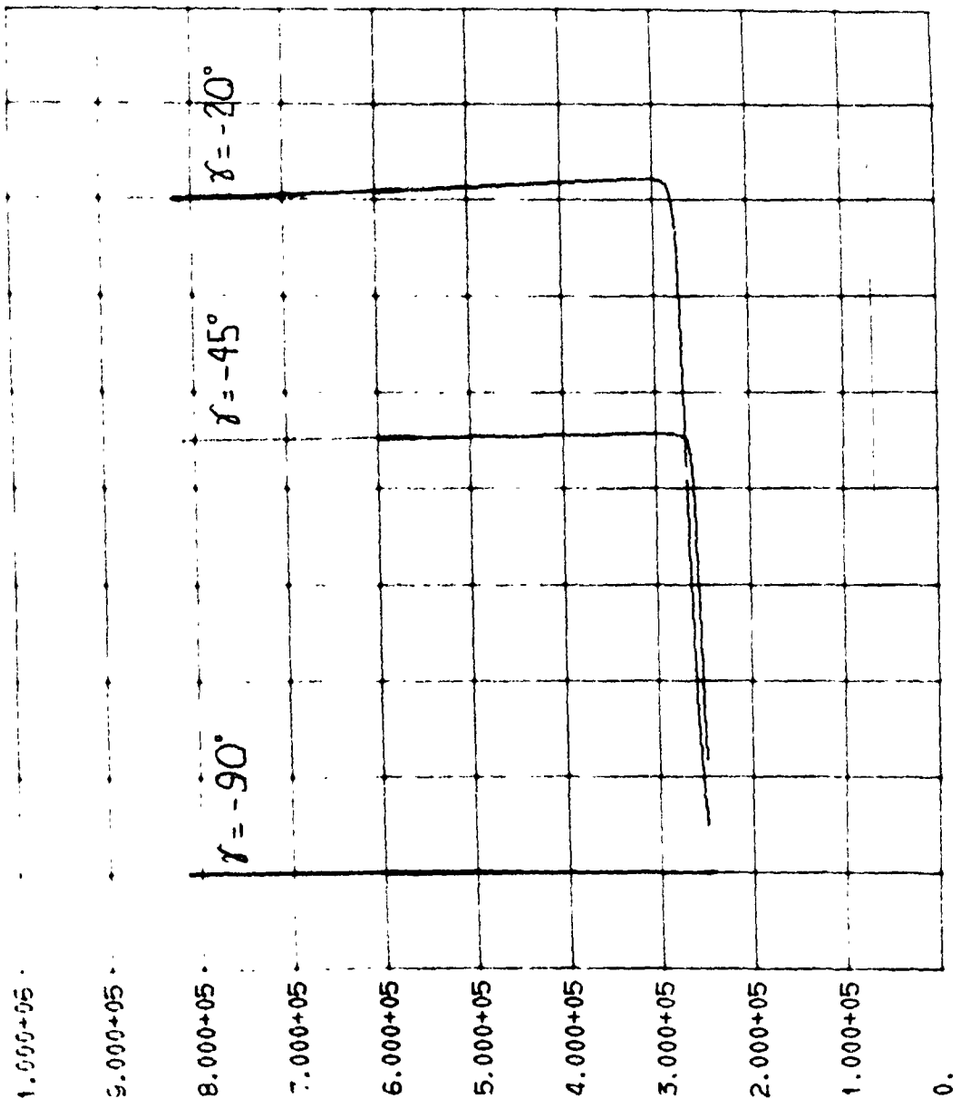


Fig. H-77

1 ...ENS MVP ...NCT ...E=36000FPS BE=.2 ...SM

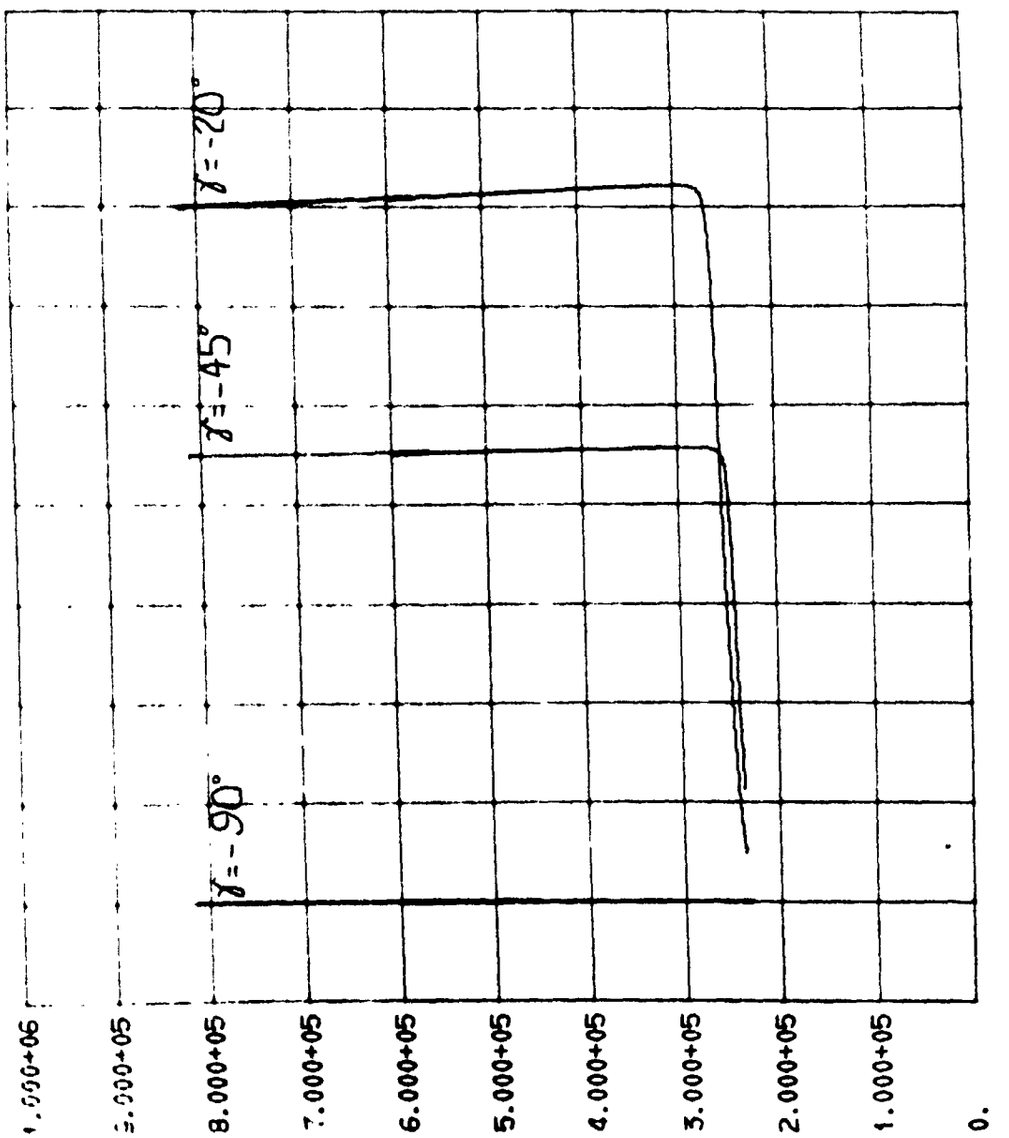


Fig. H-78

1 ENLS MVP CNCT VE=36000FPS BE=.4 15M

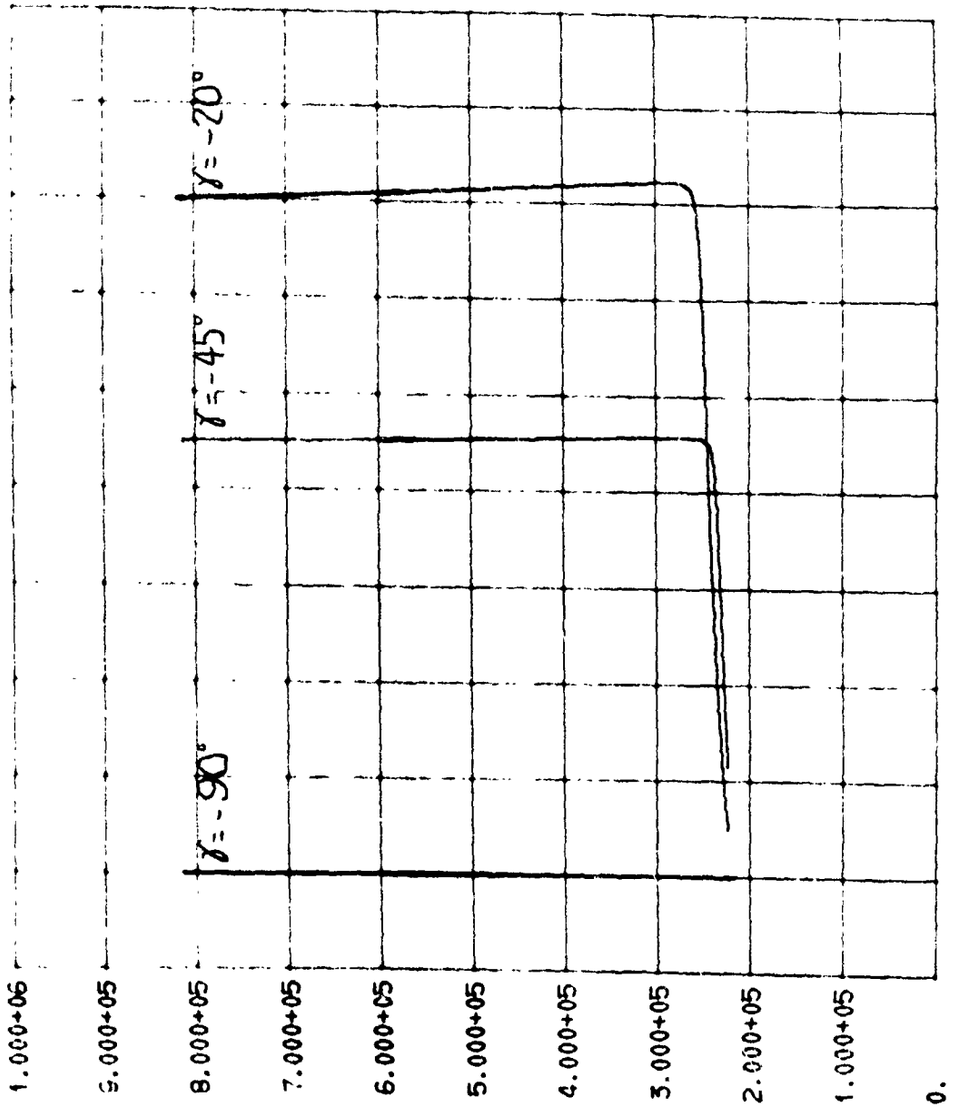


Fig. H-79

,ENLS M/P [illegible] ,E=36000FPS BE=.8 ,5M

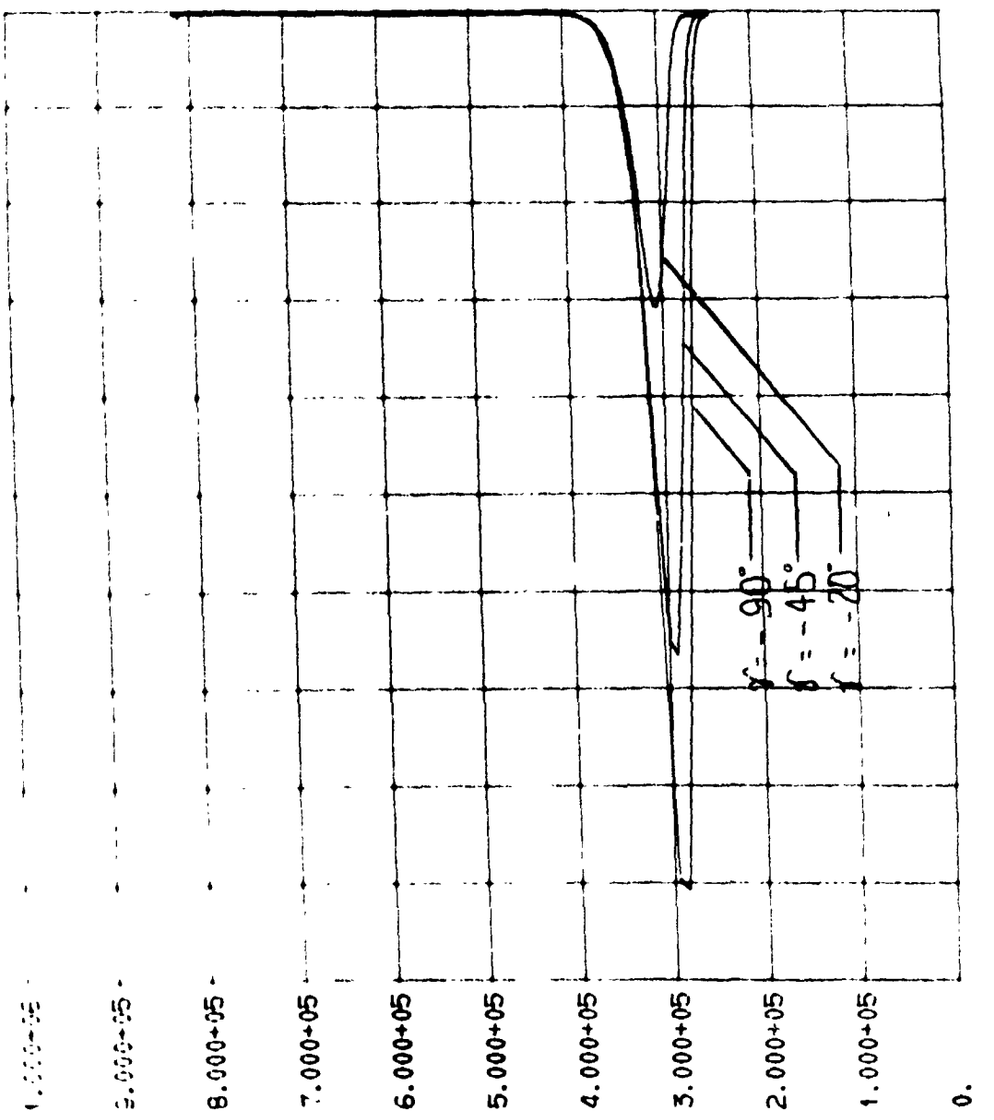

8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-5.000+02
-4.000+02
-3.000+02
-2.000+02
-1.000+02
0.
γ = -90°
γ = -45°
γ = -20°

Fig. H-80

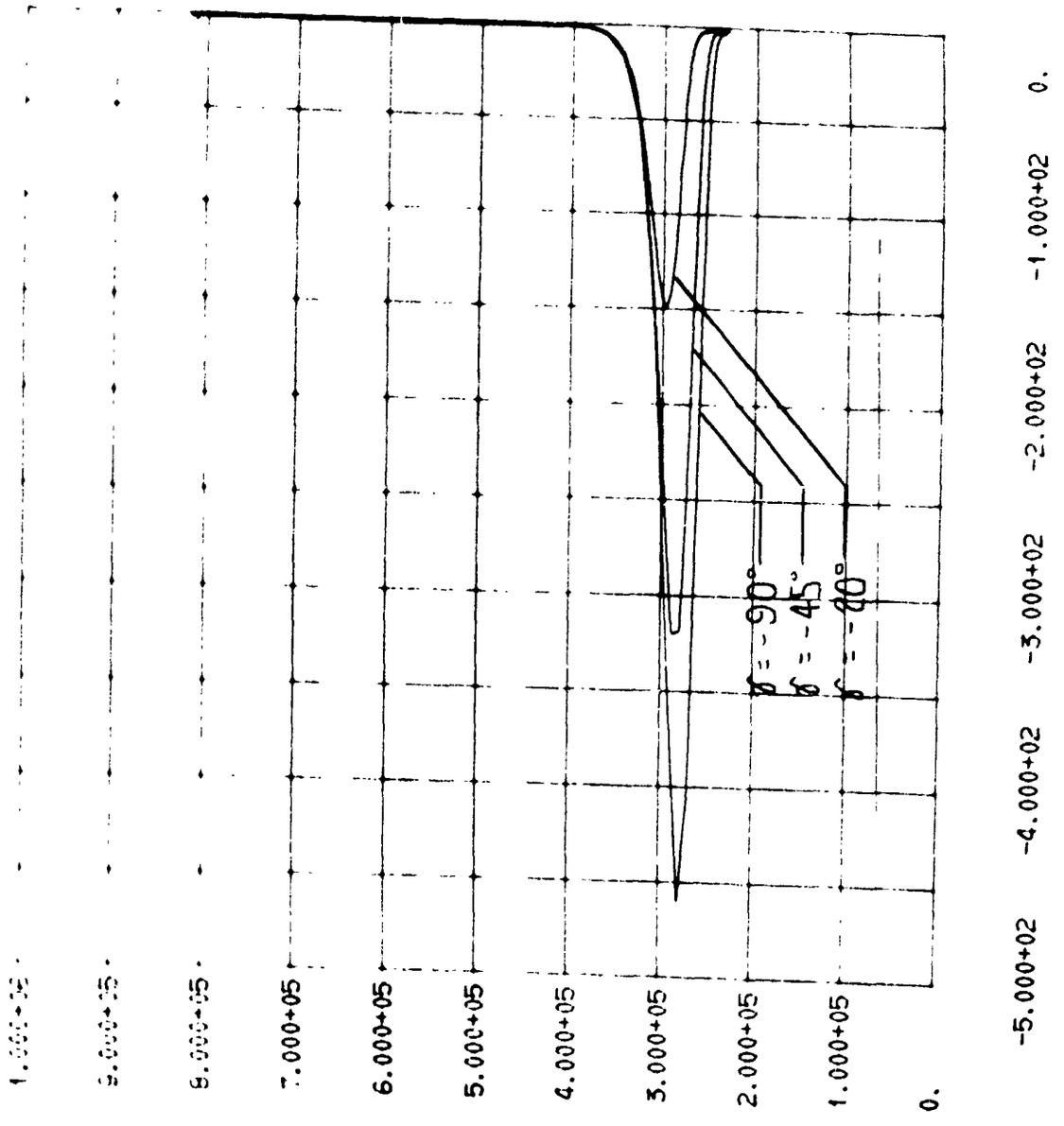

ALTUDE
VS
DRAG
-5.000+02
-4.000+02
-3.000+02
-2.000+02
-1.000+02
0.
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
β = -90°
β = -45°
β = -00°

Fig. H-81

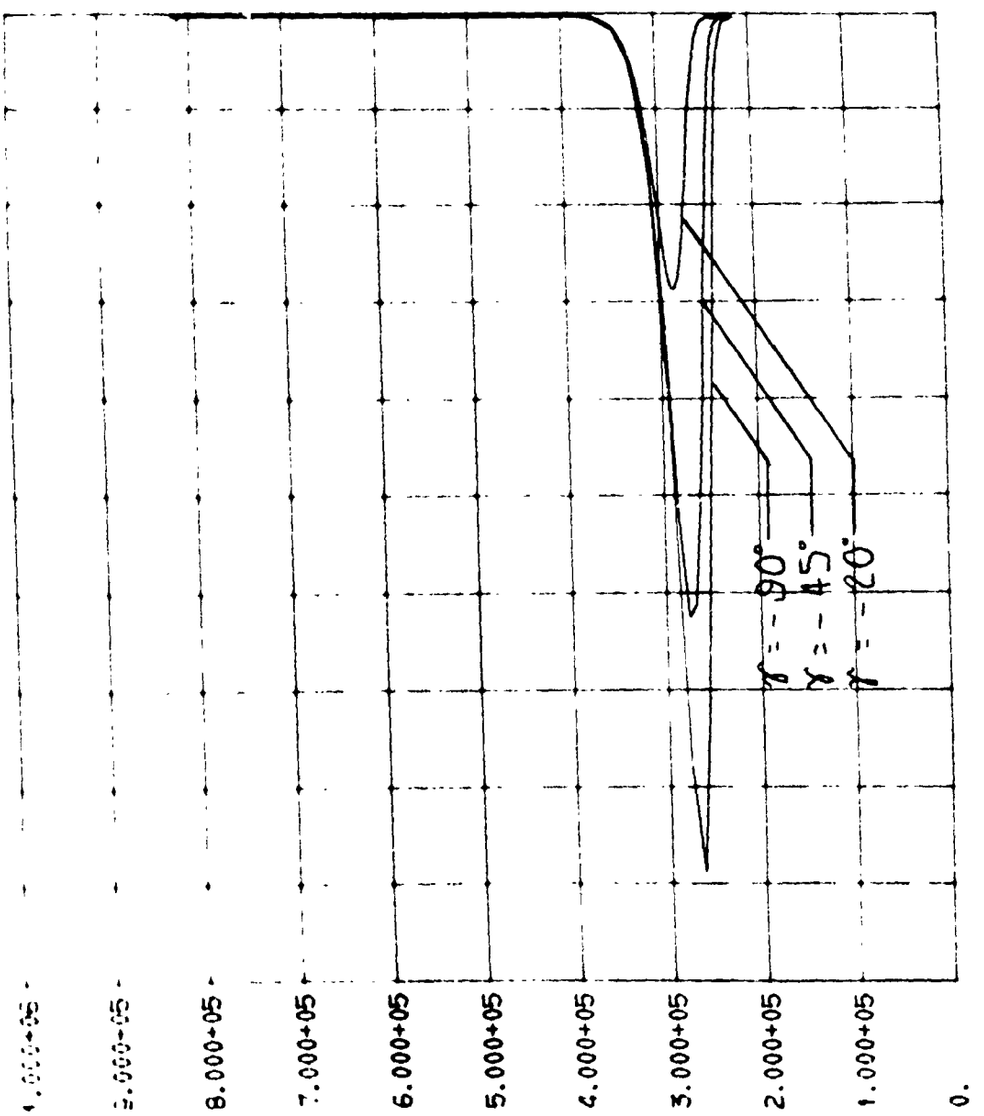

8.000+05
7.000+05
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
-5.000+02
-4.000+02
-3.000+02
-2.000+02
-1.000+02
0.
γ = -90°
γ = -45°
γ = -20°

Fig. H-82

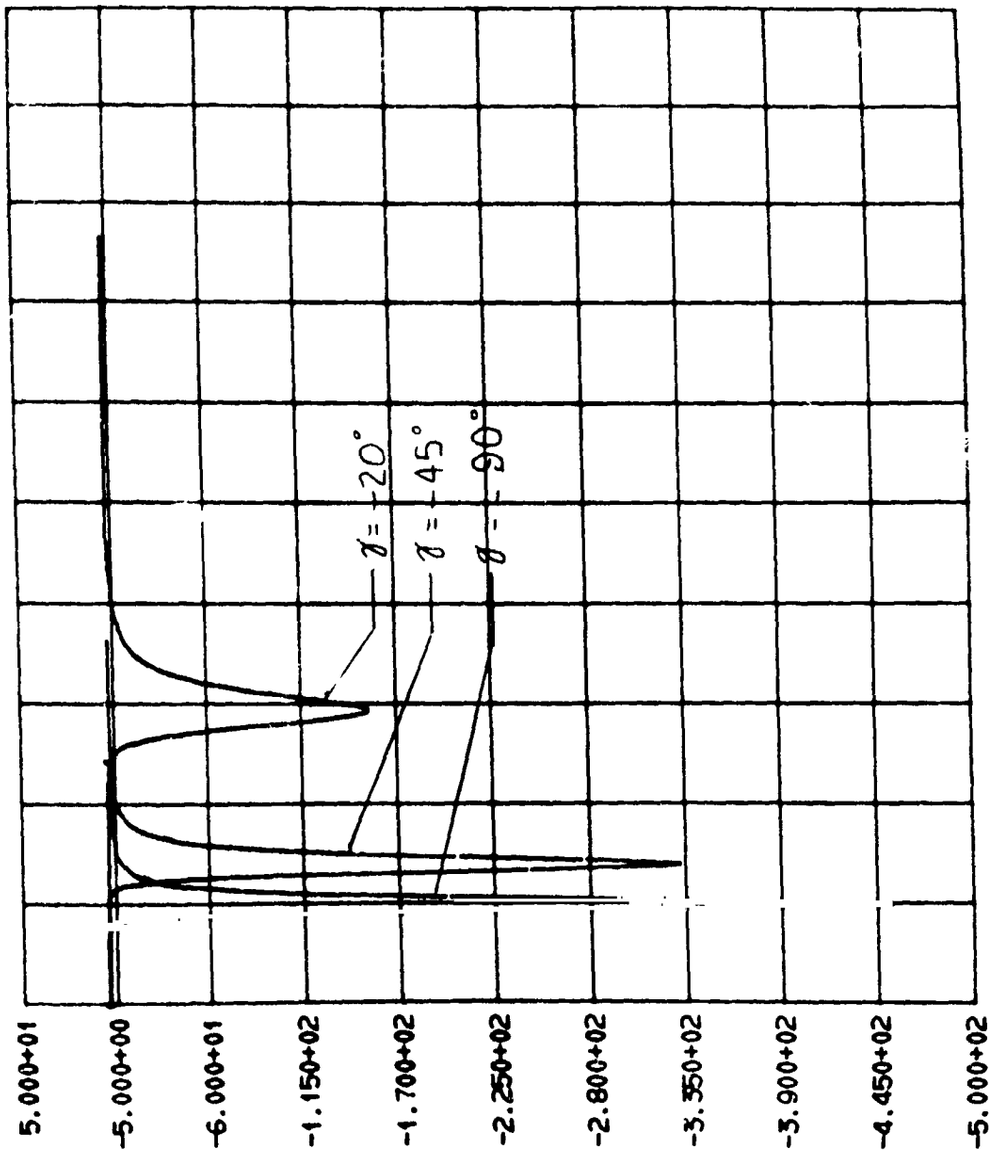

5.000+01
-5.000+00
-6.000+01
-1.150+02
-1.700+02
-2.250+02
-2.800+02
-3.350+02
-3.900+02
-4.450+02
-5.000+02
γ= -20°
γ = -45°
γ = -90°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DGACC VS TIME
1
VENUS MVP CNCT VE=36000FPS BE=.2 VSH

Fig. H-83

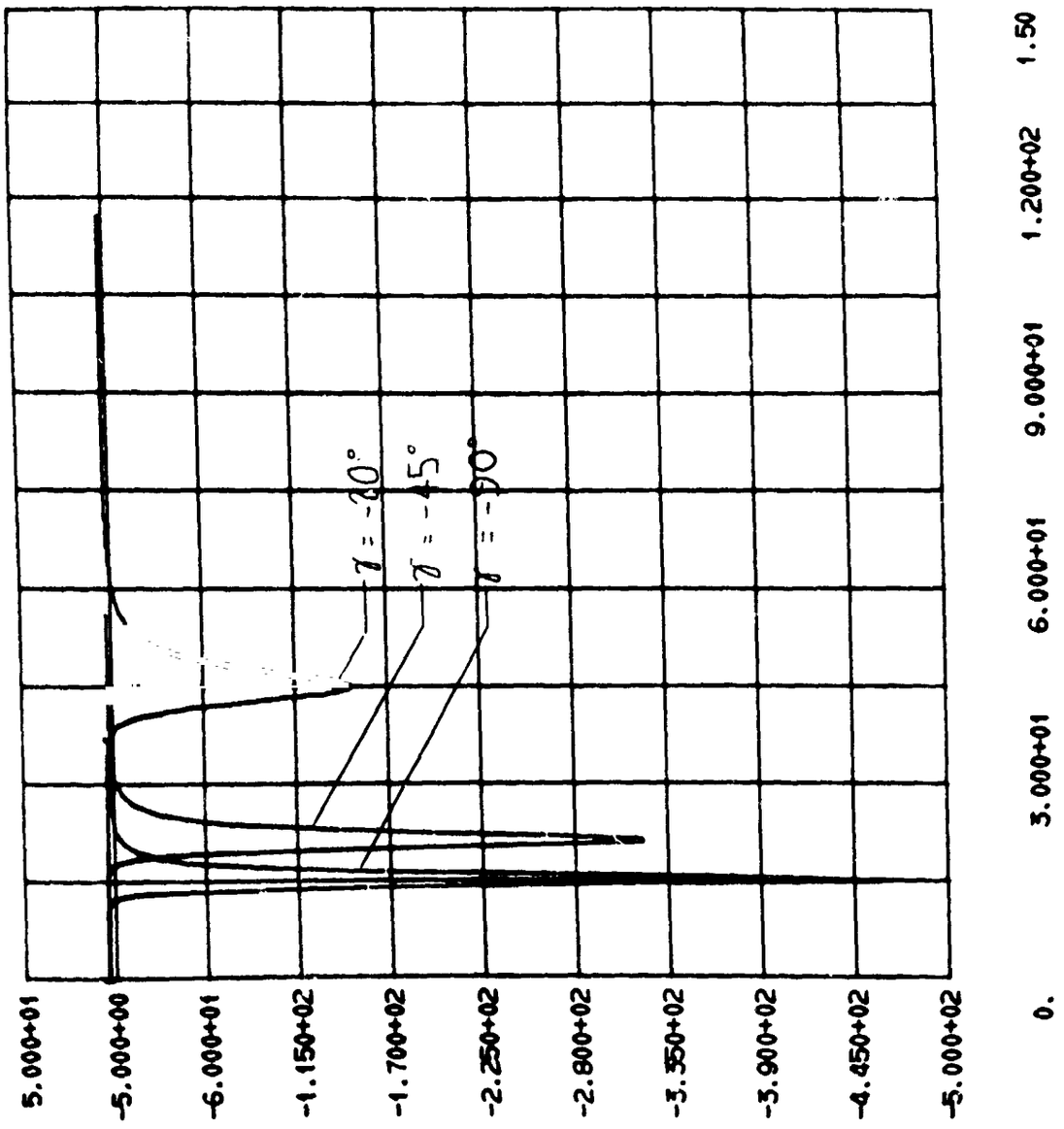

γ = -30°
γ = -45°
γ = -90°
5.000+01
-5.000+00
-6.000+01
-1.150+02
-1.700+02
-2.250+02
-2.800+02
-3.350+02
-3.900+02
-4.450+02
-5.000+02
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DGACC
VS
TIME
1
VENUS M/P CNCT VE=36000FPS BE=.4 VSN

Fig. H-84

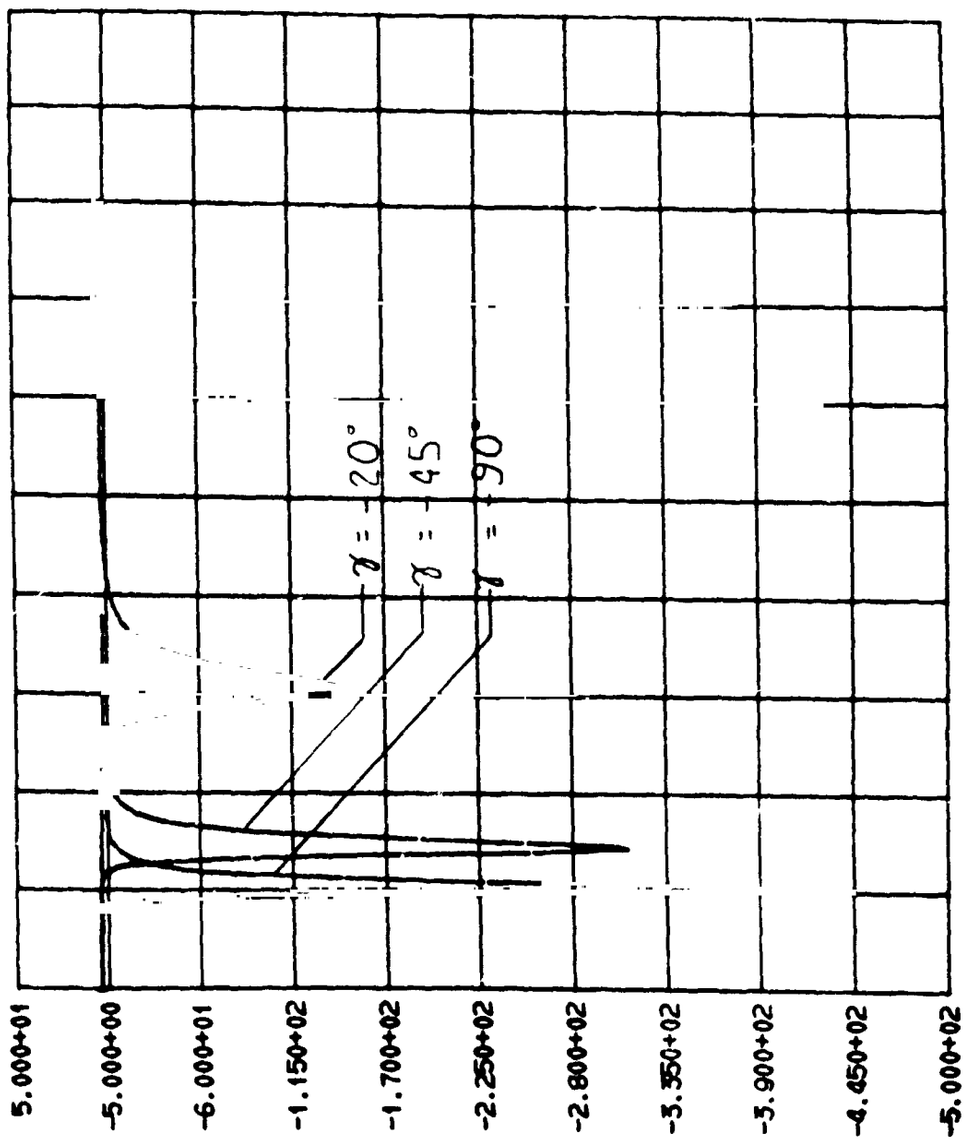

5.000+01
-5.000+00
-6.000+01
-1.150+02
-1.700+02
-2.250+02
-2.800+02
-3.350+02
-3.900+02
-4.450+02
-5.000+02
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
DGACC
VS
TIME
1
γ = -20°
γ = -45°
γ = -90°
VENUS MVP CNCT VE=36000FPS BE=.8 VSH

Fig. H-85

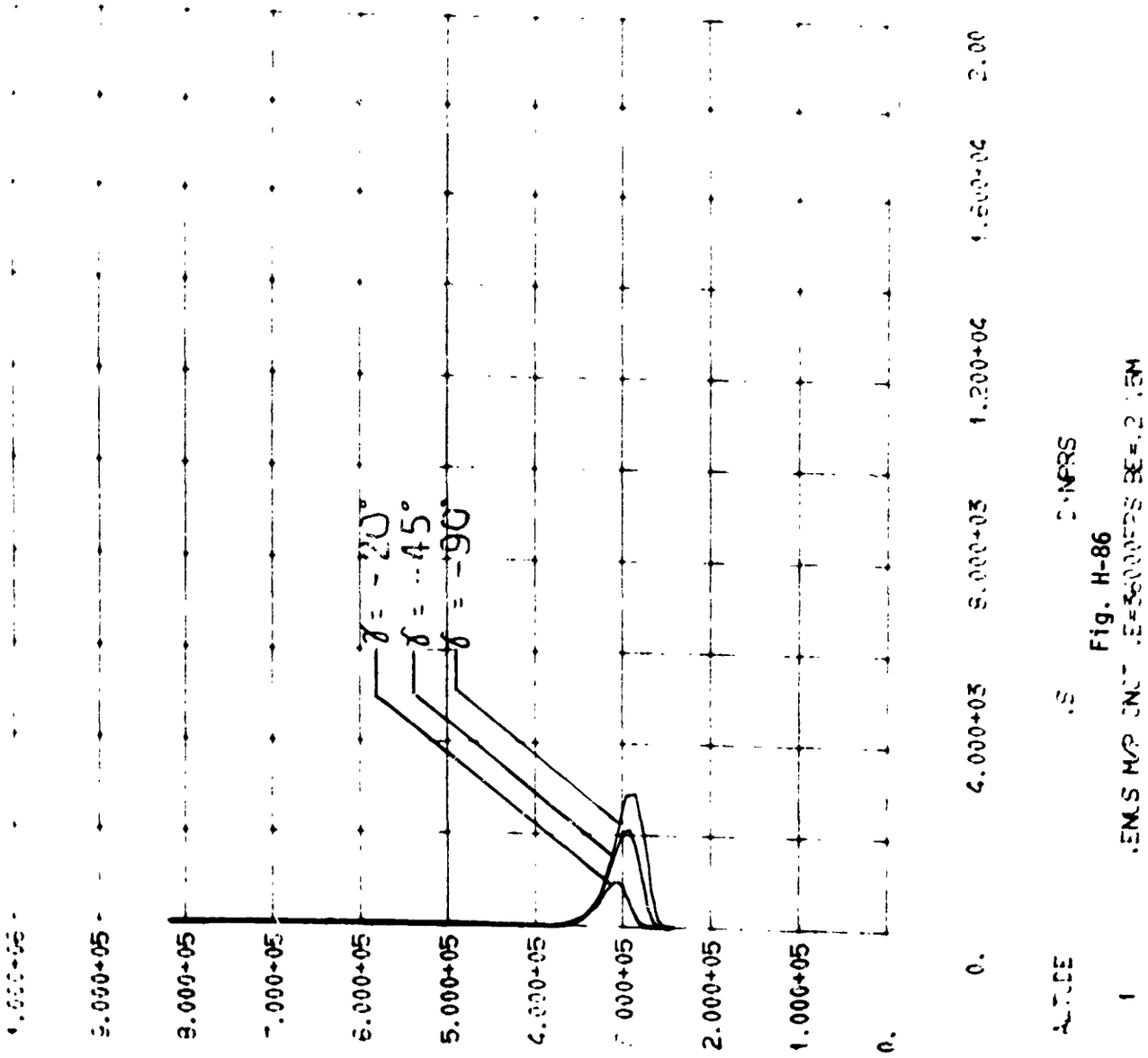

γ = -20°
γ = -45°
γ = -90°
6.000+05
5.000+05
4.000+05
3.000+05
2.000+05
1.000+05
0.
0.
4.000+03
8.000+03
1.200+04
2.00

Fig. H-86

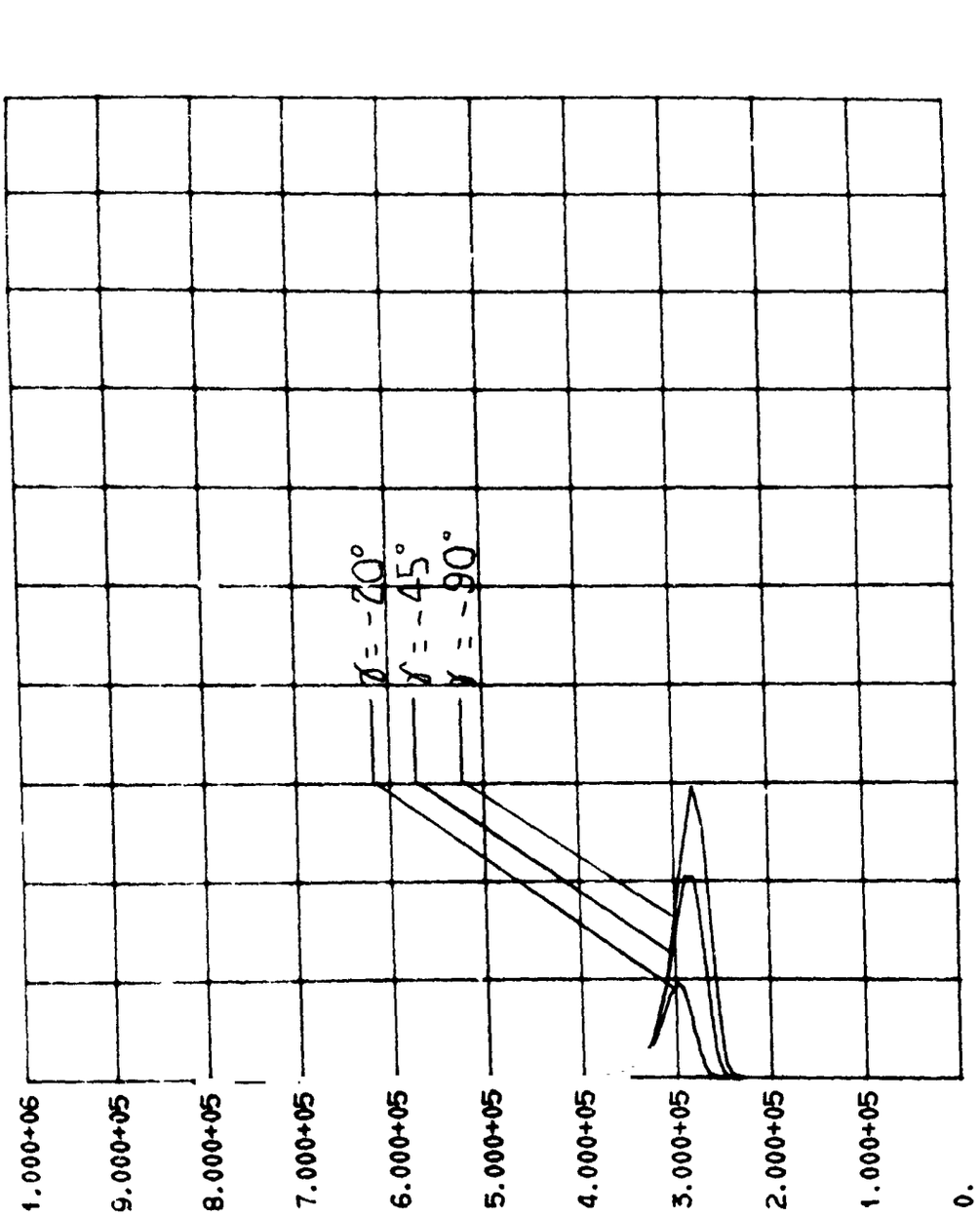


Fig. H-87
VENUS MVP CNCT VE=36000FPS BE=.4 VSM

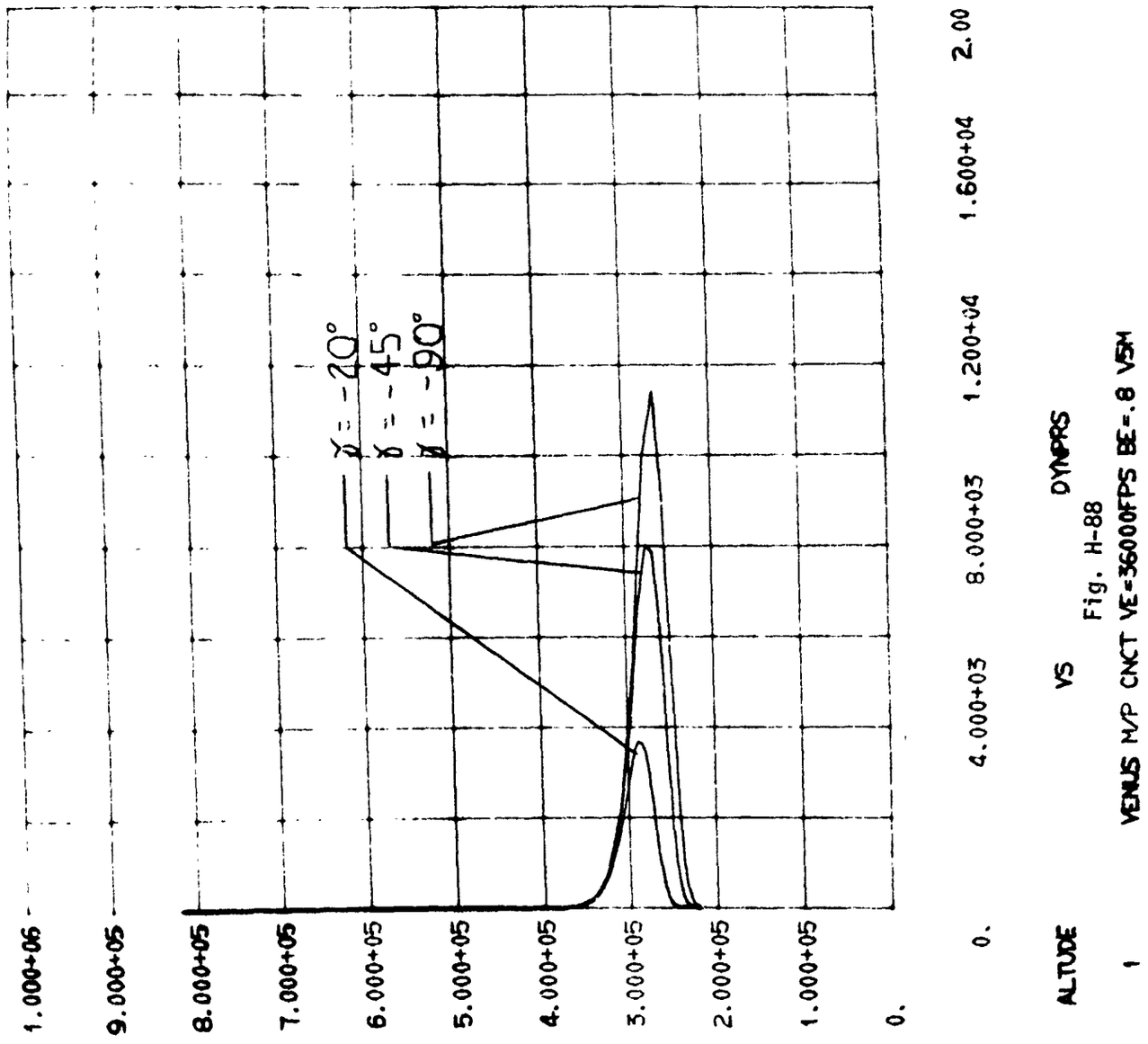


Fig. H-88

VENUS M/P CNCT VE=36000FPS BE=.8 VSM

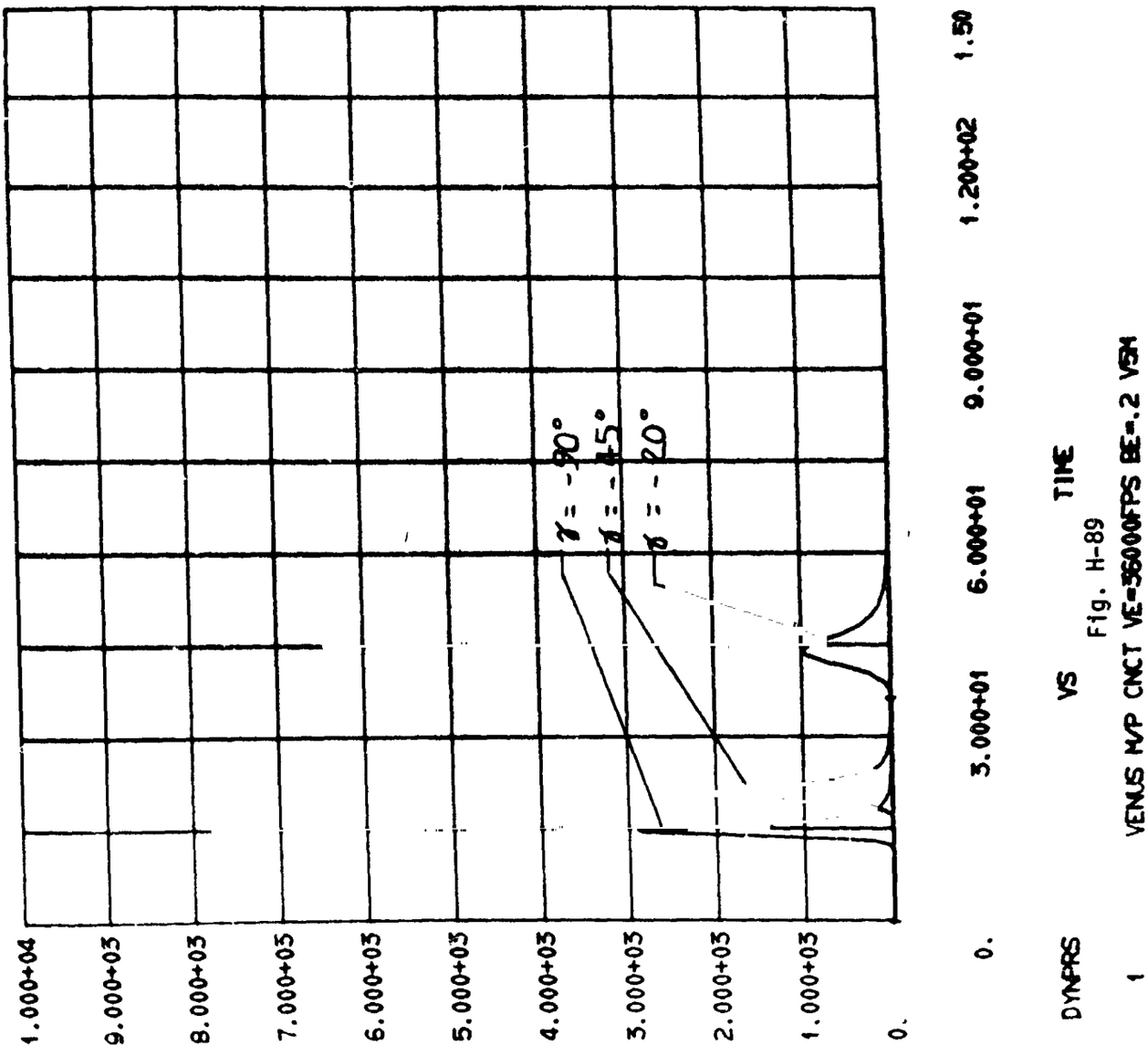

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
γ = -90°
γ = -45°
γ = -20°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VS TIME
DYNPRS
1
VENUS M/P CNCT VE=36000FPS BE=.2 VSH

Fig. H-89

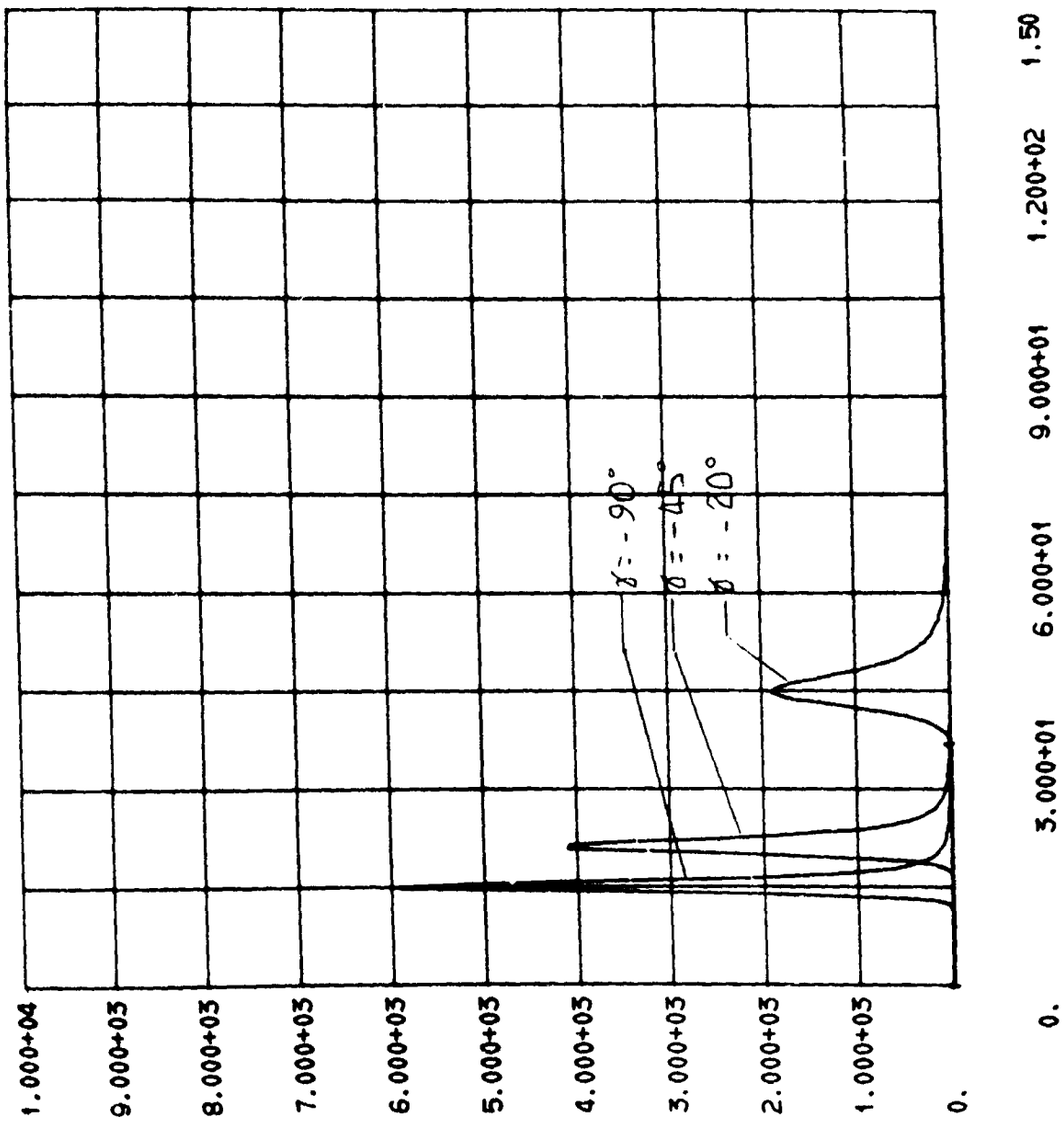

1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
γ = - 90°
γ = - 45°
γ = - 20°
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VS
TIME
DYNPRS
1
VENUS M/P CNCT VE=36000FPS BE=.4 VSH

Fig. H-90

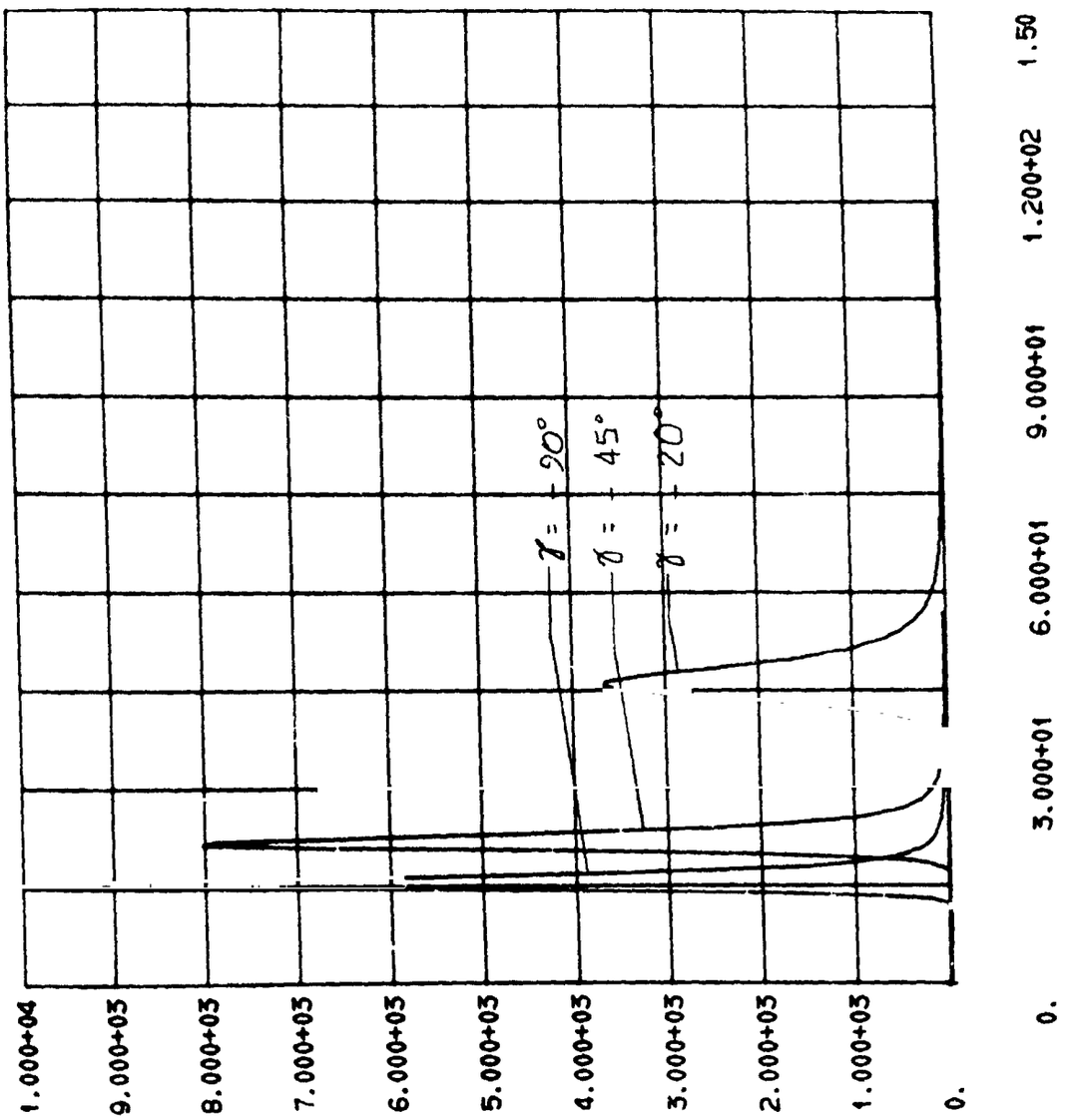

γ = +20°
γ = -45°
γ = +20°
1.000+04
9.000+03
8.000+03
7.000+03
6.000+03
5.000+03
4.000+03
3.000+03
2.000+03
1.000+03
0.
0.
3.000+01
6.000+01
9.000+01
1.200+02
1.50
VS
TIME
DYNPRS
1
VENUS M/P CNCT VE=36000FPS BE=.8 VSH

Fig. H-91

APPENDIX I

STUDY GROUND RULES AND CONSTRAINTS

I. INTRODUCTION

The information contained in this document is intended to serve as a basis for all study activities, guiding them in direction and in certain cases limiting their scope as required.

The constraints have been assembled from throughout the contract statement of work and from the subsequent technical direction memorandums from JPL.

II. STUDY GROUND RULES AND CONSTRAINTS

A. The study shall be directed towards a multiple probe mission with entry probes targeted to significantly different planet locations for atmospheric exploration.

B. The level of detail in the terminal descent capsule(s) design (as well as planetary vehicle and entry capsules) shall be only that required to obtain (and substantiate) conceptual design, alternate design approaches, and identify problem areas.

C. Interplanetary transfer trajectory data shall be based upon JPL tabulated data, 1975 launch opportunities for Venus missions.

D. All mission equipment and operations shall be compatible with the "Deep Space Communication Net" (DSN).

E. The science mission shall be as identified in contract statement of work and is not to evaluated and optimized. (By use of mission effectiveness model).

F. The technology and design approaches defined in AVCO Report AVSSO-080-68-RR shall be utilized to the maximum possible degree.

G. The AVCO Mariner configuration 20a shall be utilized with minimum modifications as required by the mission.

H. If supersonic decelerators are utilized, only designs with successful flight test experience shall be considered.

I. System state of the art shall be as of July 1972.

J. Planetary quarantine shall be as defined in NASA Management Manual 4-4-1, "NASA Unmanned Spacecraft Decontamination Policy" 9/63, which is interpreted to mean that region of the atmosphere which might be conducive to forms of life will not be contaminated.

K. The systems shall be assembled in clean rooms.

L. All hardware entering the planet's atmosphere must be capable of withstanding ETO exposure.

M. Entering equipment which might outgas or vent to the atmosphere must be capable of withstanding heat sterilization.

N. The planetary entry systems shall be enclosed in a bacteriological barrier, which shall not be opened within the Earth's atmosphere subsequent to decontamination.

O. No contamination control is to be implemented for the spacecraft.

P. Priorities on the science objectives are as follows:

Priority 1. Composition and distribution of the clouds.

Priority 2. Atmospheric circulation from just above the cloud layer and below.

Priority 3. Vertical structure of atmosphere, particularly in regions not covered by Veneras 4, 5 and 6.

Priority 4. Upper atmosphere.

The priorities are not intended to be used as a basis for excluding any of the science objectives or instruments specified in the work statement.

Q. Consideration of Buoyant Stations is to be limited to utilization of existing designs and related information. The balloons must be applicable to the region from just above the cloud layer and below.

III. MISSION DEFINITION GROUND RULES AND CONSTRAINTS

A. Consider the 1975 launch opportunity

B. The science objectives shall be as defined in JPL Document 131-03 dated 3/3/69.

C. The science instruments shall be as defined in JPL Document 131-03 dated 3/3/69.

D. The Venus environmental model shall be as defined in MMC report "Venus Planetary Environment Models - Part I," MCR-69-488, 9/69 and as modified by MMC Memorandum "Venus Model Atmospheres for Use in Multiple Probe Study" from A. R. Barger to S. J. Ducsai, 10/1/69.

E. The launch vehicle shall be Titan IIIC as defined in JPL Document 131-04, 3/3/69.

F. All communication links shall be direct to Earth.

G. Trajectory related constants shall be as defined in JPL Document TR-32-1306, 7/15/68.

H. The mission shall consider both fly-by and impacting spacecraft modes.

I. The launch azimuth shall be limited to 90 to 114°.

J. The declination of the launch asymptote shall be greater than $\pm 2^{\circ}$.

K. For targeting purposes the communications mask shall be considered as within 70° from S.E.

L. The planet surface radius shall be considered as 6050 km, with entry occurring at elevation = 815,000 ft.

IV. SYSTEM SYNTHESIS GROUND RULES AND CONSTRAINTS.

A. Heat Shield technology shall be as defined by JPL Document 131-05, as modified by JPL technical direction memorandum #3 dated, 10/3/69.

B. Entry probes need not survive surface impact, and need not be identical.

C. Probes must be subsonic prior to impact, consistent with science sampling and data transmission.

APPENDIX J

DESCENT PROBE THERMAL AND STRUCTURAL DESIGN PROGRAM

A flow chart of the descent probe thermal and structural design program is given in Fig. J-1. In general, the program takes as input the characteristics and properties of the planet atmosphere, the mass of instruments to be carried, the aerodynamic characteristics of the probe, thermal and structural material properties, and computes the overall descent probe weight.

Referring to the flow chart, the first step in the program is the computation of the descent profile. This computation is carried out beginning with the chute deployment at a given arbitrary altitude and ballistic coefficient. The program allows, then, a step change in ballistic coefficient at any altitude between chute deployment and the planet surface. This feature simulates release from the chute.

The computational technique used to identify the descent profile is a linearalized terminal velocity calculation. First, equal increments of altitude are selected between chute deployment and chute release, and between chute release and planet surface. These increments are set so that 20 computational steps are taken in both the ranges before and after chute release. With the step size in altitude defined, the corresponding atmospheric gas density is interpolated from the input array of altitude vs density. Linear interpolation is used in identifying these densities. It is then assumed that the probes will descend at terminal velocity given by the equation

$$V = \sqrt{\frac{2g_V B}{\rho}}$$

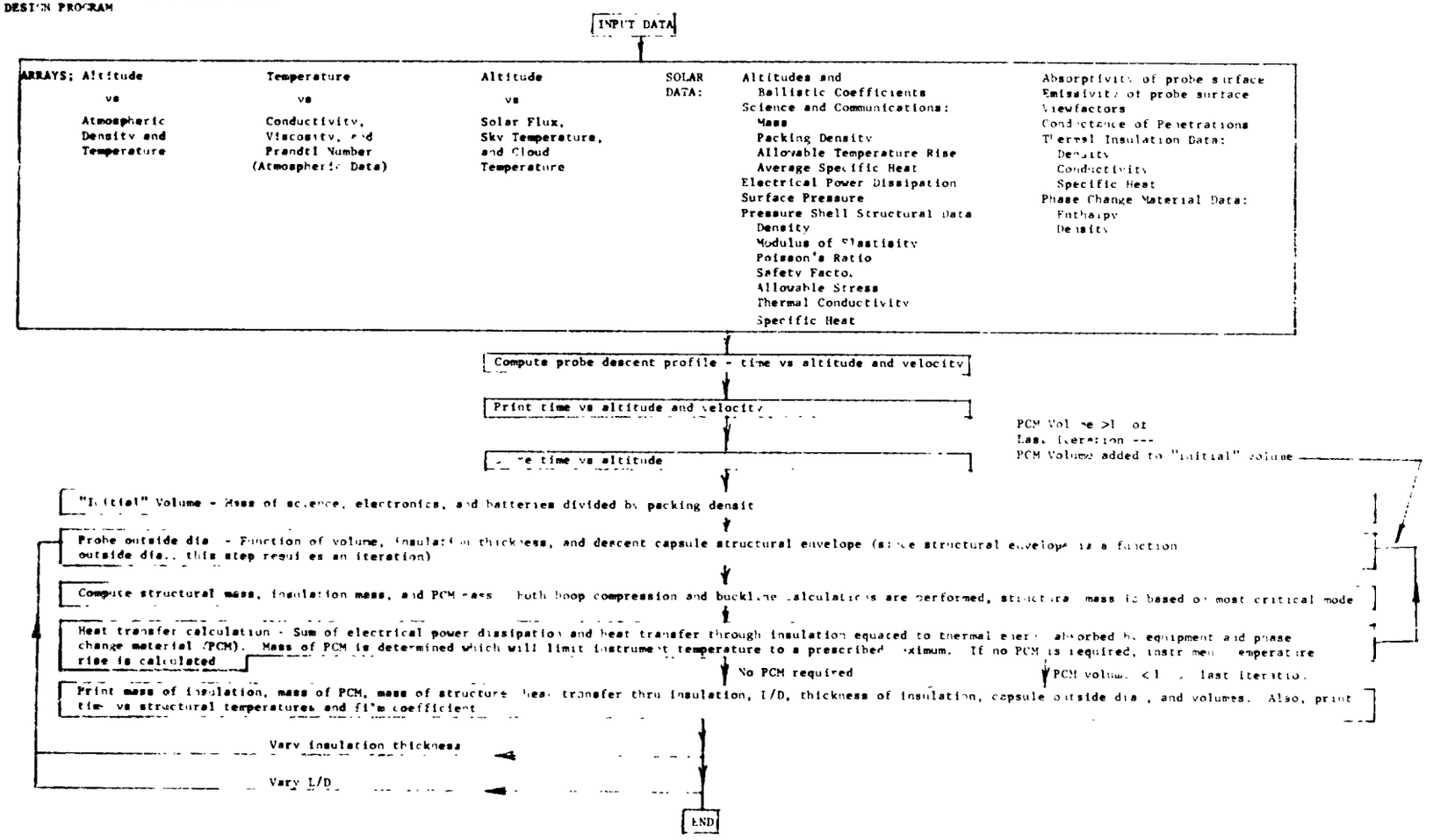


Fig. J-1 Descent Probe Thermal and Structural Design Program

where

g_V = planet gravitational constant,

B = ballistic coefficient,

ρ = density of the atmosphere.

The time to descend between increments in altitude is found by integrating the above equation. This integration results in the equation

$$\Delta\tau = \frac{2\left(h_i - h\right)}{3\left(2g_V\ B\right)^{1/2}} \left(\frac{\rho_i^{3/2} - \rho^{3/2}}{\rho_i - \rho}\right),$$

where

$\Delta\tau$ = time required to descend from altitude h_i to altitude h,

h_i = initial altitude for step,

h = final altitude for step,

g_V = gravitational constant of planet,

B = ballistic coefficient = Mass $/ C_D A$,

ρ_i = density at altitude h_i,

ρ = density at altitude h.

The descent profile (velocity vs altitude and time vs altitude) predicted by this procedure is printed out and stored for later use.

The next step in the program is the computation of the probe internal volume and outside diameter. Basic input data required for these calculations are the payload mass, payload packaging density, insulation thickness and probe L/D ratio. (The probe is assumed to be made up of two spherical ends joined by a cylindrical center section. An L/D of unity represents a spherical probe). The program is designed so that, for a given run, the

insulation thickness and L/D can be varied from initial values, stepping in even increments, to maximum values. This allows total probe weights to be computed as a function of both insulation thickness and L/D with a single computer run.

An initial value for the internal volume of the probe is calculated by dividing payload weight by the packaging density. This initial value is iterated in the program logic so the volume of PCM, required to limit final instrument temperatures, is taken into account.

With an internal volume specified the outside diameter of the probe is computed using the equation

$$D = 2t_s + 2t_I + \left[\frac{V}{\left[\pi \frac{1}{6} + \frac{1}{4}\left(\frac{L}{D} - 1\right) + \frac{1}{4}\left(\frac{L}{D} - 1\right) \frac{2t_s + 2t_I}{D - 2t_s - 2t_I}\right]}\right]^{1/3},$$

where

D = probe outside diameter,

t_s = thickness of structural shell envelope (it is assumed that $t_s = 0.025D$ for L/D = 1 and $t_s = 0.05D$ for L/D > 1),

t_I = insulation thickness,

L = length of probe,

V = payload volume + volume of PCM.

Note that this equation is implicit in D and requires an iteration process to solve for D. The convergence of this equation was found to be very rapid.

Having a value for D allows the specification of outside surface area and effective insulation area. These items are defined by

$$A_s = \pi D^2 (L/D),$$

$$A_I = \pi \left(D - 2t_s\right)\left(D - 2t_s - 2t_I\right) + \frac{\pi D (L/D - 1) 2t_I}{\ell n\left(D - 2t_s\right) - \ell n\left(D - 2t_s\right) - 2t_I}$$

where

A_s = outside surface area,

A_I = effective insulation area,

Other quantities are defined above.

At this point, the program determines the weight of the pressure vessel by applying hoop stress and buckling equations, basing the weight on criteria that require the maximum wall thickness.

With the descent profile, probe geometry, and insulation configuration specified, a heat transfer analysis is carried out to determine the heat transfer through the insulation. The thermal model used for this analysis is shown in Fig. J-2. The computational method used is a backward differencing or implicit technique with 40 equal time steps.

The main features of the heat transfer analysis include provisions for solar heating, probe surface emission to deep space, and radiation from the cloud tops during the descent above the clouds. Once below the cloud tops, black-body radiation is assumed from the local ambient atmosphere. Throughout the entire descent convective heat transfer is calculated between the probe surface and the local atmosphere. At each computation step, an average exterior film coefficient is calculated using the equation

$$h = \frac{k}{D}\left(2 + 0.6\ Re^{1/2}\ Pr^{1/3}\right),$$

where

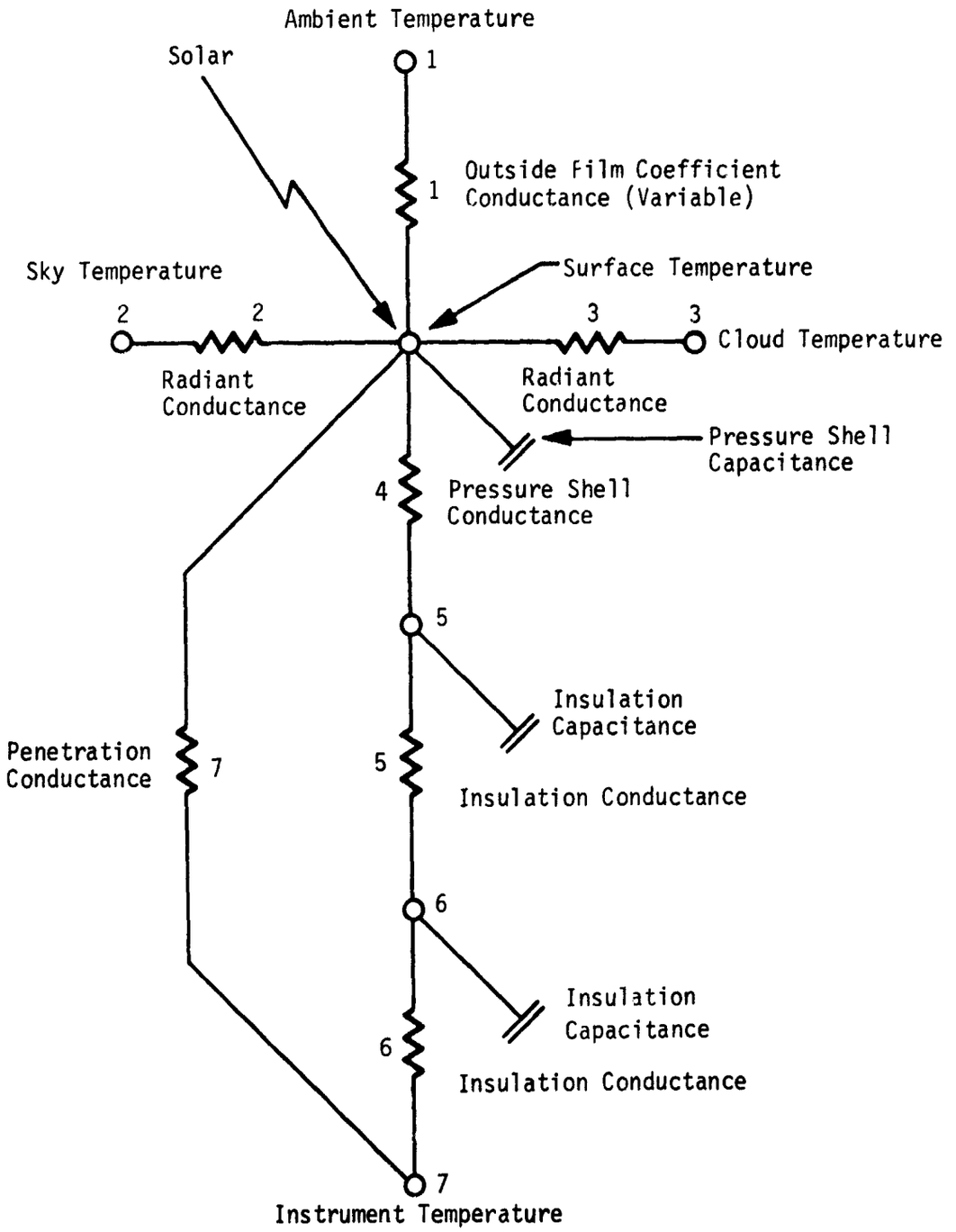


Fig. J-2 Thermal Model Used in Descent Probe Thermal and Structural Design Program

Re = Reynolds number, $\rho VD/\mu$,

Pr = Prandtl number, $\mu C_p/k$,

h = film coefficient,

D = probe diameter,

k = thermal conductivity of the atmosphere,

ρ = density of the atmosphere,

μ = viscosity of the atmosphere,

C_p = specific heat of the atmosphere,

V = probe velocity.

The velocity is found at each time step by applying the equation for terminal velocity given above.

The altitude at any given time is determined by interpolation from the previously computed altitude vs time array. Using this altitude, the temperature and density of the atmosphere are found by interpolating the input altitude vs temperature and altitude vs density arrays. Thermophysical properties (conductivity, viscosity, and Prandtl number) are then evaluated from input arrays in a similar manner using the atmospheric temperature determined above. These properties are taken to be those of CO_2 and variation with temperature only is accounted for.

Referring to Fig. J-2, the capacitance of the external structure is applied at Node 4, while the capacitance of the insulation is divided equally between Nodes 5 and 6. Conductor 4 represents the external structure; Conductors 5 and 6 account for the insulation. A thermal path through insulation penetrations is provided by Conductor 7. Node 7 is a constant temperature node and represents the instruments. Of course, the temperature of Node 7 would increase with time; however, the total heat transfer through the insulation is only slightly affected by assuming a constant temperature because the temperature rise at this location is very small relative to the atmospheric temperature.

Once the heat transfer through the insulation is determined, a heat balance is applied to establish the mass of PCM required to limit the payload to a prescribed temperature increase. This equation is given by

$$Q_I + Q_E = M_I Cv_I \Delta T_I + M_{PCM} H_{PCM},$$

where

Q_I = heat transfer through the insulation,

Q_E = electrical dissipation,

M_I = mass of instruments and communication equipment,

Cv_I = average specific heat of instruments and communication equipment,

ΔT_I = allowable temperature rise $\leq 60°F$,

M_{PCM} = mass of PCM,

H_{PCM} = heat of fusion of PCM.

If a negative mass of PCM results from application of the previous equation, this mass is set equal to zero, and the equation is used to determine the payload temperature rise. If a positive mass of PCM is specified, its volume is then circulated. This volume is added to the initial or previous volume estimate and the calculations are repeated, starting with a recalculation of the probe outside diameter. These calculations are cycled until the "new" and "old" values of total internal volume differ by less than 1%. Once this criterion is satisfied, the iteration is performed one final time to output a time/temperature profile of probe temperatures and to determine final weights and volumes of the PCM, insulation, and structure.

The chosen value of 100 Btu/lb_m for the heat of fusion of PCM is probably not achievable in a real situation. This optimistic value is balanced in the program by neglecting the sensible heat of the PCM in changing temperature.

A list of penetration conductances used in the analysis is tabulated below.

	Penetration Conductances (Btu/Hr -°F)	
	Large Probe	Small Probe
Strap Supports	0.08	0.04
Lateral Supports	0.16	0.08
Pressure Transducer and Mass Spec.	0.01	0.01
Thermal Radiometer	0.09	
Nephelometer	0.06	0.06
Cloud Particle	0.09	
Cloud Composition	0.10	
Evaporimeter - Condensimeter	0.06	
Antenna Coaxial Cable	0.02	0.02
All Wire Penetrations (Umbilical, Solar, Radiometer, Temperature Sensors, etc)	0.09	0.09
	0.76	0.30

The complete program input data for the baseline probe designs is given in Table J-1, followed by a sample program output. The output includes the large probe baseline descent profile and sizing data for the large probe baseline design.

Table J-1 Program Input Data for Baseline Design

	Large Probe	Small Probe
Model Atmosphere	V5M	V5M
Altitude at Beginning of Subsonic Descent (km above 6050)	72.5	72.5
Altitude at Chute Release (km above 6050)	40.0	53.5
Ballistic Coefficient before Chute Release ($slug/ft^2$)	0.035	0.015
Ballistic Coefficient after Chute Release ($slug/ft^2$)	2.0	2.0
Mass of Science and Communication Equipment (lb_m)	125.6	62.4
Packaging Density of Payload (lb_m/ft^3)	40.0	40.0
Allowable Temperature Rise of Instrumentation (°F)	60.0	60.0
Initial Instrument Temperature (°F)	70.0	70.0
Average Specific Heat of Instrumentation (Btu/lb_m-°F)	0.2	0.2
Electric Power Dissipation (w)	274.0	110.7
Pressure on Planet Surface (psia)	2210.0	2210.0
Initial Pressure Shell Temperature (°F)	70.0	70.0
Density of Structural Material ($lb_m/in.^3$)	0.16	0.16
Modulus of Elasticity of Structural Material (psi)	9.6×10^6	9.6×10^6
Poisson's Ratio of Structural Material	0.31	0.31
Safety Factor	1.1	1.1
Allowable Stress	7×10^4	7×10^4
Conductivity of Structural Material (Btu/hr-ft-°F)	5.86	5.86
Specific Heat of Structural Material (Btu/lb_m-°F)	0.154	0.154
Absorptivity of Probe Surface	0.69	0.69
Emissivity of Probe Surface	0.24	0.24
View Factor between Probe and Sky, Probe and Clouds	0.5	0.5
View Factor between Sun and Probe	0.5	0.5
Conductivity of Insulation (Btu/hr-ft-°F)	0.0004	0.0004
Conductance of Penetrations (Btu/hr-°F)	0.76	0.3
Density of Insulation (lb_m/ft^3)	10.0	10.0
Enthalpy of Fusion PCM (Btu/lb_m)	100.0	100.0
Density of PCM (lb_m/ft^3)	50.0	50.0
Specific Heat of Insulation (Btu/lb_m-°F)	0.2	0.2

ILLUSTRATION

TEXT

DESCENT PROBE THERMAL
AND STRUCTURAL DESIGN PROGRAM LISTING

TEXT

IMAGE IMAGE

PG NO. ILLUSTRATION PROG

J-11

```
*IOCS(CARD,1132 PRINTER)
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
C PROBE WT. PROGRAM
      DIMENSION TEMPP(12),TAMB(41)
      DIMENSION XH(41),XHTD(41),DENB(41),DENH(41),TAUA(41),TAMBK(41)
      DIMENSION TSKY(41),TCLO(41),GSUN(41),CONA(12),PR3(12),VISA(12)
      DIMENSION VEL(41)
C XH1- ALT. AT BIGINNING OF SUBSONIC DESCENT, KM ABOVE 6050 RADIUS
      XH1 = 72.5
C XH2- ALT. AT CHUTE RELEASE, KM ABOVE 6050 RADIUS
      XH2 = 40.0
C BE1- BALLISTIC COEF. CORRESPONDING TO XH1, SLUGS/FT**2
      BE1  =    .035
C BE2- BALLISTIC COEF. CORRESPONDING TO XH2, SLUGS/FT**2
      BE2 = 2.0
C XMASI- MASS OF SCI. AND COMM. EQUIP., LB-M
      XMASI = 125.6
C DENI- PACKING DENSITY OF INSTRUMENTS, LB-M/FT**3
      DENI = 40.
C DTI- ALLOWABLE TEMP. RISE OF INSTRUMENTS, DEG-F
      DTI  = 60.0
C TEMPI- INSTRUMENT TEMPERATURE, DEG-F
      TEMPI = 70.
C CPI- AVG. SPECIFIC HEAT OF INSTRUMENTS, BTU/(LB-M--DEG-F)
      CPI=.20
C QI- ELECTRICAL POWER DISSIPATION, WATTS
      QI = 274.0
C SPRES- SURFACE PRESSURE, PSIA
      SPRES  =  2210.
C TSHI- INITIAL SHELL TEMP. DEG-F
      TSHI = 70.
C DENSH- DENSITY OF STRUCTURAL MATERIAL, LB-M/IN**3
      DENSH=.16
C EMOD- MODULAS OF ELASTISITY, PSI
      EMOD = 9.6E6
C PRAT- POISSON'S RATIO
      PRAT = .31
C SFACH- SAFETY FACTOR
      SFACH = 1.1
C STREA- ALLOWABLE STRESS, PSI
      STREA = 7.E4
C CONDS- CONDUCTIVITY OF STRUTURAL MATERIAL, BTU/(HR-FT-DEG-F)
      CONDS = 5.86
C CPS- SPECIFIC HEAT OF STRUCTURAL MATERIAL, BTU/(LB-M--DEG-F)
      CPS = .154
C ALPS- ABSORPTIVITY OF PROBE SURFACE
      ALPS = .69
C EMIS- EMISSIVITY OF PROBE SURFACE
      EMIS= .24
C VFAC2 - VIEWFACTOR BETWEEN PROBE AND SKY, PROBE AND CLOUDS
      VFAC2= .5
C VIEWF- VIEW FACTOR BETWEEN SUN AND PROBE
      VIEWF = 0.5
C SB- STEPHAN -BOLTZMANN CONSTANT, BTU/(HR-FT**2-DEG-R**4)
      SB= .1714E-8
C CONDI- INSULATION CONDUCTIVITY, BTU/(HR-FT-DEG-F)
      CONDI = .0004
C CON7  =  CONDUCTANCE OF PENETRATIONS, BTU/(HR-DEG-F)
```

E2

```
      CON7 = .76
C DENK-  INSULATION DENSITY, LB-M/**3
      DENK = 10.0
C XHPCM- ENTHALPY OF PCM, BTU/LB-M
      XHPCM = 100.0
C DPCM- DENSITY OF PCM, LB-M/FT**3
      DPCM= 50.
C THICI- INITIAL INSULATION THICHNESS,INCHES
      THICI  =  .8
C DTHIC- INCRIMENTAL CHANGE IN INSULATION THICKNESS, INCHES
      DTHIC = .2
C THICM- MAX. INSULATION THICHNESS, INCHES
      THICM = 1.3
C XLODI- INITIAL L/D RADIO
      XLODI = 1.5
C DLOD- INCRIMENTAL CHANGE IN L/D RATIO
      DLOD=.5
C XLODM- MAX. L/D RATIO
      XLODM = 1.9
C  CPII - INSULATION SP. HEAT, BTU/(LB-M--DEG-F)
      CPII = .20
      PI=3.1416
      E=2.71828
  950 FORMAT(7E10.4)
      READ(2,950) DENH
      READ(2,950) TAMBK
      READ(2,950) CONA
      READ(2,950) PR3
      READ(2,950) VISA
      READ(2,950) TEMPP
      DO 960 N=1,41
      XXN= FLOAT(N)-1.
  960 XHTD(N)= 2.*XXN
      DO 952 N=1,41
  952 TAMB(N) = TAMBK(N)*1.8 - 460.0
      DO 953 N= 1,31
  953 TSKY(N) = TAMB(N)
      DO 954 N= 32,41
  954 TSKY(N) = -450.
      DO 955 N = 1,31
  955 TCLO(N) = TAMB(N)
      DO 956 N = 32,41
  956 TCLO(N) = TAMB(31)
      DO 957 N= 1,31
  957 QSUN(N)= 0.0
      DO 958 N= 32,41
  958 QSUN(N) = 1.5*858.*ALPS*VIEWF
      DH1= (XH1-XH2)/20.
      DH2= XH2/20.
      XH(1)=XH1
      DO 900 N=2,21
  900 XH(N)= XH(N-1)-DH1
      DO 901 N= 22,41
  901 XH(N)= XH(N-1)-DH2
      DO 902 N=1,41
      DO 903 K=1,41
      TEST1 = XH(N) -XHTD(K)
```

```
      IF(TEST1) 904,905,903
  905 DENB(N)= DENH(K)
      GO TO 902
  903 CONTINUE
  904 FACT1 =(XH(N)-XHTD(K-1))/(XHTD(K)-XHTD(K-1))
      DENB(N)= DENH(K-1)+ FACT1*(DENH(K)-DENH(K-1))
  902 CONTINUE
      TAUA(1)= 0.0
      V90= (2./(3.*7.48))/(BE1**.5)
      DO 906 N= 2,21
      V91= XH(N)-XH(N-1)
      V92= DENB(N)**1.5 - DENB(N-1)**1.5
      V93= DENB(N) - DENB(N-1)
      VEL(1) = 7.48*(BE1/DENB(1))**.5
      VEL(N) = 7.48*(BE1/DENB(N))**.5
      DTAU1 =-(V90*V91*V92/(V93*3600.))*3280.
  906 TAUA(N)=TAUA(N-1) + DTAU1
      V90 = (2./(3.*7.48))/(BE2**.5)
      DO 907 N= 22,41
      V91= XH(N)- XH(N-1)
      V92= DENB(N)**1.5 - DENB(N-1)**1.5
      V93= DENB(N) - DENB(N-1)
      VEL(N)  = 7.48 * (BE2/DENB(N))**.5
      DTAU2 = -(V90*V91*V92/(V93*3600.))*3280.
  907 TAUA(N)= TAUA(N-1)+ DTAU2
  910 FORMAT(1H1)
      WRITE(3,910)
      WRITE(3,500)
  801 FORMAT(' XH1- ALT. AT BEGINNING OF SUBSONIC DESCENT, KM ABOVE 605
     1 RADIUS = ',E13.5)
      WRITE(3,801) XH1
  802 FORMAT(' XH2- ALT. AT CHUTE RELEASE, KM ABOVE 6050 RADIUS = ',
     1E13.5)
      WRITE(3,802) XH2
  803 FORMAT(' BE1- BALLISTIC COEF. CORRESPONDING TO XH1, SLUGS/FT**2 =
     1',E13.5)
      WRITE(3,803) BE1
  804 FORMAT(' BE2- BALLISTIC COEF. CORRESPONDING TO XH2, SLUGS/FT**2 =
     1',E13.5)
      WRITE(3,804) BE2
  805 FORMAT(' XMASI- MASS OF SCI. AND COMM. EQUIP.,LB-M = ',E13.5)
      WRITE(3,805) XMASI
      WRITE(3,500)
  908 FORMAT('   ALTITUDE,KM   TIME,HOURS   VELOCITY,FPS   ')
      WRITE(3,908)
  909 FORMAT(4X,F8.3,7X,F7.3,7X,F8.3)
      WRITE(3,909)(XH(N),TAUA(N),VEL(N), N=1,41)
      WRITE(3,910)
      ICONT= 0
      WRITE(3,500)
  500 FORMAT('*************************************************************
     1*****************************************')
      WRITE(3,500)
  420 FORMAT('  STRUCTURAL WT INCLUDES 25 PERCENT OF INSTRU. WT ')
  440 FORMAT(' WHICH ACCOUNTS FOR INTERNAL STRUCTURE, THIS INTERNAL
     1STRUCTURE ACTS AS HEAT SINK, CP=.20')
      WRITE(3,420)
```

```
      WRITE(3,440)
      WRITE(3,500)
  400 FORMAT(1X,'INSUL.',2X,'L/D',2X,'OUTSIDE',2X,'TOTAL',6X,'MASS OF',
     13X,'MASS OF',2X,'MASS OF',3X,'MASS OF',2X,'VOLUME',6X,'VOLUME',
     23X,'VOLUME',4X,'HEAT TRANSFER,')
  401 FORMAT(1X,'THICK-',7X,'DIA.,IN.',1X,'MASS-',6X,'INSTRU.,',2X,
     1'INSUL.,',2X,'STRUC-',4X,'PCM,LB,',2X,'OF INSTRU.',2X,'OF PCM,',
     22X,'OF',13X,'BTU')
  402 FORMAT(1X,'NESS,',17X,'INSTRU.,',3X,'LB-MASS',3X,'LB-MASS',2X,
     1'TURE,LB-',2X,'MASS',5X,'FT-CU',7X,'FT-CU',4X,'INSUL.,',3X,
     2'THRU    ELECT.')
  403 FORMAT(1X,'INCHES',16X,'INSUL.,',23X,'MASS',36X,'FT-CU',5X,
     1'INSUL.  DISSIP-')
  404 FORMAT(23X,'STRUCTURE',79X,'ATION')
  405 FORMAT(23X,'AND PCM,')
  406 FORMAT(24X,'LB-MASS')
      VOLIP=XMASI/DENI
      VOLI=XMASI/DENI
      THICK=THICI
      XLOD=XLODI
  102 DIA1=2.*THICK+((VOLIP/(PI*(.1666+.25*(XLOD-1.))))**.333)*12.
      IF(XLOD-1.05)50,50,51
   50 DIA= DIA1/.95
      THICS=0.025*DIA
      GO TO 52
   51 THICS=0.05*DIA1
      V1=(2.*THICS+2.*THICK)/(DIA1-2.*THICS -2.*THICK)
      V2=.25*(XLOD-1.)*V1
      V3=(.16666+.25*(XLOD-1.)+V2)*PI
      DIA=(2.*THICK+((VOLIP/V3)**.333)*12.)/.9
      THICS=0.050*DIA
   52 CONTINUE
      APS=(PI*XLOD*DIA**2)/144.
      V4=DIA-2.*THICS -2.*THICK
      V5=DIA-2.*THICS
      V6= PI*DIA*(XLOD-1.)*2.*THICK/144.
      AK1 = V6/(ALOG(V5/V4))
      AK2 = PI*V5*V4 / 144.
      AK = AK1 + AK2
      XMK  =AK*THICK*DENK/12.
      VOLK = AK*THICK/12.
      TH1 = SPRES*SFACH*(DIA/2.)**2/(2.*EMOD)
      TH2= 3.*(1.-PRAT**2)
      THS= (TH1*(TH2**.5))**.5
      THS1  = SPRES*DIA*SFACH/(4.*STREA)
      IF(THS-THS1)702,702,703
  702 THS = THS1
  703 XMSTS = THS*PI*(DIA**2)*DENSH
      IF(XLOD-1.05)300,300,301
  300 XMSTR = XMSTS + .25*XMASI
      XMTOT = XMK + XMPCM + XMSTR + XMASI
      GO TO 302
  301 TH3 = SPRES*SFACH*(DIA/2.)**1.5
      TH4=  TH3/(.736*EMOD)
      THC= TH4**.4
      THC1  = SPRES*DIA*SFACH/(2.*STREA)
      IF(THC-THC1) 704,704,705
```

BK

```
704 XMSTC = THC1*PI*(DIA**2)*(XLOD-1.)*DENSH
    GO TO 706
705 XMSTC = THC*PI*(DIA**2)*(XLOD-1.)*DENSH*1.5
706 CONTINUE
    XMSTR = XMSTC+XMSTS+ .25*XMASI
    XMTOT = XMK + XMPCM + XMSTR + XMASI
302 CONTINUE
    T4  = TSHI
    T5  =  TSHI
    T6  =  TSHI
    T7  =  TEMPI
    CON1P= APS
    CON2P = EMIS*SB*APS*VFAC2
    CON3P= EMIS*SB*APS*VFAC2
    CON4  =  1728.*CONDS*(APS**2)*DENSH/(XMSTR-.25*XMASI)
    CON5 = 2.*CONDI*AK/(THICK/12.)
    CON6  =  CON5
    CAP4 = (XMSTR - .25*XMASI)*CPS
    CAP5 = .5*XMK*CPII
    CAP6 = CAP5
    DTAUC = TAUA(41)/40.
    TNEW4 = T4
    TNEW5 = T5
    TNEW6 = T6
    QTOTI = 0.0
    TIME = 0.0
    XN = 1.0
929 CONTINUE
    QTEST = TIME + DTAUC - TAUA(41)
    IF(QTEST) 973,974,974
974 DTAUC = TAUA(41) - TIME - .000001
973 CONTINUE
    T4 = TNEW4
    T5 = TNEW5
    T6 = TNEW6
    T4OLD= T4
    T5OLD= T5
    T6OLD= T6
    TIME = TIME + DTAUC
    Q47 = CON7*(T4OLD-T7)*DTAUC
    Q67 = CON6*(T6OLD-T7)*DTAUC
    QTOTI = QTOTI + Q47 + Q67
    QRATE = (Q47+Q67) /DTAUC
    DO 917 N= 1,41
    TEST2 = TIME - TAUA(N)
    IF(TEST2) 918,919,917
919 XHT = XH(N)
    GO TO 920
917 CONTINUE
918 FACT2 = (TIME - TAUA(N-1))/(TAUA(N)-TAUA(N-1))
    XHT = XH(N-1) + FACT2*(XH(N)-XH(N-1))
920 CONTINUE
    DO 921 N= 1,41
    TEST3 = XHT - XHTD(N)
    IF(TEST3) 922,923,921
923 T1= TAMB(N)
    T2= TSKY(N)
```

B-16

```
      T3= TCLO(N)
      QS = QSUN(N)
      DATM= DENH(N)
      GO TO 924
  921 CONTINUE
  922 FACT3 = (XHT - XHTD(N-1))/(XHTD(N) - XHTD(N-1))
      T1 = TAMB(N-1) + FACT3*(TAMB(N) - TAMB(N-1))
      T2 = TSKY(N-1) + FACT3*(TSKY(N)- TSKY(N-1))
      T3 = TCLO(N-1) + FACT3*(TCLO(N)- TCLO(N-1))
      QS = QSUN(N-1) + FACT3*(QSUN(N)- QSUN(N-1))
      DATM= DENH(N-1)+ FACT3*(DENH(N)- DENH(N-1))
  924 CONTINUE
      DO 940 N = 1,12
      TEST4 = T1 - TEMPP(N)
      IF(TEST4) 925,926,940
  926 CONAS = CONA(N)
      PR3S = PR3(N)
      VISAS = VISA(N)
      GO TO 941
  940 CONTINUE
  925 CONTINUE
      FACT4 = (T1 - TEMPP(N-1))/(TEMPP(N)- TEMPP(N-1))
      PR3S = PR3(N-1)+ FACT4*(PR3(N)- PR3(N-1))
      VISAS = VISA(N-1) + FACT4*(VISA(N)- VISA(N-1))
      CONAS = CONA(N-1) + FACT4*(CONA(N)- CONA(N-1))
  941 CONTINUE
      IF(XHT - XH2 ) 970,971,971
  971 BE = BE1
      GO TO 928
  970 BE = BE2
  928 CONTINUE
      VELT = 7.48 *(BE/DATM)**.5
      RE = (DATM*VELT*DIA/VISAS)*(32.2/12.)
      XNU = 2. + .6*(RE**.5)*PR3S
      FILM=  (XNU*CONAS/DIA)*12.
      CON1 = FILM* CON1P
      CON2 = CON2P*(T2**2 + T4OLD**2)*(T2+T4OLD)
      CON3 = CON3P*(T3**2 + T4OLD**2)*(T3+T4OLD)
      SCON1 = -CON1*T1-CON2*T2-CON3*T3-CON7*T7-QS*APS*CAP4 *T4/DTAUC
      SCON2  = CON1+CON2+CON3+CON4+CON7+CAP4/DTAUC
      SCON3 = -CAP5*T5/DTAUC
      SCON4  =  CON4+CON5+CAP5/DTAUC
      SCON5 = -CON6*T7-CAP6*T6/DTAUC
      SCON6  =  CON5+CON6+CAP6/DTAUC
      SCON7 = SCON3+CON4*SCON1/SCON2+CON5*SCON5/SCON6
      SCON8 = (CON4**2)/SCON2+(CON5**2)/SCON6-SCON4
      TNEW5 = SCON7/SCON8
      TNEW6 = (CON5*TNEW5-SCON5)/SCON6
      TNEW4 = (CON4*TNEW5-SCON1)/SCON2
      IF(ICONT) 980,980,981
  981 CONTINUE
  982 FORMAT(1X,'TIME=',F7.3,' AMB.TEMP=',F7.1,' SURF.TEMP=',F7.1,
     1' T2=',F7.1,' T3=',F7.1,' T5=',F7.1,' T6=',F7.1,' FILM=',F7.2)
      WRITE(3,982) TIME,T1,T4,T2,T3,T5,T6,FILM
  980 CONTINUE
      IF(TAUA(41)-TIME-.0001) 933,933,929
  933 CONTINUE
```

B7

```
      QTOTE  =  QI*3.412*TAUA(41)
      XMPCM  =  (QTOTI+QTOTE-1.25*XMASI*CPI*DTI)/XHPCM
      IF(XMPCM)  700,700,701
  700 XMPCM  = 0.0
  701 DTIP = (QTOTI + QTOTE )/( 1.25*XMASI*CPI)
      VPCM = XMPCM/DPCM
      VTOT  = VOLI+VPCM
      TESTV=  (VOLIP-VTOT)  /VOLIP
      TESTV=ABS(TESTV)
      IF(ICONT) 103,103,104
  104 CONTINUE
      WRITE(3,500)
      WRITE(3,400)
      WRITE(3,401)
      WRITE(3,402)
      WRITE(3,403)
      WRITE(3,404)
      WRITE(3,405)
      WRITE(3,406)
  407 FORMAT(1X,F6.3,1X,F4.1,2X,F6.2,3X,F6.1,5X,F6.1,4X,F6.1,3X,F6.1,
     14X,F6.1,4X,F5.2,7X,F5.2,4X,F5.2,3X,F7.1,2X,F7.1)
      WRITE(3,407)THICK,XLOD,DIA,XMTOT,XMASI,XMK,XMSTR,XMPCM,VOLI,VPCM
     1,VOLK,QTOTI,QTOTE
      IF(XMPCM) 707,707,708
  707 CONTINUE
  709 FORMAT('    CHANGE IN INSTRUMENT TEMP. = ',F8.2)
      WRITE (3,709) DTIP
  708 CONTINUE
      WRITE(3,500)
      WRITE(3,910)
      WRITE(3,500)
      GO TO 105
  103 IF(TESTV -.01) 100,100,101
  101 VOLIP= VOLI +VPCM
      GO TO 102
  100 VOLIP= VOLI +VPCM
      ICONT =1
      GO TO 102
  105 ICONT =0
      THICK=THICK+DTHIC
      IF(THICK-THICM )102,102,107
  107 XLOD=XLOD+DLOD
      THICK=THICI
      IF(XLOD-XLODM)102,102,108
  108 CONTINUE
      STOP
      END

FEATURES SUPPORTED
 ONE WORD INTEGERS
 IOCS

CORE REQUIREMENTS FOR
 COMMON       0  VARIABLES    1302  PROGRAM    3448

END OF COMPILATION
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E.18

ILLUSTRATION

TEXT

DESCENT PROBE THERMAL
AND STRUCTURAL DESIGN PROGRAM SAMPLE OUTPUT

TEXT

```
**********************************************************************
XH1= ALT. AT BEGINNING OF SUBSONIC DESCENT, KM ABOVE 6050 RADIUS =   0.72500E 02
XH2= ALT. AT CHUTE RELEASE, KM ABOVE 6050 RADIUS =   0.40000E 02
RE1= BALLISTIC COEF. CORRESPONDING TO XH1, SLUGS/FT**2 =   0.35000E-01
RE2= BALLISTIC COEF. CORRESPONDING TO XH2, SLUGS/FT**2 =   0.20000E 01
XMASS= MASS OF SC, AND COMPL EQUIP, LB-M =   0.12560E 03
**********************************************************************
   ALTITUDE,KM    TIME,HOURS    VELOCITY,FPS
        72.500         0.000           9.875
        70.875         0.017          79.965
        69.250         0.037          69.860
        67.625         0.059          61.228
        66.000         0.085          53.798
        64.375         0.115          47.624
        62.750         0.148          41.314
        61.125         0.187          36.088
        59.500         0.231          31.767
        57.875         0.280          28.106
        56.250         0.336          25.250
        54.625         0.398          22.771
        53.000         0.466          20.667
        51.375         0.541          18.875
        49.750         0.623          17.334
        48.125         0.712          15.967
        46.500         0.809          14.738
        44.875         0.914          13.652
        43.250         1.026          12.688
        41.625         1.147          11.828
        40.000         1.277          11.056
        38.000         1.299          77.082
        36.000         1.324          71.318
        34.000         1.351          66.179
        32.000         1.379          61.577
        30.000         1.410          57.442
        28.000         1.443          53.710
        26.000         1.478          50.214
        24.000         1.515          47.033
        22.000         1.555          44.131
        20.000         1.598          41.477
        18.000         1.643          39.045
        16.000         1.691          36.811
        14.000         1.742          34.755
        12.000         1.796          32.841
        10.000         1.853          31.052
         8.000         1.914          29.394
         6.000         1.978          27.856
         4.000         2.045          26.429
         2.000         2.116          25.097
         0.000         2.190          23.857
```

BASE LINE CAPTION (VERTICAL)

CLASSIFICATION
IF PERCENT

STRUCTURAL WT INCLUDES 25 PERCENT OF INSTRU. WT
WHICH ACCOUNTS FOR INTERNAL STRUCTURE. THIS INTERNAL STRUCTURE ACTS AS HEAT SINK. CP=.20

TIME=	0.054	AMB.TEMP=	1.3	SURF.TEMP=	70.0	T2=	-450.0	T3=	26.1	T5=	70.0	T6=	70.0	FILM=	1.07
TIME=	0.109	AMB.TEMP=	11.9	SURF.TEMP=	97.2	T2=	-450.0	T3=	26.1	T5=	97.2	T6=	70.2	FILM=	1.25
TIME=	0.164	AMB.TEMP=	19.9	SURF.TEMP=	122.4	T2=	-450.0	T3=	26.1	T5=	122.3	T6=	70.7	FILM=	1.41
TIME=	0.219	AMB.TEMP=	26.2	SURF.TEMP=	145.2	T2=	26.2	T3=	26.2	T5=	145.1	T6=	71.4	FILM=	1.55
TIME=	0.273	AMB.TEMP=	31.6	SURF.TEMP=	135.0	T2=	31.6	T3=	31.6	T5=	135.0	T6=	72.0	FILM=	1.69
TIME=	0.328	AMB.TEMP=	52.7	SURF.TEMP=	125.5	T2=	52.7	T3=	52.7	T5=	125.5	T6=	72.5	FILM=	1.85
TIME=	0.383	AMB.TEMP=	72.8	SURF.TEMP=	118.2	T2=	72.8	T3=	72.8	T5=	118.2	T6=	72.9	FILM=	2.01
TIME=	0.438	AMB.TEMP=	91.6	SURF.TEMP=	113.3	T2=	91.6	T3=	91.6	T5=	113.3	T6=	73.3	FILM=	2.16
TIME=	0.492	AMB.TEMP=	110.3	SURF.TEMP=	110.7	T2=	110.3	T3=	110.3	T5=	110.7	T6=	73.6	FILM=	2.29
TIME=	0.547	AMB.TEMP=	129.0	SURF.TEMP=	110.6	T2=	129.0	T3=	129.0	T5=	110.6	T6=	74.0	FILM=	2.42
TIME=	0.602	AMB.TEMP=	146.9	SURF.TEMP=	112.7	T2=	146.9	T3=	146.9	T5=	112.7	T6=	74.3	FILM=	2.54
TIME=	0.657	AMB.TEMP=	163.8	SURF.TEMP=	117.0	T2=	163.8	T3=	163.8	T5=	117.0	T6=	74.7	FILM=	2.65
TIME=	0.711	AMB.TEMP=	180.2	SURF.TEMP=	123.2	T2=	180.2	T3=	180.2	T5=	123.1	T6=	75.1	FILM=	2.76
TIME=	0.766	AMB.TEMP=	195.3	SURF.TEMP=	130.9	T2=	195.3	T3=	195.3	T5=	130.9	T6=	75.6	FILM=	2.87
TIME=	0.821	AMB.TEMP=	210.2	SURF.TEMP=	140.0	T2=	210.2	T3=	210.2	T5=	140.0	T6=	76.1	FILM=	3.00
TIME=	0.876	AMB.TEMP=	224.2	SURF.TEMP=	150.3	T2=	224.2	T3=	224.2	T5=	[illegible]	T6=	76.8	FILM=	3.14
TIME=	0.930	AMB.TEMP=	237.9	SURF.TEMP=	161.5	T2=	237.9	T3=	237.9	T5=	[illegible]	T6=	77.5	FILM=	3.27
TIME=	0.985	AMB.TEMP=	250.8	SURF.TEMP=	173.5	T2=	250.8	T3=	250.8	T5=	173.[illegible]	T6=	78.4	FILM=	3.40
TIME=	1.040	AMB.TEMP=	263.6	SURF.TEMP=	186.1	T2=	263.6	T3=	263.6	T5=	186.0	T6=	79.4	FILM=	3.53
TIME=	1.095	AMB.TEMP=	275.7	SURF.TEMP=	199.1	T2=	275.7	T3=	275.7	T5=	199.0	T6=	80.4	FILM=	3.65
TIME=	1.150	AMB.TEMP=	287.7	SURF.TEMP=	212.2	T2=	287.7	T3=	287.7	T5=	212.2	T6=	81.6	FILM=	3.78
TIME=	1.204	AMB.TEMP=	299.0	SURF.TEMP=	225.6	T2=	299.0	T3=	299.0	T5=	225.5	T6=	82.9	FILM=	3.90
TIME=	1.259	AMB.TEMP=	310.3	SURF.TEMP=	238.8	T2=	310.3	T3=	310.3	T5=	238.8	T6=	84.3	FILM=	4.01
TIME=	.314	AMB.TEMP=	366.1	SURF.TEMP=	252.0	T2=	366.1	T3=	366.1	T5=	251.9	T6=	85.7	FILM=	12.51
TIME=	1.369	AMB.TEMP=	433.6	SURF.TEMP=	299.9	T2=	433.6	T3=	433.6	T5=	299.7	T6=	87.7	FILM=	14.49
TIME=	1.423	AMB.TEMP=	492.5	SURF.TEMP=	360.9	T2=	492.5	T3=	492.5	T5=	360.7	T6=	90.1	FILM=	16.37
TIME=	1.478	AMB.TEMP=	540.9	SURF.TEMP=	424.9	T2=	540.9	T3=	540.9	T5=	424.6	T6=	93.2	FILM=	18.10
TIME=	1.533	AMB.TEMP=	582.0	SURF.TEMP=	484.1	T2=	582.0	T3=	582.0	T5=	483.9	T6=	96.7	FILM=	19.70
TIME=	1.588	AMB.TEMP=	620.0	SURF.TEMP=	536.1	T2=	620.0	T3=	620.0	T5=	535.9	T6=	100.7	FILM=	21.22
TIME=	1.642	AMB.TEMP=	655.2	SURF.TEMP=	582.1	T2=	655.2	T3=	655.2	T5=	581.9	T6=	105.1	FILM=	22.67
TIME=	1.697	AMB.TEMP=	687.9	SURF.TEMP=	623.2	T2=	687.9	T3=	687.9	T5=	623.1	T6=	109.7	FILM=	24.06
TIME=	1.752	AMB.TEMP=	718.4	SURF.TEMP=	660.5	T2=	718.4	T3=	718.4	T5=	660.4	T6=	114.7	FILM=	25.35
TIME=	1.807	AMB.TEMP=	745.9	SURF.TEMP=	694.5	T2=	745.9	T3=	745.9	T5=	694.4	T6=	119.8	FILM=	26.57
TIME=	1.861	AMB.TEMP=	771.0	SURF.TEMP=	725.2	T2=	771.0	T3=	771.0	T5=	725.1	T6=	125.2	FILM=	27.72
TIME=	1.916	AMB.TEMP=	794.8	SURF.TEMP=	752.9	T2=	794.8	T3=	794.8	T5=	752.8	T6=	130.7	FILM=	28.84
TIME=	1.971	AMB.TEMP=	817.5	SURF.TEMP=	778.6	T2=	817.5	T3=	817.5	T5=	778.5	T6=	136.4	FILM=	29.92
TIME=	2.026	AMB.TEMP=	839.2	SURF.TEMP=	802.7	T2=	839.2	T3=	839.2	T5=	802.6	T6=	142.2	FILM=	30.97
TIME=	2.081	AMB.TEMP=	860.0	SURF.TEMP=	825.6	T2=	860.0	T3=	860.0	T5=	825.5	T6=	147.1	FILM=	31.99
TIME=	2.135	AMB.TEMP=	880.1	SURF.TEMP=	847.4	T2=	880.1	T3=	880.1	T5=	847.3	T6=	154.1	FILM=	32.99
TIME=	2.190	AMB.TEMP=	899.5	SURF.TEMP=	868.2	T2=	899.5	T3=	899.5	T5=	868.2	T6=	160.2	FILM=	33.95

INSUL. THICKNESS, INCHES	L/D	OUTSIDE DIA., IN.	TOTAL MASS= INSTRU.+ INSUL.+ STRUCTURE AND PCM, LB=MASS	MASS OF INSTRU., LB=MASS	MASS OF INSUL., LB=MASS	MASS OF STRUCTURE, LB=MASS	MASS OF PCM, LB. MASS	VOLUME OF INSTRU. FT=CU	VOLUME OF PCM, FT=CU	VOLUME OF INSUL., FT=CU	HEAT TRANSFER. BTU THRU INSUL.	HEAT TRANSFER. BTU ELECT. DISSIPATION
0.800	1.5	21.53	258.3	125.6	7.9	118.5	6.3	3.13	0.12	0.79	466.8	2047.9

TIME=	0.054	AMB.TEMP=	1.3	SURF.TEMP=	70.0	T2=	-450.0	T3=	26.1	T5=	70.0	T6=	70.0	FILM=	1.06		
TIME=	0.109	AMB.TEMP=	11.9	SURF.TEMP=	96.6	T2=	-450.0	T3=	26.1	T5=	96.5	T6=	70.1	FILM=	1.23		
TIME=	0.164	AMB.TEMP=	19.9	SURF.TEMP=	121.2	T2=	-450.0	T3=	26.1	T5=	121.1	T6=	70.4	FILM=	1.40		
TIME=	0.219	AMB.TEMP=	26.2	SURF.TEMP=	143.5	T2=	26.2	T3=	26.2	T5=	143.4	T6=	70.9	FILM=	1.54		
TIME=	0.273	AMB.TEMP=	31.6	SURF.TEMP=	133.9	T2=	31.6	T3=	31.6	T5=	133.9	T6=	71.3	FILM=	1.67		
TIME=	0.328	AMB.TEMP=	52.7	SURF.TEMP=	124.8	T2=	52.7	T3=	52.7	T5=	124.8	T6=	71.6	FILM=	1.84		
TIME=	0.383	AMB.TEMP=	72.8	SURF.TEMP=	117.8	T2=	72.8	T3=	72.8	T5=	117.8	T6=	71.9	FILM=	1.99		
TIME=	0.438	AMB.TEMP=	91.6	SURF.TEMP=	113.1	T2=	91.6	T3=	91.6	T5=	113.1	T6=	72.1	FILM=	2.14		
TIME=	0.492	AMB.TEMP=	110.3	SURF.TEMP=	110.6	T2=	110.3	T3=	110.3	T5=	110.7	T6=	72.3	FILM=	2.27		
TIME=	0.547	AMB.TEMP=	129.0	SURF.TEMP=	110.5	T2=	129.0	T3=	129.0	T5=	110.5	T6=	72.6	FILM=	2.40		
TIME=	0.602	AMB.TEMP=	146.9	SURF.TEMP=	112.6	T2=	146.9	T3=	146.9	T5=	112.6	T6=	72.8	FILM=	2.51		
TIME=	0.657	AMB.TEMP=	163.8	SURF.TEMP=	116.8	T2=	163.8	T3=	163.8	T5=	116.8	T6=	73.1	FILM=	2.63		
TIME=	0.711	AMB.TEMP=	180.2	SURF.TEMP=	122.8	T2=	180.2	T3=	180.2	T5=	122.7	T6=	73.3	FILM=	2.74		
TIME=	0.766	AMB.TEMP=	195.3	SURF.TEMP=	130.4	T2=	195.3	T3=	195.3	T5=	130.3	T6=	73.7	FILM=	2.84		
TIME=	0.821	AMB.TEMP=	210.2	SURF.TEMP=	139.2	T2=	210.2	T3=	210.2	T5=	139.2	T6=	74.1	FILM=	2.97		
TIME=	0.876	AMB.TEMP=	224.2	SURF.TEMP=	149.3	T2=	224.2	T3=	224.2	T5=	149.3	T6=	74.5	FILM=	3.11		
TIME=	0.930	AMB.TEMP=	237.9	SURF.TEMP=	160.4	T2=	237.9	T3=	237.9	T5=	160.3	T6=	75.0	FILM=	3.24		
TIME=	0.985	AMB.TEMP=	250.8	SURF.TEMP=	172.2	T2=	250.8	T3=	250.8	T5=	172.2	T6=	75.6	FILM=	3.37		
TIME=	1.040	AMB.TEMP=	263.6	SURF.TEMP=	184.6	T2=	263.6	T3=	263.6	T5=	184.6	T6=	76.2	FILM=	3.50		
TIME=	1.095	AMB.TEMP=	275.7	SURF.TEMP=	197.5	T2=	275.7	T3=	275.7	T5=	197.4	T6=	76.9	FILM=	3.62		
TIME=	1.150	AMB.TEMP=	287.7	SURF.TEMP=	210.5	T2=	287.7	T3=	287.7	T5=	210.5	T6=	77.7	FILM=	3.75		
TIME=	1.204	AMB.TEMP=	299.0	SURF.TEMP=	223.8	T2=	299.0	T3=	299.0	T5=	223.7	T6=	78.6	FILM=	3.86		
TIME=	1.259	AMB.TEMP=	310.3	SURF.TEMP=	237.0	T2=	310.3	T3=	310.3	T5=	236.9	T6=	79.5	FILM=	3.97		
TIME=	1.314	AMB.TEMP=	366.1	SURF.TEMP=	250.1	T2=	366.1	T3=	366.1	T5=	250.1	T6=	80.5	FILM=	12.40		
TIME=	1.369	AMB.TEMP=	433.6	SURF.TEMP=	297.8	T2=	433.6	T3=	433.6	T5=	297.6	T6=	81.8	FILM=	14.37		
TIME=	1.423	AMB.TEMP=	492.5	SURF.TEMP=	358.5	T2=	492.5	T3=	492.5	T5=	358.3	T6=	83.5	FILM=	16.23		
TIME=	1.478	AMB.TEMP=	540.9	SURF.TEMP=	422.5	T2=	540.9	T3=	540.9	T5=	422.2	T6=	85.5	FILM=	17.95		
TIME=	1.533	AMB.TEMP=	582.0	SURF.TEMP=	481.9	T2=	582.0	T3=	582.0	T5=	481.7	T6=	87.9	FILM=	19.53		
TIME=	1.588	AMB.TEMP=	620.0	SURF.TEMP=	534.2	T2=	620.0	T3=	620.0	T5=	534.0	T6=	90.5	FILM=	21.04		
TIME=	1.642	AMB.TEMP=	655.2	SURF.TEMP=	580.5	T2=	655.2	T3=	655.2	T5=	580.3	T6=	93.5	FILM=	22.48		
TIME=	1.697	AMB.TEMP=	687.9	SURF.TEMP=	621.9	T2=	687.9	T3=	687.9	T5=	621.8	T6=	96.6	FILM=	23.85		
TIME=	1.752	AMB.TEMP=	718.4	SURF.TEMP=	659.4	T2=	718.4	T3=	718.4	T5=	659.3	T6=	99.9	FILM=	25.14		
TIME=	1.807	AMB.TEMP=	745.9	SURF.TEMP=	693.6	T2=	745.9	T3=	745.9	T5=	693.5	T6=	103.5	FILM=	26.34		
TIME=	1.861	AMB.TEMP=	771.0	SURF.TEMP=	724.4	T2=	771.0	T3=	771.0	T5=	724.3	T6=	107.1	FILM=	27.49		
TIME=	1.916	AMB.TEMP=	794.8	SURF.TEMP=	752.2	T2=	794.8	T3=	794.8	T5=	752.1	T6=	110.9	FILM=	28.59		
TIME=	1.971	AMB.TEMP=	817.5	SURF.TEMP=	778.0	T2=	817.5	T3=	817.5	T5=	777.9	T6=	114.8	FILM=	29.67		
TIME=	2.026	AMB.TEMP=	839.2	SURF.TEMP=	802.2	T2=	839.2	T3=	839.2	T5=	802.1	T6=	118.8	FILM=	30.71		
TIME=	2.081	AMB.TEMP=	860.0	SURF.TEMP=	825.1	T2=	860.0	T3=	860.0	T5=	825.0	T6=	122.9	FILM=	31.72		
TIME=	2.135	AMB.TEMP=	880.1	SURF.TEMP=	847.0	T2=	880.1	T3=	880.1	T5=	846.9	T6=	127.1	FILM=	32.70		
TIME=	2.190	AMB.TEMP=	899.5	SURF.TEMP=	867.9	T2=	899.5	T3=	899.5	T5=	867.8	T6=	131.3	FILM=	33.66		

INSUL. THICK-NESS, INCHES	L/D	OUTSIDE DIA., IN.	TOTAL MASS-INSTRU., INSUL., STRUCTURE AND PCM, LB-MASS	MASS OF INSTRU., LB-MASS	MASS OF INSUL., LB-MASS	MASS OF STRUC-TURE, LB-MASS	MASS OF PCM, LB-MASS	VOLUME OF INSTRU. FT-CU	VOLUME OF PCM, FT-CU	VOLUME OF INSUL., FT-CU	HEAT TRANSFER, BTU THRU INSUL.	HEAT TRANSFER, BTU ELECT. DISSIP-ATION
1.000	1.5	21.90	265.0	125.6	10.0	123.1	6.2	3.13	0.12	1.00	461.7	2047.9

TIME=	0.054	AMB.TEMP=	1.3	SURF.TEMP=	70.0	T2=	-450.0	T3=	26.1	T5=	70.0	T6=	70.0	FILM=	1.05		
TIME=	0.109	AMB.TEMP=	11.9	SURF.TEMP=	95.9	T2=	-450.0	T3=	26.1	T5=	95.8	T6=	70.1	FILM=	1.22		
TIME=	0.164	AMB.TEMP=	19.9	SURF.TEMP=	120.0	T2=	-450.0	T3=	26.1	T5=	119.9	T6=	70.3	FILM=	1.39		
TIME=	0.219	AMB.TEMP=	26.2	SURF.TEMP=	142.0	T2=	26.2	T3=	26.2	T5=	141.9	T6=	70.6	FILM=	1.53		
TIME=	0.273	AMB.TEMP=	31.6	SURF.TEMP=	132.8	T2=	31.6	T3=	31.6	T5=	132.8	T6=	70.9	FILM=	1.66		
TIME=	0.328	AMB.TEMP=	52.7	SURF.TEMP=	124.1	T2=	52.7	T3=	52.7	T5=	124.1	T6=	71.1	FILM=	1.82		
TIME=	0.383	AMB.TEMP=	72.8	SURF.TEMP=	117.4	T2=	72.8	T3=	72.8	T5=	117.4	T6=	71.3	FILM=	1.98		
TIME=	0.438	AMB.TEMP=	91.6	SURF.TEMP=	112.9	T2=	91.6	T3=	91.6	T5=	112.9	T6=	71.5	FILM=	2.12		
TIME=	0.492	AMB.TEMP=	110.3	SURF.TEMP=	110.5	T2=	110.3	T3=	110.3	T5=	110.6	T6=	71.6	FILM=	2.25		
TIME=	0.547	AMB.TEMP=	129.0	SURF.TEMP=	110.4	T2=	129.0	T3=	129.0	T5=	110.4	T6=	71.8	FILM=	2.38		
TIME=	0.602	AMB.TEMP=	146.9	SURF.TEMP=	112.5	T2=	146.9	T3=	146.9	T5=	112.5	T6=	71.9	FILM=	2.49		
TIME=	0.657	AMB.TEMP=	163.8	SURF.TEMP=	116.5	T2=	163.8	T3=	163.8	T5=	116.5	T6=	72.1	FILM=	2.61		
TIME=	0.711	AMB.TEMP=	180.2	SURF.TEMP=	122.4	T2=	180.2	T3=	180.2	T5=	122.3	T6=	72.3	FILM=	2.71		
TIME=	0.766	AMB.TEMP=	195.3	SURF.TEMP=	129.8	T2=	195.3	T3=	195.3	T5=	129.8	T6=	72.6	FILM=	2.82		
TIME=	0.821	AMB.TEMP=	210.2	SURF.TEMP=	138.5	T2=	210.2	T3=	210.2	T5=	138.4	T6=	72.9	FILM=	2.95		
TIME=	0.876	AMB.TEMP=	224.2	SURF.TEMP=	148.4	T2=	224.2	T3=	224.2	T5=	148.3	T6=	73.2	FILM=	3.08		
TIME=	0.930	AMB.TEMP=	237.9	SURF.TEMP=	159.2	T2=	237.9	T3=	237.9	T5=	159.2	T6=	73.5	FILM=	3.22		
TIME=	0.985	AMB.TEMP=	250.8	SURF.TEMP=	170.9	T2=	250.8	T3=	250.8	T5=	170.9	T6=	73.9	FILM=	3.34		
TIME=	1.040	AMB.TEMP=	263.6	SURF.TEMP=	183.2	T2=	263.6	T3=	263.6	T5=	183.1	T6=	74.4	FILM=	3.47		
TIME=	1.095	AMB.TEMP=	275.7	SURF.TEMP=	195.9	T2=	275.7	T3=	275.7	T5=	195.8	T6=	74.9	FILM=	3.59		
TIME=	1.150	AMB.TEMP=	287.7	SURF.TEMP=	208.9	T2=	287.7	T3=	287.7	T5=	208.8	T6=	75.5	FILM=	3.71		
TIME=	1.204	AMB.TEMP=	299.0	SURF.TEMP=	222.0	T2=	299.0	T3=	299.0	T5=	221.9	T6=	76.1	FILM=	3.83		
TIME=	1.259	AMB.TEMP=	310.3	SURF.TEMP=	235.2	T2=	310.3	T3=	310.3	T5=	235.1	T6=	76.7	FILM=	3.94		
TIME=	1.314	AMB.TEMP=	366.1	SURF.TEMP=	248.3	T2=	366.1	T3=	366.1	T5=	248.2	T6=	77.5	FILM=	12.30		
TIME=	1.369	AMB.TEMP=	433.6	SURF.TEMP=	295.7	T2=	433.6	T3=	433.6	T5=	295.5	T6=	78.4	FILM=	14.25		
TIME=	1.423	AMB.TEMP=	492.5	SURF.TEMP=	356.2	T2=	492.5	T3=	492.5	T5=	355.9	T6=	79.5	FILM=	16.09		
TIME=	1.478	AMB.TEMP=	540.9	SURF.TEMP=	420.1	T2=	540.9	T3=	540.9	T5=	419.8	T6=	81.0	FILM=	17.79		
TIME=	1.533	AMB.TEMP=	582.0	SURF.TEMP=	479.7	T2=	582.0	T3=	582.0	T5=	479.4	T6=	82.7	FILM=	19.36		
TIME=	1.588	AMB.TEMP=	620.0	SURF.TEMP=	532.3	T2=	620.0	T3=	620.0	T5=	532.0	T6=	84.6	FILM=	20.86		
TIME=	1.642	AMB.TEMP=	655.2	SURF.TEMP=	578.9	T2=	655.2	T3=	655.2	T5=	578.6	T6=	86.6	FILM=	22.29		
TIME=	1.697	AMB.TEMP=	687.9	SURF.TEMP=	620.6	T2=	687.9	T3=	687.9	T5=	620.4	T6=	88.9	FILM=	23.65		
TIME=	1.752	AMB.TEMP=	718.4	SURF.TEMP=	658.3	T2=	718.4	T3=	718.4	T5=	658.1	T6=	91.3	FILM=	24.93		
TIME=	1.807	AMB.TEMP=	745.9	SURF.TEMP=	692.7	T2=	745.9	T3=	745.9	T5=	692.5	T6=	93.8	FILM=	26.12		
TIME=	1.861	AMB.TEMP=	771.0	SURF.TEMP=	723.7	T2=	771.0	T3=	771.0	T5=	723.5	T6=	96.4	FILM=	27.25		
TIME=	1.916	AMB.TEMP=	794.8	SURF.TEMP=	751.6	T2=	794.8	T3=	794.8	T5=	751.4	T6=	99.1	FILM=	28.35		
TIME=	1.971	AMB.TEMP=	817.5	SURF.TEMP=	777.5	T2=	817.5	T3=	817.5	T5=	777.3	T6=	102.0	FILM=	29.42		
TIME=	2.026	AMB.TEMP=	839.2	SURF.TEMP=	801.7	T2=	839.2	T3=	839.2	T5=	801.6	T6=	104.9	FILM=	30.45		
TIME=	2.081	AMB.TEMP=	860.0	SURF.TEMP=	824.7	T2=	860.0	T3=	860.0	T5=	824.6	T6=	107.8	FILM=	31.45		
TIME=	2.135	AMB.TEMP=	880.1	SURF.TEMP=	846.6	T2=	880.1	T3=	880.1	T5=	846.4	T6=	110.9	FILM=	32.43		
TIME=	2.190	AMB.TEMP=	899.5	SURF.TEMP=	867.5	T2=	899.5	T3=	899.5	T5=	867.4	T6=	114.0	FILM=	33.38		

INSUL. THICK-NESS, INCHES	L/D	OUTSIDE DIA., IN.	TOTAL MASS-INSTRU., INSUL., STRUCTURE AND PCM, LB-MASS	MASS OF INSTRU., LB-MASS	MASS OF INSUL., LB-MASS	MASS OF STRUC-TURE, LB-MASS	MASS OF PCM, LB-MASS	VOLUME OF INSTRU. FT-CU	VOLUME OF PCM, FT-CU	VOLUME OF INSUL., FT-CU	HEAT TRANSFER, BTU THRU INSUL.	HEAT TRANSFER, BTU ELECT. DISSIP-ATION
1.200	1.3	22.28	272.0	125.6	12.2	127.9	6.2	3.13	0.12	1.22	456.4	204789

APPENDIX K

PLANETARY VEHICLE ATTITUDE CONTROL SYSTEM STUDY

This appendix documents the results of the preliminary ACS propellant usage study for the 1975 multiprobe mission. The baseline configuration for this study was Configuration 20a taken from a previous study performed for JPL by AVCO.

A. STABILIZATION OF INITIAL TIPOFF RATES

Following separation from the launch vehicle, the ACS is required to stabilize in a limit cycle made from any orientation within a 30-minute period and from an initial tumbling rate of 50×10^{-3} rad/sec. The following data were taken from the AVCO report* for configuration 20a:

Pitch and yaw thrust = 4.18×10^{-3} lb;

Roll thrust = 7.03×10^{-3} lb;

Pitch and yaw inertia = 100 slug/ft^2;

Roll inertia = 160 slug/ft^2;

Control moment arm = 9.5 ft.

The angular acceleration in each axis is through:

1) Pitch/yaw - $\ddot{\theta} = \frac{2\ Fl}{I} = \frac{(2)\ (4.18 \times 10^{-3})\ (9.5)}{100}$

$= 0.80 \times 10^{-3}$ rad/sec^2;

2) Roll - $\ddot{\phi} = \frac{2\ Fl}{I} = \frac{(2)\ (7.03 \times 10^{-3})\ (9.5)}{160}$

$= 0.835 \times 10^{-3}$ rad/sec^2.

*1972 Venus Flyby/Entry Probe Mission Study. AVSSD-080-68-RR. AVCO Corp, April 1968.

The time required to drive the initial tipoff rate of 50 x 10^{-3} rad/sec to zero is:

1) Pitch/yaw - $t = \frac{\dot{\theta}_o}{\ddot{\theta}} = 62.5$ sec;

2) Roll - $t = \frac{\dot{\phi}_o}{\ddot{\phi}} = 60.0$ sec.

During this time, the following attitude angles will develop:

1) Pitch/yaw - $\theta = \dot{\theta}_o\, t - \frac{1}{2}\ddot{\theta}\, t^2 = 90°$;

2) Roll - $\phi = \dot{\phi}_o\, t - \frac{1}{2}\ddot{\phi}\, t^2 = 86°$.

Because the moments of inertia for the proposed spacecraft are considerably higher than those of AVCO Configuration 20a, one approach is to increase the thrust levels so that the angular accelerations of the Configuration 20a vehicle are applicable to the current spacecraft:

1) Pitch/yaw - $T = \frac{1000}{100} \times 4.18 \times 10^{-3} = 43 \times 10^{-3}$ lb;

2) Roll - $T = \frac{570}{160} \times 7.03 \times 10^{-3} = 25 \times 10^{-3}$ lb.

Using the above-calculated values of thrust, the multiprobe spacecraft will null out initial tipoff rates in the same time span as the Configuration 20a vehicle.

The amount of propellant required to null out the initial tipoff rates is given below:

1) Pitch/yaw - $\omega = \frac{2T\dot{\theta}}{I_{sp}} = 76.8 \times 10^{-3}$ lb;

2) Roll - $\omega = \frac{2T\dot{\phi}}{I_{sp}} = 43 \times 10^{-3}$ lb.

B. REORIENTATION OF SPACECRAFT TO SUN REFERENCE

After the initial tipoff rates have been reduced to zero, the spacecraft must perform pitch and yaw maneuvers to align the sun sensor with the sun. The assumptions were made that each maneuver required a 180° turn and that the commanded rate of $\pi \times 10^{-3}$ used by the Mariner Mars would be retained.

Pitch/Yaw Channels - The on-time to reach the commanded rate is

$$t = \frac{\dot{\theta}_c}{\ddot{\theta}} = \frac{3.1416 \times 10^{-3}}{0.80 \times 10^{-3}} = 3.93 \text{ sec.}$$

During this time, the change in attitude is

$$\theta = \tfrac{1}{2} \ddot{\theta} t^2 = 6.2 \times 10^{-3} \text{ rad.}$$

The distance the spacecraft must coast is

$$\theta_{coast} = 3.1416 - 12.4 \times 10^{-3} \cong 3.1416 \text{ rad,}$$

and the time of coast is

$$t = \frac{\theta}{\dot{\theta}_c} = \frac{3.1416}{3.1416 \times 10^{-3}} = 1000 \text{ sec} = 16.7 \text{ min.}$$

The propellant usage for this maneuver is

$$\omega = \frac{2Tt}{I_{sp}} (2) = 9.6 \times 10^{-3} \text{ lb.}$$

C. ORIENTATION OF SPACECRAFT TO CANOPUS

After the spacecraft has oriented itself with the sun, a roll maneuver will be performed to align the star tracker with Canopus. An attitude error of 180° was assumed for this maneuver, along with a commandel rate of $\pi \times 10^{-3}$ rad/sec.

The on-time to reach the commanded rate is

$$t = \frac{\dot{\theta}_c}{\ddot{\theta}} = 3.75 \text{ sec.}$$

Because the change in attitude during this time is small with respect to the total required attitude change, the time of coast will be

$$t_t = \frac{\theta}{\dot{\theta}_c} = 1000 \text{ sec.}$$

The propellant usage for this maneuver is

$$\omega = \frac{2T}{I_{sp}} (2) = 5.36 \times 10^{-3} \text{ lb.}$$

D. NORMAL LIMIT CYCLE OPERATION

Once the spacecraft has aligned itself with the sun/Canopus reference, it will enter the limit cycle phase of operation. The deadband was held at the Mariner Mars value, and the minimum on-time was taken to be 20 msec. From Fig. K-1, Δt_1 is equal to one-half of the total on-time, or 10 msec. Then,

$$\dot{\theta}_{LC} = \ddot{\theta} \, \Delta t_1.$$

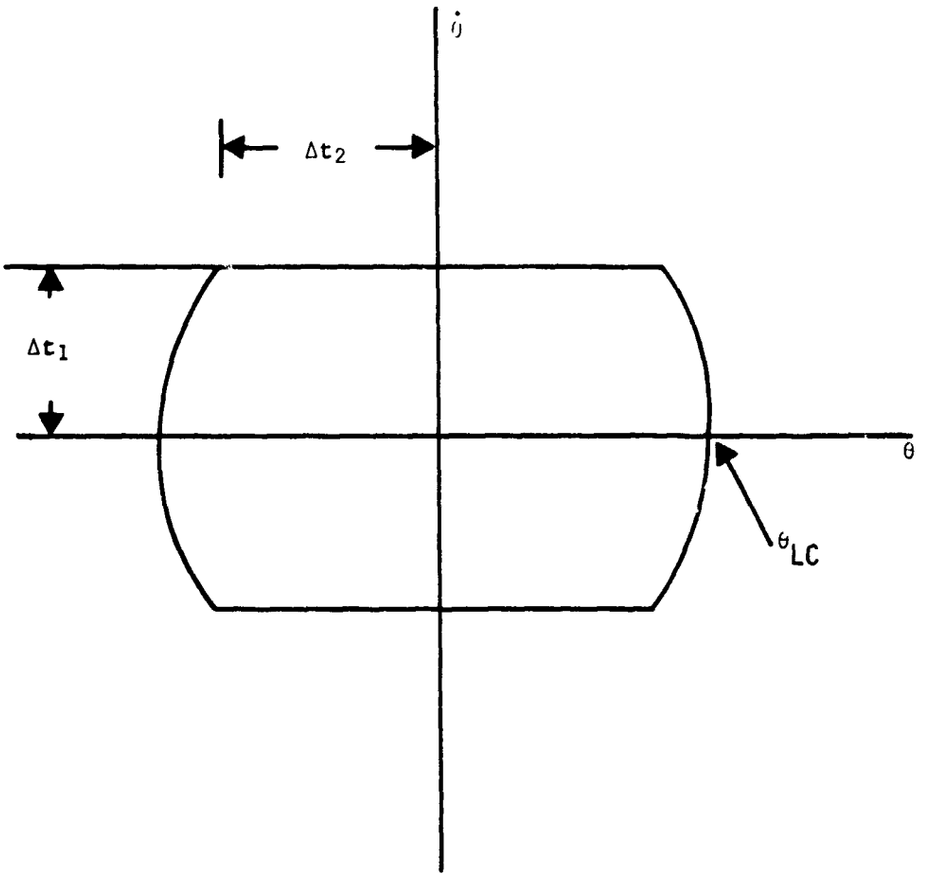


Fig. K-1 Limit Cycle Diagram

a. Pitch/Yaw $\left(\theta_{LC} = \pm 4 \times 15^{\circ} \text{ rad}\right)$

$\dot{\theta}_{LC} = (0.8 \times 10^{-3})\ (10 \times 10^{-3}) = 8 \times 10^{-6}$ rad/sec.

The attitude change that takes place during the time span Δt_1 is

$$\theta = \tfrac{1}{2}\, \ddot{\theta}\, \left(\Delta t_1\right)^2 = \frac{(0.8 \times 10^{-3})\ (10^{-4})}{2},$$

$$= 4 \times 10^{-8} \text{ rad.}$$

The distance to be traveled during Δt_2 is

$$4 \times 10^{-3} - 4 \times 10^{-8} \cong 4 \times 10^{-3} \text{ rad;}$$

therefore,

$$\Delta t_2 = \frac{4 \times 10^{-3}}{8 \times 10^{-6}} = 500 \text{ sec}$$

The total time per limit cycle is then approximately 2000 sec, or 1.8 limit cycles per hour, and the total on-time per limit cycle is 40×10^{-3} sec. The propellant usage per limit cycle is

$$\omega = \frac{2T\left(4\ \Delta t_1\right)}{I_{sp}} = 49.2 \times 10^{-6} \text{ lb/limit cycle}$$

The length of the mission was taken to be 153 days or 3.672×10^3 hr. The total propellant used for limit cycles (for either the pitch or yaw channel) is

$$\omega_T = (49.2 \times 10^{-6})\ (1.8)\ (3.672 \times 10^3),$$

$$= 0.326 \text{ lb/channel.}$$

b. Roll $\left(\theta_{LC} = \pm 4.3 \times 10^{-3} \text{ rad}\right)$

$$\dot{\theta}_{LC} = 8.35 \times 10^{-6} \text{ rad/sec,}$$

$$\Delta t_2 = \frac{4.3 \times 10^{-3}}{8.35 \times 10^{-6}} = 515 \text{ sec.}$$

The total time per limit cycle is then 2060 sec, or 1.75 limit cycles per hour. The propellant usage per limit cycle is

$$\omega = \frac{2T\left(4\ \Delta t_1\right)}{I_{sp}} = 28.6 \times 10^{-6} \text{ lb/limit cycle,}$$

$$\omega_T = \left(28.6 \times 10^{-6}\right)(1.75)(3.672 \times 10^3),$$

$$= 0.184 \text{ lb.}$$

E. MIDCOURSE MANEUVER

The ACS will be used to orient the spacecraft so that the main engine is directed to provide the required midcourse correction. Assuming a commanded rate of $\pi \times 10^{-3}$ rad/sec as before, the propellant usage for each channel (from Sections B and C) is

Pitch - 9.6×10^{-3} lb

Yaw - 9.6×10^{-3} lb

Roll - 5.4×10^{-3} lb

The ACS will be used to null out cg offsets and thrust misalignments during the main engine burn. The ΔV requirement on the main engine is 27 m/sec or 88.5 fps. The vehicle weight at this time is 2700 lb, and the mass is 84 slugs. The impulse applied to the spacecraft is $M\Delta V = 7.44 \times 10^3$ lb-sec. Assuming that the main engine is mounted 3 ft from the cg and with a 1° thrust misalignment,

$$\ell_1 = 3 \tan 1° = 0.05 \text{ ft},$$

$$M\Delta V\ \ell_1 = I\ \dot{\theta} = 2TL\Delta t.$$

The propellant usage to control main engine thrust misalignments is then

$$\omega = \frac{2T\Delta t}{I_{sp}} = \frac{M\Delta V\ \ell_1}{L\ I_{sp}} = 0.56 \text{ lb (pitch or yaw roll)}.$$

Assuming a cg uncertainty of $\ell_2 = 0.1$ in., the propellant usage is:

$$= \frac{M\Delta V\ \ell_2}{L\ I_{sp}} = 0.0932 \text{ lb}.$$

To be conservative, the above-calculated values were added directly, rather than using an RSS value. The total usage to control offsets during main engine burn is then (0.560 + 0.093) = 0.653 lb.

F. PROBE EJECT

There will be four probes on the Mariner Venus '72 spacecraft. For each probe, the spacecraft must go through a series of pitch and roll maneuvers to orient the probe to the proper attitude for ejection. Also, after the last probe ejection, the spacecraft must be reoriented to the sun-Canopus reference. For conservatism in the propellant usage calculations, three basic assumptions were made:

1) The spacecraft must reorient itself to the sun-Canopus reference after each probe is ejected, so a total of 10 maneuvers in each plane was assumed;
2) A separation ΔV of 1 fps was assumed for each probe, and the resulting impulse was assumed to be totally applied to the spacecraft;
3) The probes will all be mounted on the spacecraft so that the ejection forces pass through the cg of the spacecraft. Thus, the moments imparted to the spacecraft during probe ejection will be due only to cg uncertainties and the misalignment of the ejection mechanism.

1. First Probe (Hi-Cloud)

The weight of this probe is 220 lb,* its mass is 6.83 slugs, and $M\Delta V$ is equal to 6.83 lb-sec. The propellant used to compensate for ejection uncertainties is calculated as follows:

$$M\Delta V l = I \dot{\theta} \quad 2TL\Delta t,$$

where l is the ejection mechanism offset of 0.05 ft (due to 1° misalignment) or the cg uncertainty of 0.1 in. Then,

$$\omega = \frac{2T\Delta t}{I_{sp}} = \frac{M\Delta V l}{L\, I_{sp}}.$$

*Updated probe weight = 268 lb.

For the ejection mechanism offset,

$$\omega = \frac{(6.83)\ (0.05)}{(9.5)\ (70)} = 0.515 \times 10^{-3} \text{ lb.}$$

For the cg uncertainty,

$$\omega = \frac{(6.83)\ (0.1)}{(9.5)\ (70)\ (12)} = 0.086 \times 10^{-3} \text{ lb.}$$

For conservatism, these values are added directly. Thus, the total usage for the first probe is 0.601×10^{-3} lb.

2. Second and Third Probes (Small)

Weight = 270 lb;

Mass = 8.4 slugs;

MΔV = 8.4 lb-sec.

For the ejection mechanism offset,

$$\omega = \frac{M\Delta V l}{L\ I_{sp}} = 0.632 \times 10^{-3} \text{ lb.}$$

For the cg uncertainty,

$$\omega = \frac{M\Delta V l}{L\ I_{sp}} = 0.105 \times 10^{-3} \text{ lb.}$$

Thus, the total propellant usage for each of the second and third probes is 0.737×10^{-3} lb.

3. Fourth Probe (Large)

Weight = 525 lb;

Mass = 16.3 slugs;

MΔV = 16.3 lb-sec.

For the ejection mechanism offset:

$$\omega = \frac{M\Delta V l}{L\ I_{sp}} = 1.23 \times 10^{-3} \text{ lb.}$$

For the cg uncertainty,

$$\omega = \frac{M\Delta V l}{L\ I_{sp}} = 0.21 \times 10^{-3} \text{ lb.}$$

So the total usage for the ejection of the fourth probe is 1.44×10^{-3} lb.

G. PROPELLANT WEIGHT SUMMARY

Because of overshoot incurred for large attitude changes, a factor of 1.4 was applied to the propellant usage for these maneuvers. Table K-1 summarizes propellant weights.

Table K-1 Propellant Weight Summary

Description	Channel	Propellant Usage ($lb \times 10^3$) Basic	With Overshoot
Stabilize Tipoff	P	76.8	107.5
Rates	Y	76.8	107.5
	R	43.0	60.2
Sun Reference	P	9.6	13.5
	Y	9.6	13.5
Canopus Reference	R	5.4	7.6
Limit Cycle	P	326.0	326.0
	Y	326.0	326.0
	R	184.0	184.0
Midcourse			
Orient from Burn	P	9.6	13.5
	Y	9.6	13.5
	R	5.4	7.6
Null Offsets	P or Y	653.0	915.0
	R	653.0	915.0
Probe Eject			
10 Maneuvers	P	96.0	135.0
	R	54.0	76.0
First Probe	P	0.6	0.6
	R	0.6	0.6
Second and Third Probe	P	1.5	1.5
	R	1 5	1.5
Fourth Probe	P	1.4	1.4
	R	1.4	1.4
			Σ = 3.228 lb