AEROTHERM
FINAL REPORT NO. 69-51

A STUDY OF THE BOUNDARY FLOW IN A ROCKET COMBUSTION CHAMBER

PART III

DATA REPORT

by

R. D. Grose
V. I. Nicholson

AEROTHERM CORPORATION

ADVANCES IN AEROTHERMOCHEMISTRY

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Aerotherm Project 7009

A STUDY OF THE BOUNDARY FLOW IN A ROCKET COMBUSTION CHAMBER

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R. D. Grose and V. I. Nicholson

Prepared for

Jet Propulsion Laboratory
Pasadena, California

Contract No. NAS7-463

JPL Technical Monitor - D. L. Bond

FOREWORD

This report, which is one of a four-part final report, presents the data obtained with a rocket motor boundary flow sampling apparatus developed by Aerotherm in conjunction with the Jet Propulsion Laboratory. The reports in the series are:

Part I	Summary
Part II	Data Analysis, Correlation, and Prediction
Part III	Data Report
Part IV	Development of Experimental Hardware and Technique

This effort was conducted for the Jet Propulsion Laboratories of the National Aeronautics and Space Administration under Contract No. NAS7-463. Mr. Donald L. Bond was the technical monitor for this portion of the program.

The data presented in this report was obtained from the developed apparatus. Preliminary data of like nature (except for heat flux) was obtained during the development phase and is presented in Part IV. The data presented here is reduced in that much manipulation of the raw data, all of which was in oscillograph form, was required. The computer programs used to reduce all the data, with the exception of the heat flux, are described in Part IV. All of the data input to the program was checked several times so that the data reading errors have been kept to a minimum. In this regard the authors wish to express their appreciation for the efforts extended by Mrs. Ellen Cherniavsky and Miss Shirley Larsen who aided in reading and checking the hundreds of traces involved. Mrs. Cherniavsky also developed several auxiliary data reduction programs for this effort.

The tests from which the data was obtained were conducted at the United Technology Laboratory in Sunnyvale, California under subcontract to Aerotherm. The chemical analyses were conducted by the West Coast Technical Company in San Gabriel, California. All data reduction was accomplished at Aerotherm although redundant data reduction was made at UTC on the principal test stand parameters.

TABLE OF CONTENTS

Appendix A has been intentionally omitted.

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

C^*	characteristic velocity
C_f	thrust coefficient
C_H	heat transfer coefficient
E	distance from thermocouple junection to gage surface
h	enthalpy
H	hydrogen atom
H_2	hydrogen
H_2O	water
K	thermal conductivity
N	nitrogen atom
N_2	nitrogen
NA_3	ammonia
NO	nitrous oxide
O	oxygen atom
O_2	oxygen
q	heat flux
R	heat flux gage radius
T	temperature
u	velocity
x	axial distance
ρ	density
τ	time
ϕ	injector position
χ	mole fraction
ψ	atomic fraction

LIST OF SYMBOLS (concluded)

SUBSCRIPTS

b	block (chamber body)
c	chamber
C	thermocouple junction
e	boundary layer edge
f	fuel
g	gage
H	hydrogen
i	initial
N	nitrogen
N	nozzle
O	oxygen
O	oxidizer
r	recovery
w	wall, water
∞	undisturbed region

SECTION 1

INTRODUCTION AND SUMMARY

This report presents liquid rocket motor chamber boundary flow chemical and heat transfer data for a hydrazine-nitrogen tetroxide propellant system. The mixture ratio for the tests which yielded this data varied from 1.1 to 1.3. The copper heat sink chamber dimensions are approximately 2 inches in diameter by about 6 inches in length. A stainless steel 10-doublet-high pressure-drop injector was mated to this chamber. Further details concerning the design are presented in Part IV and Reference 1. The chemical data was obtained by sampling the boundary layer gas through six flush ports drilled at 3/4-inch increments down the chamber. The gases were collected in stainless steel flasks and the chemical composition determined by a specially developed mass spectrographic technique. The development of this technique is also presented in Part IV. Since water and ammonia are products formed in a combustion chamber burning N_2O_4 and N_2H_4, both the collection and analysis of the sample gases were performed above 100°C to prevent the condensation of these species from occurring. The heat flux data was obtained from calorimeters of the null point type installed directly opposite the sampling ports. These calorimeters indirectly measured a surface (chamber wall) temperature from which a heat flux was analytically determined. The theory of the null point calorimeter, the data reduction technique, and ramifications of the raw data interpretation, are presented in this report. The spatial distribution of the species concentration and heat flux in the boundary layer was obtained by rotating the injector relative to the chamber. Interpretation of the data thus relies on the degree to which conditions in the chamber can be reproduced from test to test. The departure of certain key parameters from this ideal and the possible influence this may have had on the data are also presented here.

Since a finite number of injector elements cannot produce a truly uniform flow field in the chamber, the variation of heat flux and chemical composition in the boundary layer should depend to a large extent upon the injector element array design and other injector/doublet characteristics. Such correlations of the data are presented in Part II.

Because of the large amount of data presented, this report has been divided into major sections and subsections (see margin tabs) to facilitate reading. Each of these sections is presented largely independently. The whole is tied together by the general remarks which follow.

A large portion of the heat flux data is repetitious and of limited interest. For these reasons it has been placed in an appendix (A) to this report and has been given only limited distribution. This appendix (approximately 300 pages in extent) gives the tabulated and plotted measured temperature and calculated heat flux response of each calorimeter for every test. Individuals wishing a copy of the data may obtain one from the Aerotherm Corporation or JPL.

The data show, in general, a region in the chamber which is high in oxidizer and low in fuel. The rest and greatest percentage of the chamber boundary flow shows the opposite situation. Everywhere nitrogen is a principal specie. The heat flux data does not show variation in the same regions of the chamber where composition changes are the greatest. Significant variations in heat flux are observed nonetheless. Difficulties in the data reduction procedure and uncertanties in the boundary conditions make the accuracy of the absolute level of the heat flux uncertain.

SECTION 2

GENERAL REMARKS

The data portion of the report has been divided into four sections the first of which (3.0) is devoted to the chemical composition data, and the second (4.0) to heat flux data. The third section (5.0) discusses the salient features of the motor performance and test stand system data and the influence of these variables on the data presented in the preceding two sections. The fourth section (6.0) formally presents the data in tabular form.

A complete set of data as originally envisioned was not obtained due to certain technical and budgetary problems. Originally it was desired to obtain chemical and heat flux data for the six axial positions for every fifteen degree increment in circumferential position. A reduced scope of program resulting from technical problems, especially with regard to chemical analysis, resulted in the reduced test plan shown in Table 2.1. The position schedule was varied such that the most detail would be obtained where ablation response showed the most variation. Note in this report that the data begins with run number 9--the first eight runs were part of the development activity (conducted at the ϕ=0° position) and are not presented here. All tests were performed for a nominal mixture ratio of 1.3 except for runs 23 and 31, which were accidently and intentionally lower respectively. Run 32 was a repeat of run 23 at the desired mixture ratio. Run numbers 29 and 30 were special in that only two of the six bottles were sampled. This was done in an attempt to demonstrate the existance or nonexistance of upstream sampling effects on local composition. Runs 27 and 28 were special in that different sampling durations were selected to obtain some preliminary data on the influence of sampling duration on the measured composition. It was also originally intended that the influence of sampling rate on the chemical composition be explored but this was not possible under the reduced scope. Some theoretical remarks on this last subject area can be found in Part II. The manner in which the tests were conducted is described in Part IV.

The amount of data was also limited by certain instrumentation failures. Notably two of the six heat flux gages failed after installation in the motor on the test stand and no heat flux data is available for the second and only some from the fifth station. Heat flux data from the sixth position, near the throat, is clearly nonrepeatable and therefore subject to question. A discussion of this particular data and possible reasons for the data trends are presented in Section 4.4.

Certain chemical specie data are also missing. Although for every flask two microtube samples were prepared, in a few cases both microtubes developed leaks and therefore no composition data could be obtained. Such leaks were evidenced by oxygen and nitrogen present in a four to one ratio and by low mass spectrometer pressures. These obviously erroneous mass spectrometer results have not been presented.

The azimuth position, ϕ, used to describe the pertinent experimental configuration is measured counter-clockwise from a mark on the injector (see Part II) when the injector face is viewed (i.e., looking upstream).* The axial position is measured from the face of the injector.

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*This convention conforms to the position indicating dial supplied on the motor case. It is the mirror image of the convention used in previous JPL programs.

TABLE 2.1
PROGRAM PRIME TEST PLAN

Run	Inj. Pos.	Sampling Time**	Bottles Sampled	Mixture Ratio*	Remarks
9	0	1.0	ALL	1.31	
10	30	1.0	ALL	1.29	
11	60	.6	ALL	1.25	
12	90	1.2	ALL	1.28	
13	120	1.7	ALL	1.31	
14	150	1.2	ALL	1.27	
15	180	1.1	ALL	1.28	
16	190	1.4	ALL	1.24	
17	200	1.05	ALL	1.25	
18	210	1.4	ALL	1.29	
19	220	.98	ALL	1.28	
20	230	.58	ALL	1.29	
21	240	.67	ALL	1.30	
22	250	.92	ALL	1.28	
23	260	.86	ALL	1.13***	
24	270	.62	ALL	1.31	
25	300	1.0	ALL	1.29	
26	330	.8	ALL	1.31	
27	0	.54++	ALL	1.31	Effect of sampling duration
28	0	1.9xx	ALL	1.29	Effect of sampling duration
29	0	.9	2 & 6	1.29	Effect of upstream sampling
30	0	.92	3 & 6	1.30	Effect of upstream sampling
31	0	.92	ALL	1.12+	Effect of mixture ratio
32	260	.92	ALL	1.29	Repeat of 23

* desired O/F = 1.3

\+ desired O/F = 1.1

** desired time = 1.0 seconds

++ desired time = 0.5 seconds

xx desired time = 2.0 seconds

*** injector known to have oxidizer leak in external coupling

SECTION 3

BOUNDARY FLOW COMPOSITION DATA

The boundary flow composition data is presented three ways. First, the axial distribution of the species mole fractions determined in the flasks by the mass spectrometer are presented for given injector positions (increasing run number). These are presented in Figures 3.1-a through 3.1-x. In the species plots only the six principal species are presented. The complete determination is presented in the data of Section 6. The data in these figures were renormalized for the purpose of interpretation. The second and perhaps more meaningful way in which the data is presented is by distribution of the three principal atoms present, hydrogen-H, nitrogen-N, and oxygen-O. These are presented in Figures 3.2-a through 3.2-x in the same fashion as those of Figures 3.1. The third presentation is the radial distribution of the principle atom fractions for the six stations--Figures 3.3-a through 3.5-f. The atom fraction data has also been normalized.

Two methods were used for reducing the raw mass spectrometer data. These two techniques were a least square curve fitting procedure developed at Aerotherm which uses the entire cracking pattern available for the species of interest (described in Part IV), and the more conventional peak stripping technique in which only the principal and perhaps one secondary peak from the cracking data are used. For the present system of species it is possible to obtain a unique solution with the second technique provided it is assumed that the peak at the mass number of 44 is due solely to carbon dioxide. In principle at least, it is possible that nitrous oxide could be contributing to or completely producing the peak at this mass number. This aspect is discussed further in Section 6. For the vast majority of the data the two techniques produced nearly identical results. In a few cases, the least square error procedure produced questionable results, and the data results from the second technique, shown by solid symbols in the figure, are to be preferred. Where no solid symbol appears, it may be inferred that the two techniques agreed.

SECTION 3.1

SPECIES AXIAL PROFILES

The species data of Figure 3.1 show that fairly consistent species data were obtained. In the majority of the figures smooth curves can be drawn to connect the data points both axially as shown and circumferentially (not presented). In general the data is characterized by high nitrogen content and--in a high percentage of the positions--high ammonia content. The ammonia tends to disappear for axial stations near the throat of the chamber. Presumably it is vaporized or decomposed because of the higher wall temperatures in this region (refer to Part II for a more detailed discussion). At some radial positions (i.e., ϕ=30°, and ϕ=220°/-270°) little ammonia is found.

As pointed out in Section 6, the data in general can be viewed as either nitrogen rich or water lean. Again a deeper treatment is found in Part II. Generally about twice as much water would be expected theoretically (refer to Section 6). In a few instances extremely high water was detected (Figure 3.1-o and x). These three data points are so isolated that some doubt must be cast on their validity. There seems to be some general tendency for the water and nitrogen concentrations to increase as the ammonia concentrations decrease.

Because the presence of ammonia is so highly temperature dependent (as shown theoretically in Part II), and since wall temperature was not precisely controlled run to run, it was elected not to present the circumferential distribution of species since for this reason, apparent trends could well be due to factors other than injector design parameters. For this purpose, the atomic fraction data provides a less ambiguous set from which such correlations may be drawn.

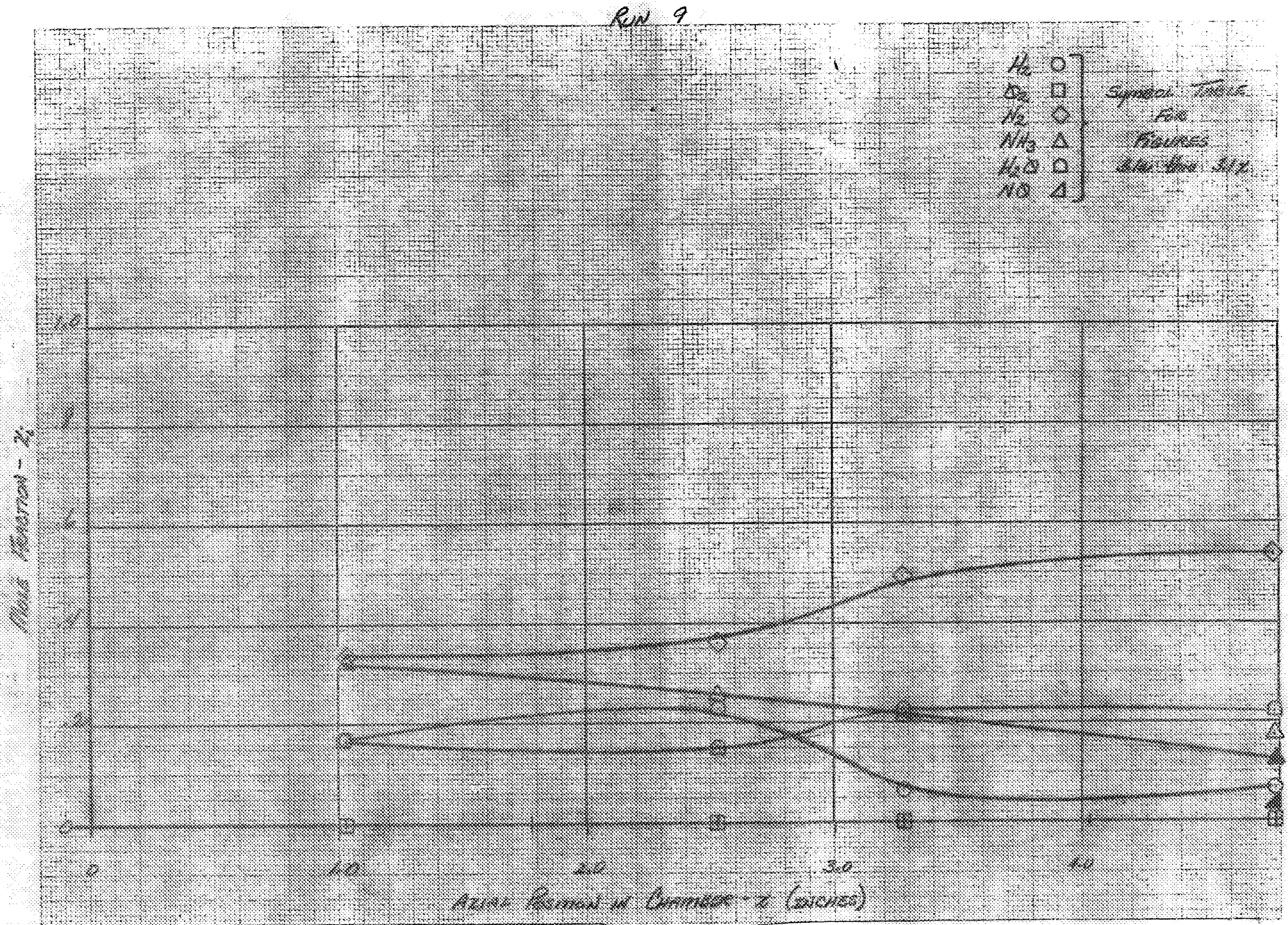

Figure 3.1. Axial Distribution of Species Concentration for a Fixed Azimuth Position
a. $\phi = 0°$

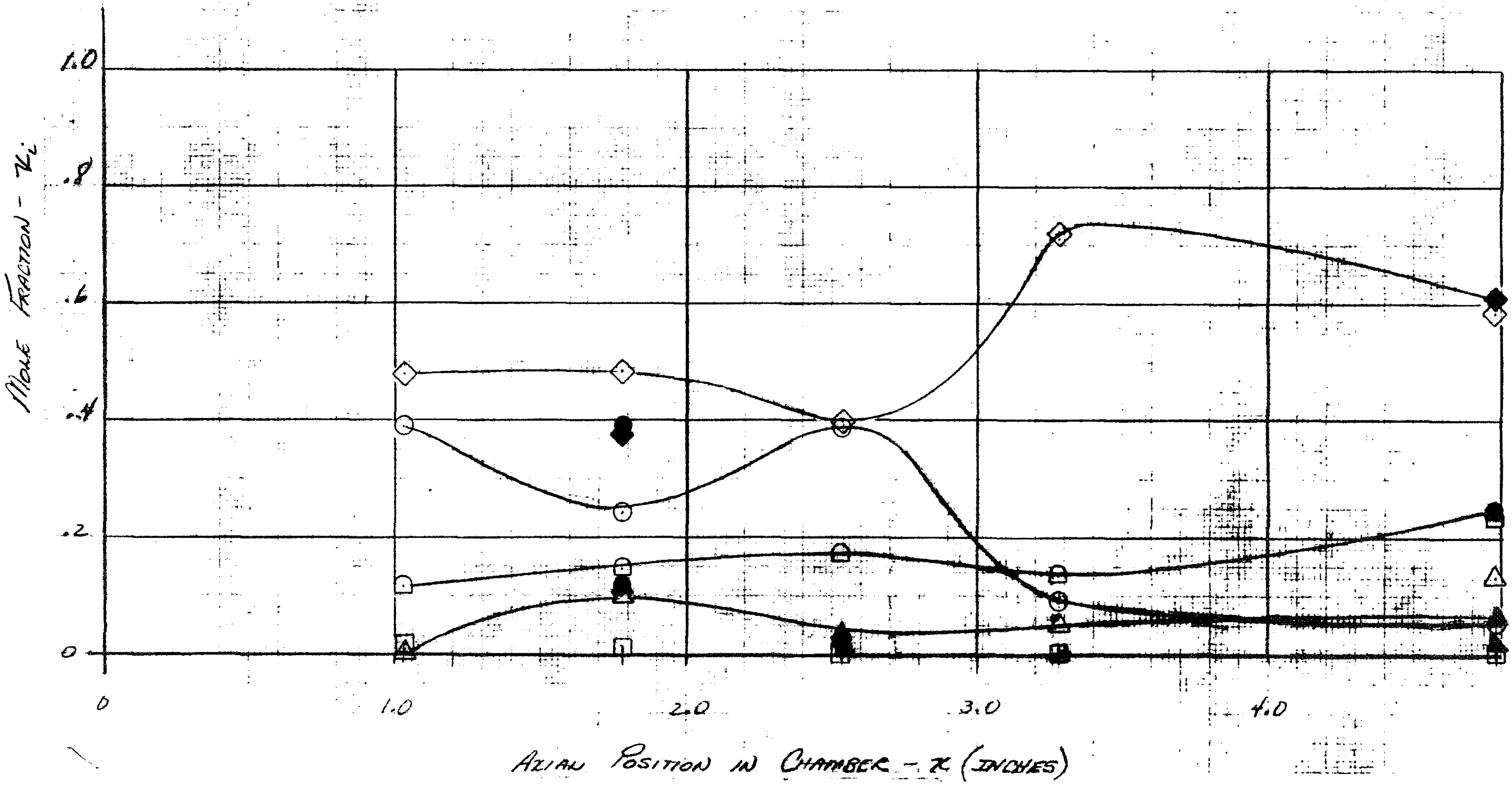

Figure 3.1. Continued
b. $\phi = 30°$

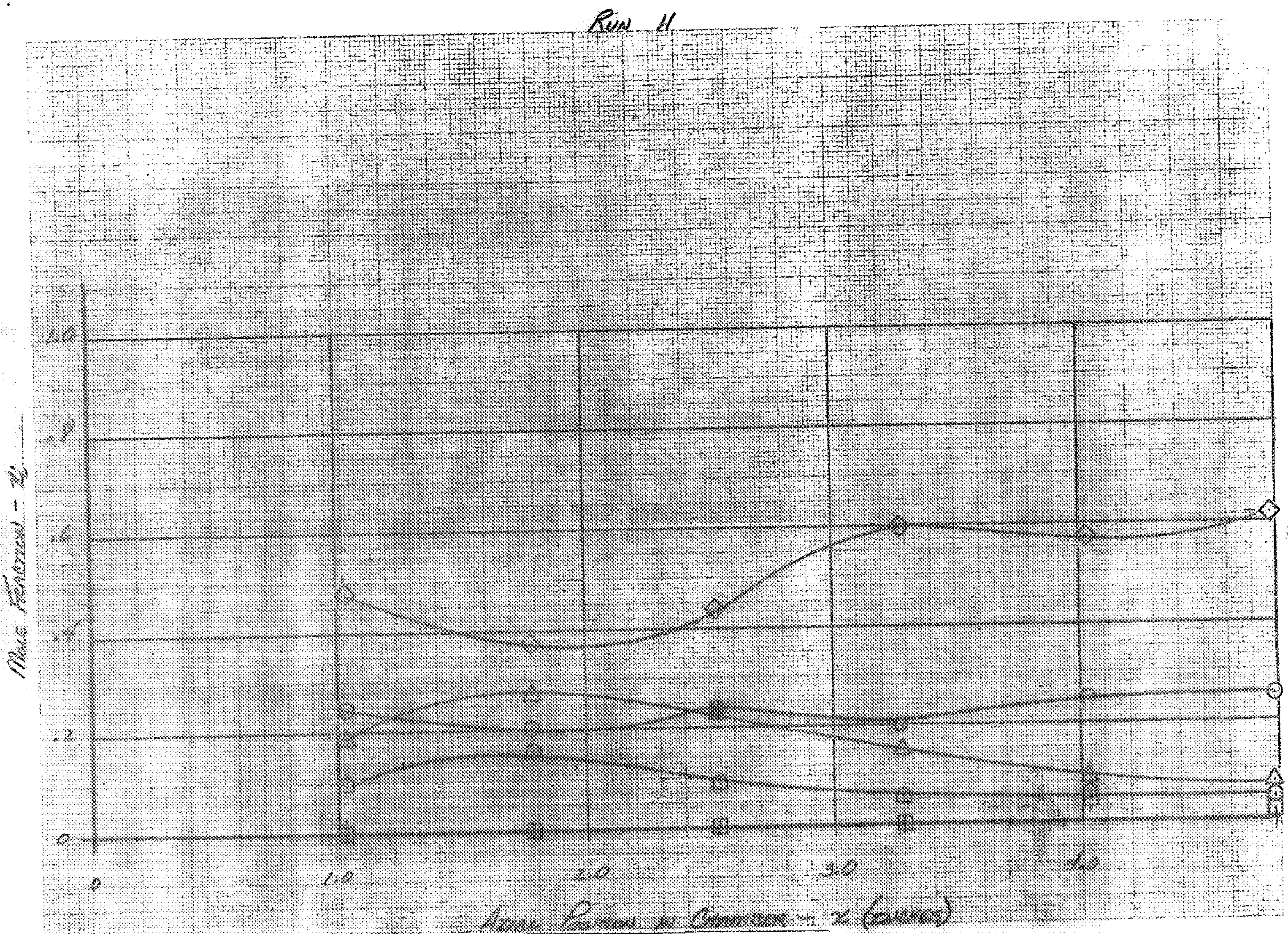

Figure 3.1. Continued
c. $\phi = 60^0$

RUN 12

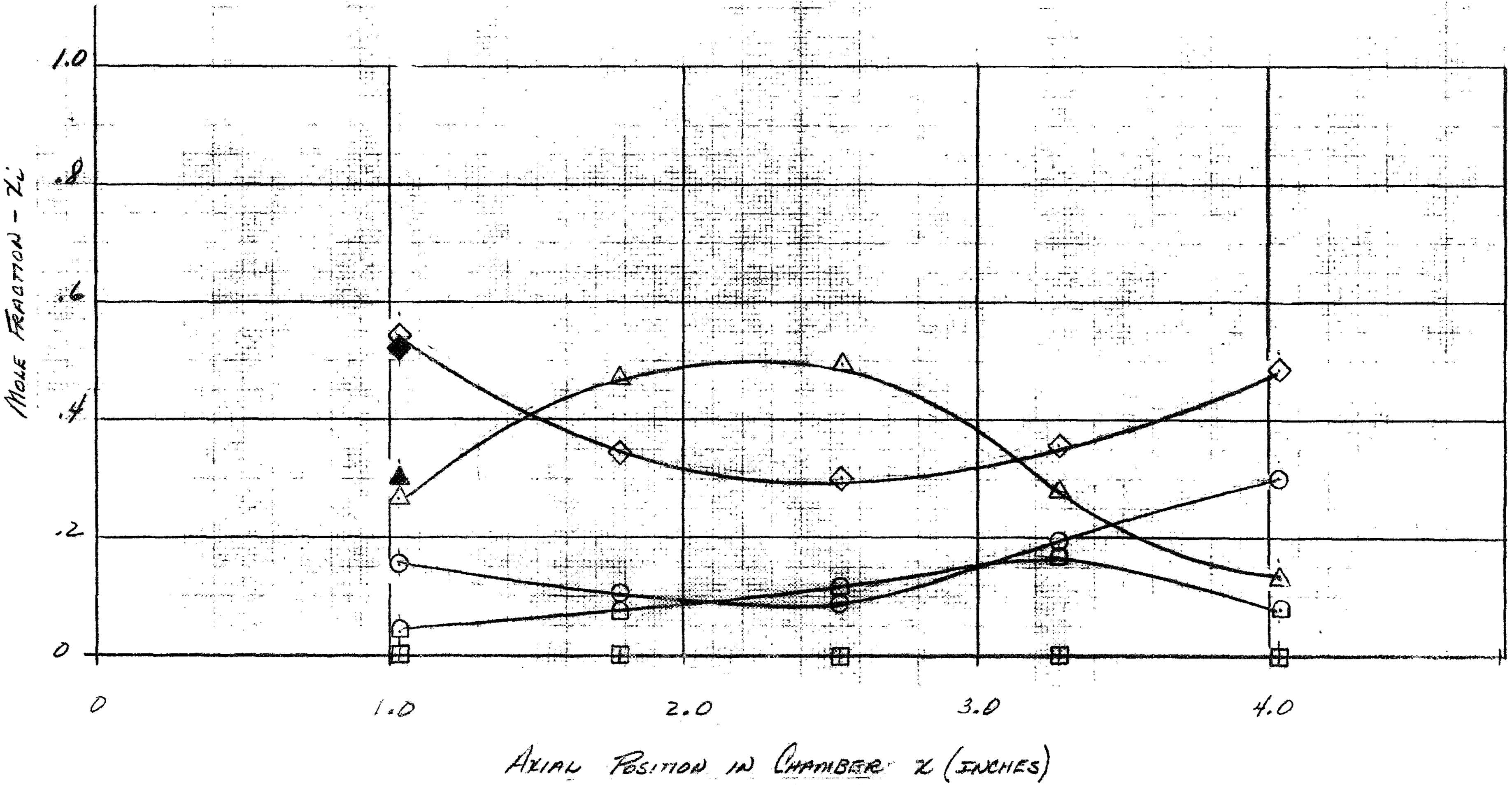

Figure 3.1. Continued
d. $\phi = 90°$

Run 13

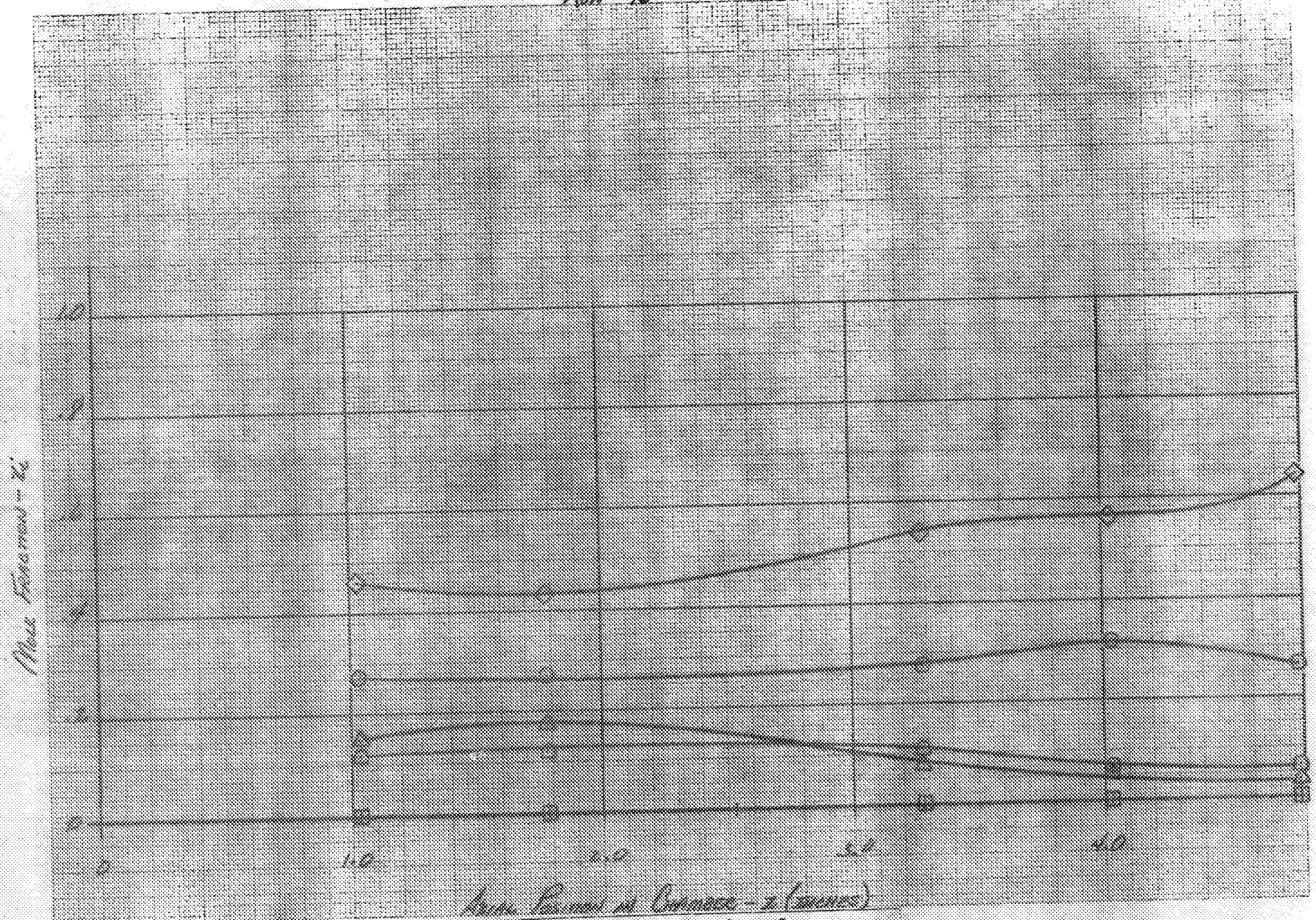

Figure 3.1. Continued
e. $\phi = 120°$

RUN 14

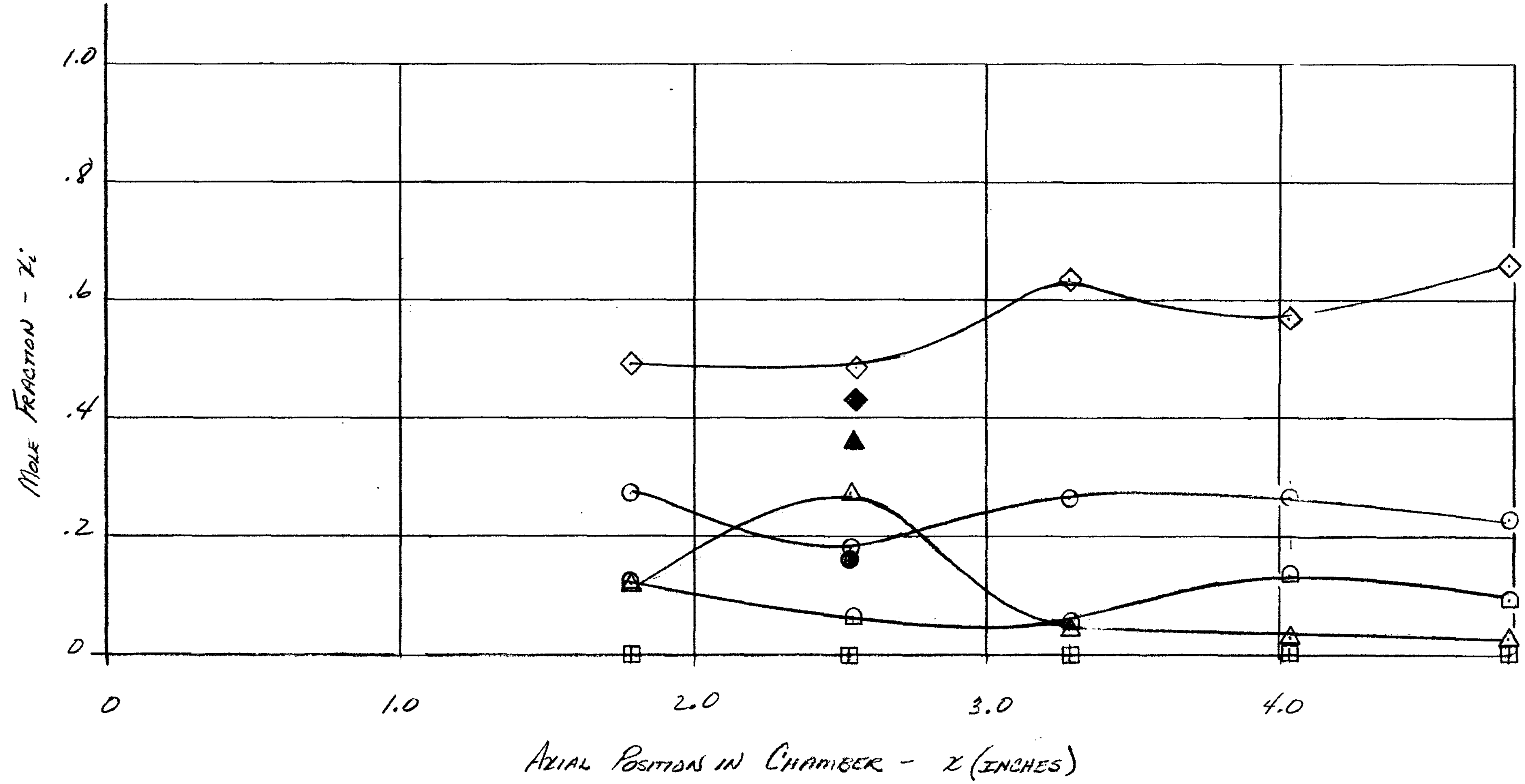

Figure 3.1. Continued
f. $\phi = 150^0$

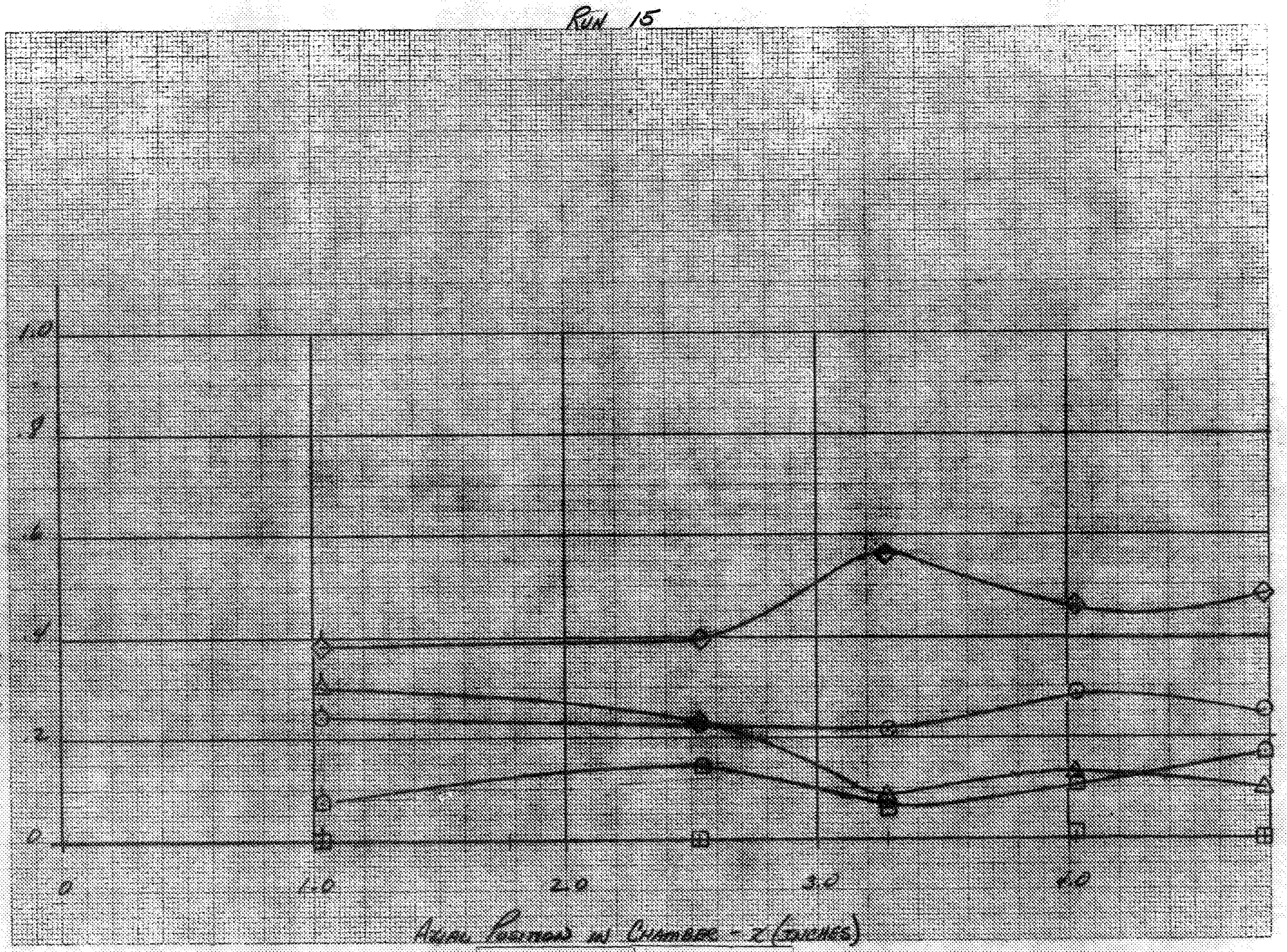

Figure 3.1 Continued
g. $\phi = 180^0$

Run 16

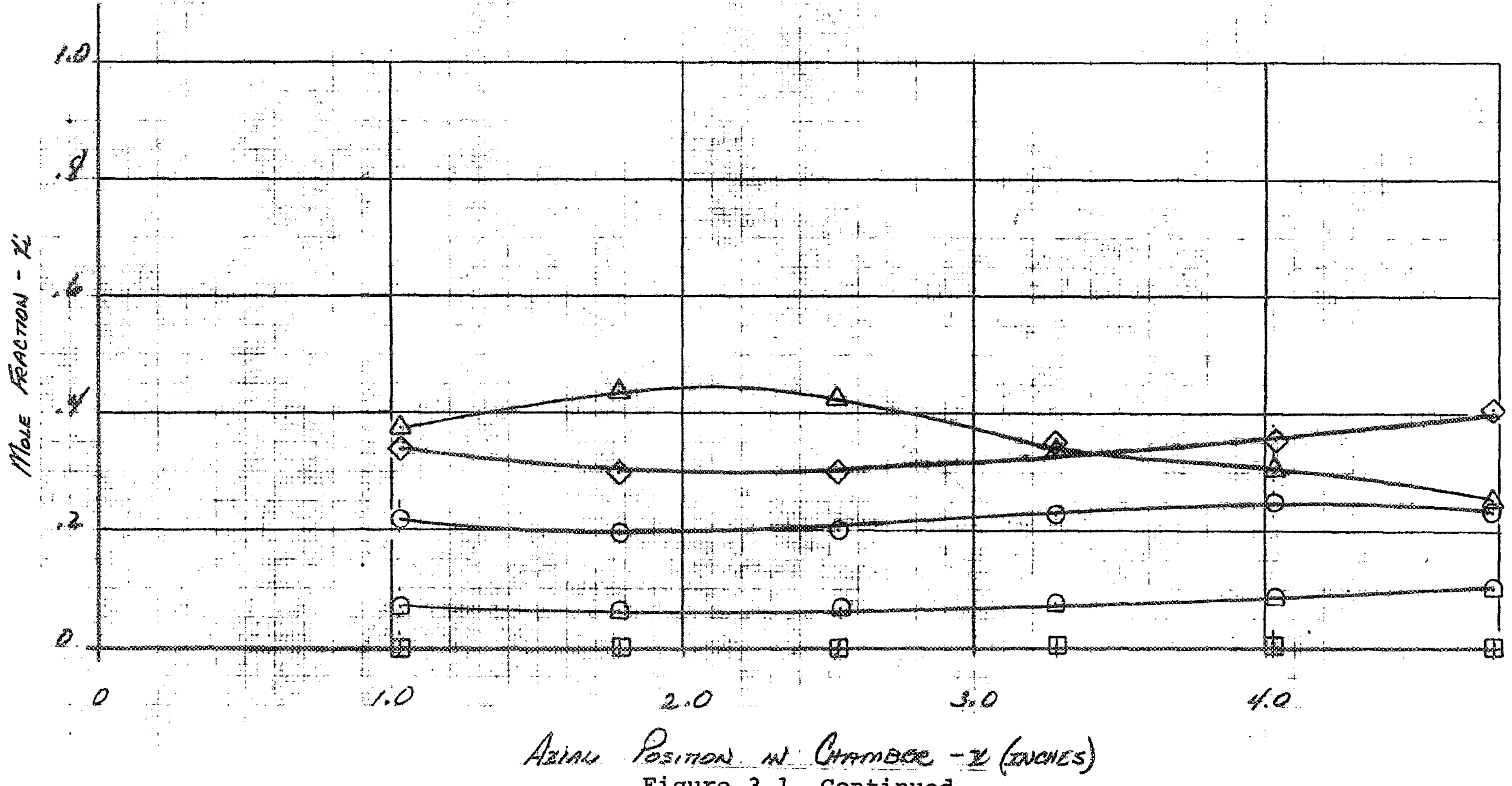

Figure 3.1. Continued
h. $\phi = 190^0$

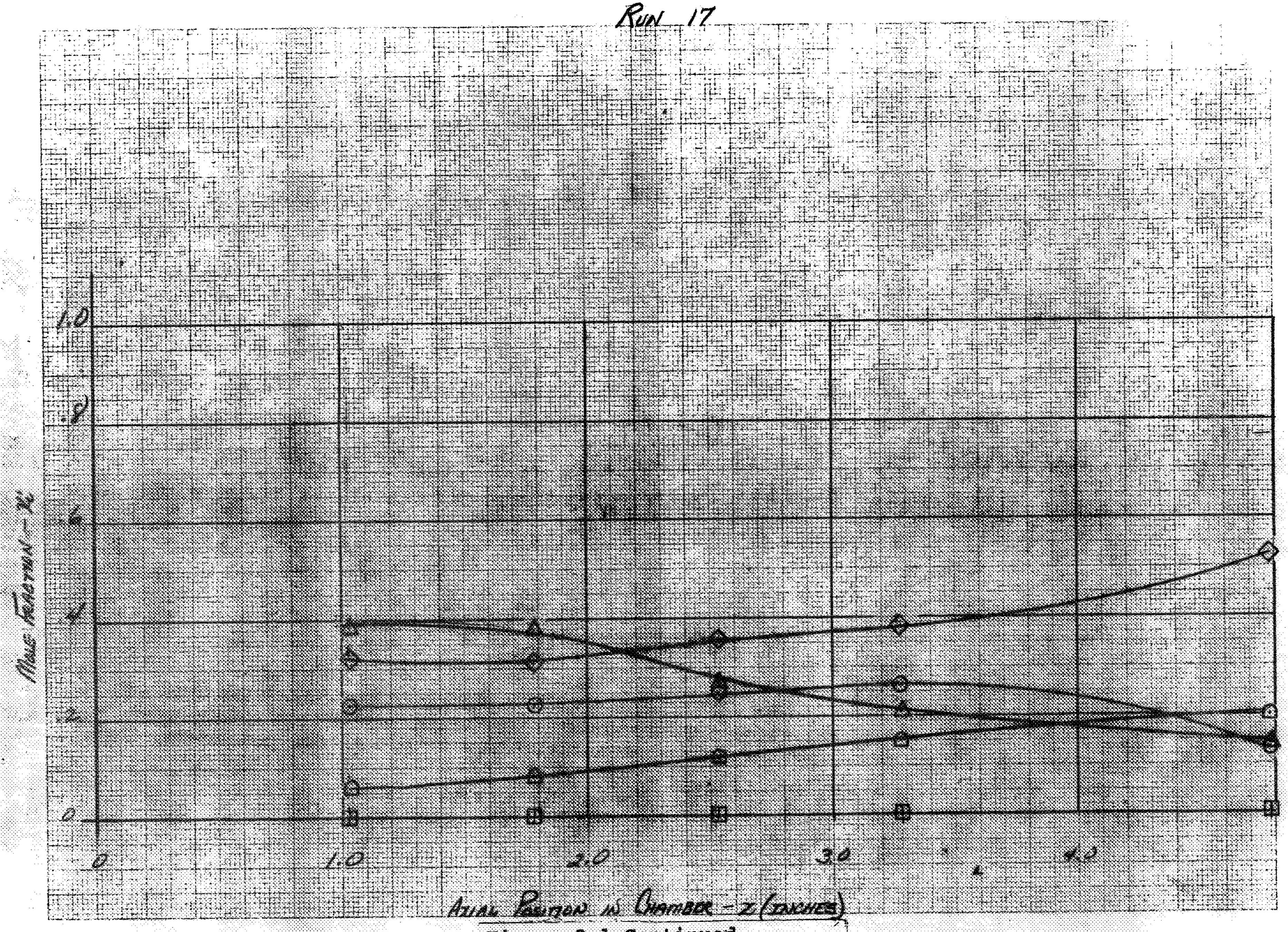

Figure 3.1 Continued
i. ϕ = 200°

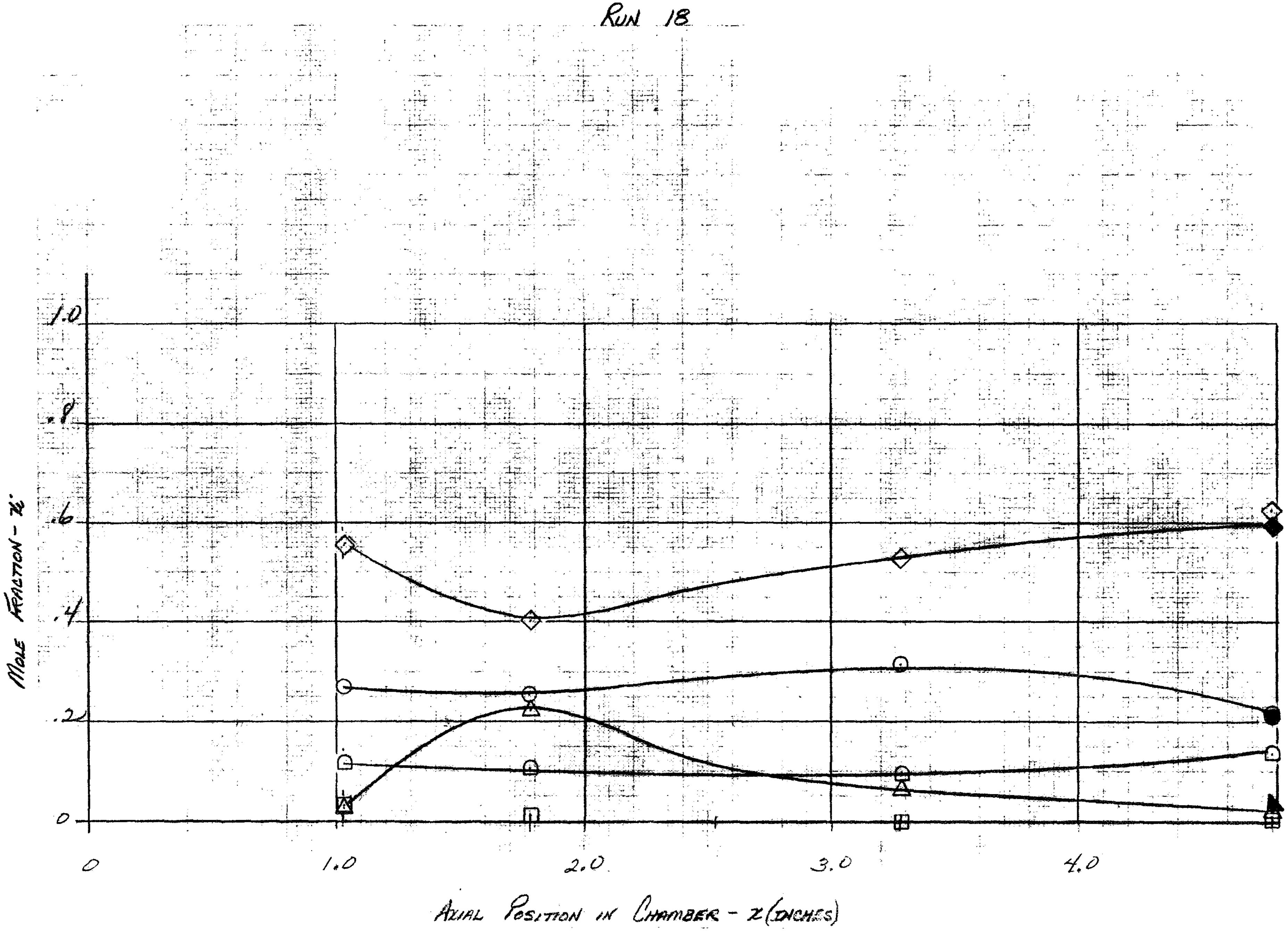

Figure 3.1. Continued

j. $\phi = 210^0$

Run 19

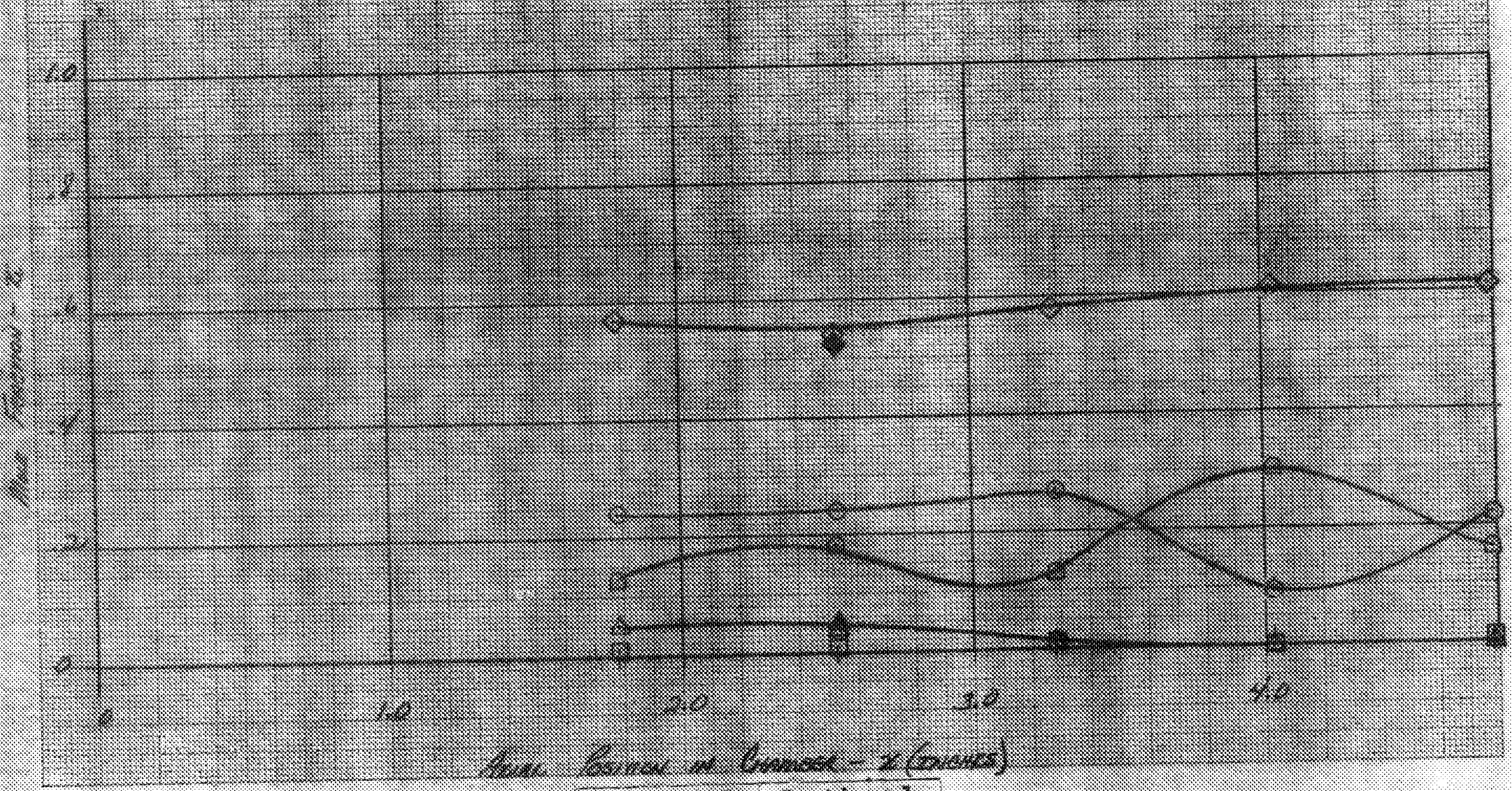

Figure 3.1. Continued
k. ϕ = 220°

RUN 20

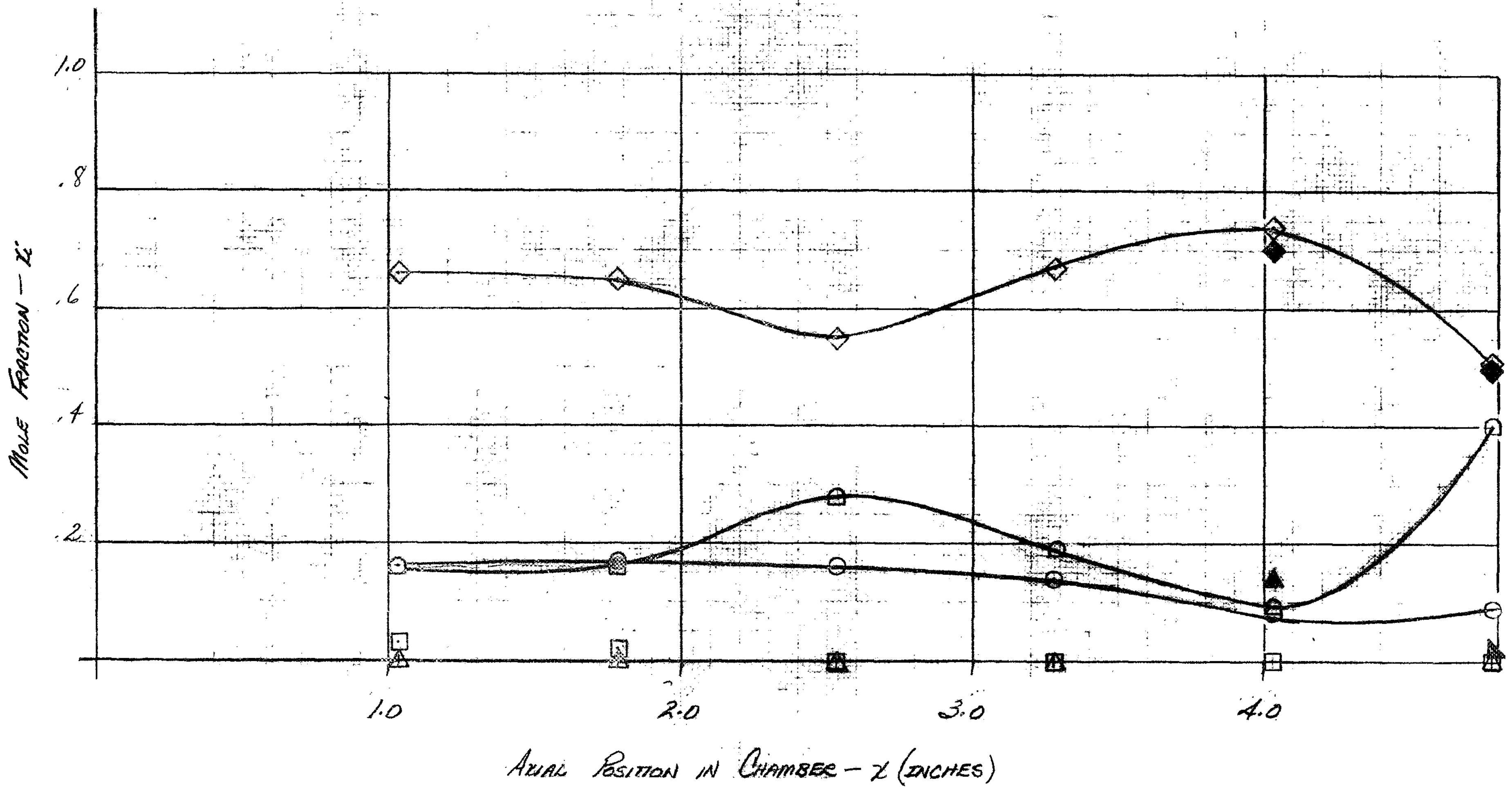

Figure 3.1. Continued
1. ϕ = 230°

Run 21

Figure 3.1. Continued
m. φ = 240°

RUN 22

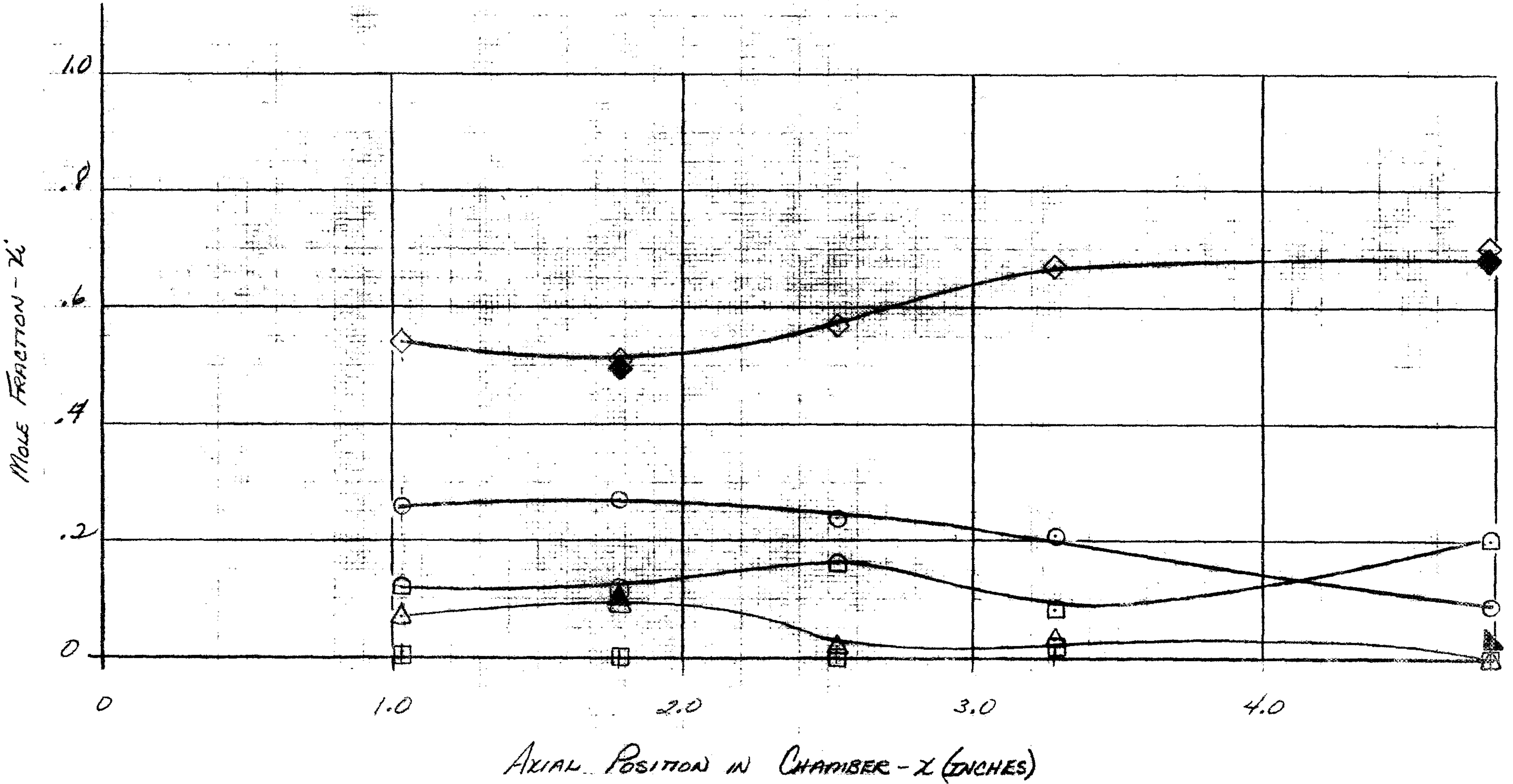

Figure 3.1 Continued
n. ϕ = 250°

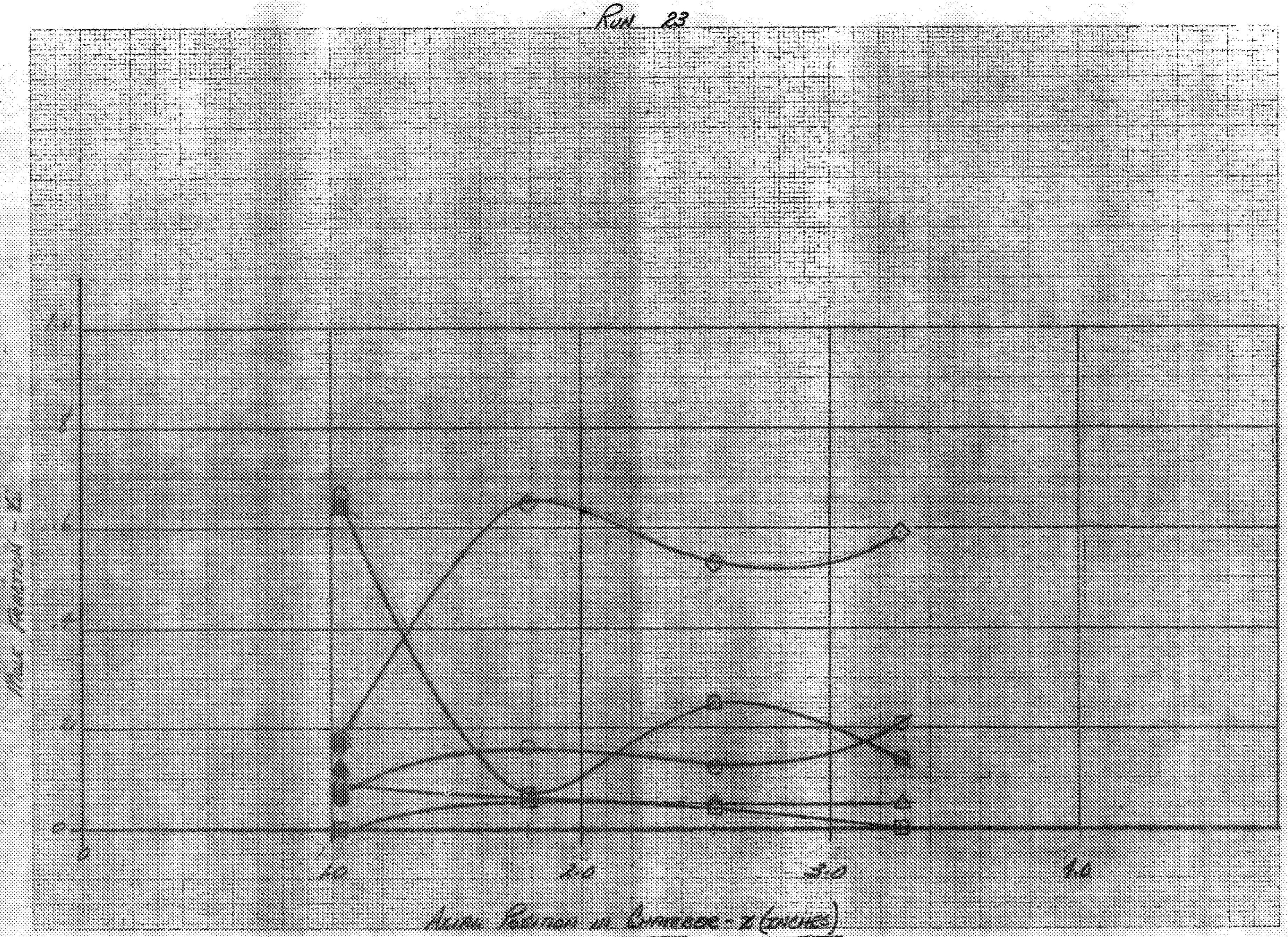

Figure 3.1. Continued
o. φ = 260°

Run 24

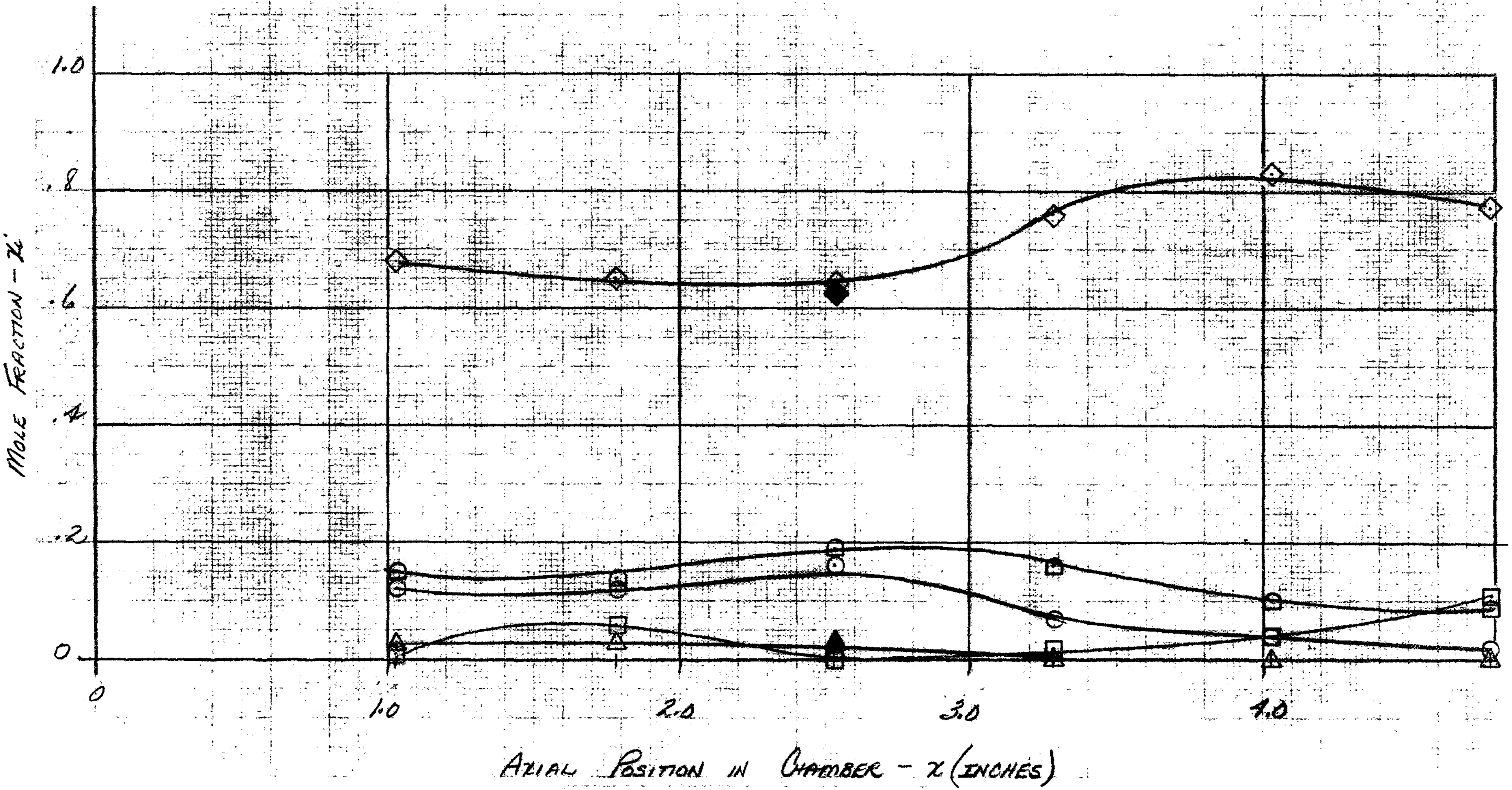

Figure 3.1. Continued
p. $\phi = 270^0$

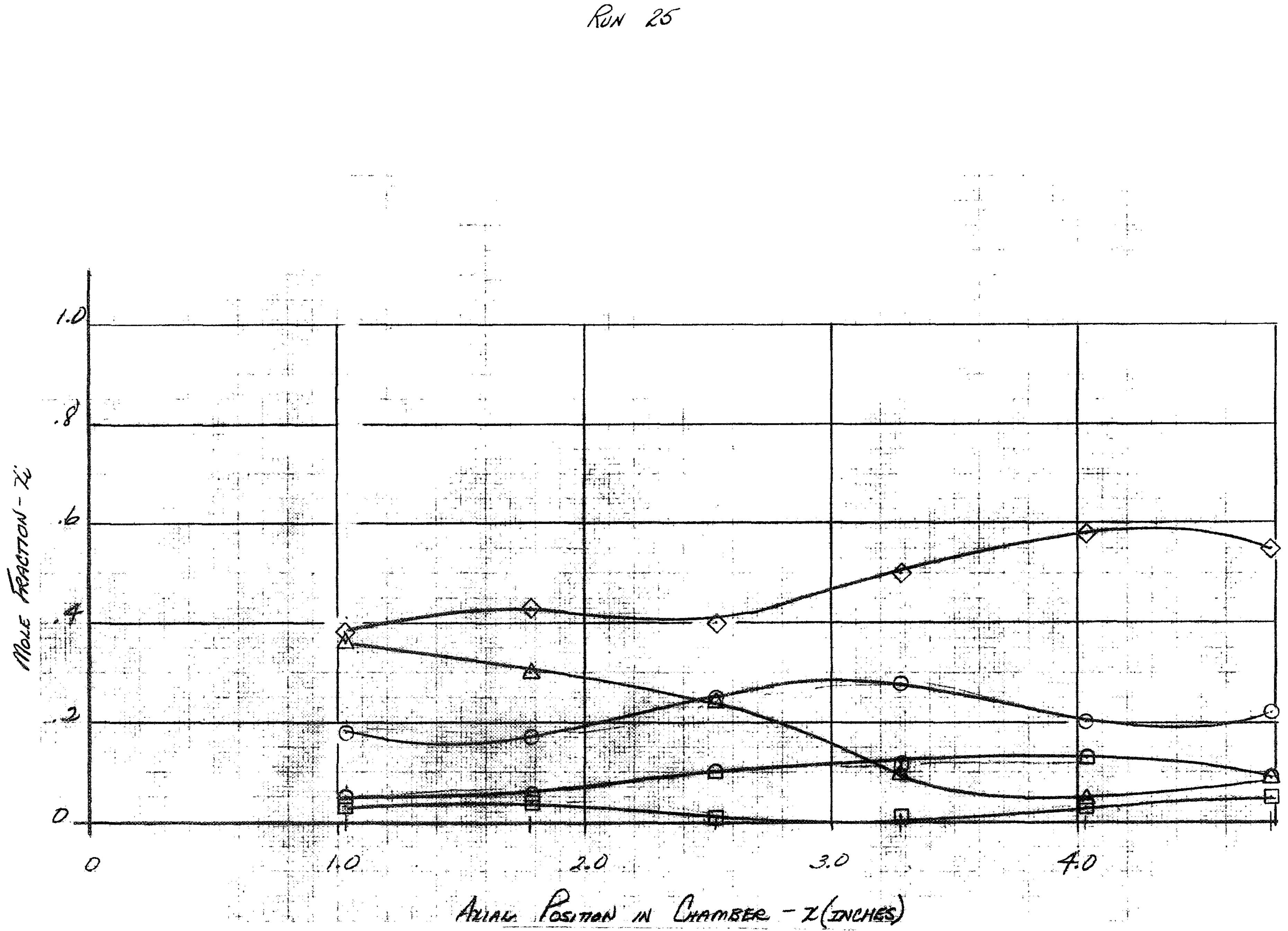

Figure 3.1. Continued
q. $\phi = 300^{0}$

Run 26

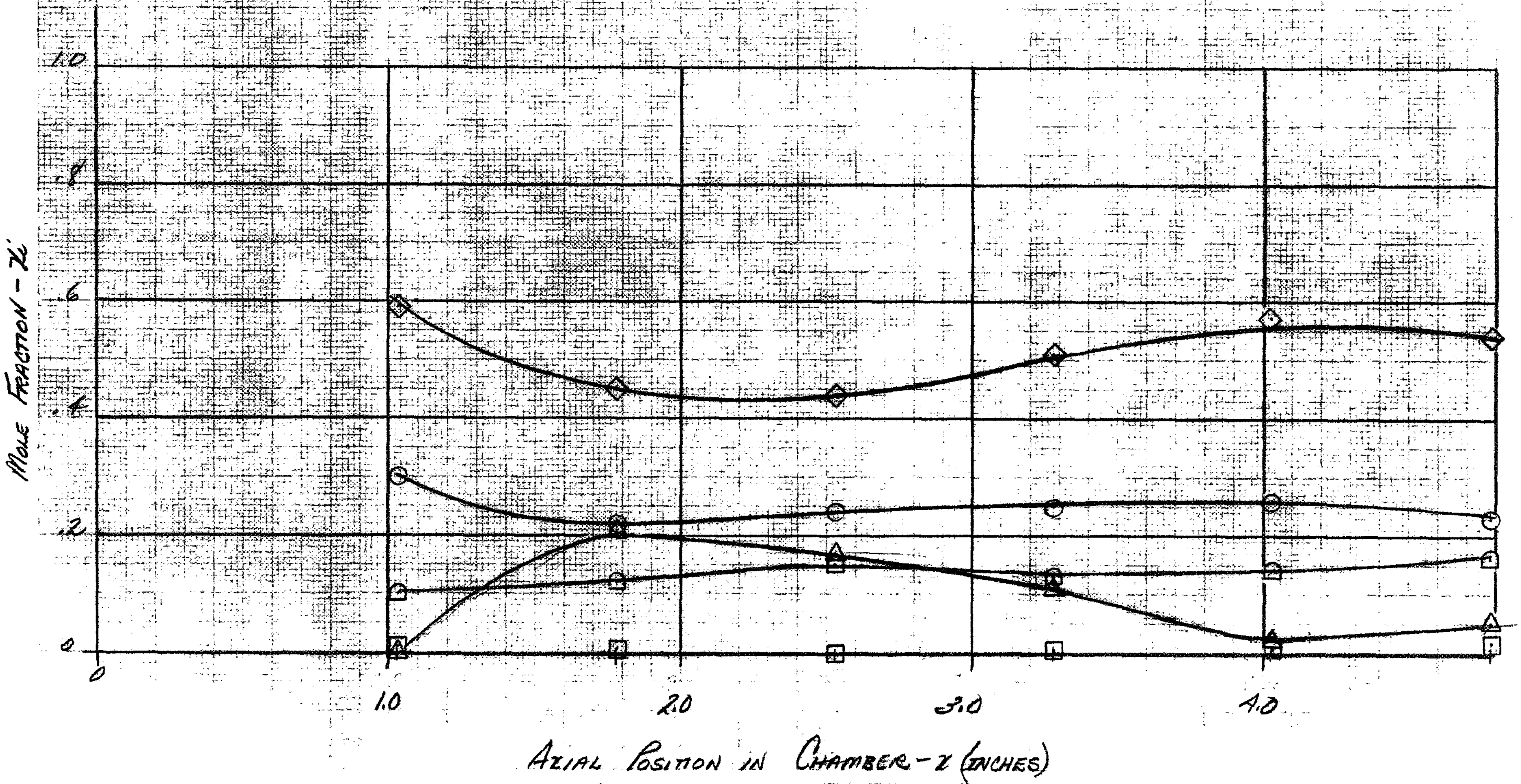

Figure 3.1. Continued
r. ϕ = 330°

RUN 27

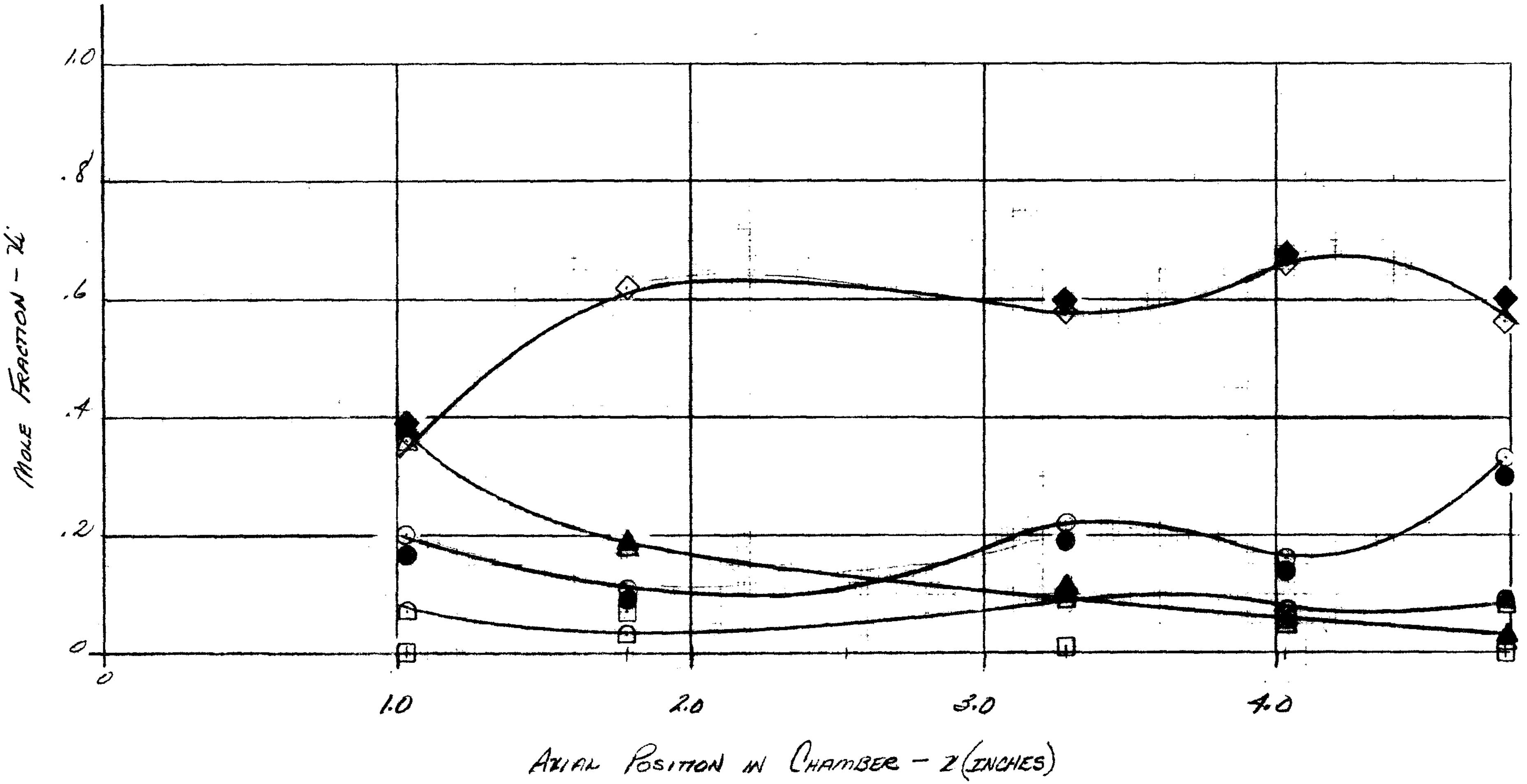

Figure 3.1. Continued
s. $\phi = 0^0$

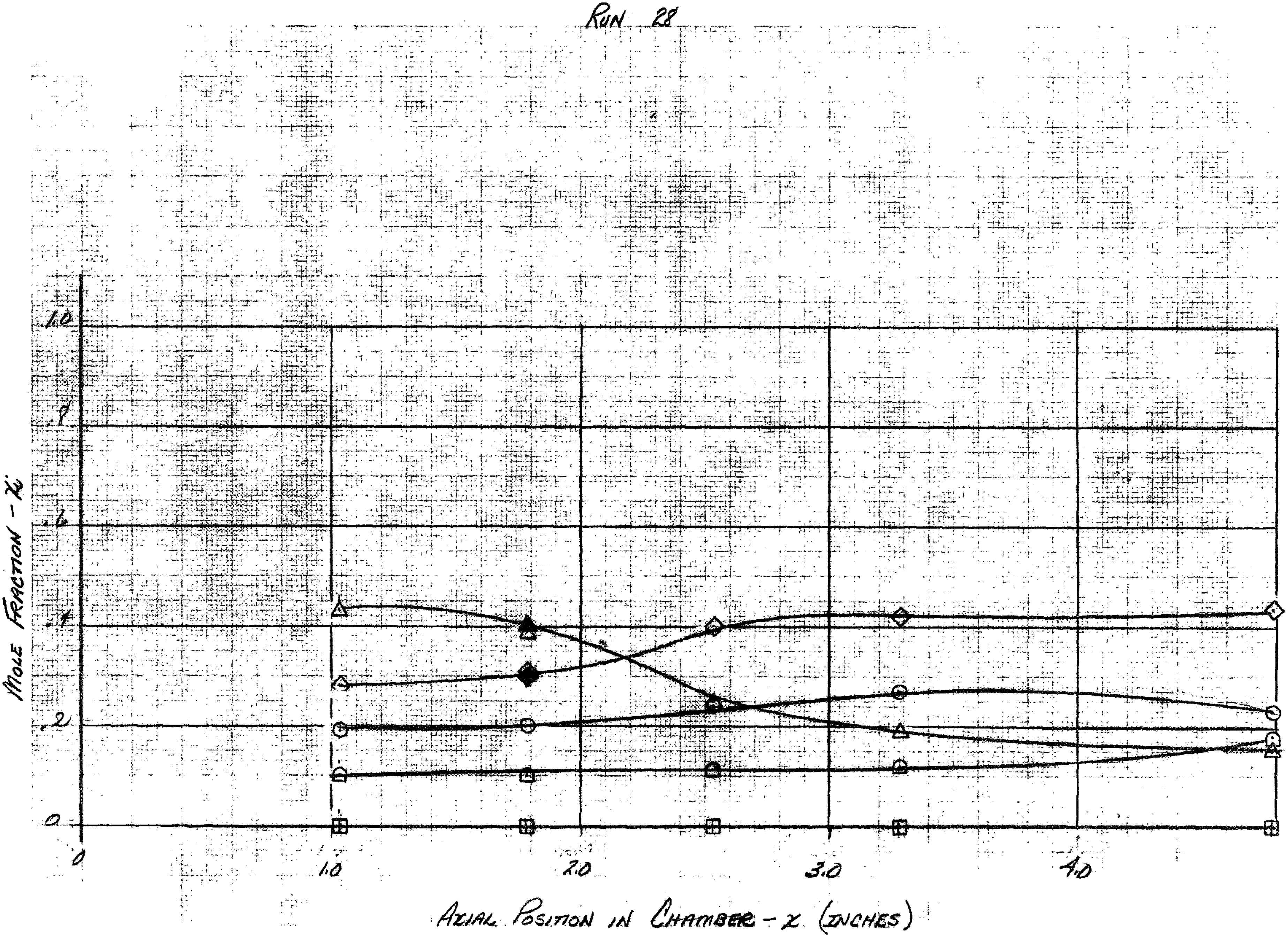

Figure 3.1. Continued
t. $\phi = 0^0$

RUN 29

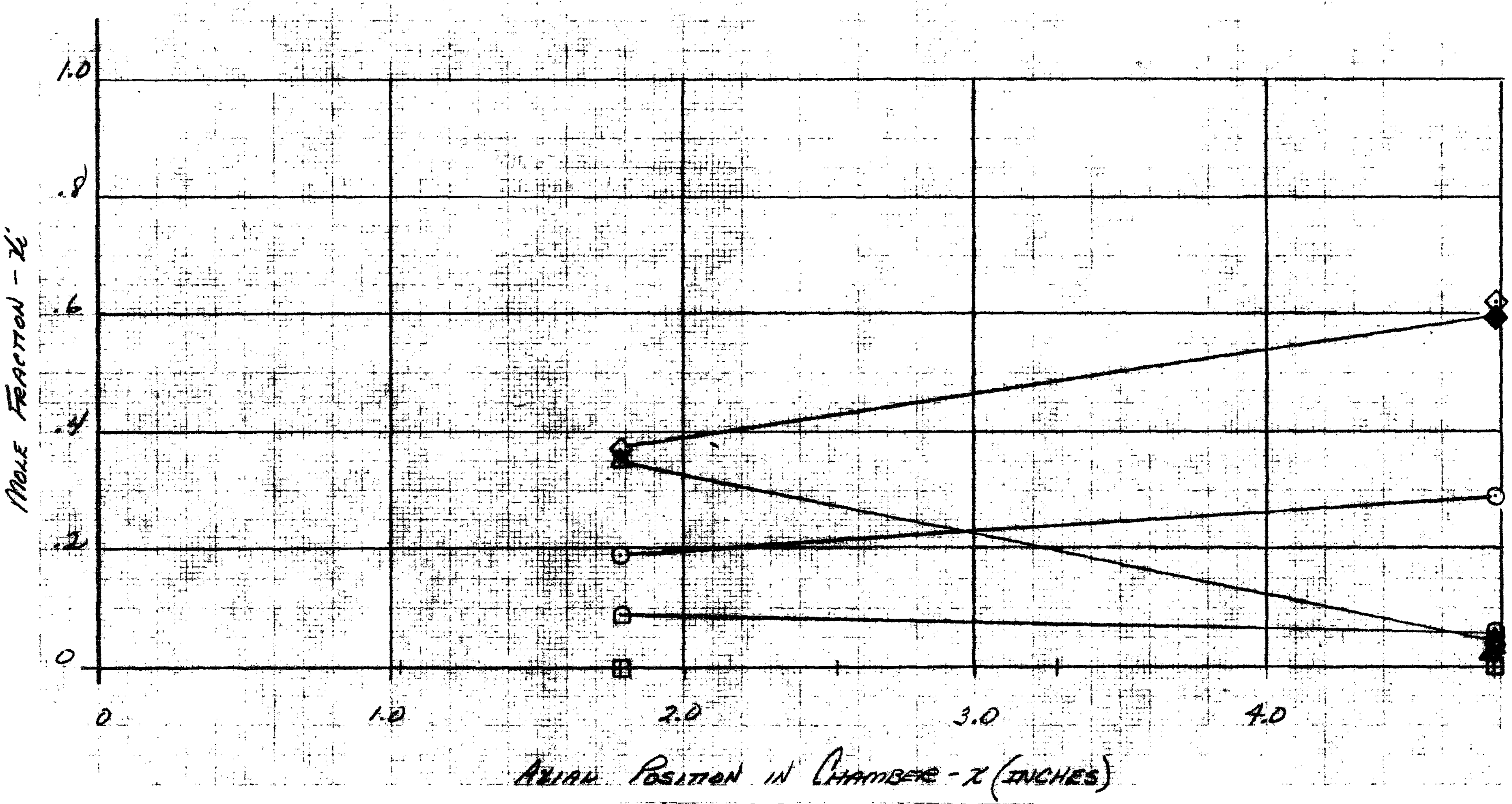

Figure 3.1. Continued
u. $\phi = 0^0$

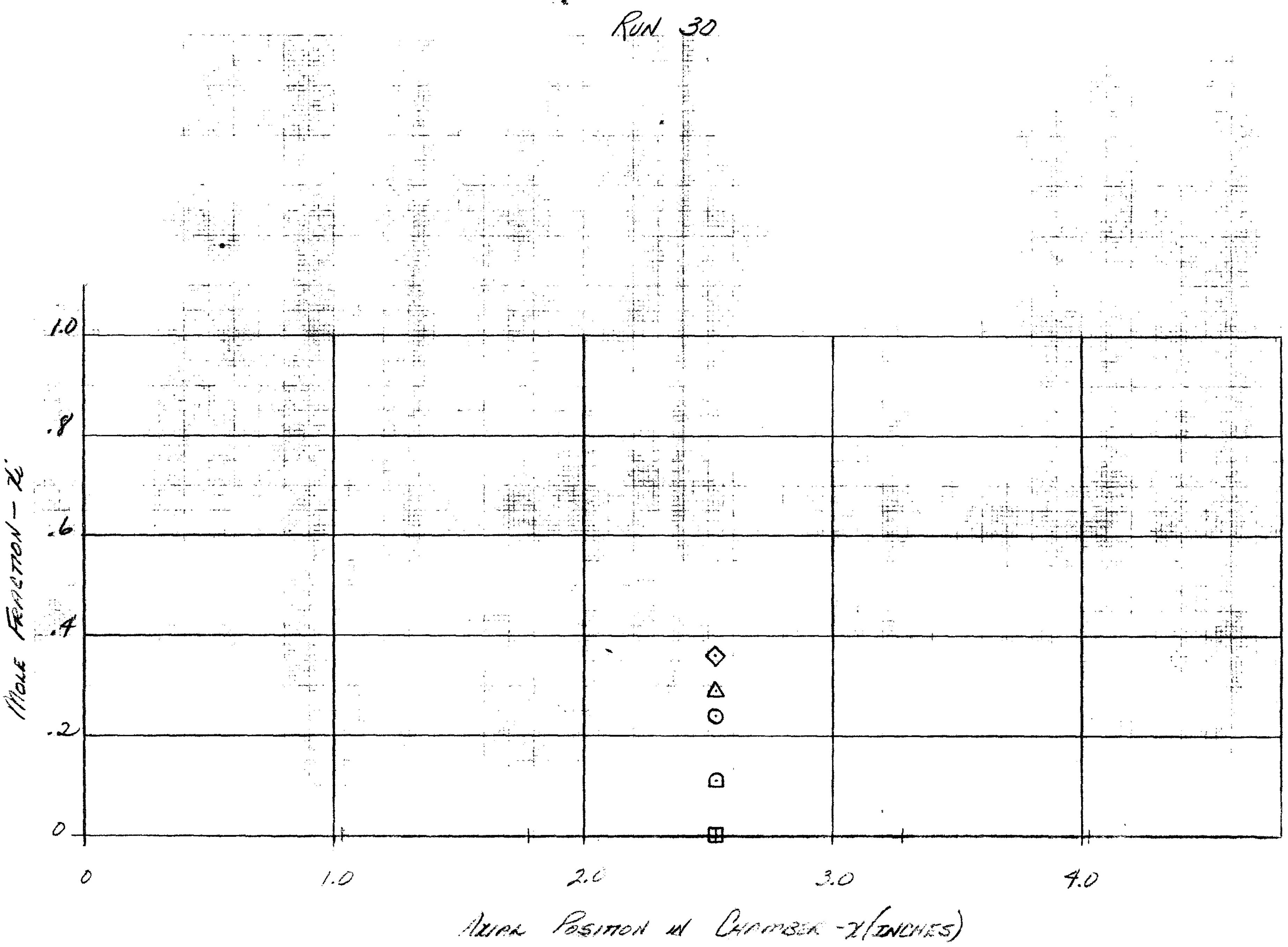

Figure 3.1. Continued
v, $\phi = 0$

RUN 31

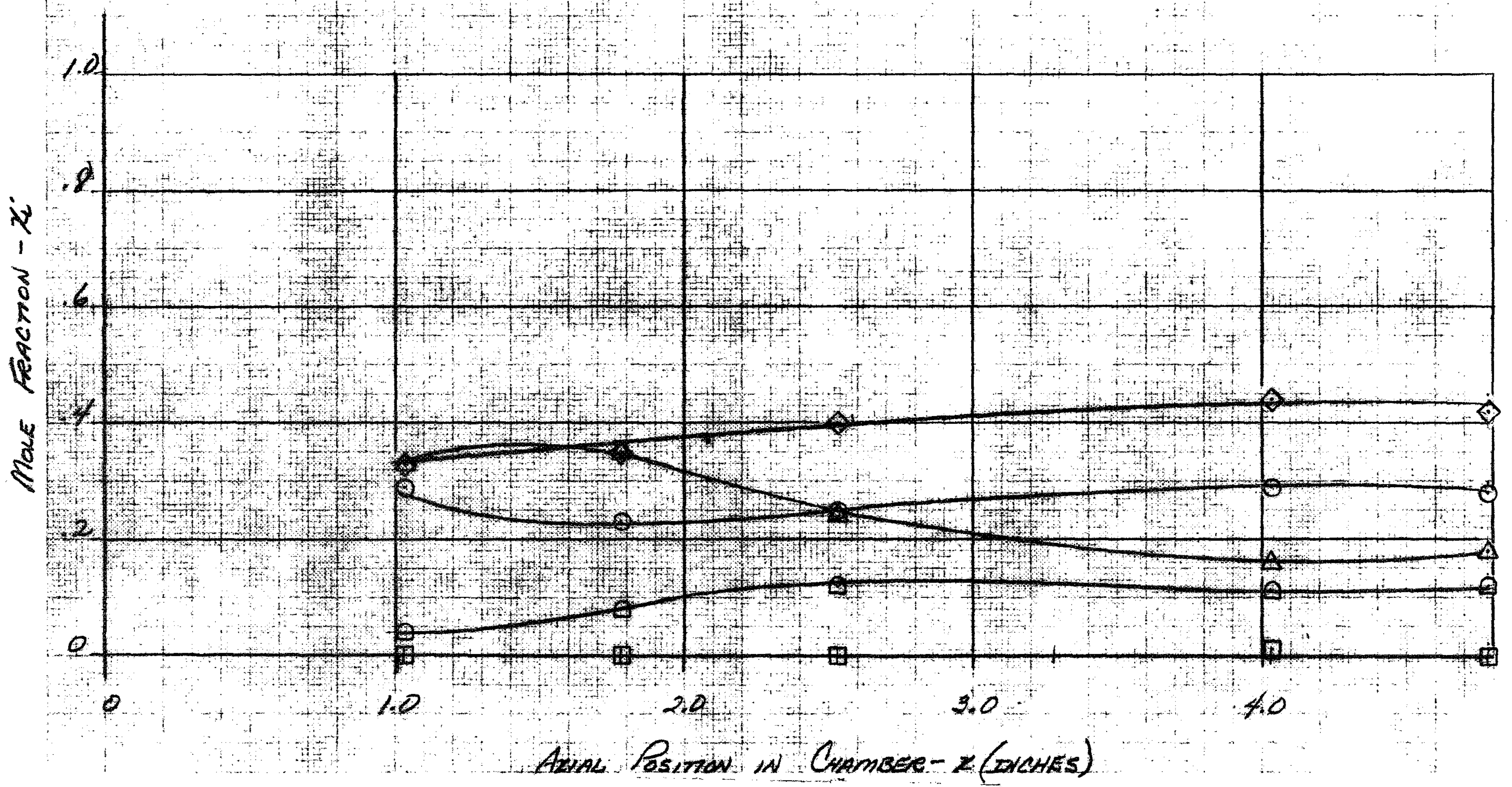

Figure 3.1. Continued
w, φ = 0

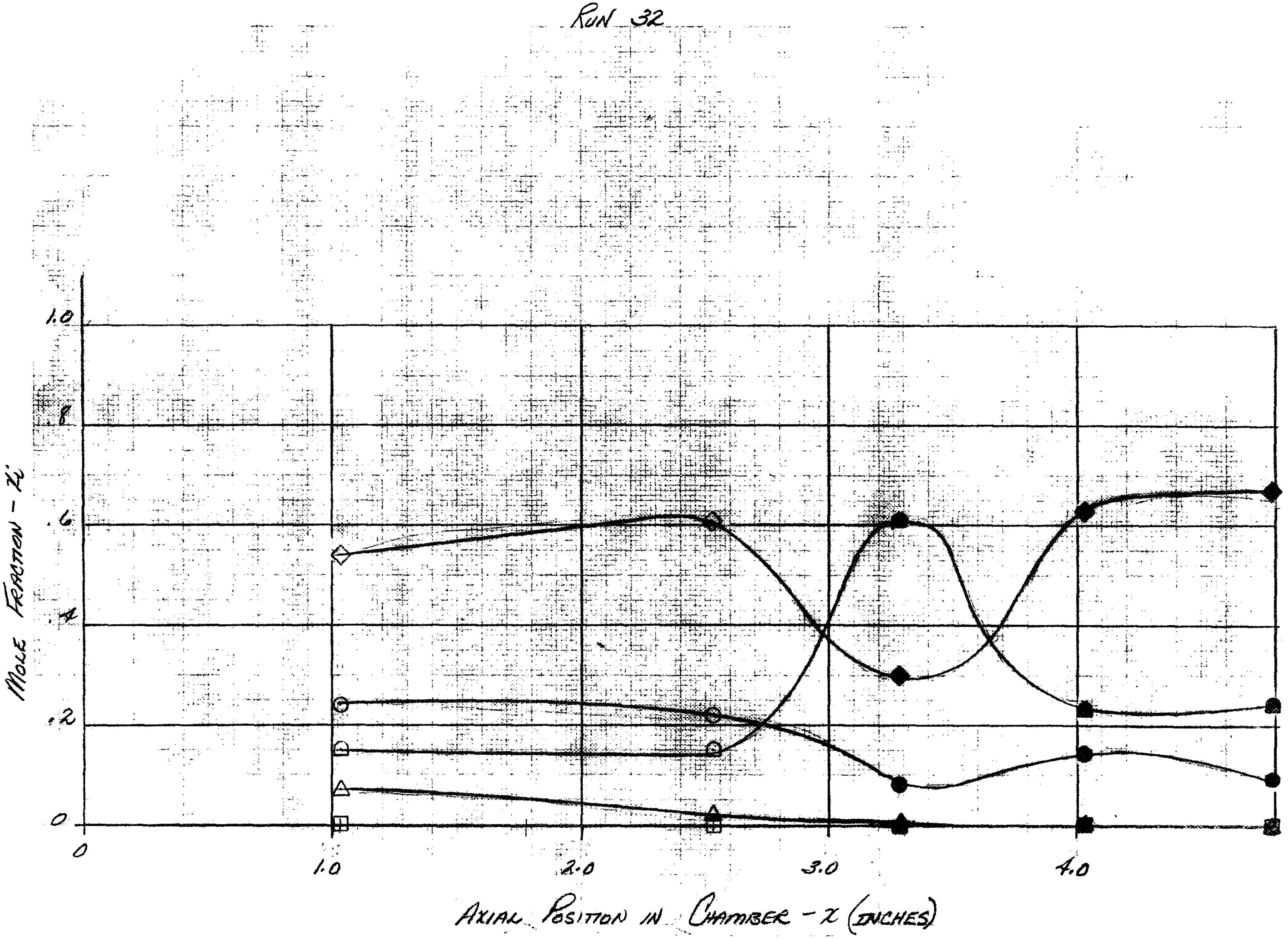

Figure 3.1. Concluded
x. φ = 260

SECTION 3.2

ATOMIC FRACTION DISTRIBUTION

The axial distribution of measured atomic fraction data for a fixed azimuth position is presented in Figure 3.2-a through 3.2-x. For the most part the data shows highly consistent trends. For most graphs the boundary flow is predominantly hydrogen rich (~50-60% H) near the injector end and nitrogen rich near the nozzle. For some ϕ positions the boundary flow appears to be nitrogen rich for all axial positions.

The high concentrations of water noted in Figures 3.1-o and x give correspondingly out-of-character atomic data adding to the evidence that the data is not valid. Again, reproducibility of the data seems good. Run 9 and runs 30 and 31 data are in quite good agreement near the injector and fair for positions near the nozzle. The sampling influence tests (Figures 3.2-u and v) data also compare favorably with that from run 9. The data from Figure 3.1-v (run 30) compares within ±2% with the data from Figure 3.1-a (run 9) for the major atoms (H and N). From these observations it can be concluded that not only is reproducibility quite good but moreover that little effect of upstream sampling is evident in the data.

RUN 9

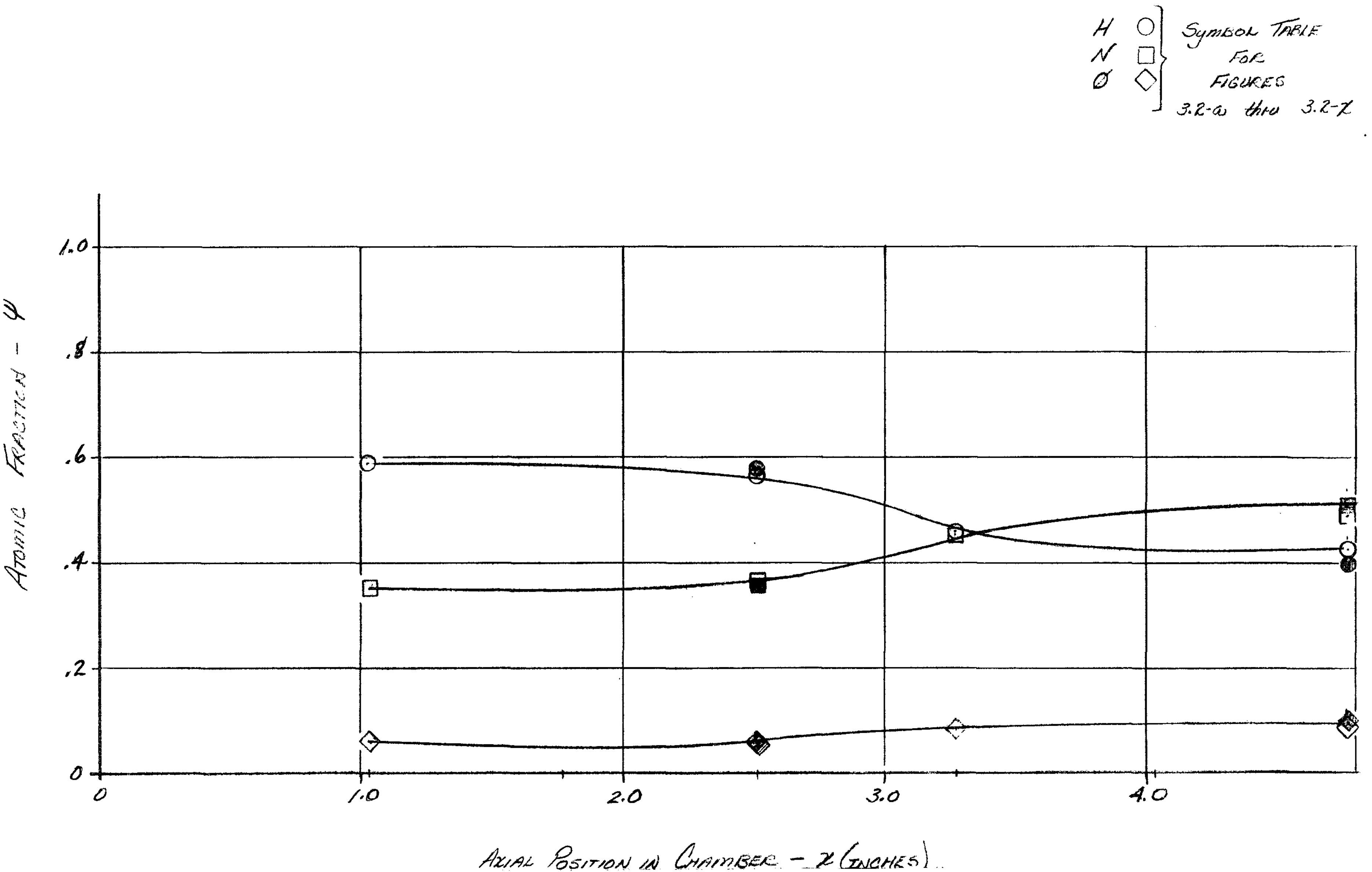

Figure 3.2. Axial Distribution of Atomic Fractions for a fixed Azimuth Position
a. $\phi = 0^{0}$

RUN 10

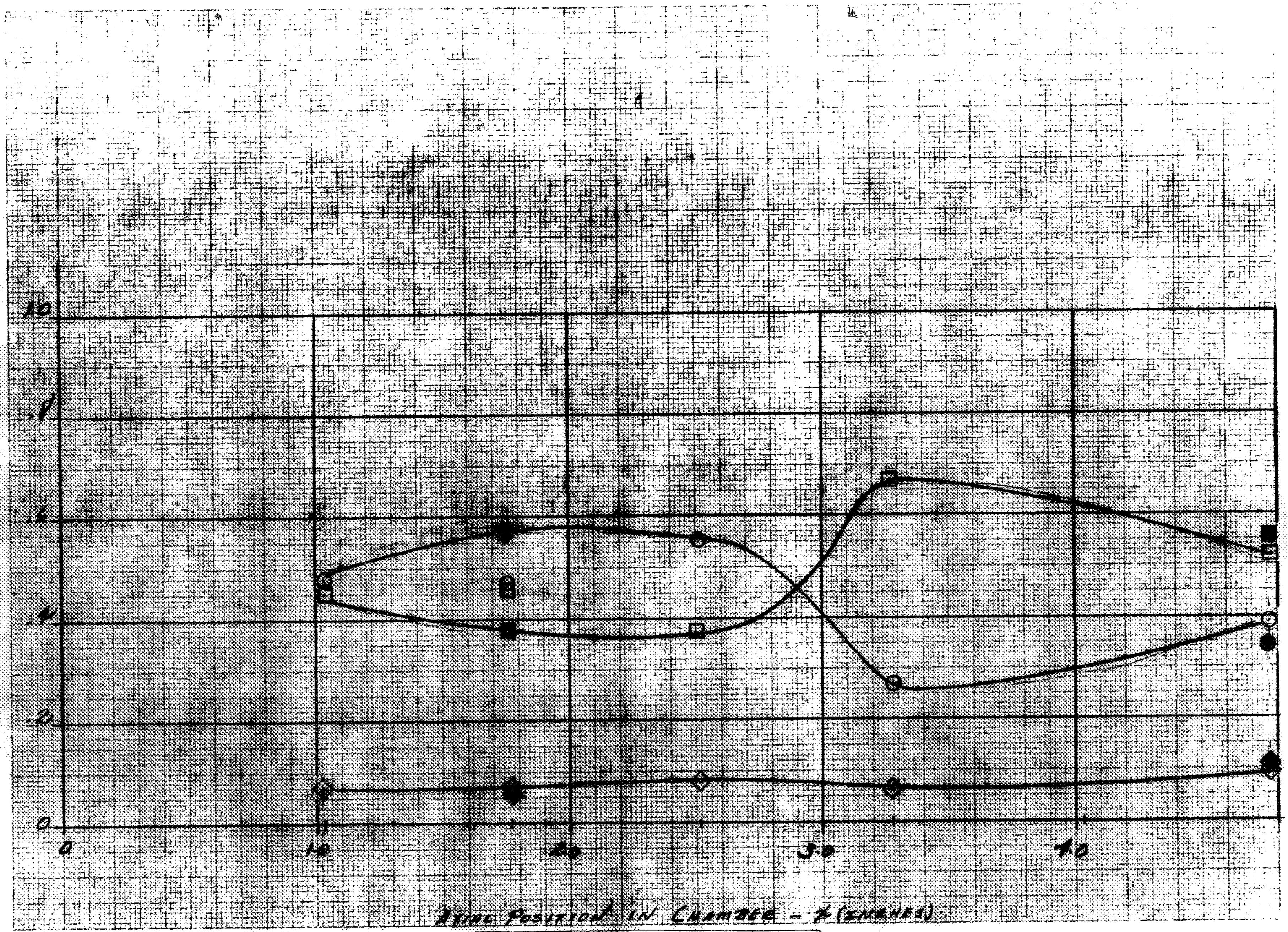

Figure 3.2. Continued
b. $\phi = 30^0$

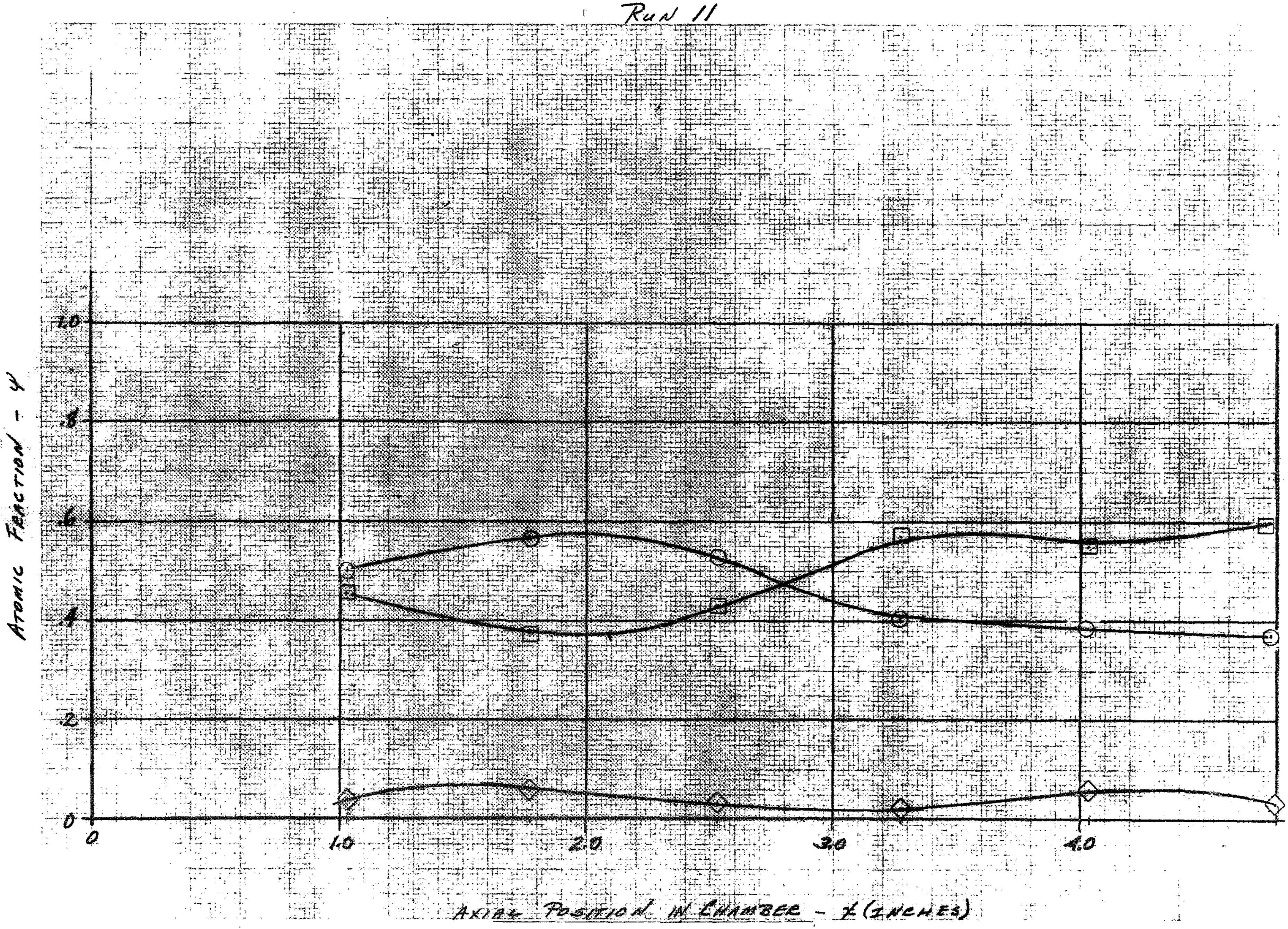

Figure 3.2. Continued
c. $\phi = 60^0$

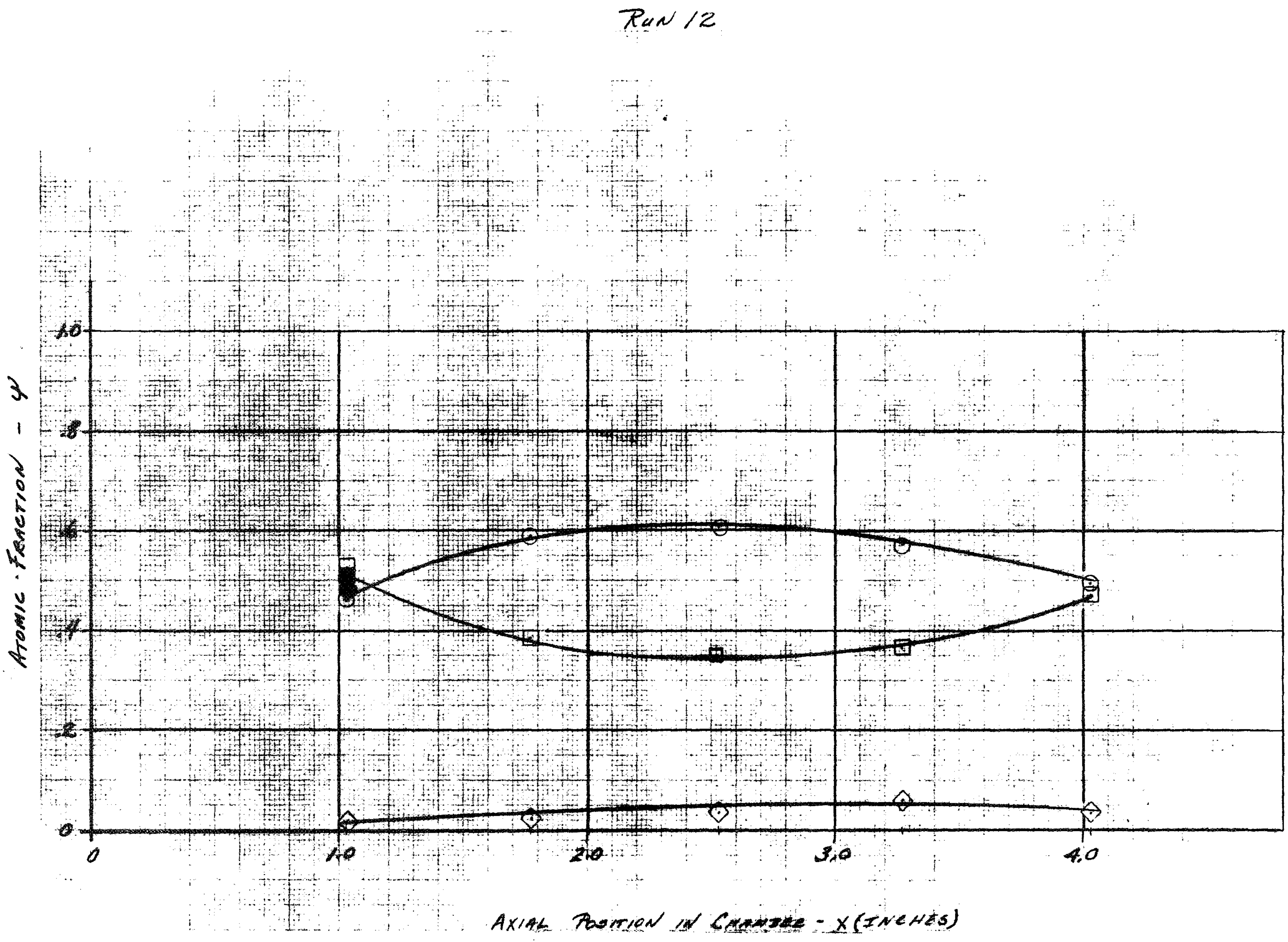

Figure 3.2. Continued
d. $\phi = 90^\circ$

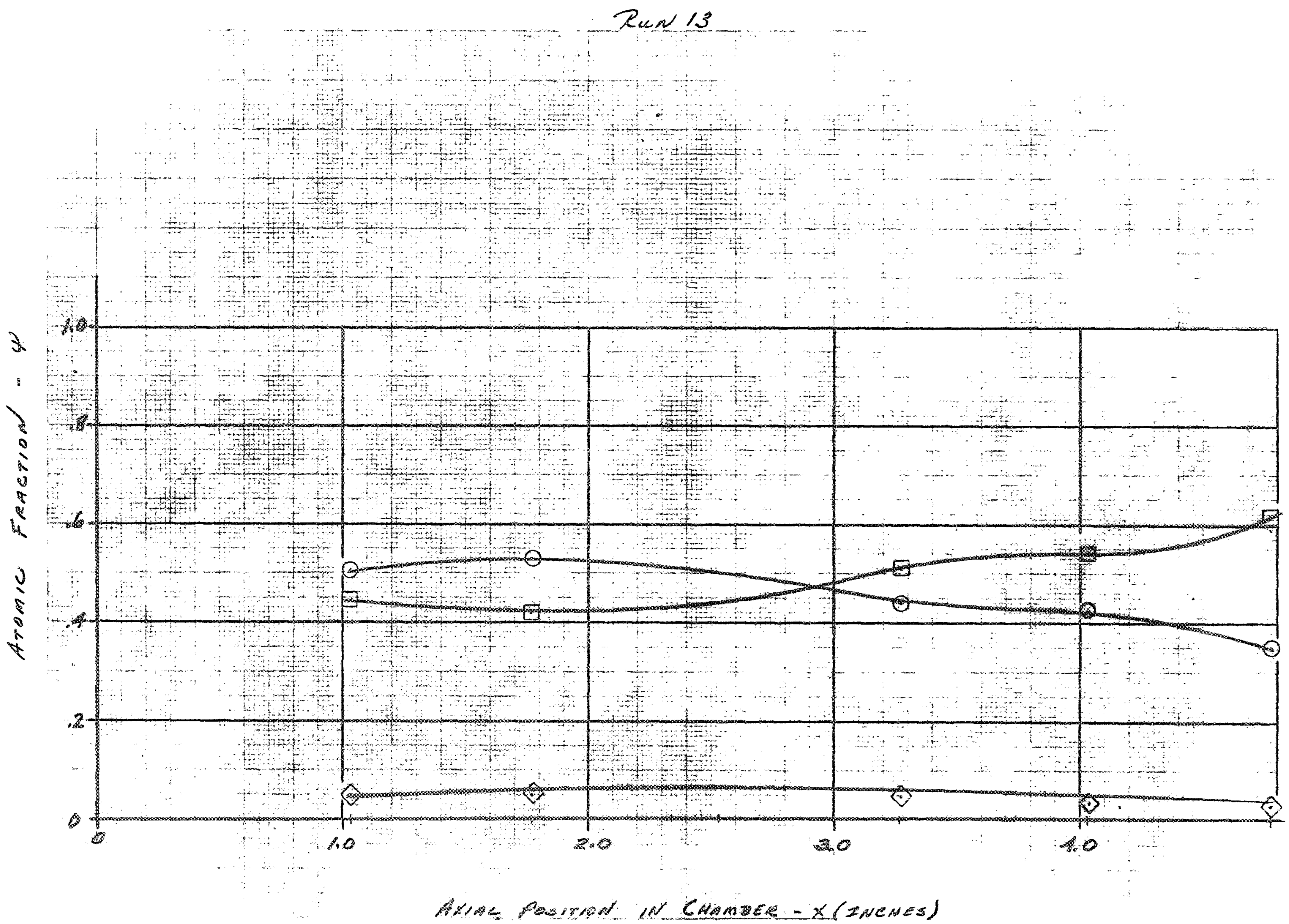

Figure 3.2. Continued
e. ϕ = 120°

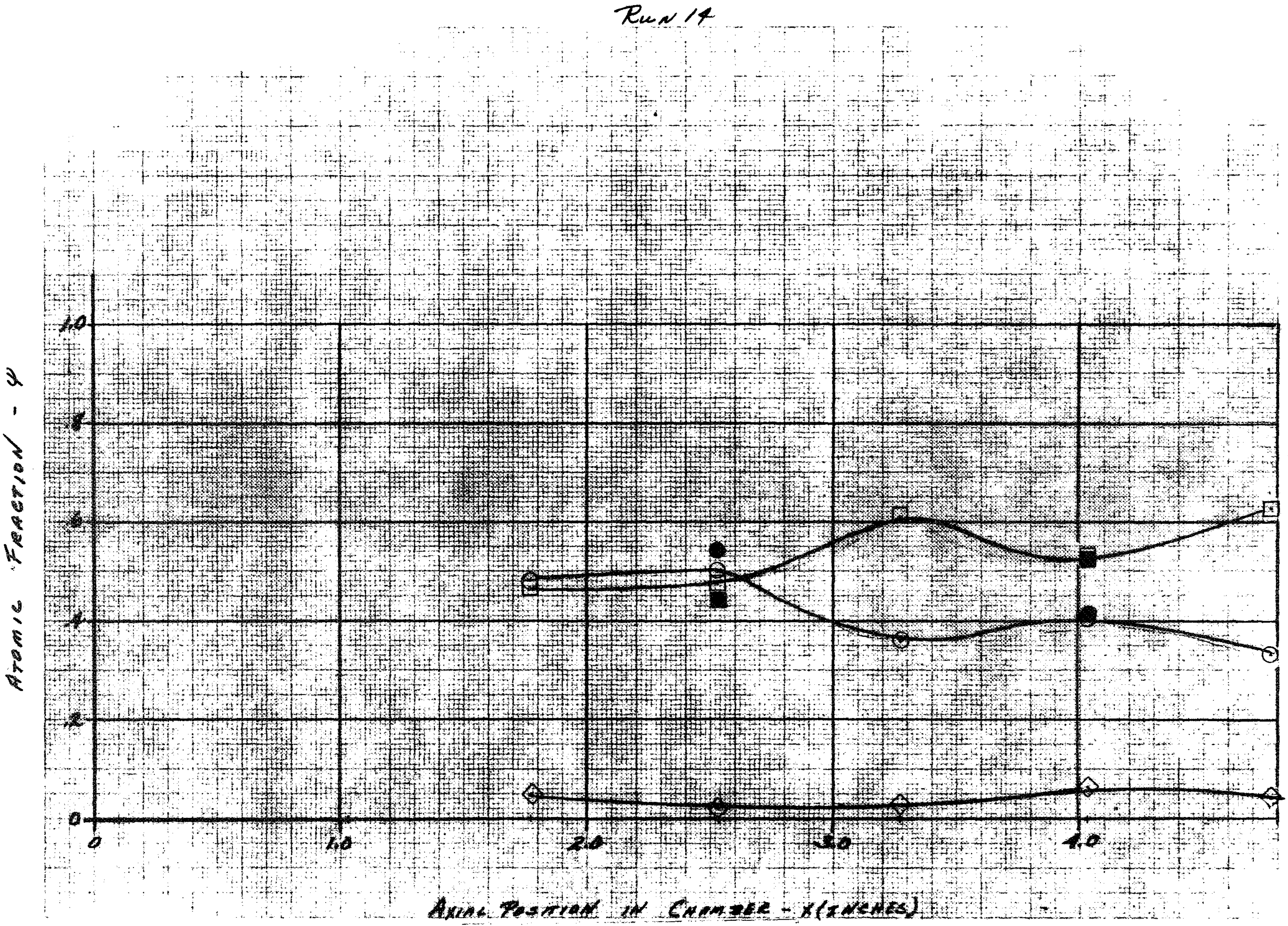

Figure 3.2. Continued
f. ϕ = 150°

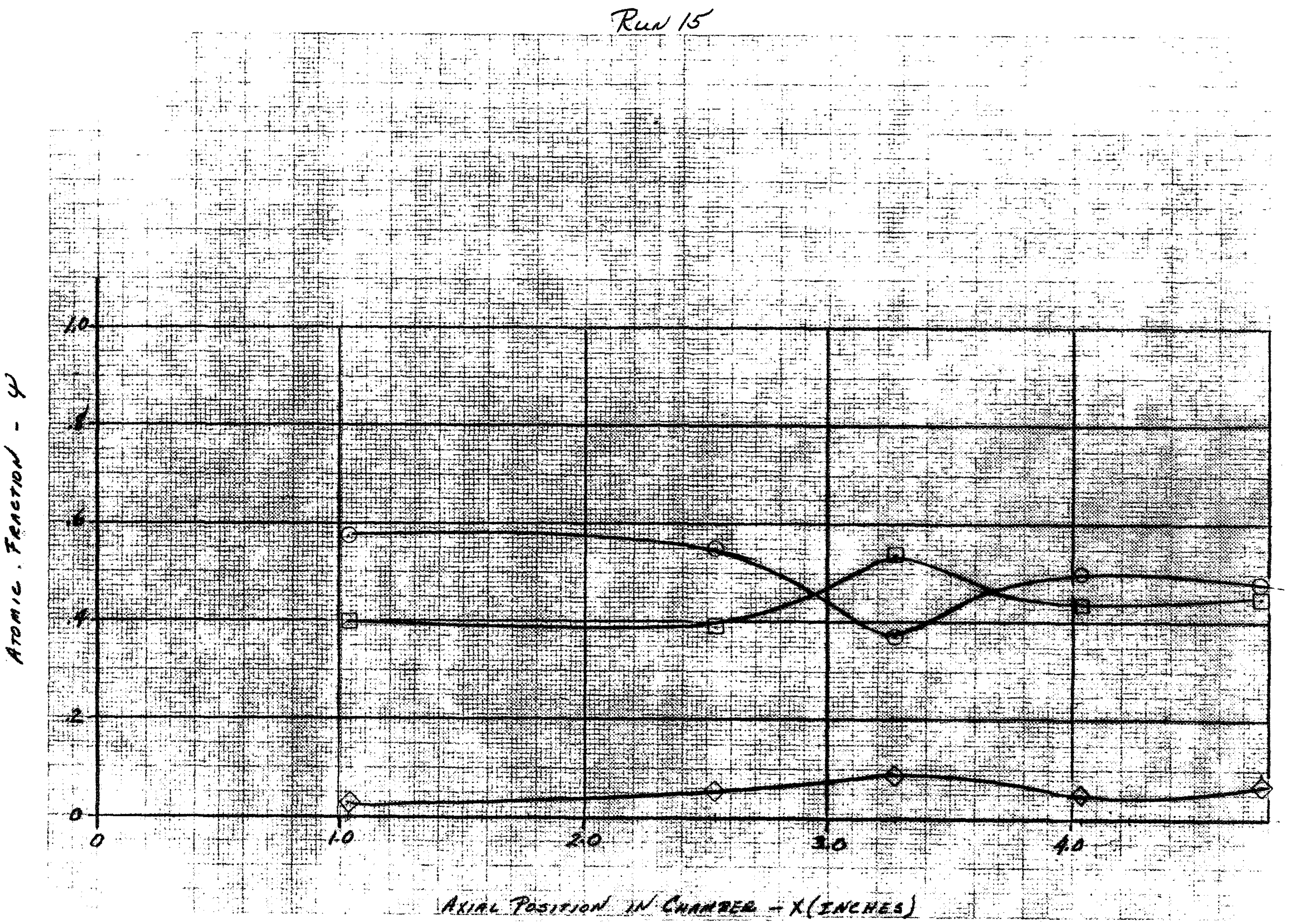

Figure 3.2. Continued
g. $\phi = 180^{\circ}$

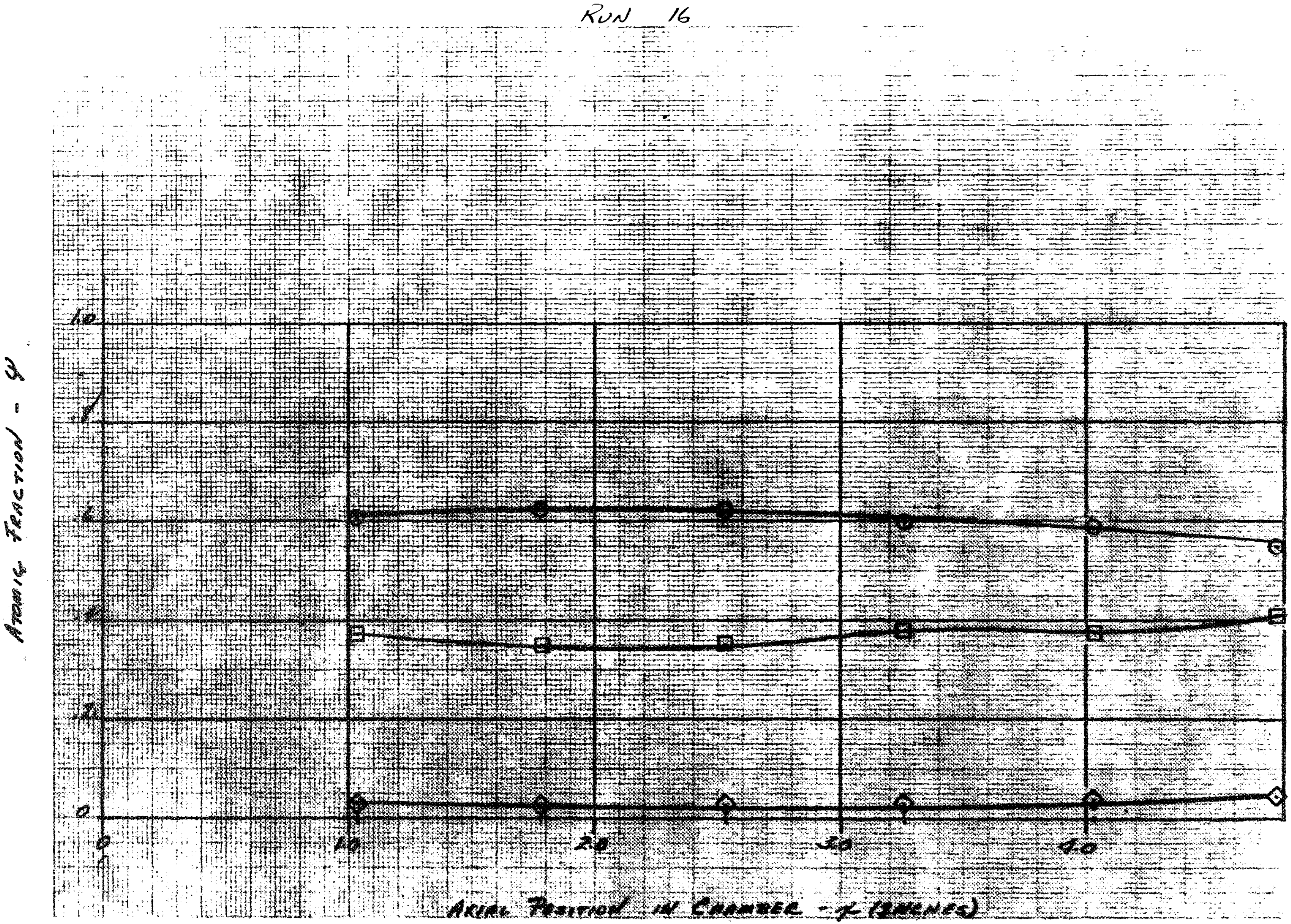

Figure 3.2. Continued
h. φ = 190°

Run 17

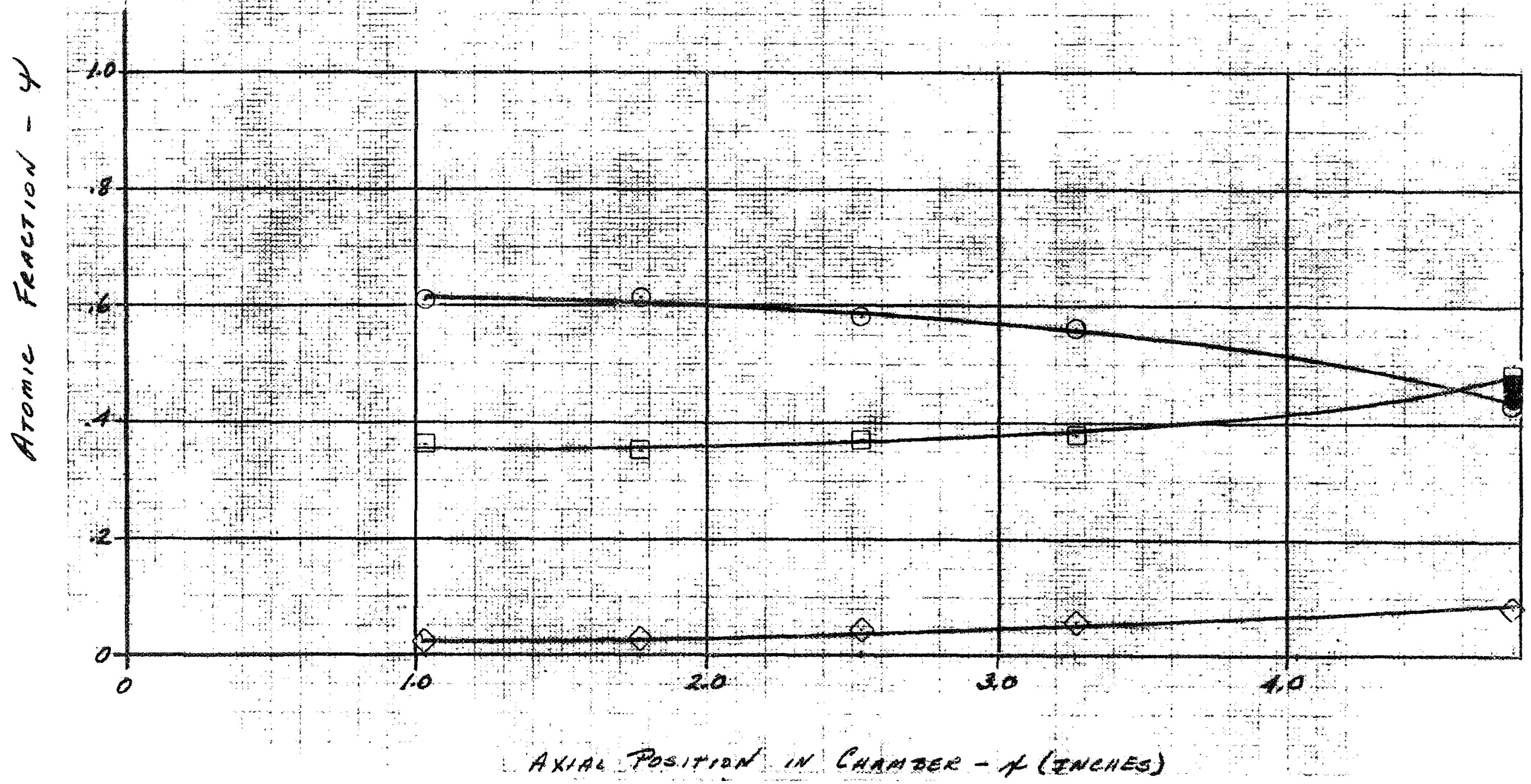

Figure 3.2. Continued
i. $\phi = 200^0$

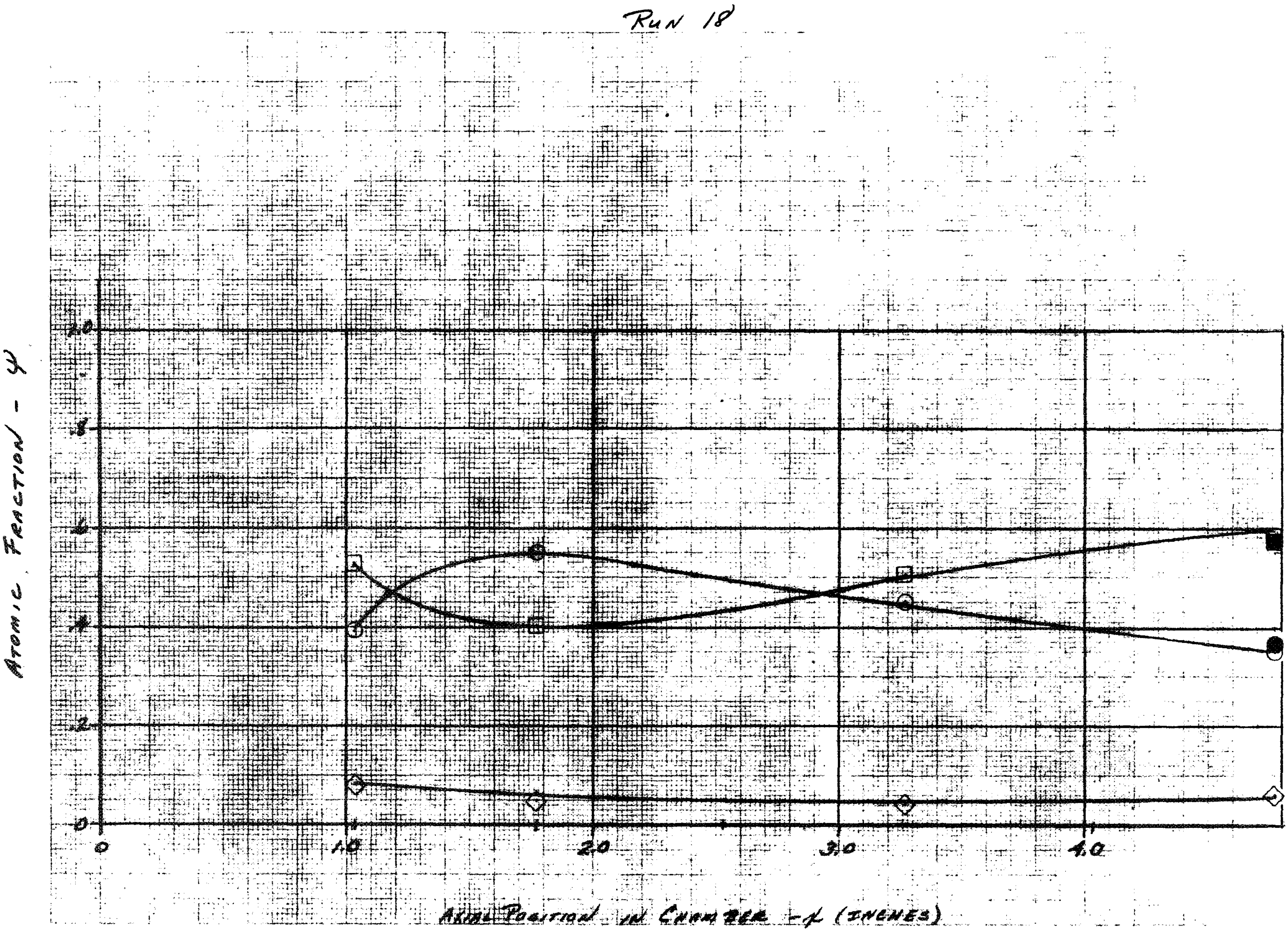

Figure 3.2 Continued
j. φ = 210°

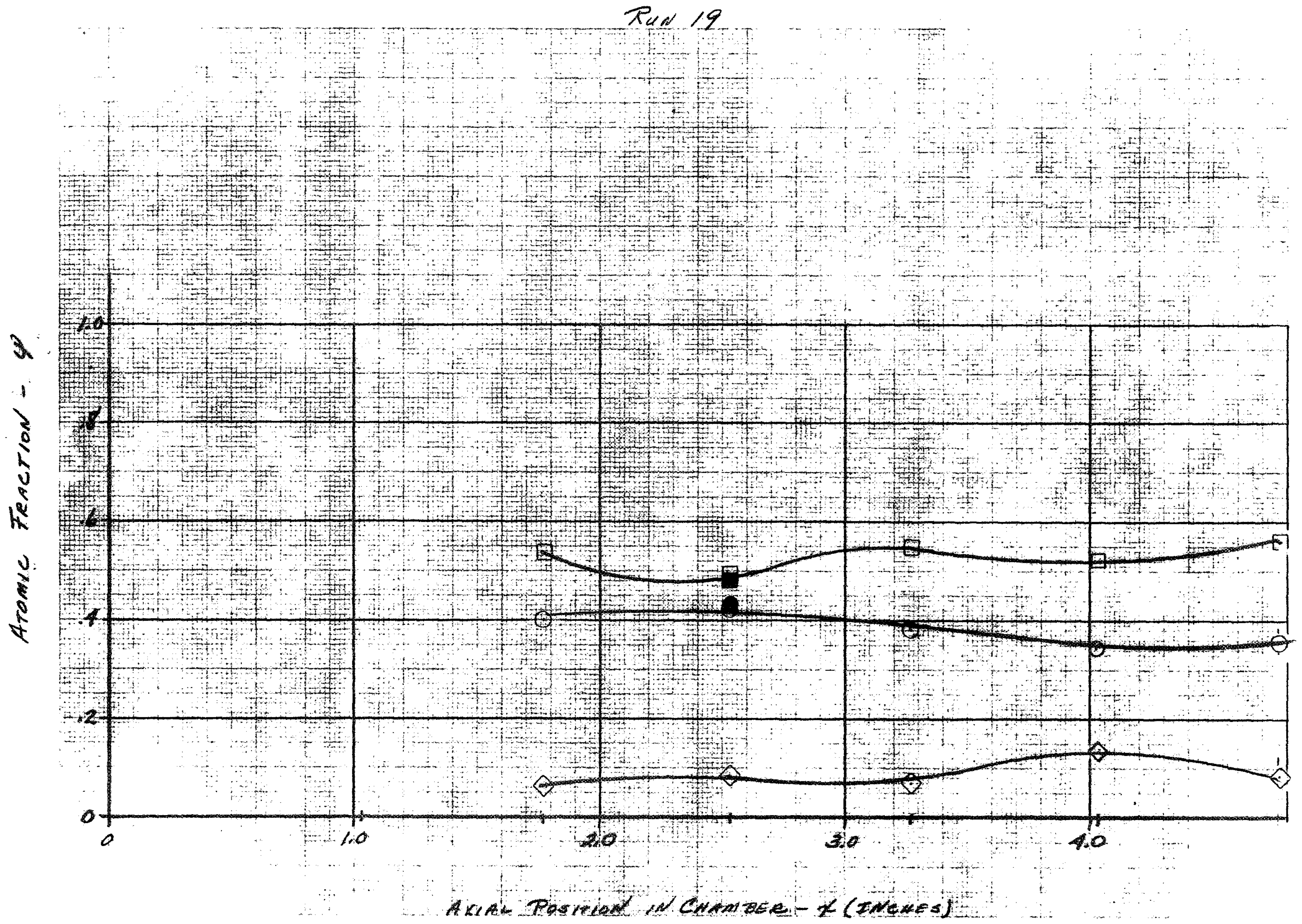

Figure 3.2. Continued
k. $\phi = 220^\circ$

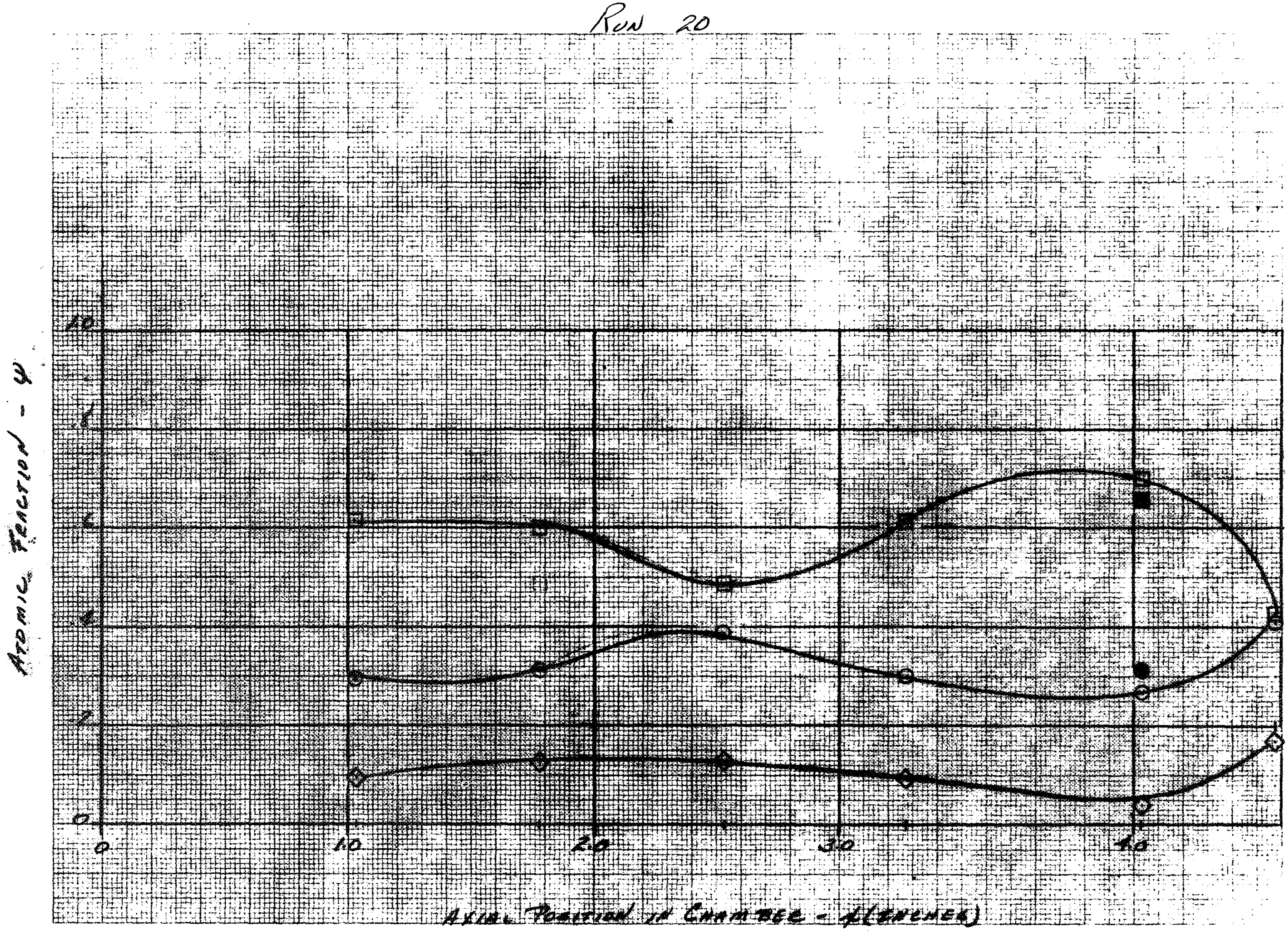

Figure 3.2. Continued
1. $\phi = 230^{\circ}$

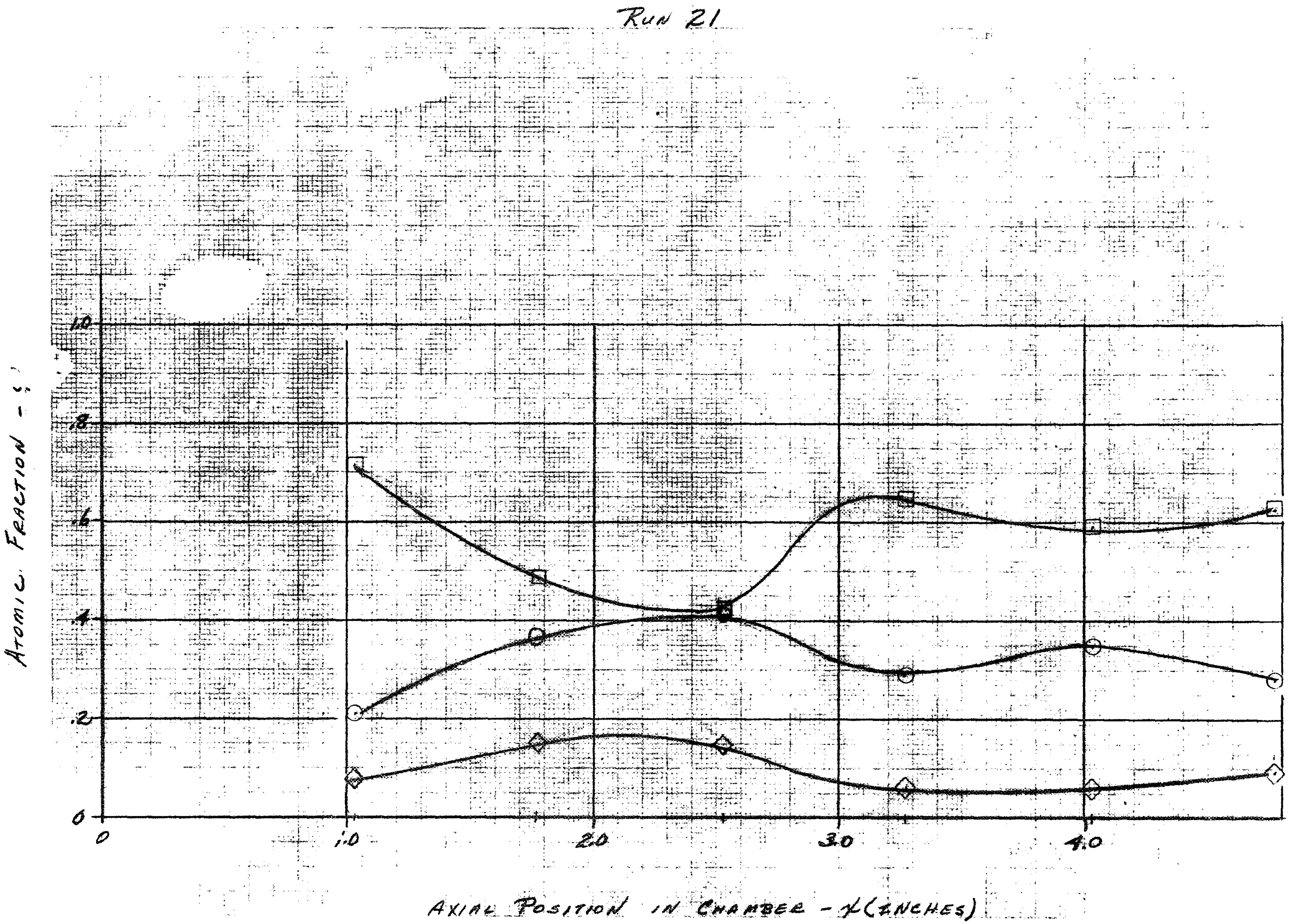

Figure 3.2. Continued
m. $\phi = 240^{0}$

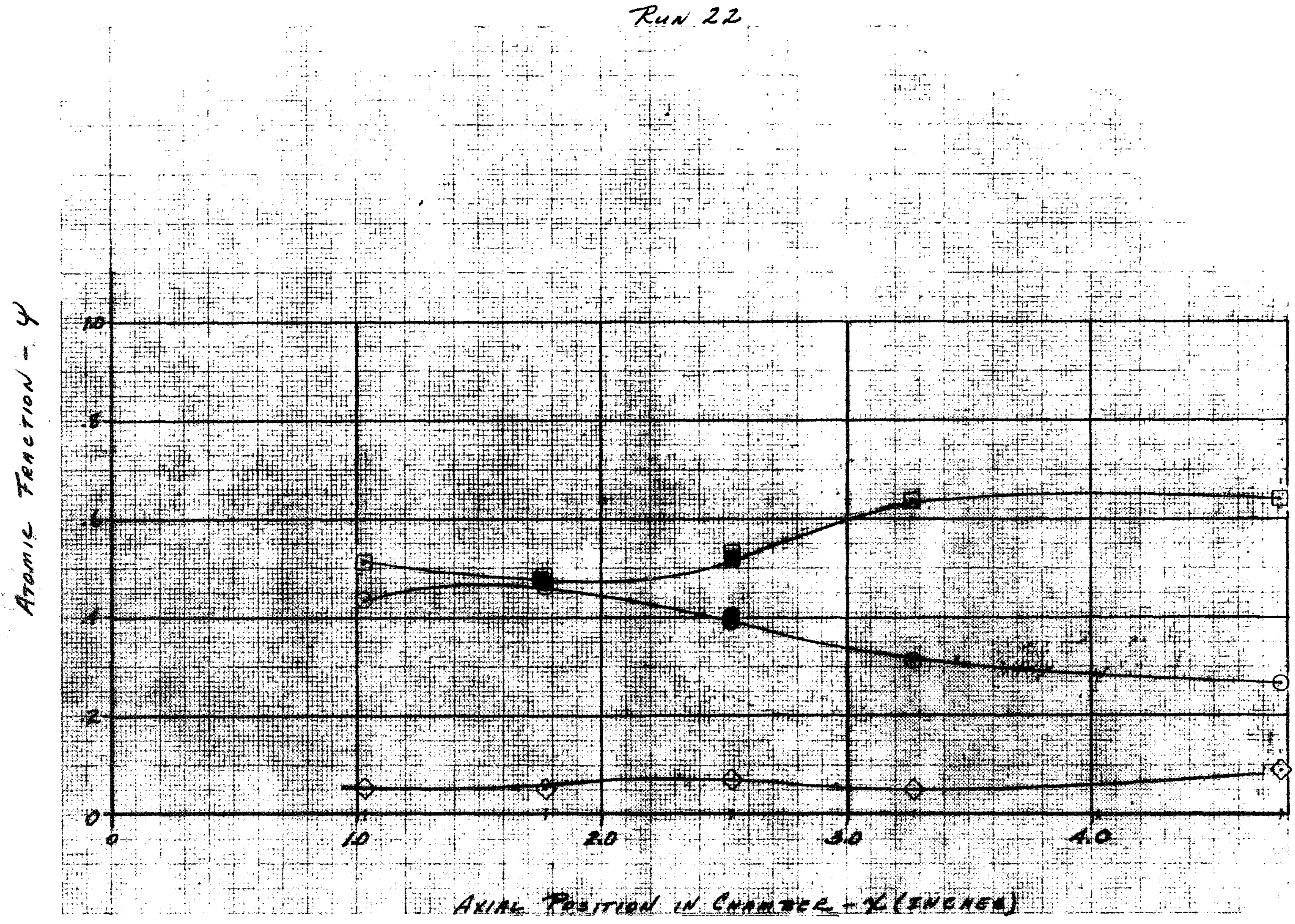

Figure 3.2 Continued
n. $\phi = 250°$

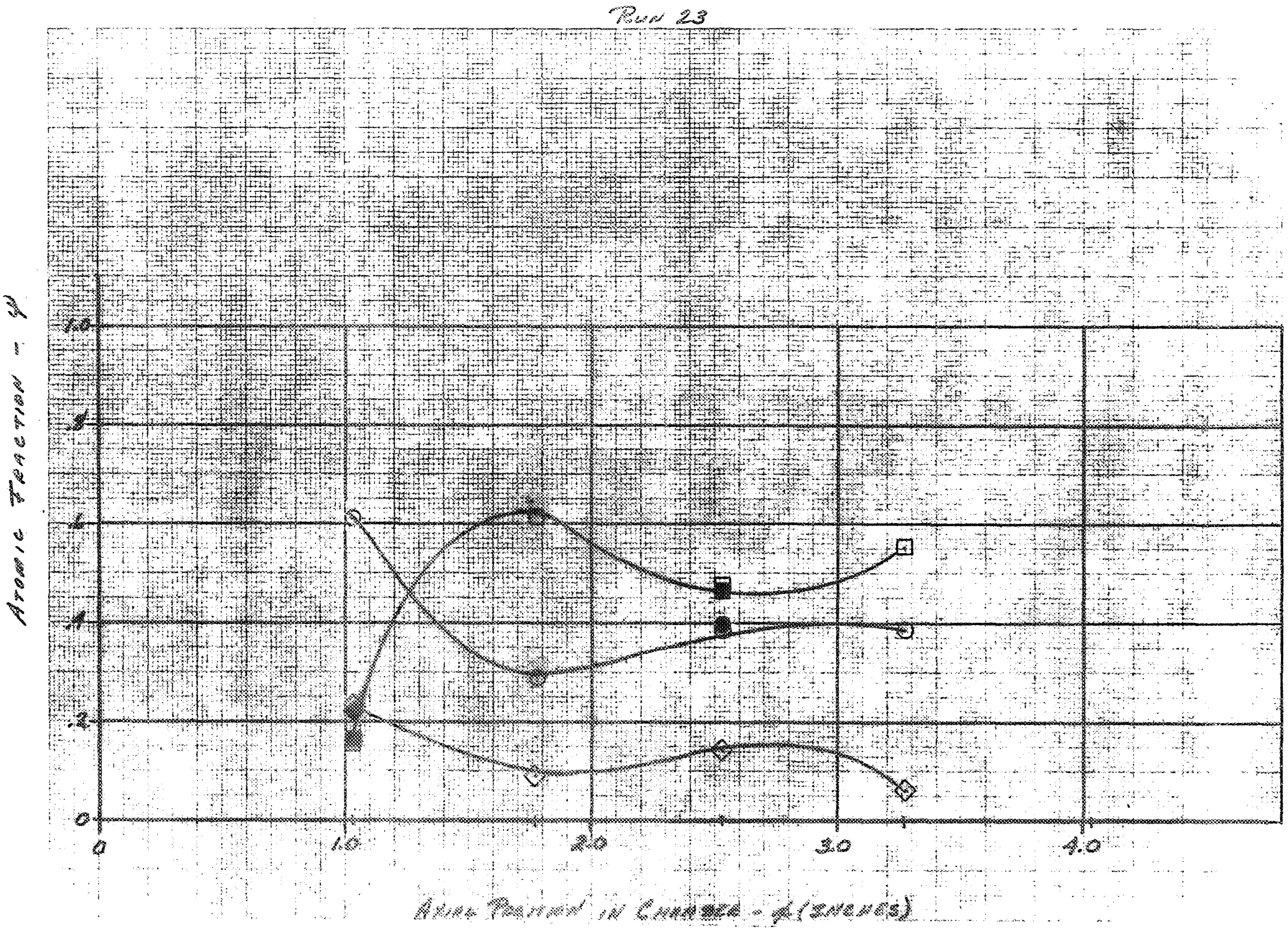

Figure 3.2. Continued
c. φ = 260°

Run 24

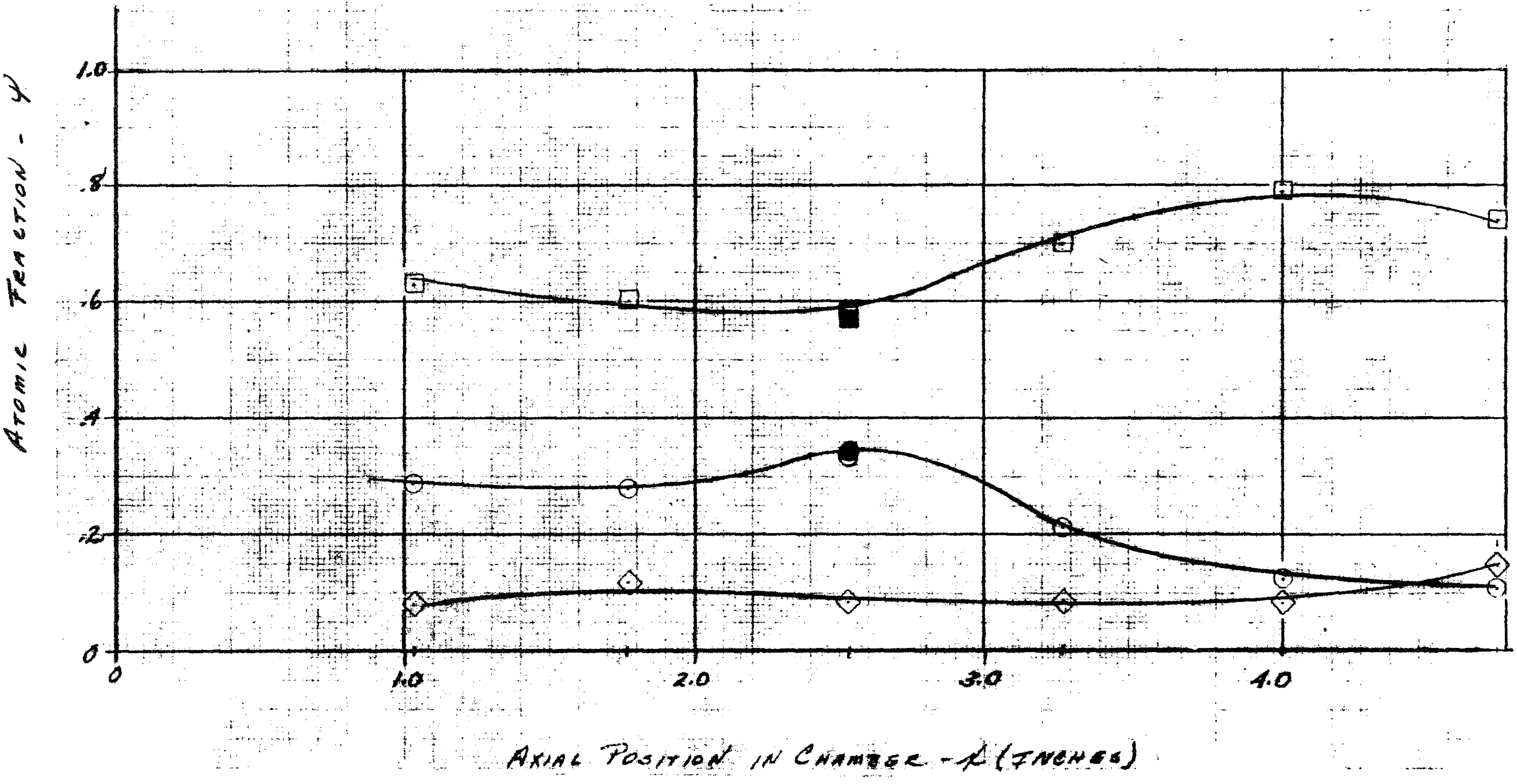

Figure 3.2. Continued
p. ϕ = 270°

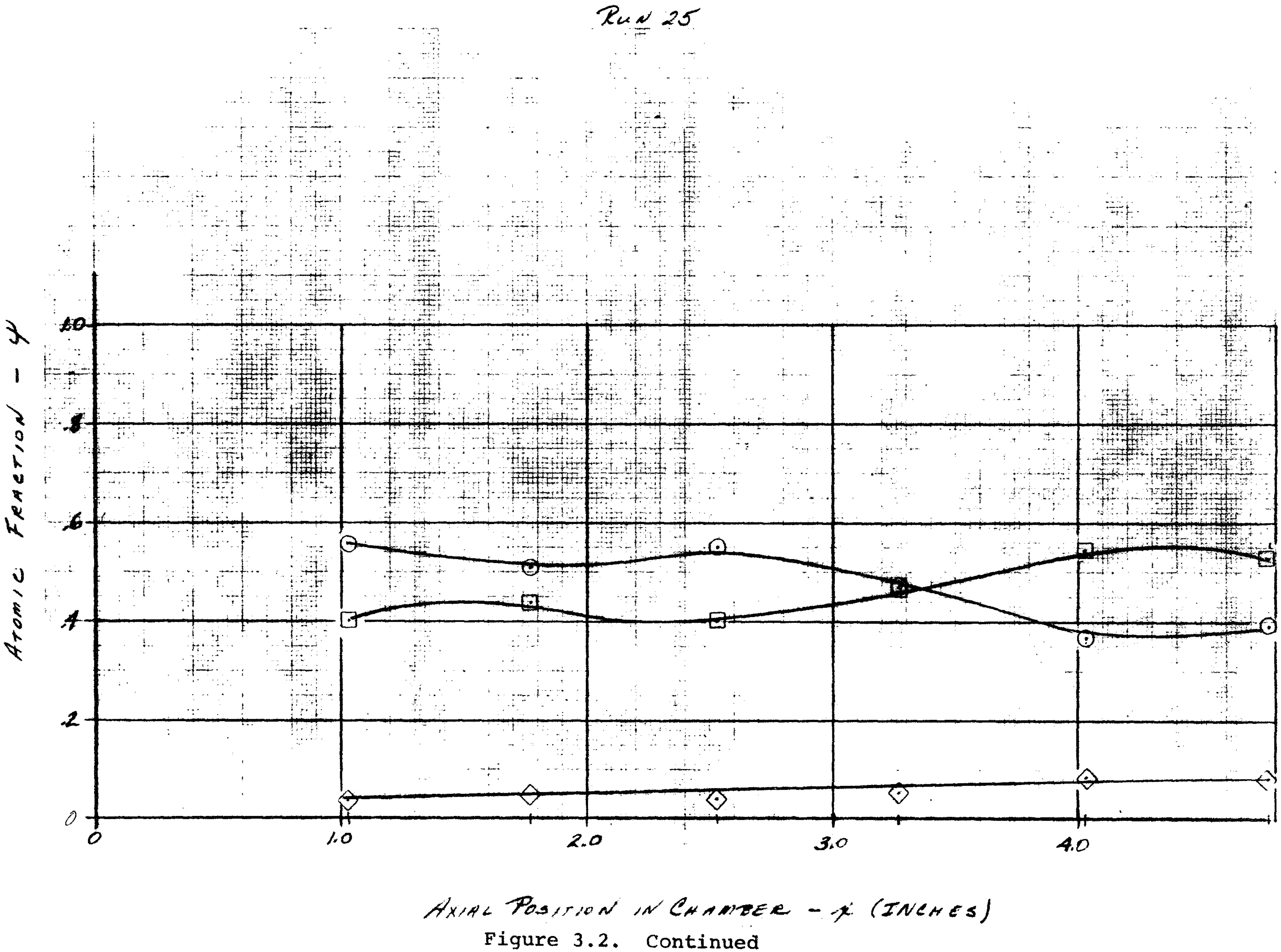

Figure 3.2. Continued
q. ϕ = 300°

Run 26

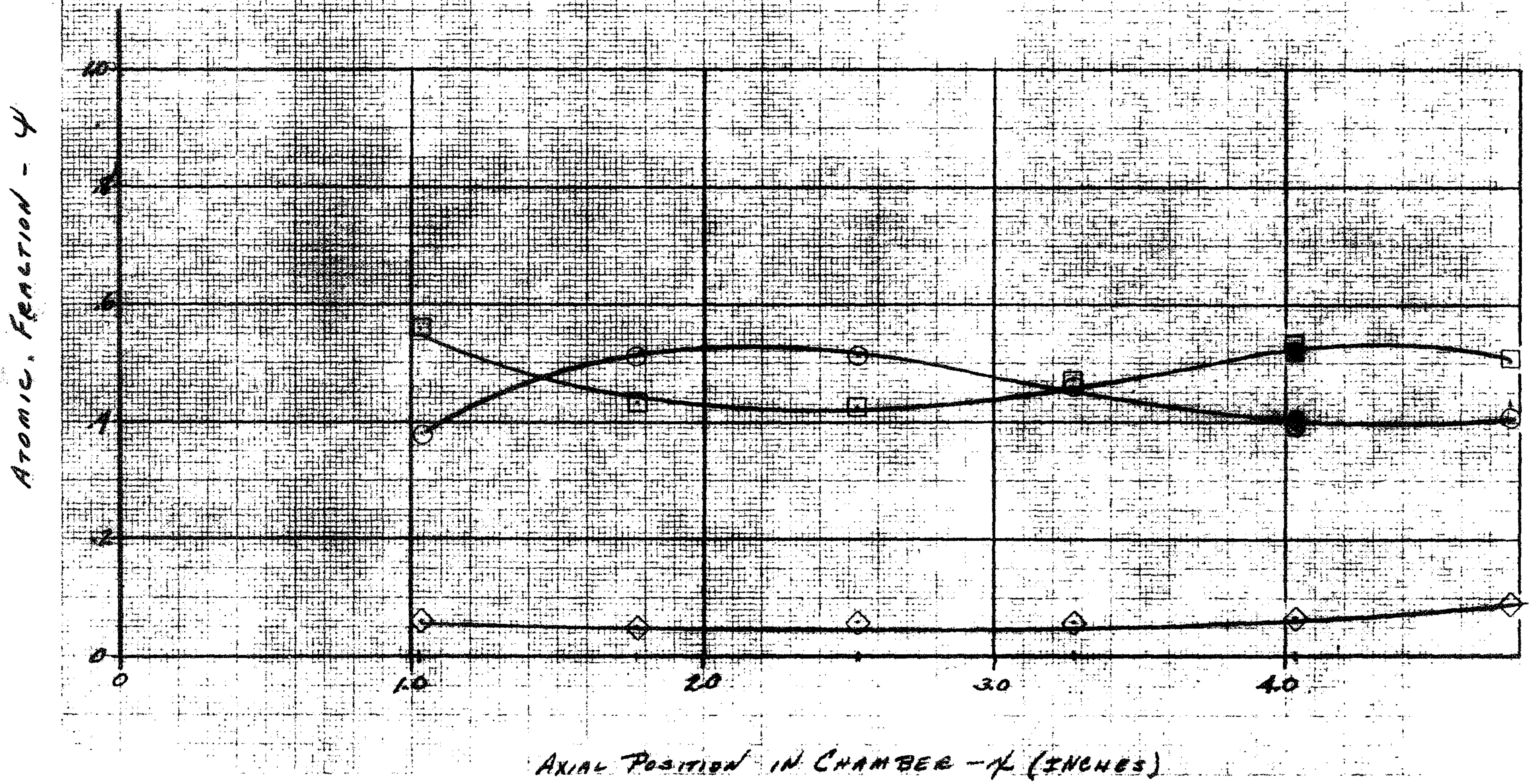

Figure 3.2. Continued
r. φ = 330°

Run 27

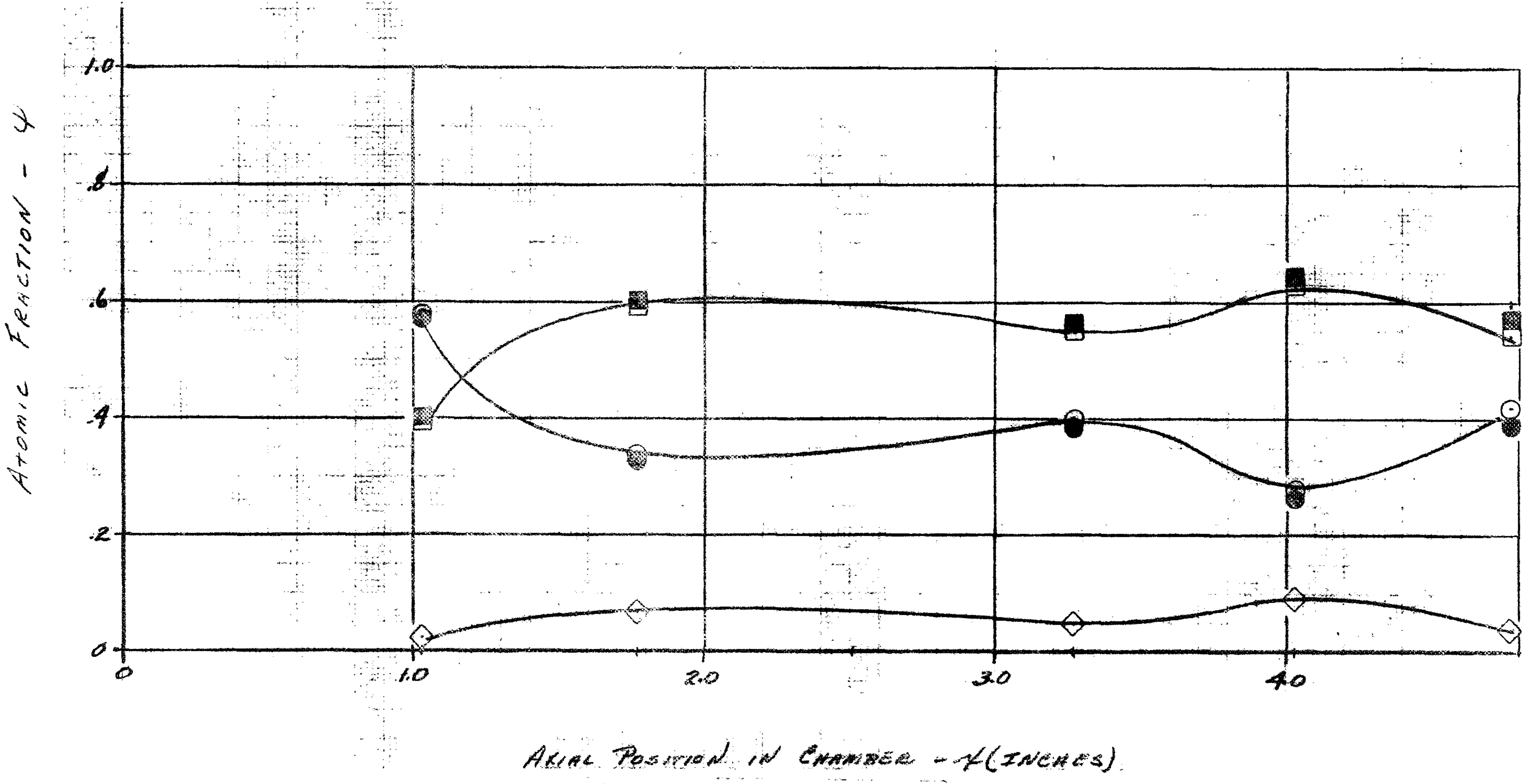

Figure 3.2. Continued
s. φ = 0°

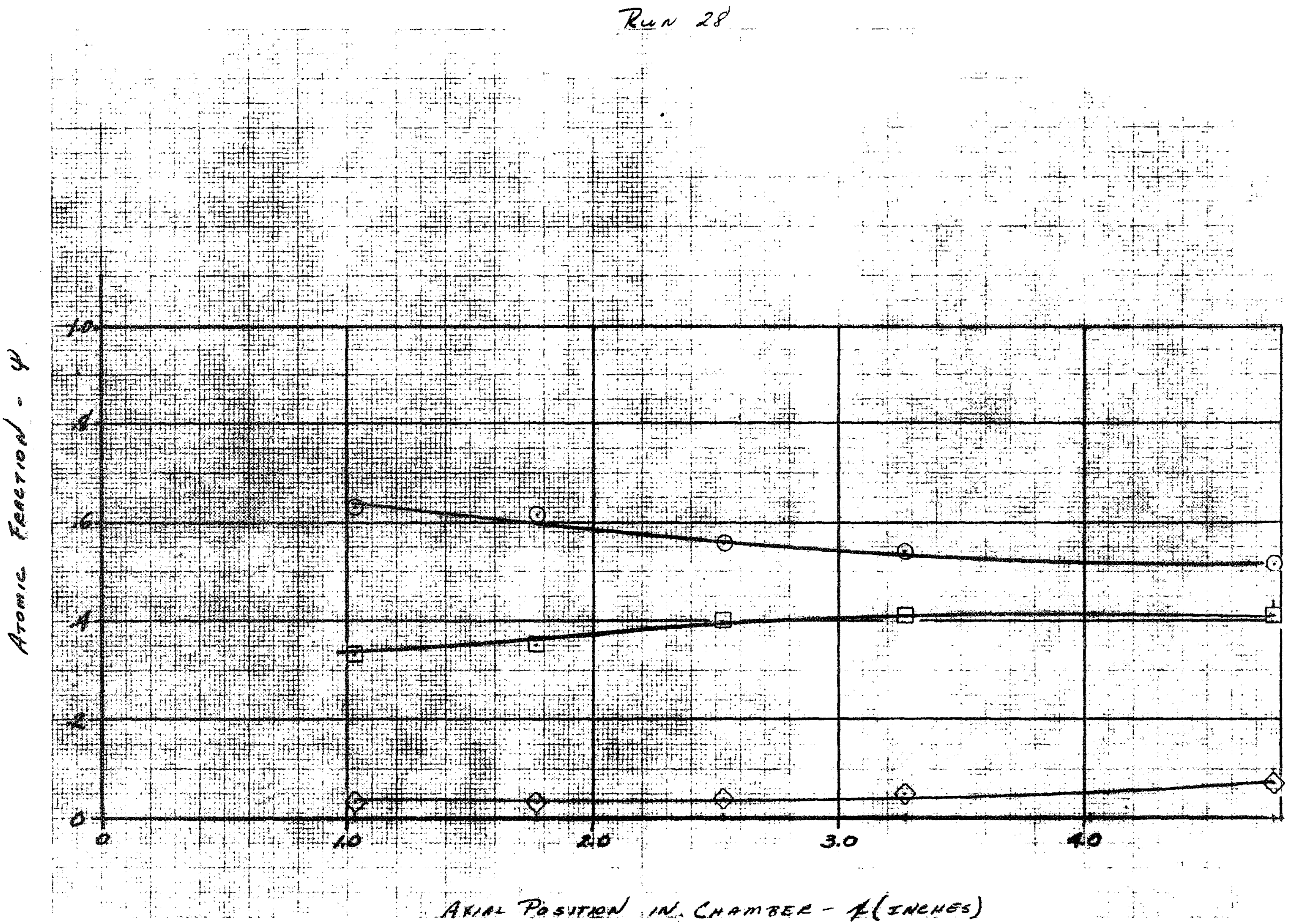

Figure 3.2. Continued
t. $\phi = 0^0$

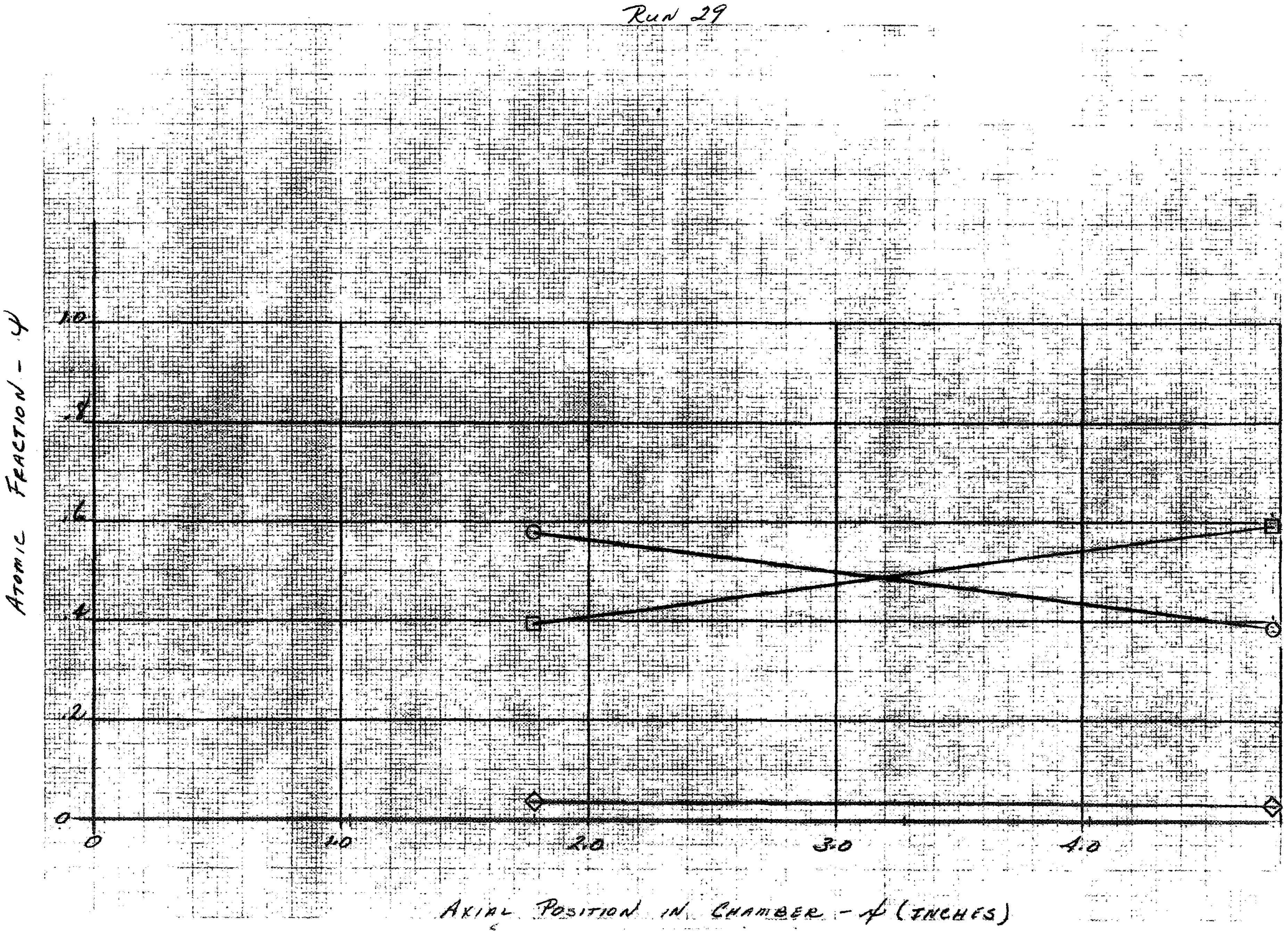

Figure 3.2. Continued
u. $\phi = 0^0$

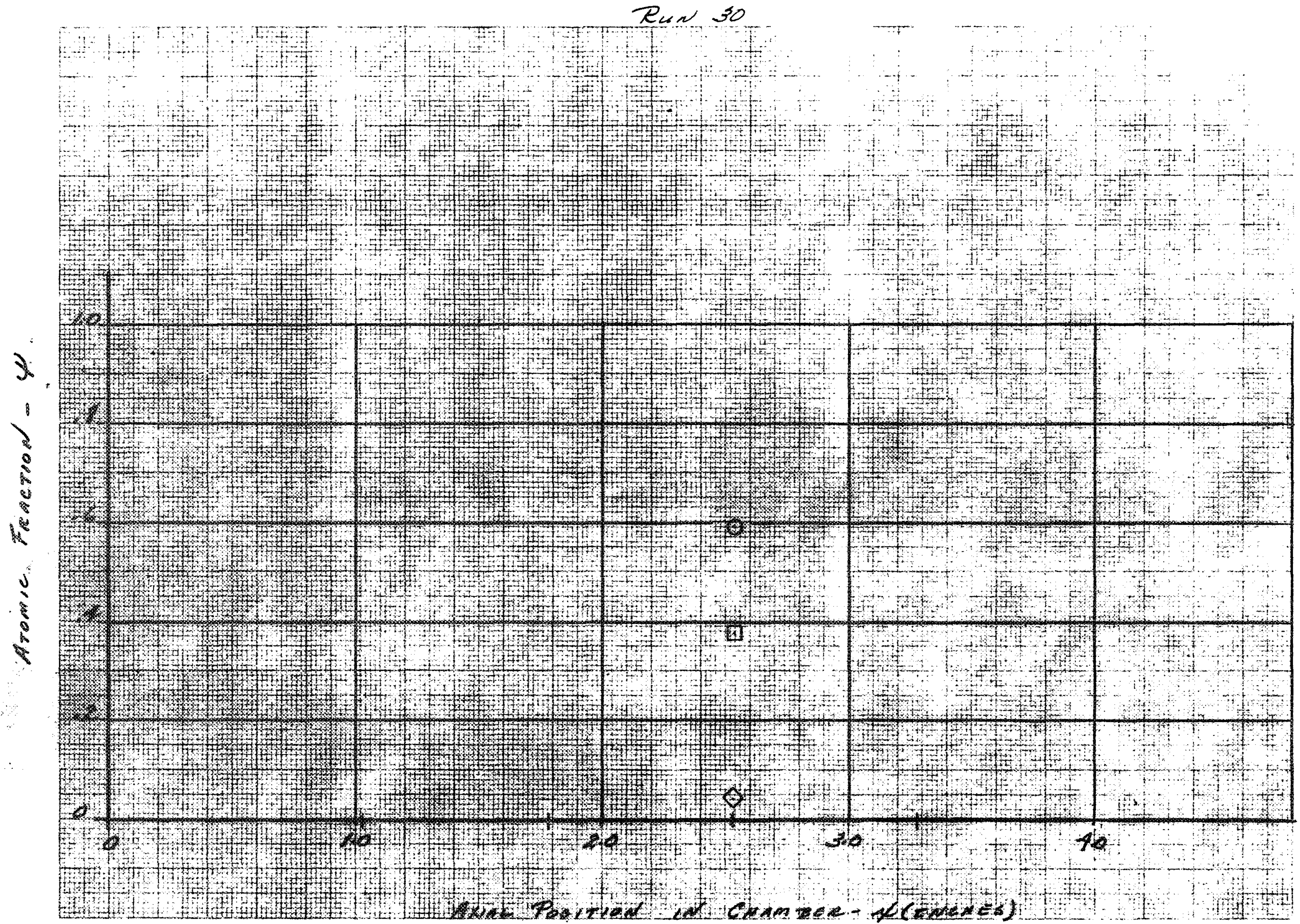

Figure 3.2. Continued
v. $\phi = 0^{0}$

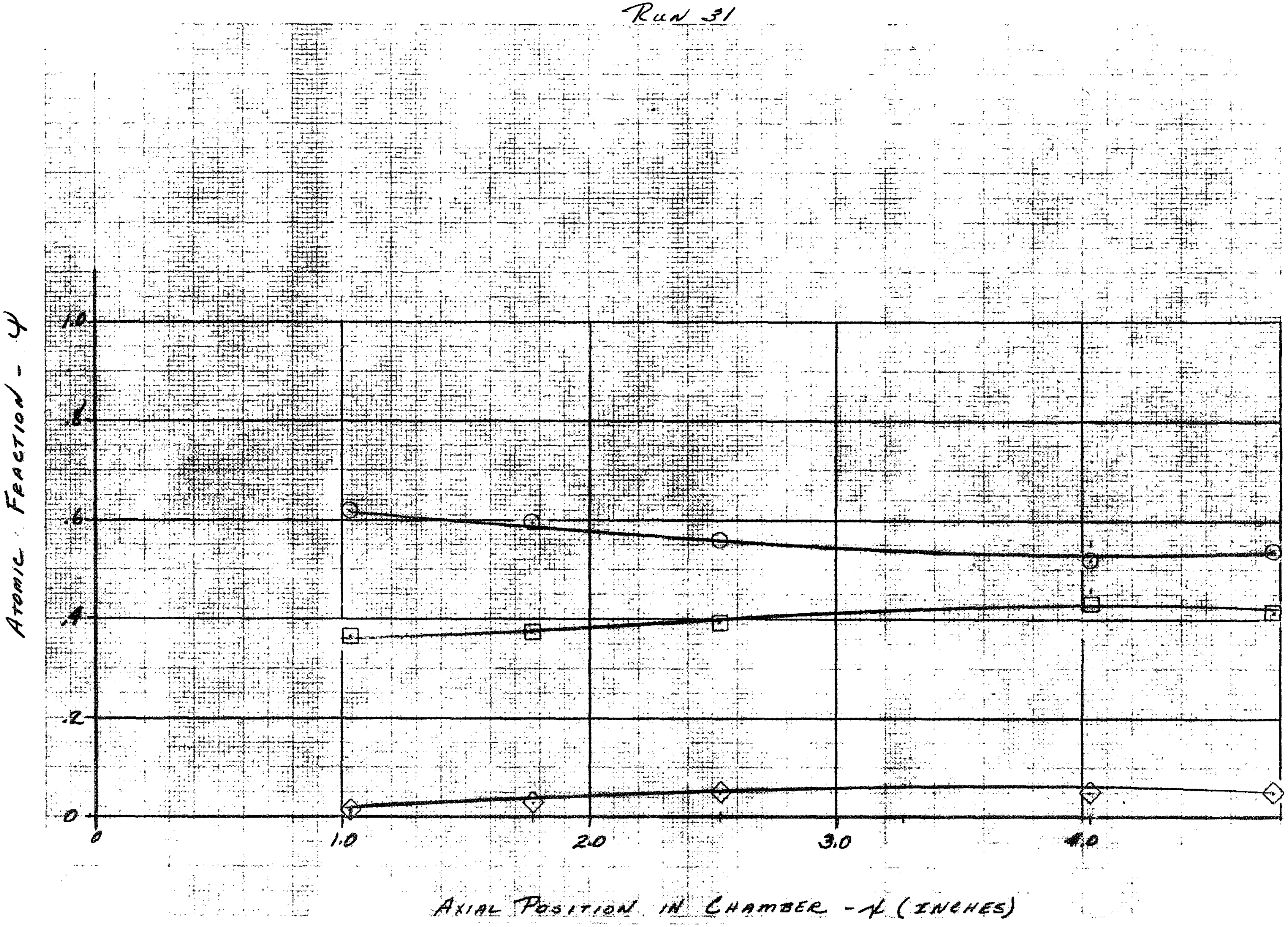

Figure 3.2. Continued
W. ϕ = 0°

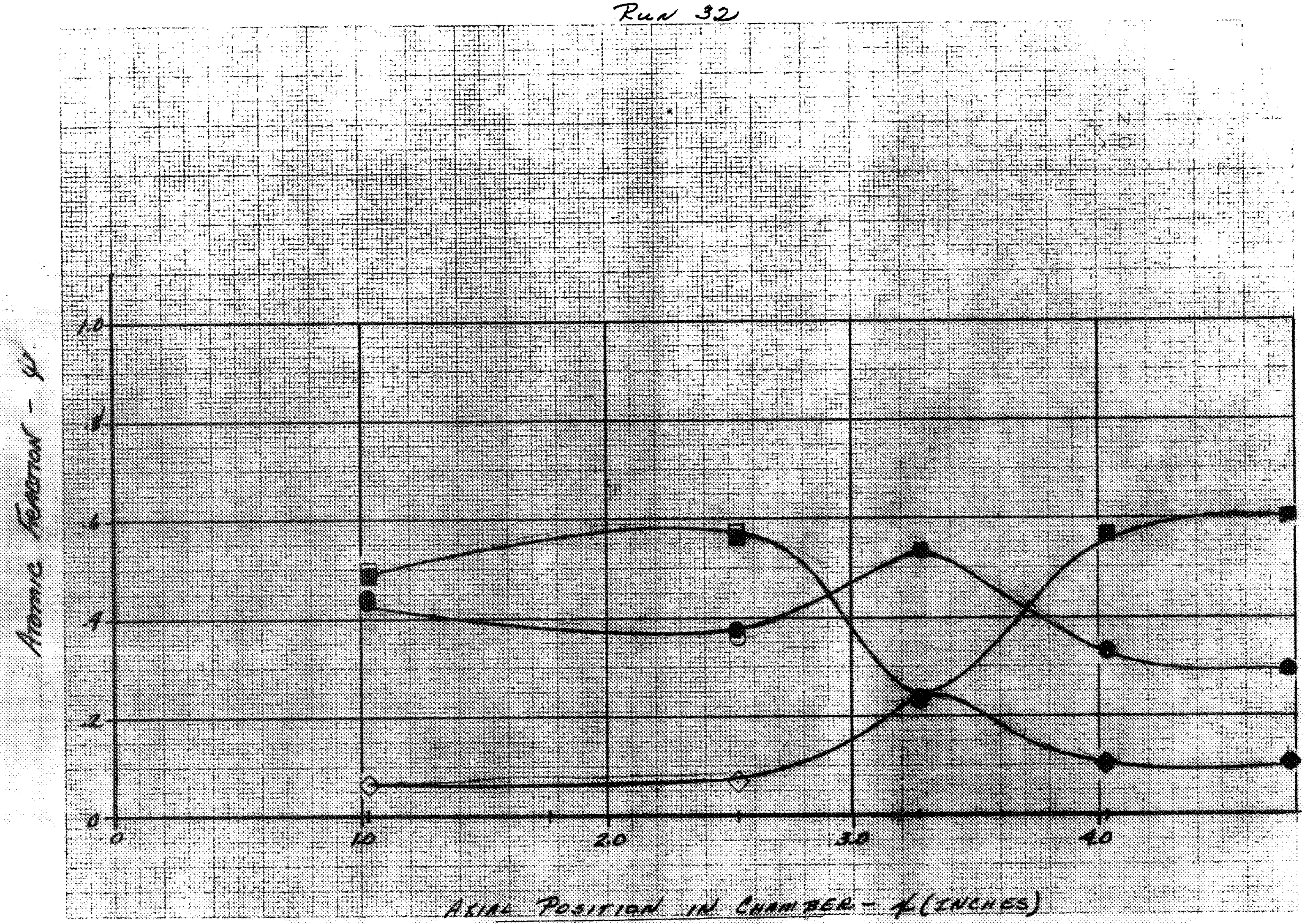

Figure 3.2. Continued
x. ϕ = 260°

SECTION 3.3

CIRCUMFERENTIAL ATOMIC FRACTION DISTRIBUTION

The circumferential data is presented in three sets corresponding to the three types of atoms present. Figures 3.3-a through 3.3-f present the hydrogen fraction distribution for the six axial locations, 3.4 those for nitrogen and 3.5 those for oxygen. These figures show the trends mentioned previously--that the major fluctuation in chemical composition occurs in the 180° to 300°+ region (the angular spread largest at the position closest to the injector). It is seen that the reproducibility of the data is fair (compared to the magnitude of the fluctuations caused by changing injector position). The oxygen fraction is found to be fairly constant--the highest level is found in the region of greatest fluctuation of H and N. The variation of the atom fractions is seen to be quite complex. The three dimensional atom fraction "surface" that may be visualized is very "wrinkled" in the regions near the injector and throat and in the quadrant bounded by 180° and 270°. While the H and N surfaces are heavily "wrinkled" the oxygen is fairly smooth although the percent changes in oxygen varies significantly (by factors of 2 or more). One should bear in mind that although the oxygen mass fraction does not change significantly, the species in which it appears do change significantly in the "wrinkled" regions. Referring to the Figure 3.1 it is seen that in this region (near the throat) significant free oxygen, O_2, is found. This fact is highly significant in understanding the ablation produced by the injector.

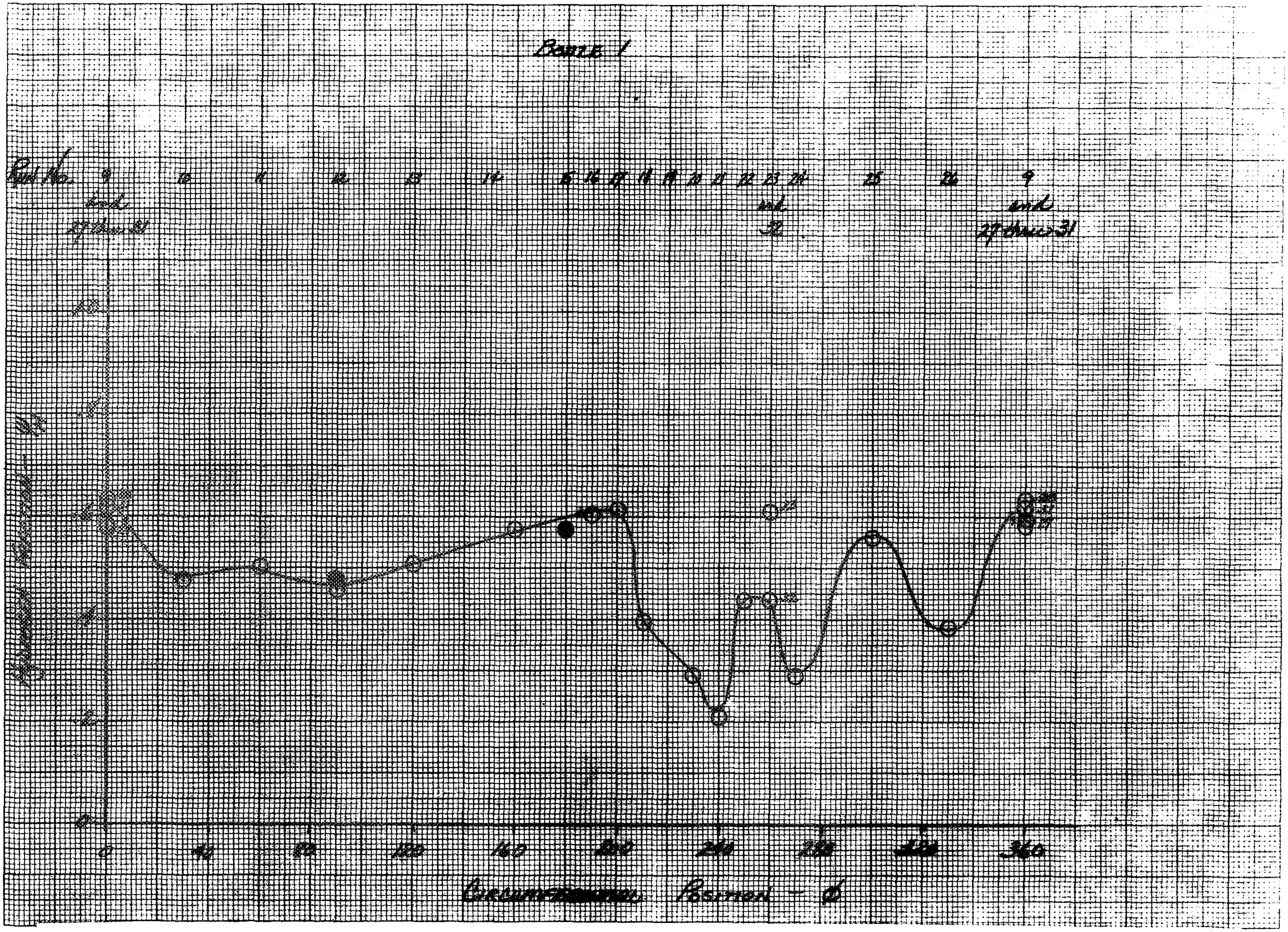

Figure 3.3. Circumferential Distribution of Hydrogen Fraction - Fixed Axial Location
a. x = 1.03 in

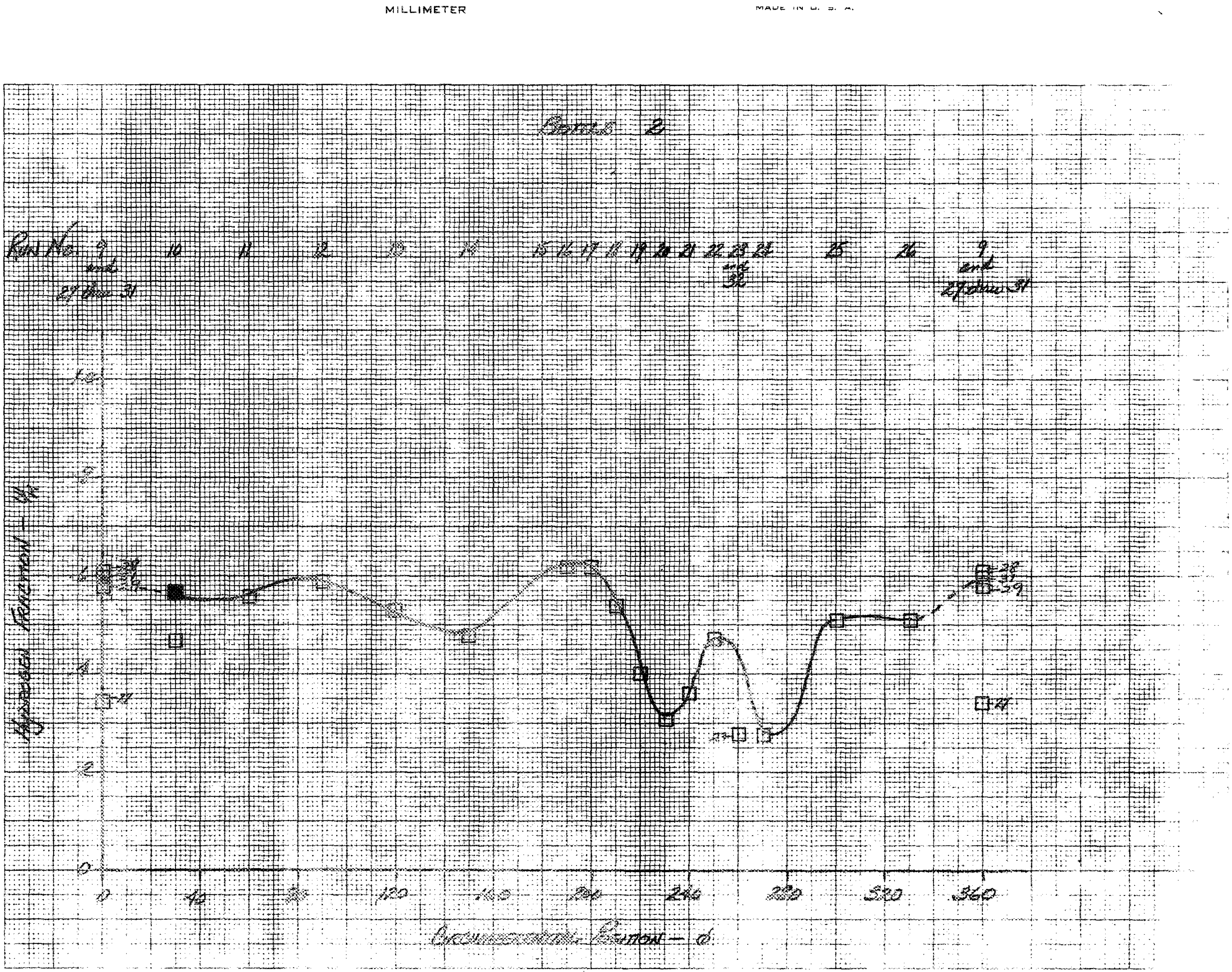

Figure 3.3. Continued
b. x = 1.78 in

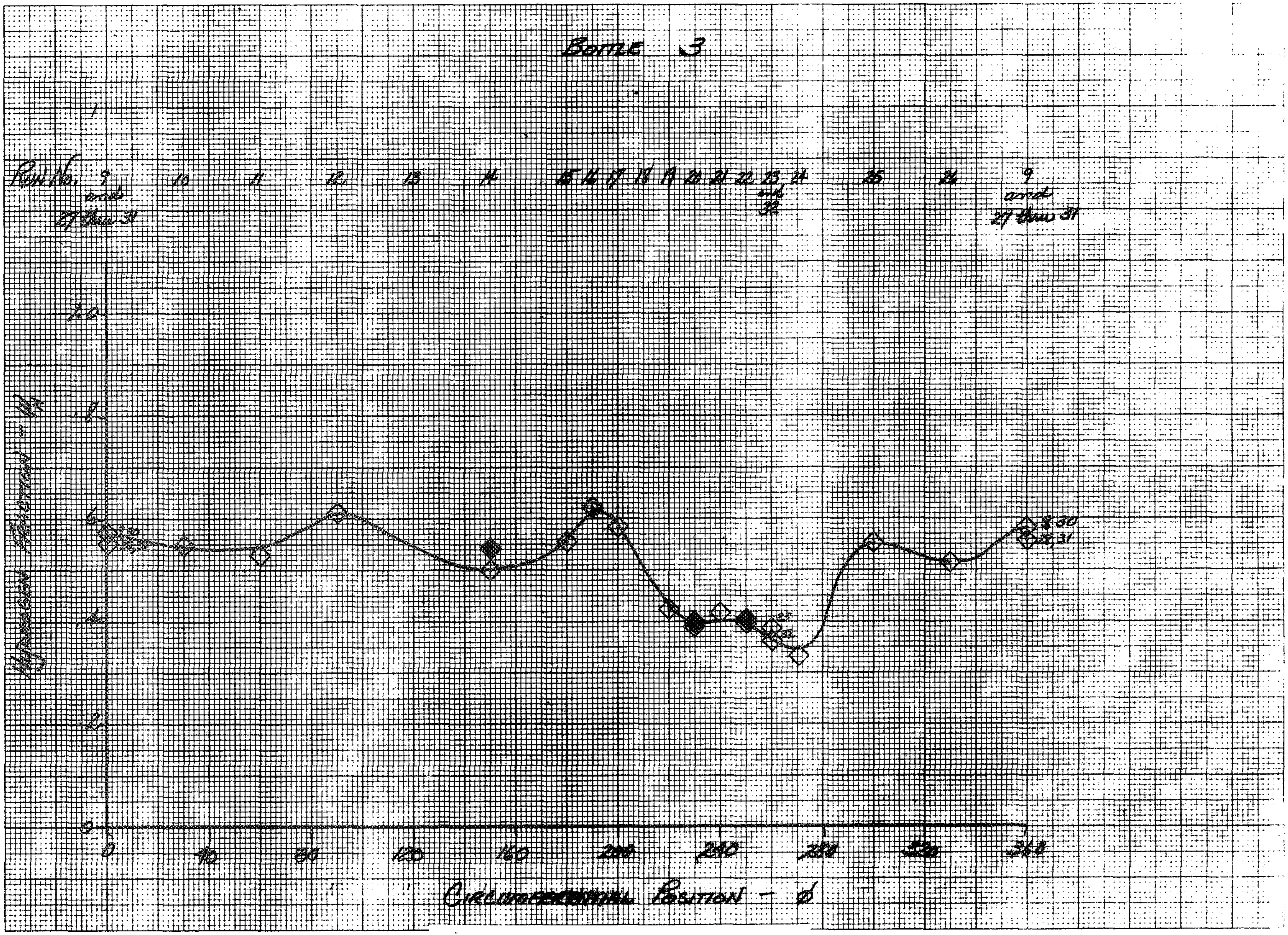

Figure 3.3. Continued
c. x = 2.53 in

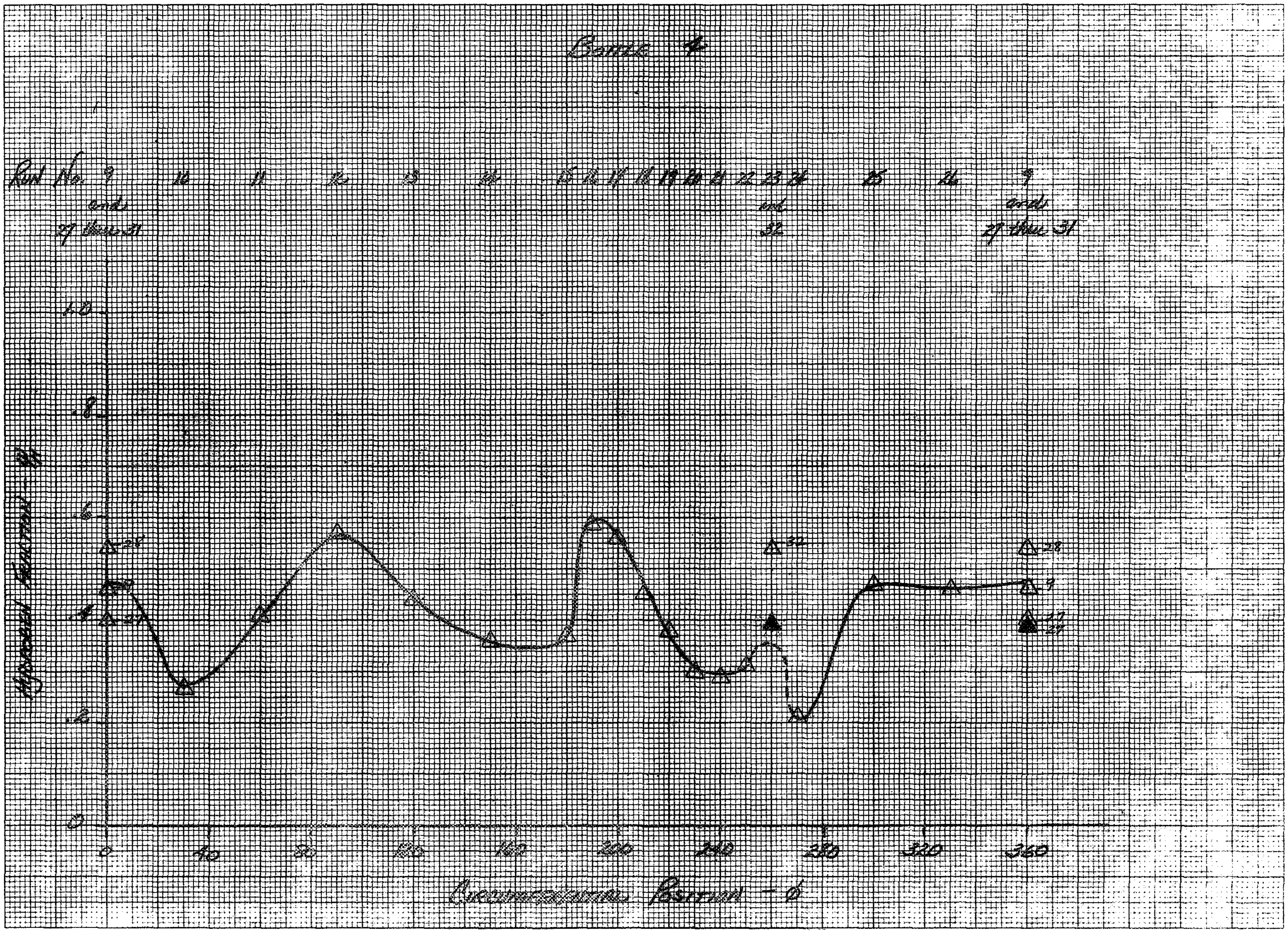

Figure 3.3. Continued
d. x = 3.28 in

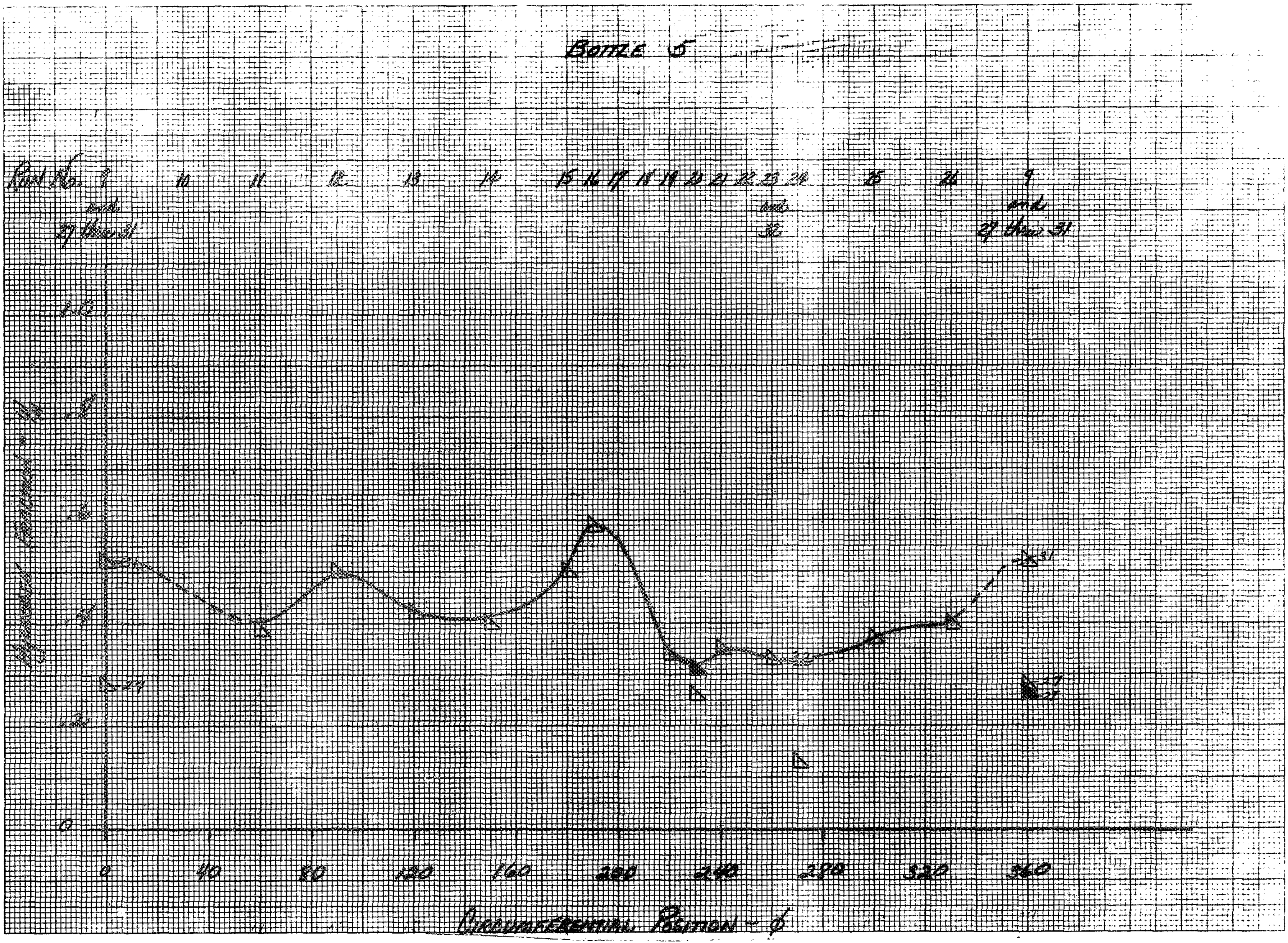

Figure 3.3. Continued
e. x = 4.03 in

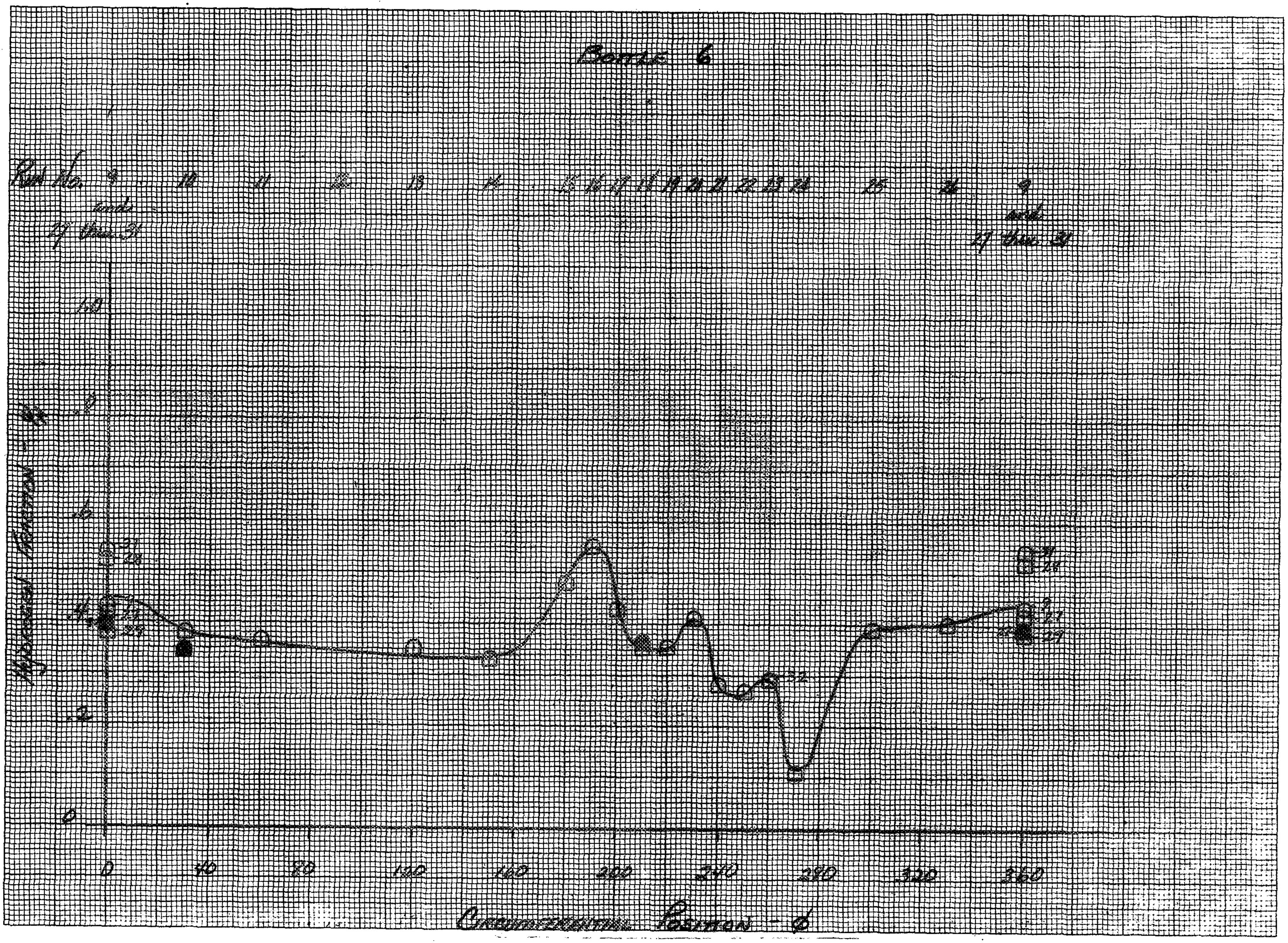

Figure 3.3. Concluded
f. x = 4.78 in

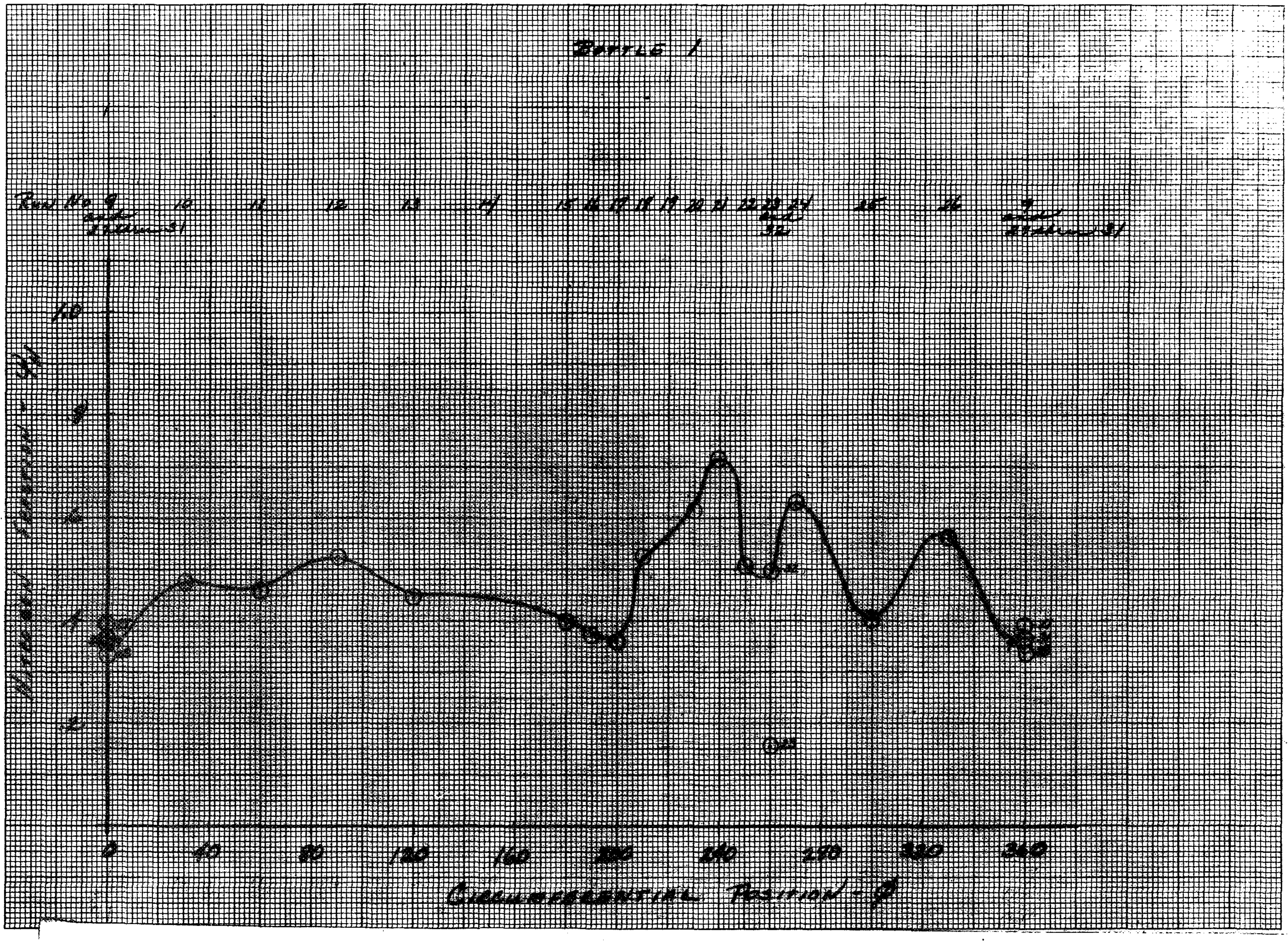

Figure 3.4. Circumferential Distribution of Nitrogen Fraction - Fixed Axial Location
a. x = 1.03 in

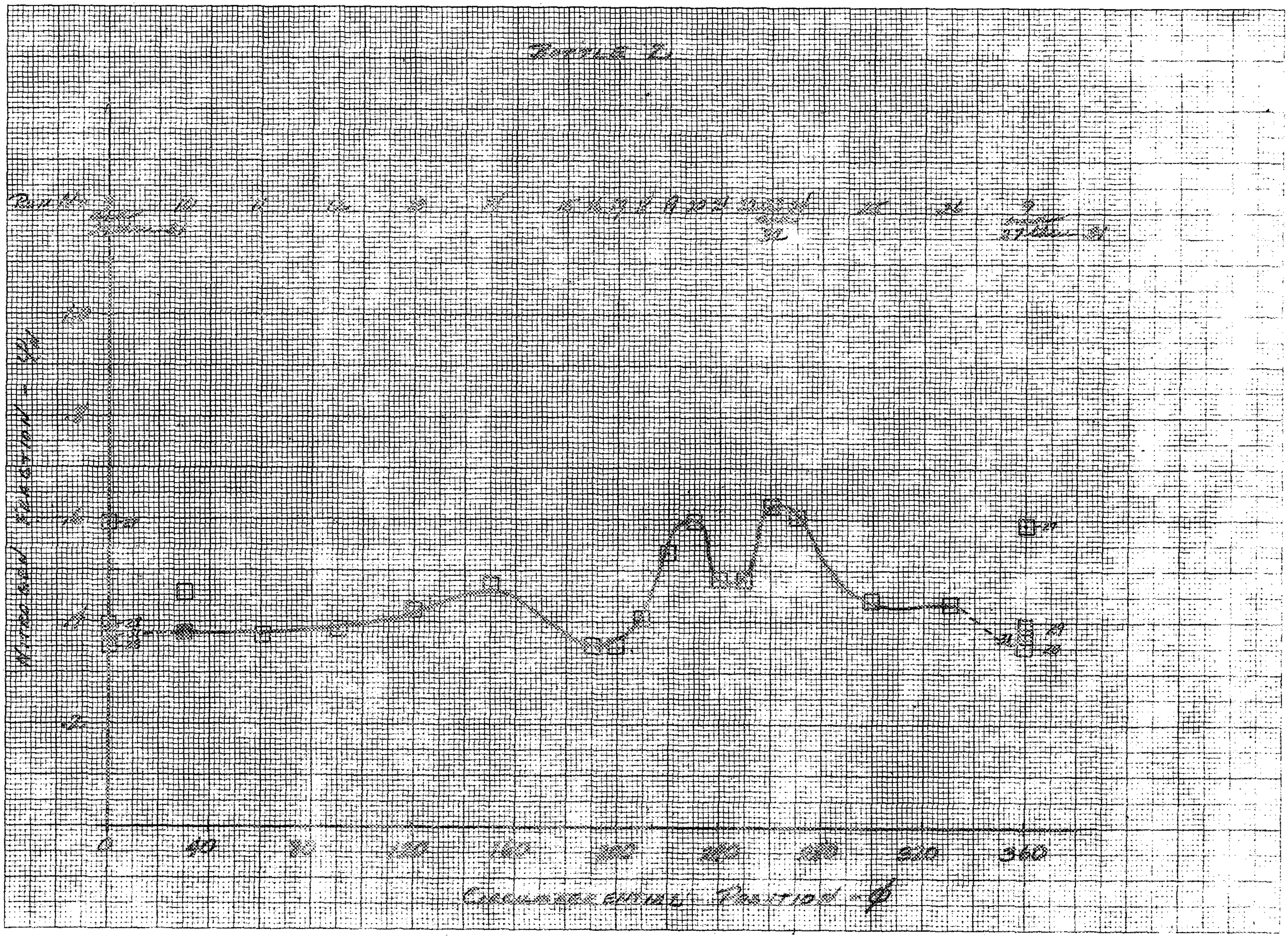

Figure 3.4. Continued
b. x = 1.78 in

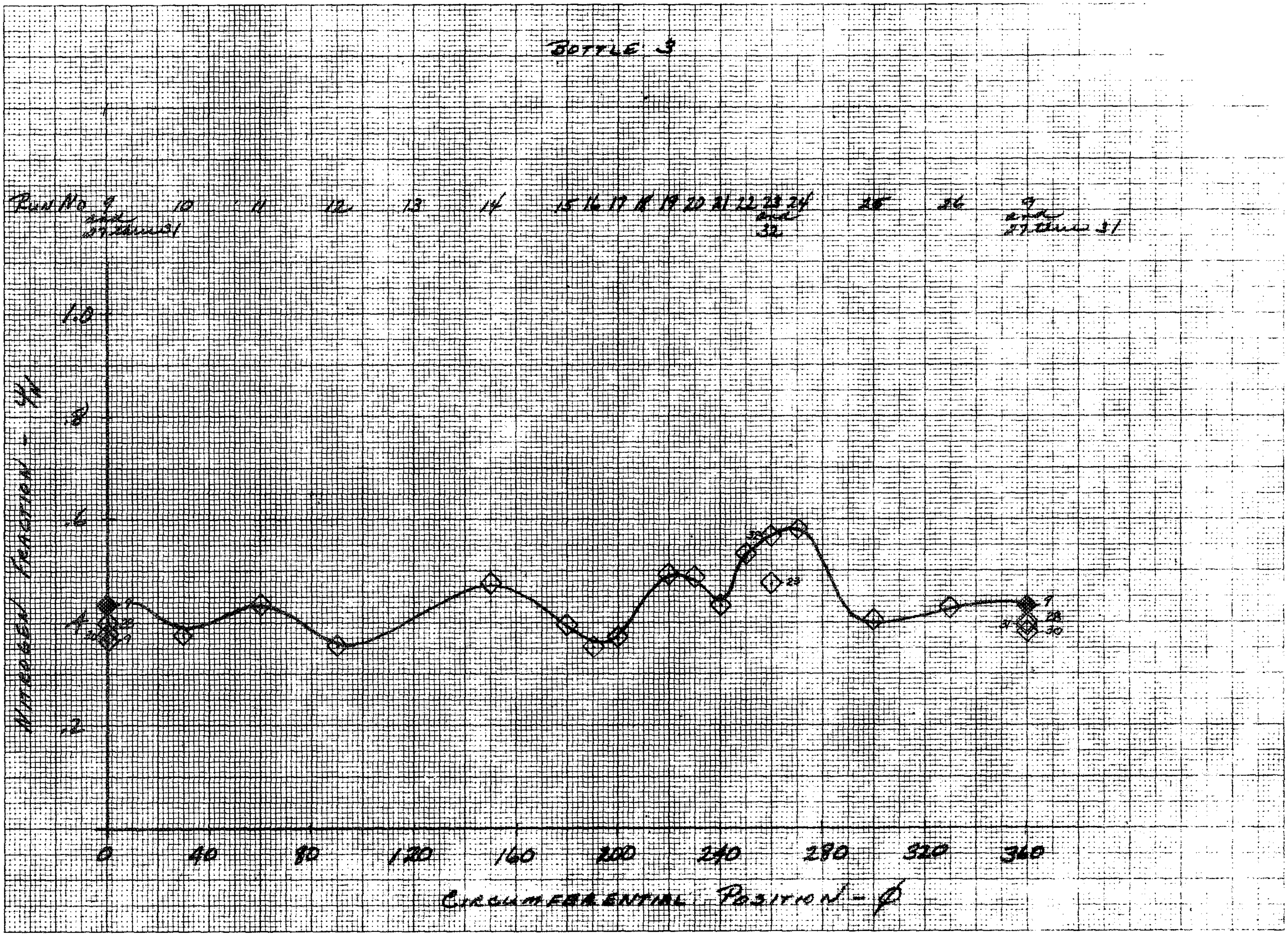

Figure 3.4. Continued
c. x = 2.53 in

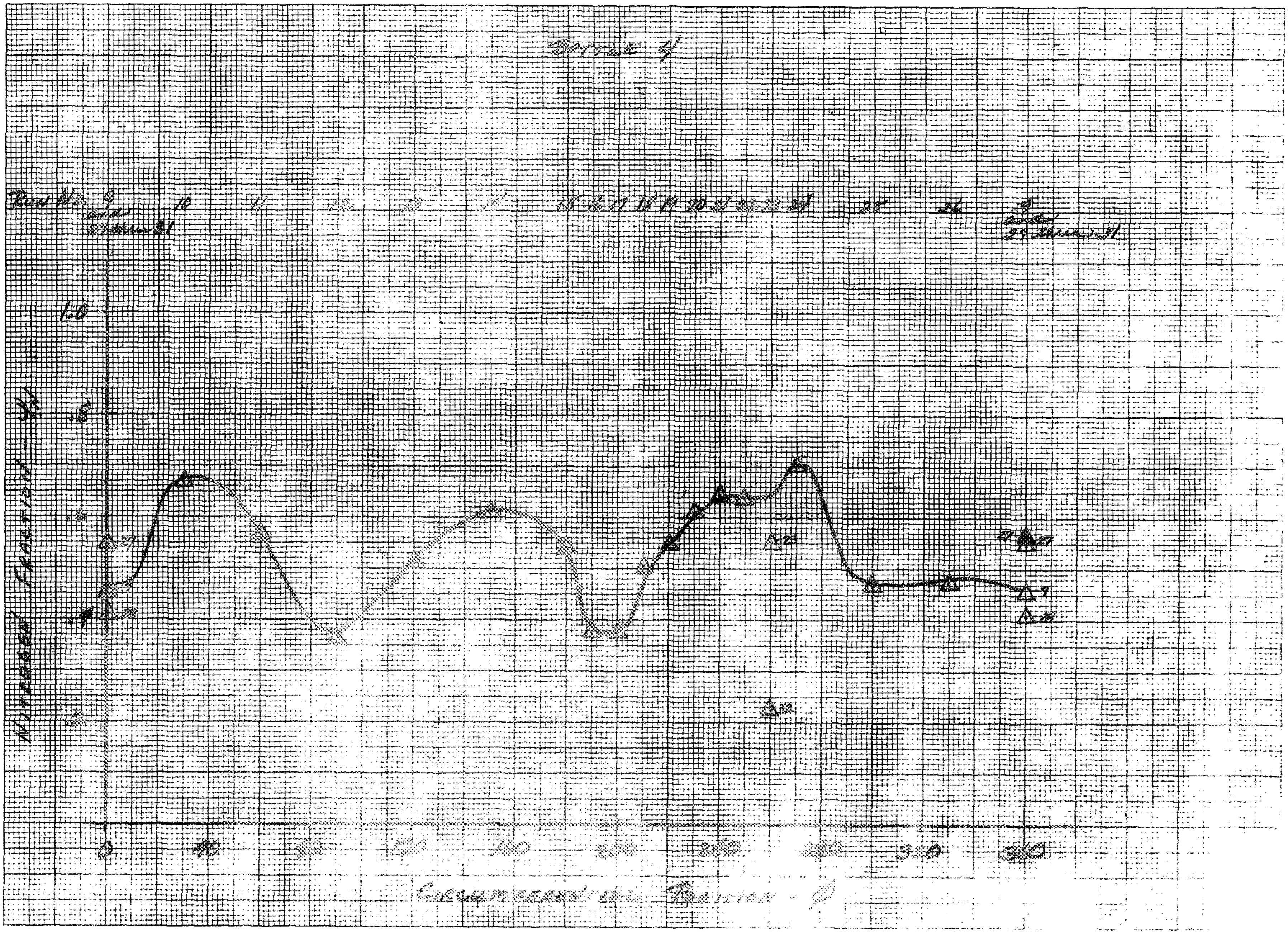

Figure 3.4. Continued
d. x = 3.28 in

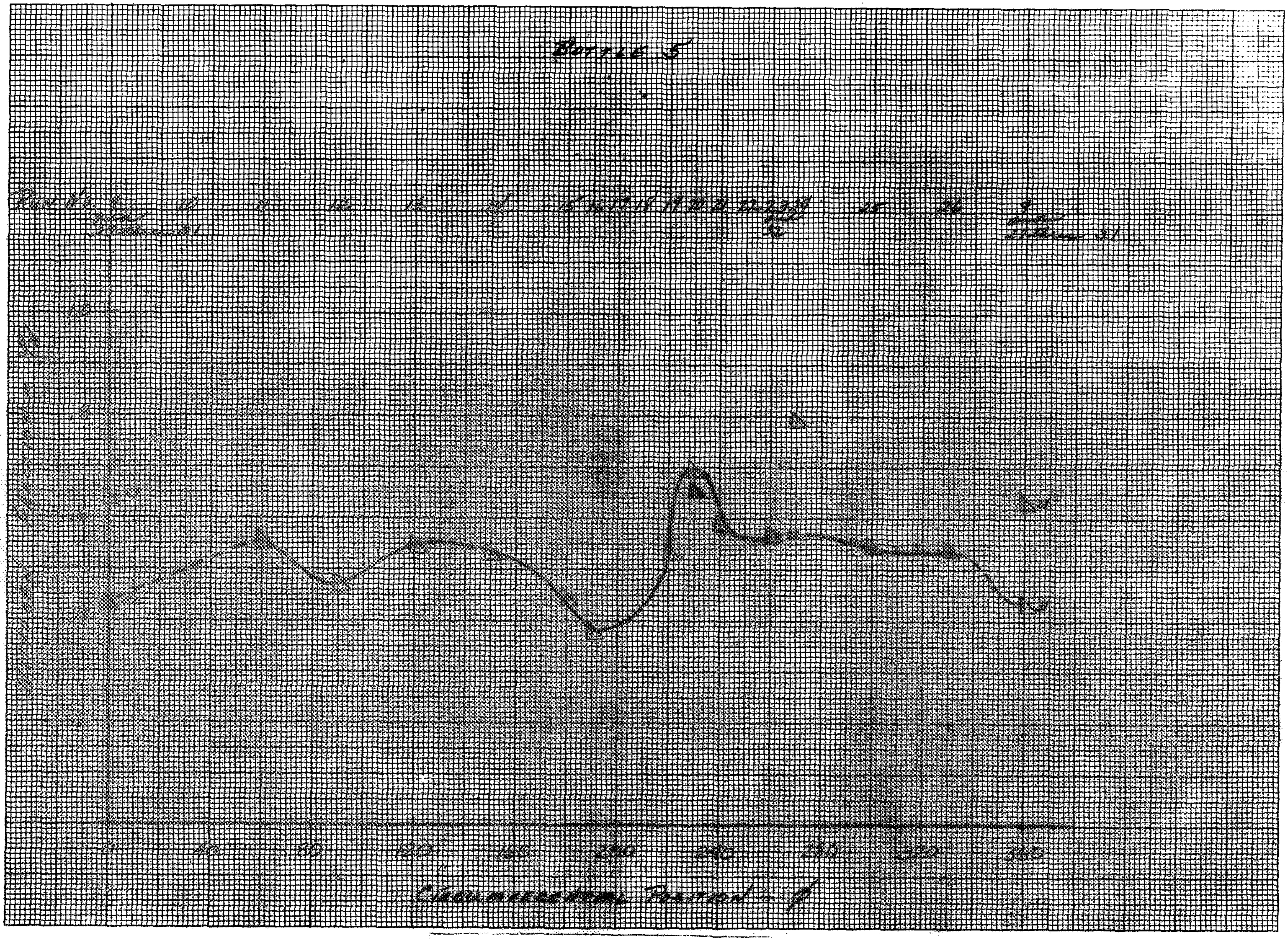

Figure 3.4. Continued
e. x = 4.03 in

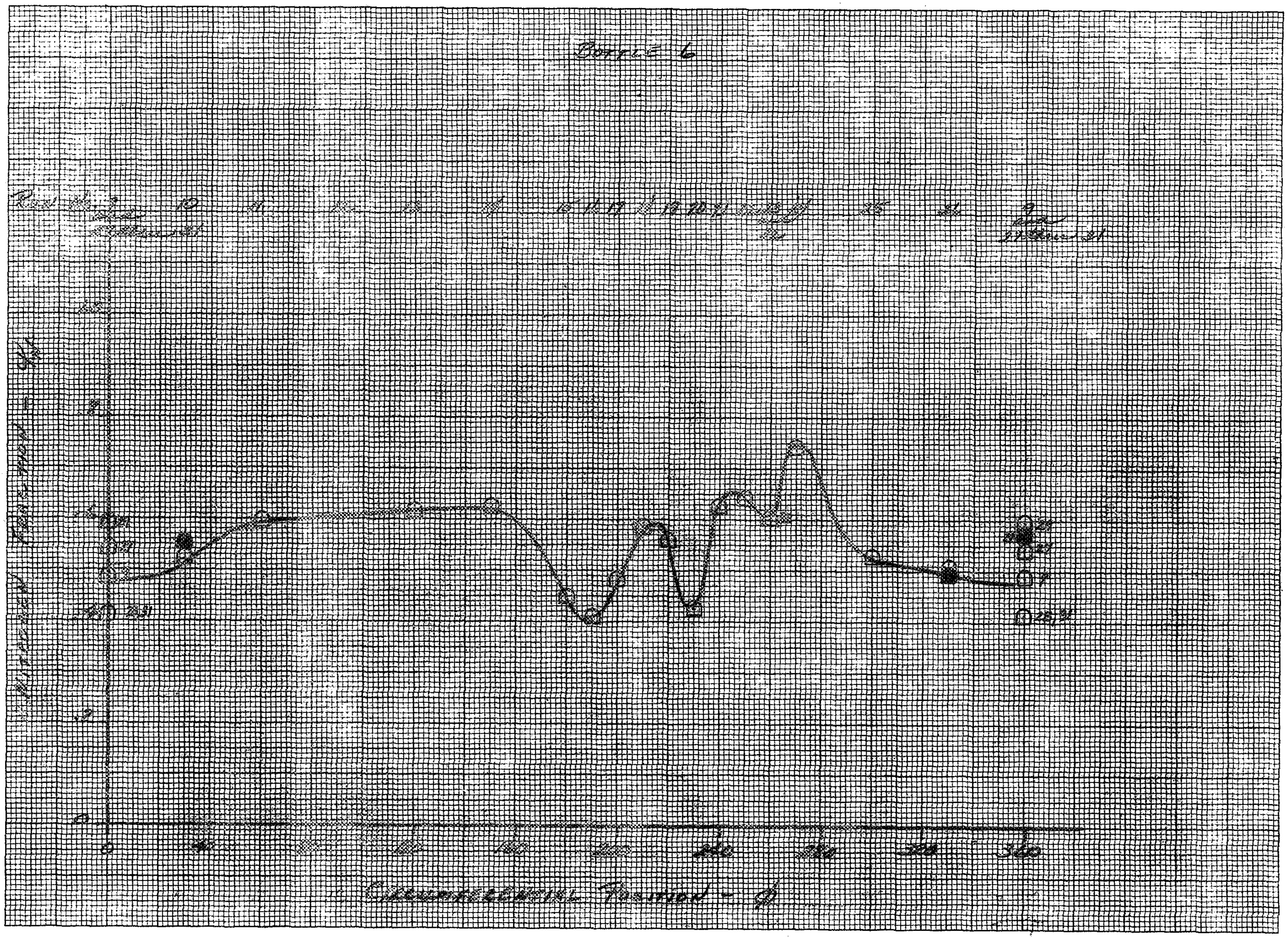

Figure 3.4. Concluded
f. x = 4.78 in

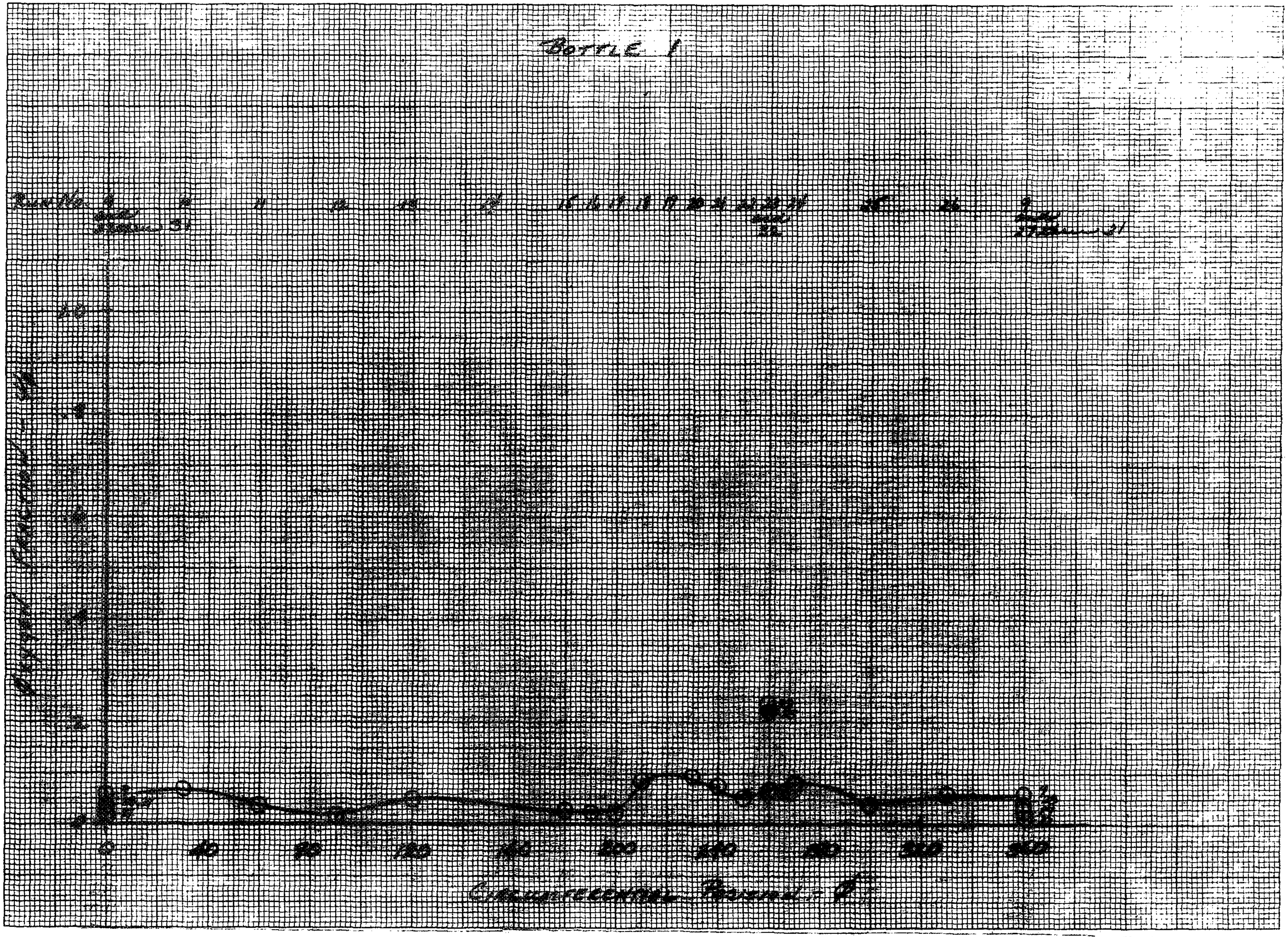

Figure 3.5. Circumferential Distribution of Oxygen Fraction - Fixed Axial Location
a. x = 1.03 in

MILLIMETER

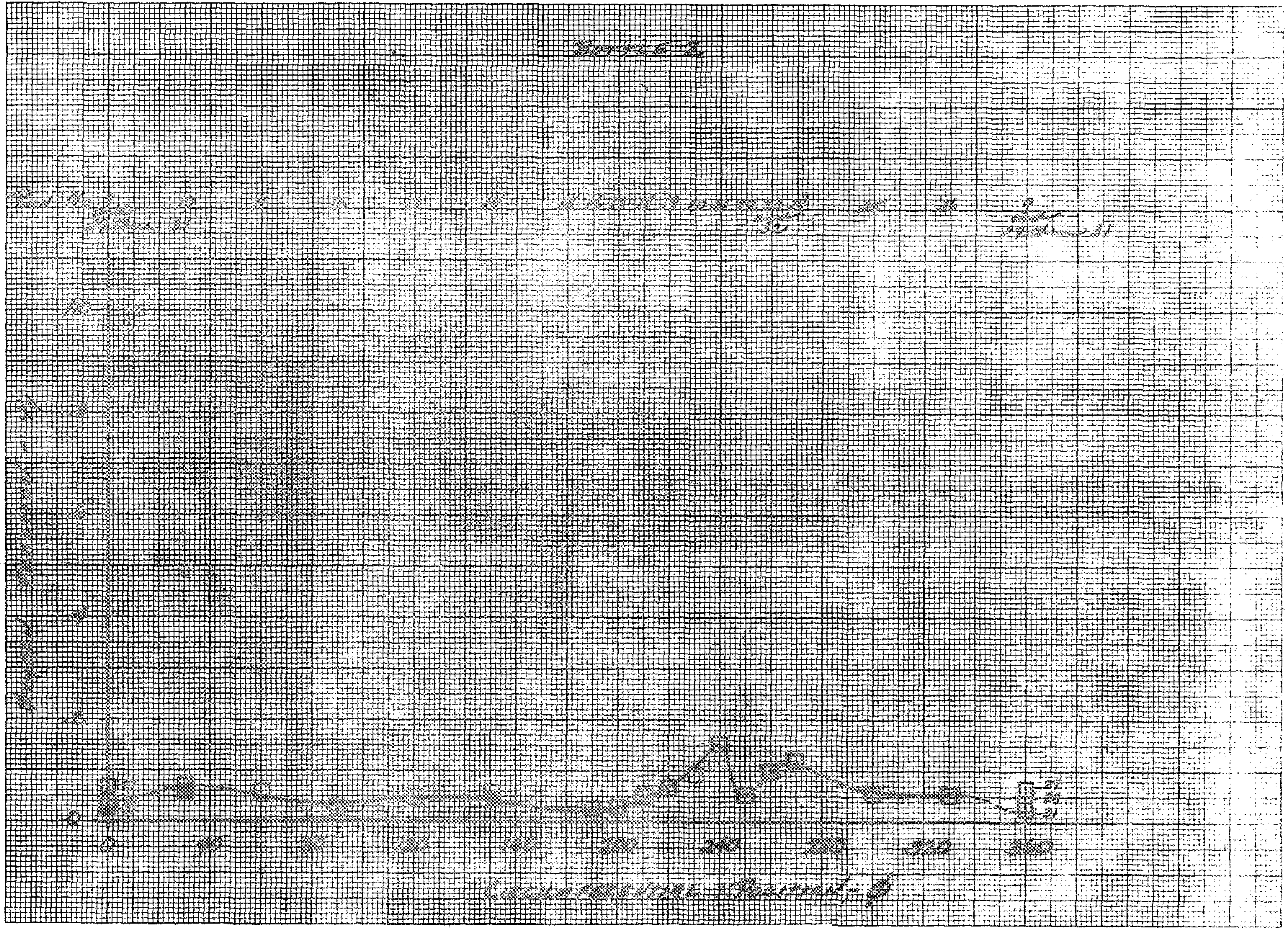

Figure 3.5. Continued
b. x = 1.78 in

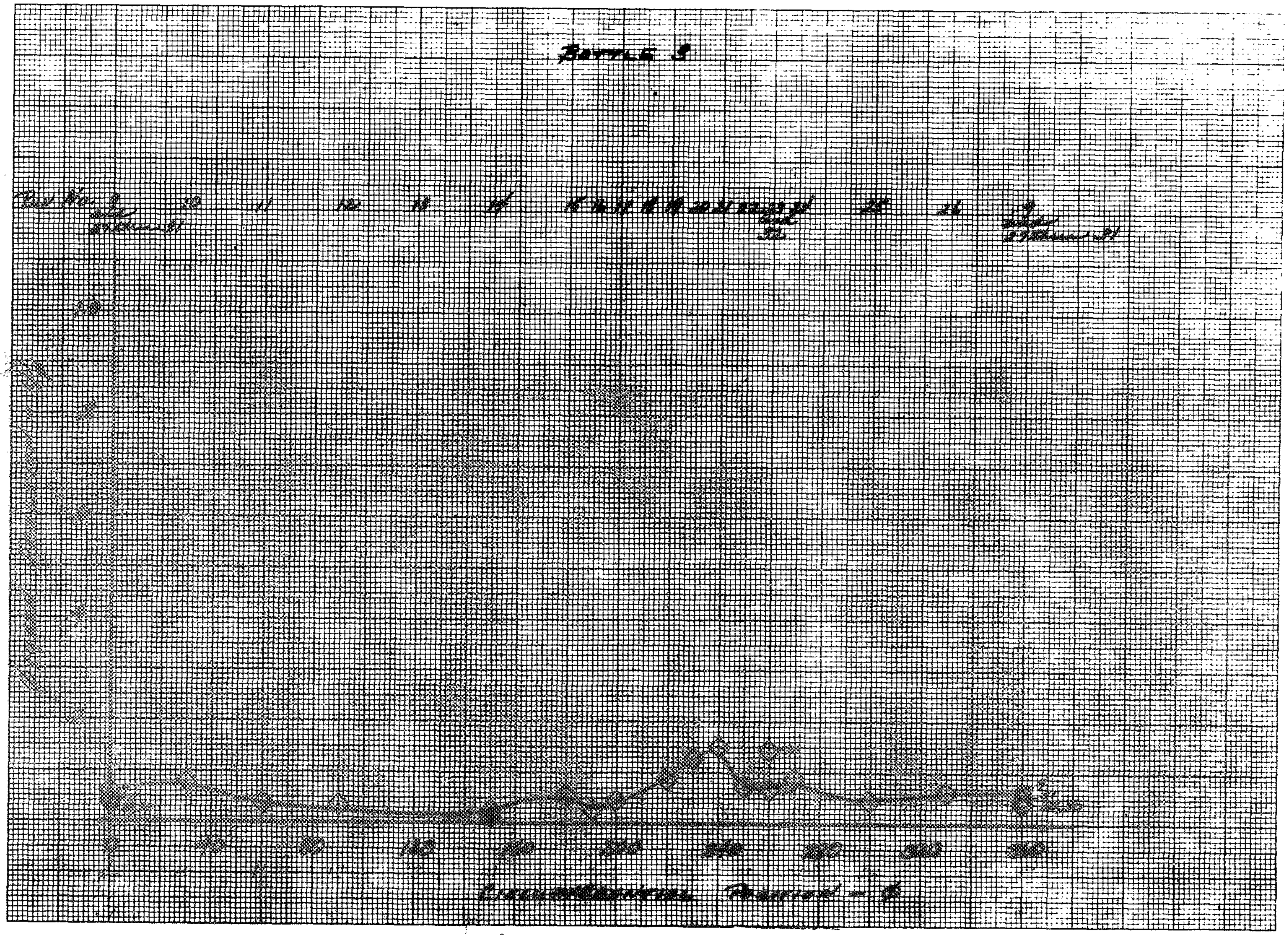

Figure 3.5. Continued 53 IN.
c. x = 2.53 in

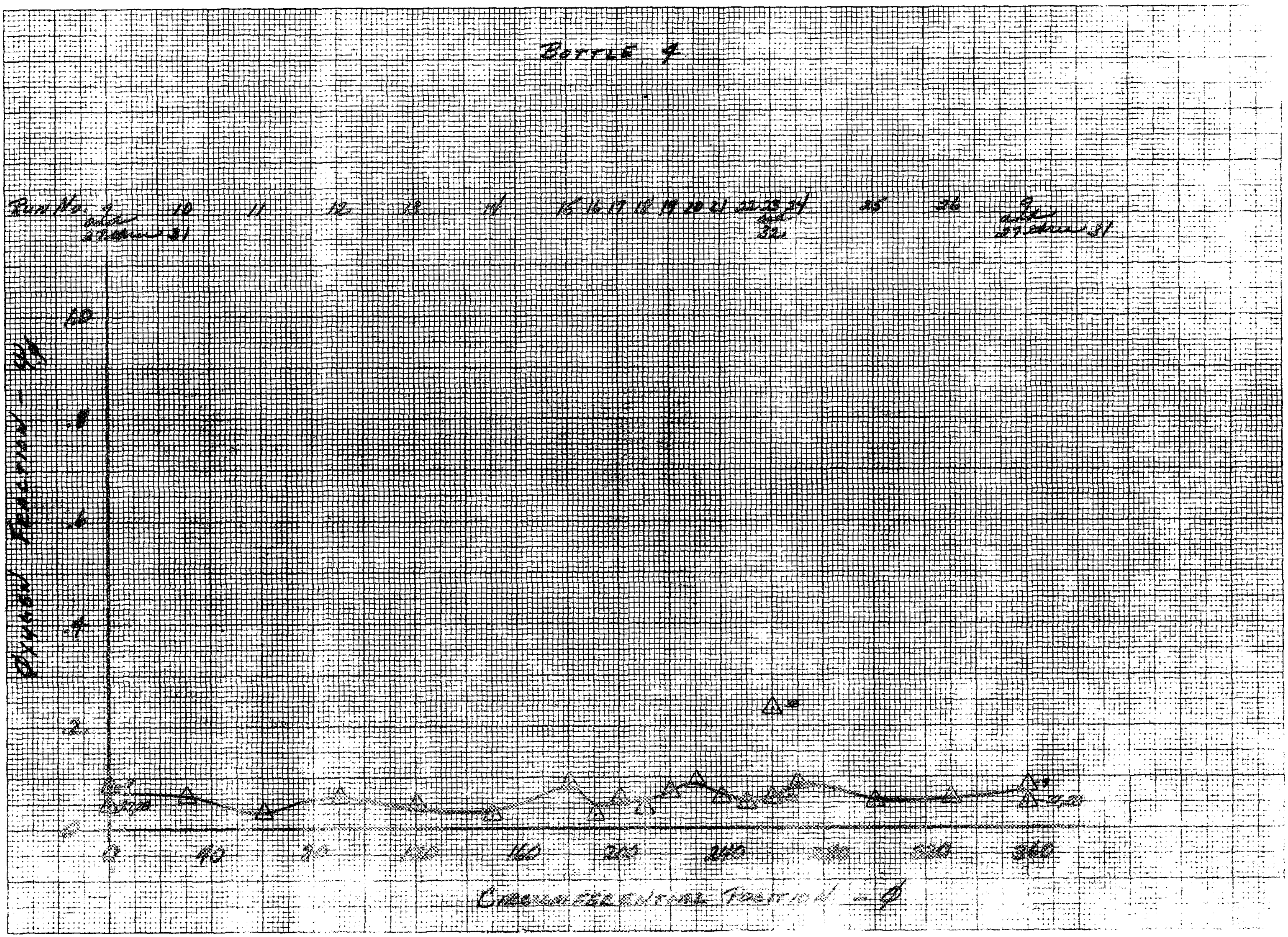

Figure 3.5. Continued
d. x = 3.28 in

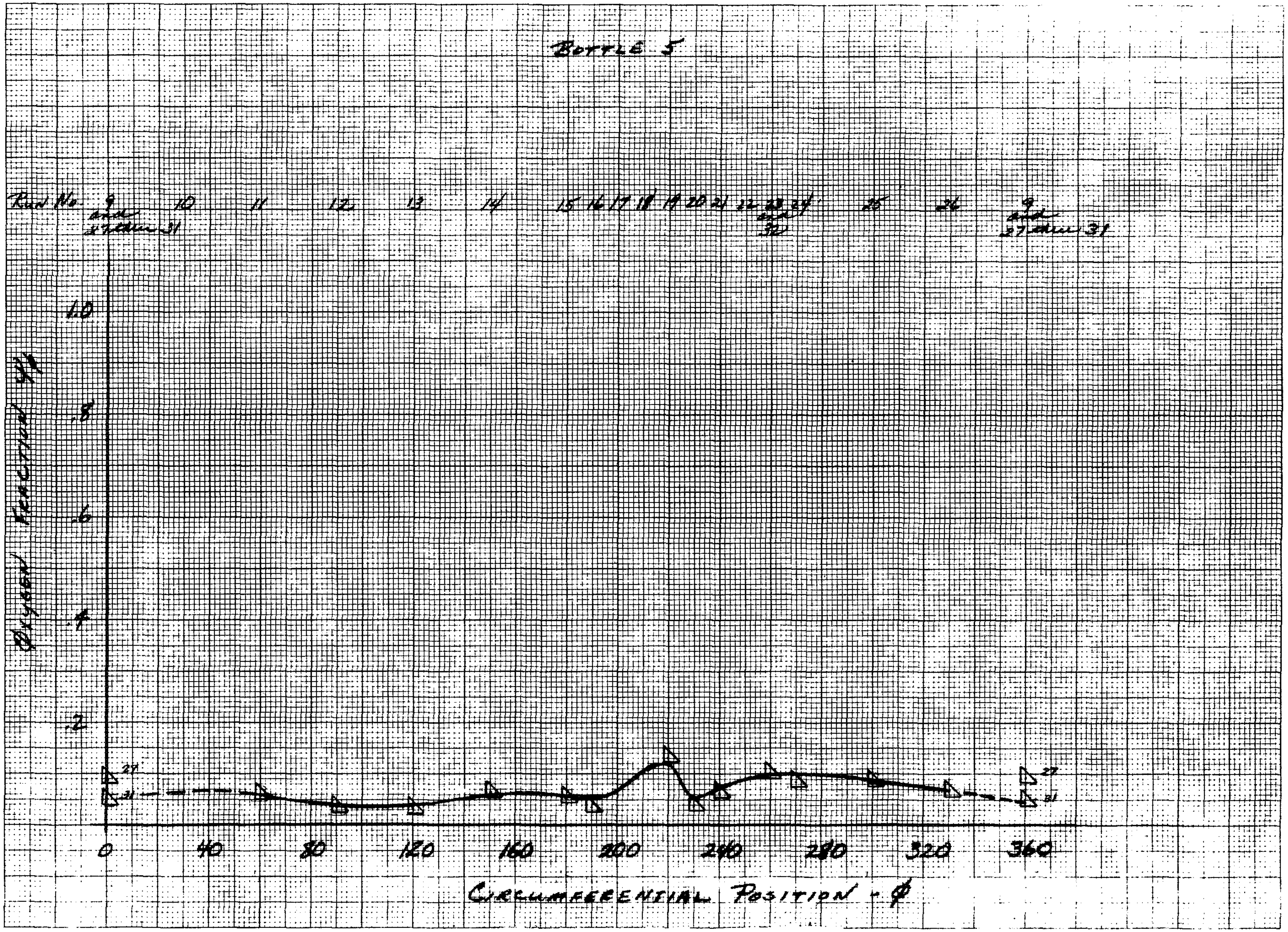

Figure 3.5. Continued
e. x = 4.03 in

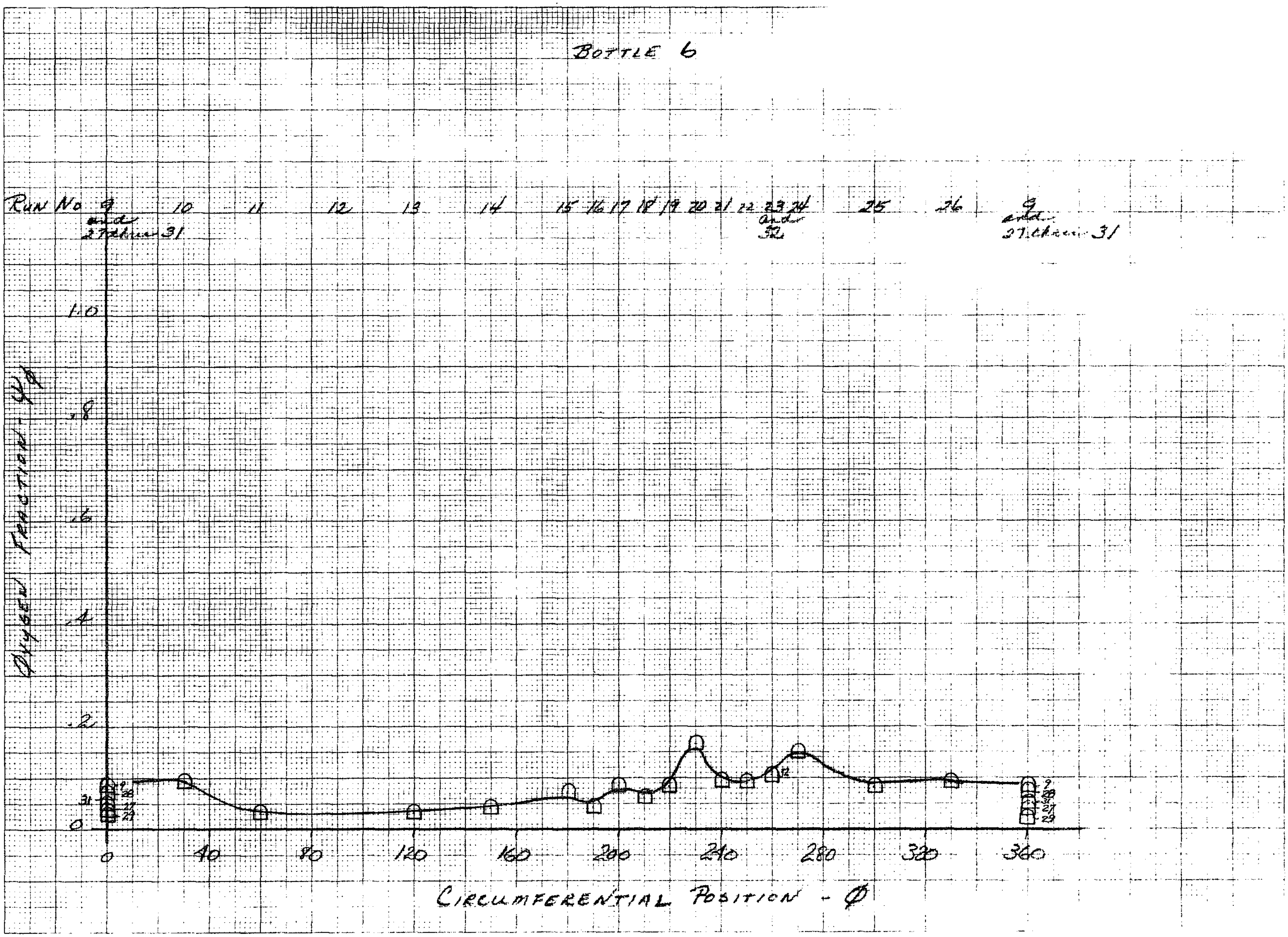

Figure 3.5. Concluded
f. x = 4.78 in

SECTION 4

HEAT FLUX DATA

This section of the data report discusses in some detail the heat flux data which was obtained in the program. The discussion is based on a graphical display of the spatial distribution of the heat flux data at a common point in time measured from ignition. Only a selected few examples of the time dependence of the heat flux are discussed. A complete set of the time dependent heat flux data is presented in Appendix A (both tabular and graphical). The data discussion is presented in the first subsection 4.1. Those readers interested in the details of the theory of operation of the calorimeter employed, the analysis technique used to calculate the heat flux data, and ramifications of this technique on the accuracy of data, can find such information in subsection 4.2. Other qualitative remarks on the absolute level accuracy of the data are presented in subsection 4.3. Finally, the unusual data trends obtained from gage number 6, located in the converging section of the chamber, are explored and possible explanations for data are given in subsection 4.4.

The heat flux data has a 180° phase shift due to the fact that the calorimeters were located across the chamber from the sampling ports. The data presented here have been shifted so that the positions reflect the sampling port locations (i.e., the sampling data and heat flux data conform to the same injector orientation).

SECTION 4.1

SPATIAL-DISTRIBUTION OF HEAT FLUX IN THE CHAMBER

The heat flux data obtained in this program is presented in Figures 4.1-a through 4.1-e. The data obtained from heat flux gage number five is suspect as the gage was not operable during a majority of the tests.

Heat flux gages 1, 3, and 4 show a fair degree of repeatability and for this reason it is to be believed that most of this data is valid. This is not the case for gage number 6 (Figure 4.1-d), where no repeatability was obtained. There is some reason to believe that the relative data (run to run) is valid for some of the tests for this gage and this is discussed further below. An explanation for the behavior of this gage is deferred to subsection 4.4.

Because of these difficulties a meaningful axial distribution of the experimental heat flux data cannot be presented. However, general trends may be observed in this regard. There is a farily constant heat flux in the chamber tending to be somewhat lower at the injector end and a significantly higher heat flux in the throat region. These trends are to be expected. The correlation of these axial trends with theoretically predicted heat flux is presented in Part II.

Superimposed on these general axial trends are circumferential variations presumably due to nonuniform flow conditions in the chamber and this variation is shown in Figures 4.1-a through 4.1-e. Contrary to the chemistry data, the heat flux data shows the most circumferential fluctuations in the 40° to 200° sector of the chamber and is relatively constant in the region where the chemistry data is most "wrinkled". A particular low heat flux point is found at or near the 80° position for every axial position. When this data is compared with the data in the preceeding section, little correlation in these variations can be found. In fact for significant composition changes there is little change in heat flux. Moreover, as shown in Part II, this rather remarkable finding can be substantiated theoretically. The cause for the factor of three variations in heat flux that is observed in the data has not been uncovered at this time, nor have circumstances permitted investigation of this data feature to any degree.

In Figure 4.1-a-c the spread of data points at 80° and 180° is possibly due to mixture ratio differences (see Section 5) with the following exceptions. In Figure 4.1-b the data from run 9 is obviously low. For the first two runs insufficient gain was applied to the oscillograph for the calorimeter signal so that accurate data for these two runs was difficult to obtain. This may be the reason for the run 9 data being so low in the figure. In Figure 4.1-c the heat flux gage 4 data is seen to be low for the last series of runs (28-31). An instrumentation error is suspected for this particular gage in these runs, but it is impossible to demonstrate it with certainty. The calibration for this set of data was normal. Another possible explanation for these data is presented in Section 4.2.

Some of the results from gage number six are believed to be usable on a relative basis. In particular, the data from runs 15-26 were obtained under repeatable motor and system conditions and appear credible. In runs 9 and 10, the data suffered from the oscillograph gain error. In runs 11-14 too much gain was applied and the galvanometer was driven off scale early in the firings. The unknown effects of the ignition tranisent introduces an additional uncertainty to this particular data.

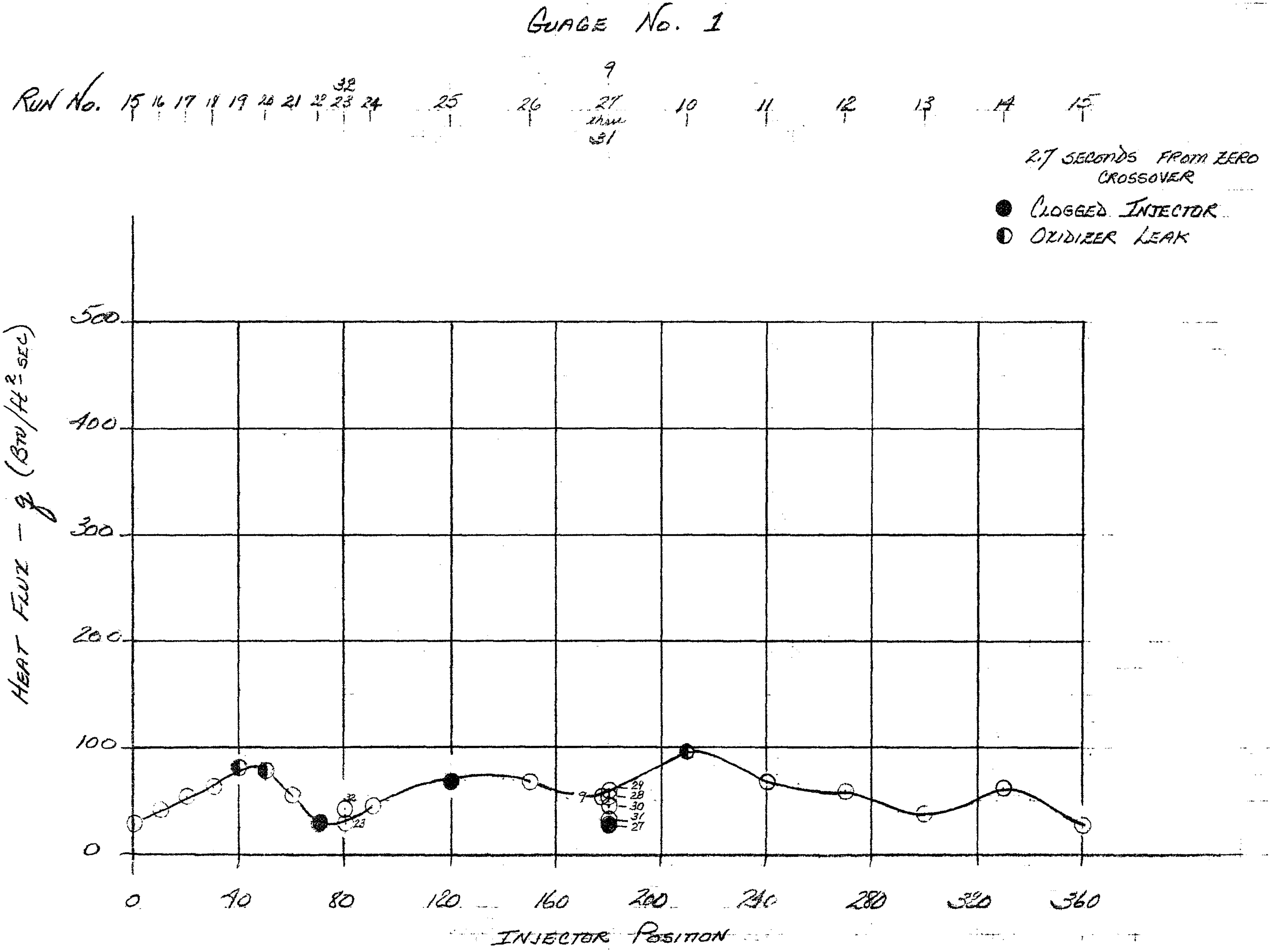

Figure 4.1. Circumferential Heat Flux Distribution for Fixed Axial Position
a. x = 1.03 in

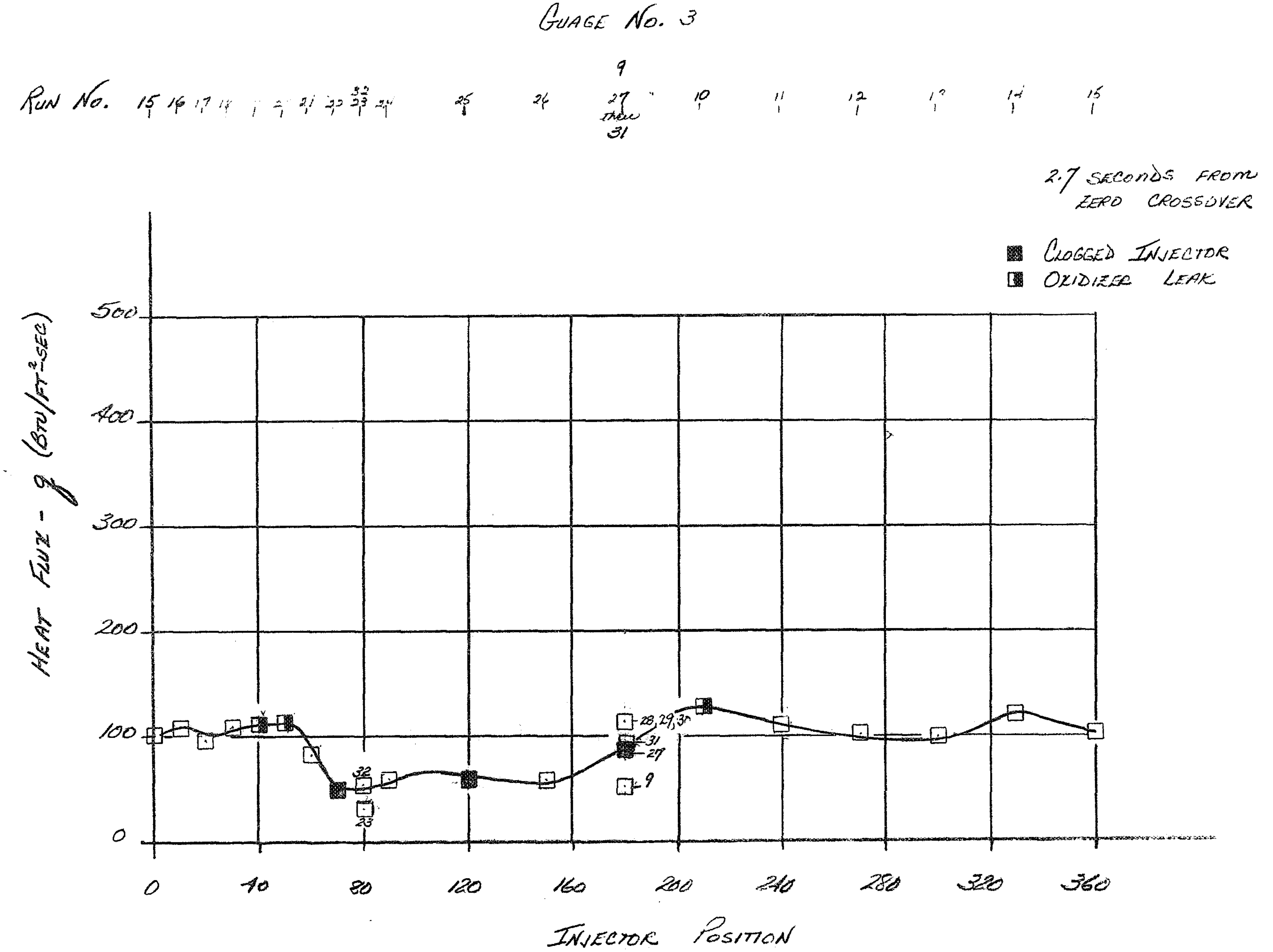

Figure 4.1. Continued
b. x = 2.53 in

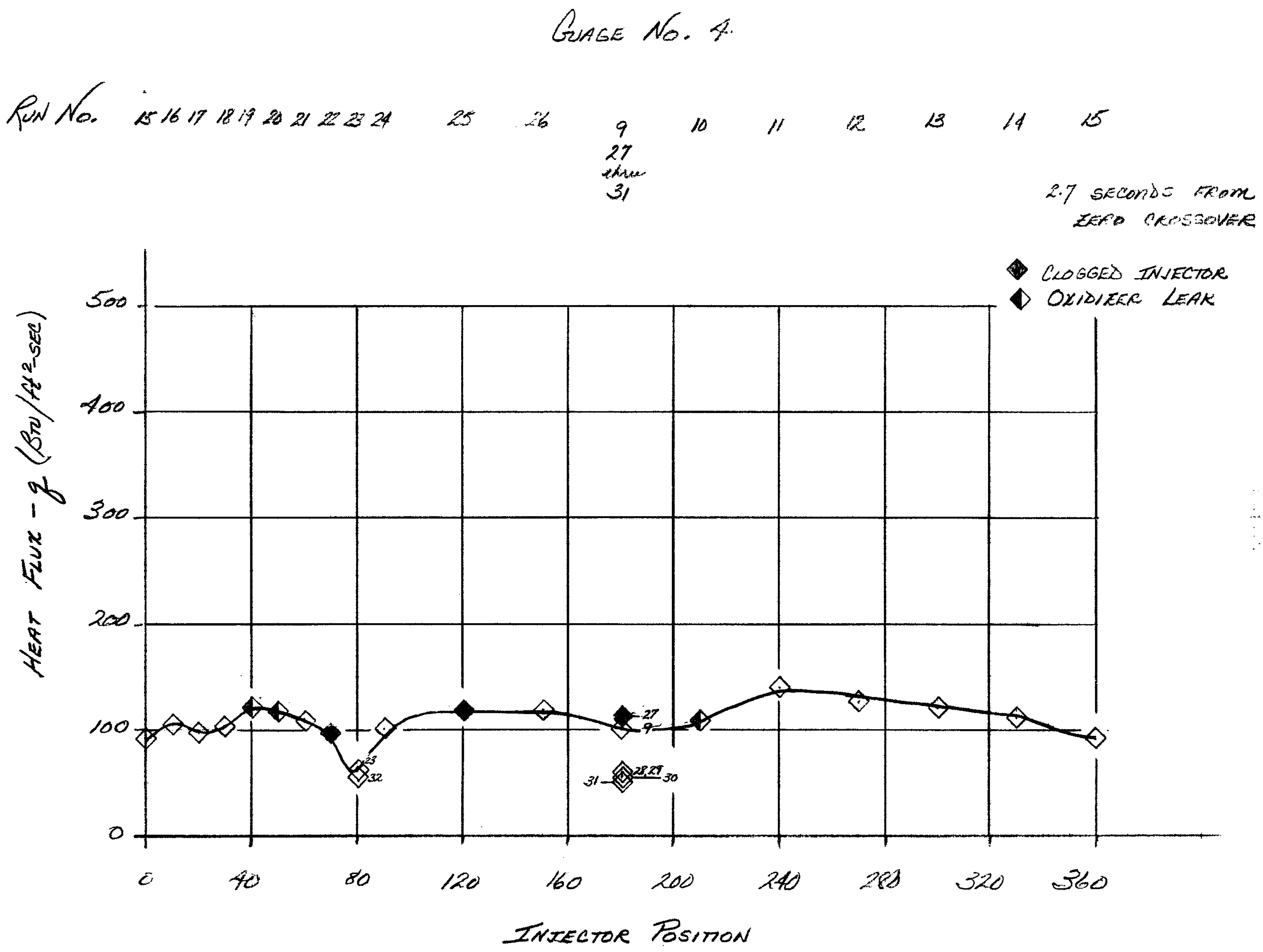

Figure 4.1. Continued
c. x = 3.28 in

#5

2.7

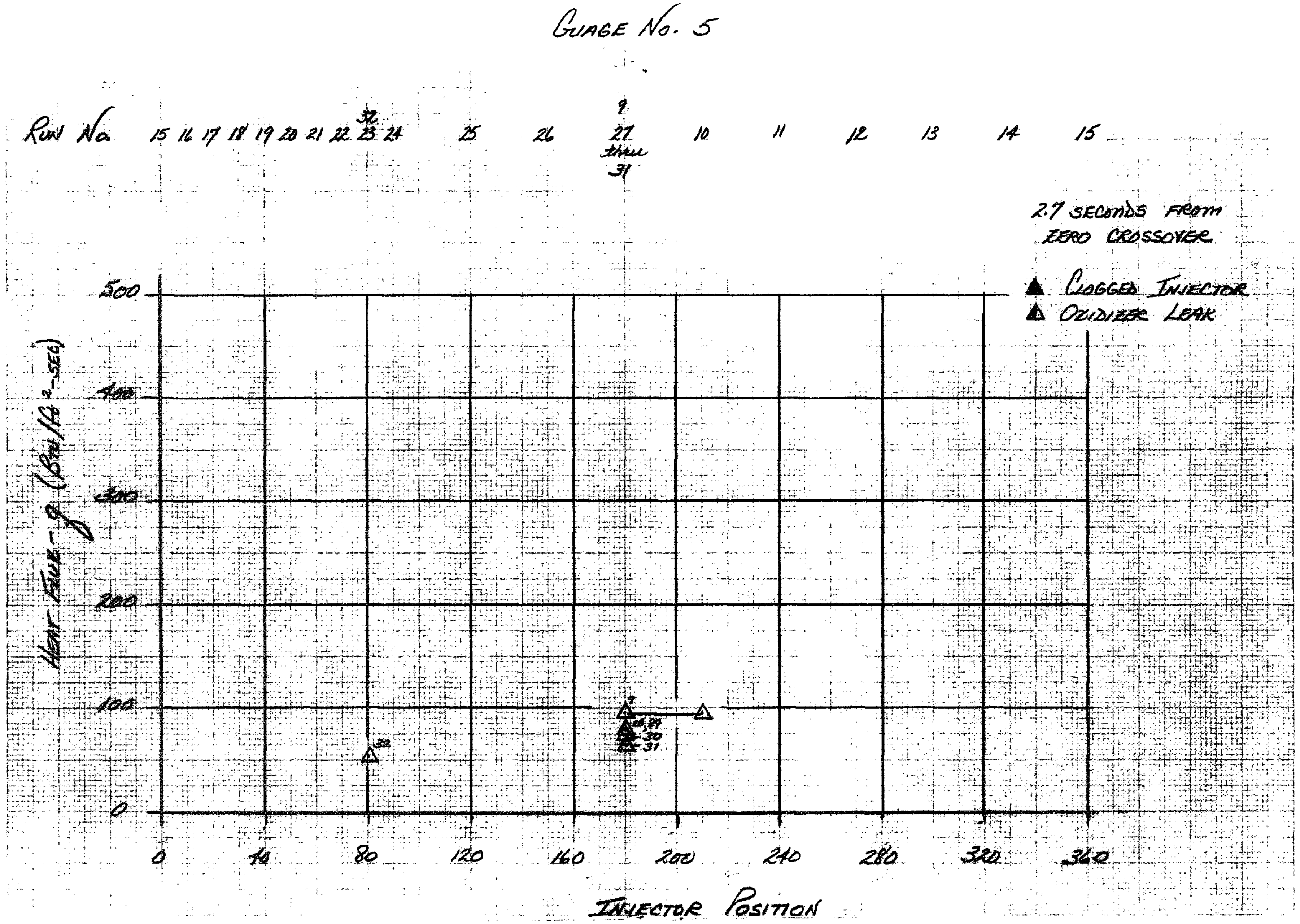

Figure 4.1. Continued
d. x = 4.03 in

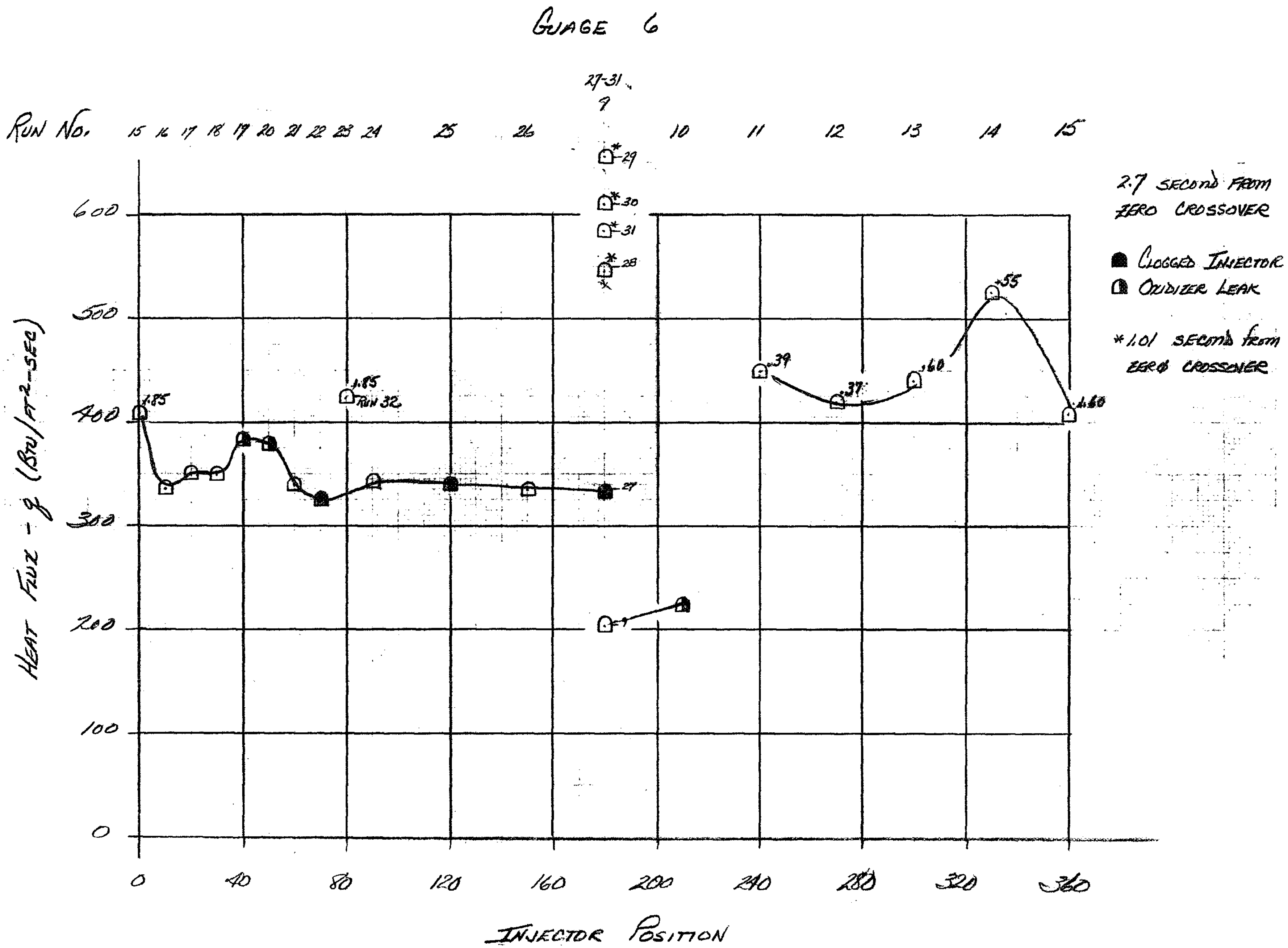

Figure 4.1. Concluded
e. x = 4.78 in

SECTION 4.2

HEAT FLUX DATA REDUCTION PROCEDURE

This section of the data report describes the procedures and underlying theoretical concepts used in obtaining the heat flux data presented in Figure 4.1. First, general remarks regarding the null point calorimeter that was used to obtain the data will be made. Next the analytical techniques used to calculate the heat flux will be discussed and finally some remarks about the interaction between test details and theoretical presumptions and their effect on the data will be made. Circumstances did not permit a thorough evaluation of these factors so that a theoretical assessment of the probable accuracy of the heat flux data cannot be made at this time.

4.2.1 Calorimetric Principle

The null point calorimeter principle used in this program, the design details of which are presented in Part IV, were developed a number of years ago.[2,3*] The principle is based on the fact that in a one-dimensional slab subjected to externally applied and uniform heat source, there exists a void geometry for the slab such that temperature of the void surface nearest the source is the same as the temperature of the surface far from the void. It follows, of course, that the actual surface temperature near the void is higher than the surrounding surface. In particular, the theory developed for this situation shows that for a cylindrically shaped void or cavity, with axis normal to the surface, and for sufficiently great elapsed times, that the particular void geometry producing the above relationship is where the radius of the cavity is the same as the distance between the void and surface (i.e., R/E = 1). The calorimeters for this program were designed to this specification.

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[*] Numbers in parenthesis refer to items in the references.

4.2.2 Data Reduction Technique

The knowledge of surface temperature response in a one-dimensional slab is sufficient information to analytically determine the heat flux causing the surface temperature variation. By applying LaPlace transforms to the Fourier conduction equation, the heat flux at the surface can be related to the rate of change of the surface temperature without any knowledge of the temperature distribution within the slab. W. E. Kennedy (Manager of the Systems Development Department at Aerotherm Corporation) had, previous to this program, derived such a relationship and had constructed a computer code to calculate heat flux from such temperature data(4). This work formed the basis of the reduction procedure used in this program.

It was found that the calorimeter signal traces from the engine data could not be read with sufficient precision such that smoothly varying heat flux data could be obtained. To rectify the situation, the temperature history was least square fitted to a parabolic equation

$$T = a\sqrt{\tau} + b$$

where T is temperature and τ is time

This form of the response equation was suggested by the theoretical surface temperature response equation for a one dimensional slab under constant heat flux.(5) The constant flux situation exists in a copper heat sink motor provided that the chamber conditions are steady following ignition. The temperature and flux data presented in Appendix A reflects this smoothing procedure. A typical example of the results such a curve fitting procedure produced is shown in Figure 4.2.

All the data was plotted in this manner to facilitate the detection of errors and to ensure a good curve fit. All the curve fits were as good or better than that shown in Figure 4.2. It follows from these curve fits that the calorimeters are indeed responding as would a one-dimensional slab.

Notice in Figure 4.2 that the gage temperature is not constant prior to ignition. This temperature variation prior to ignition has

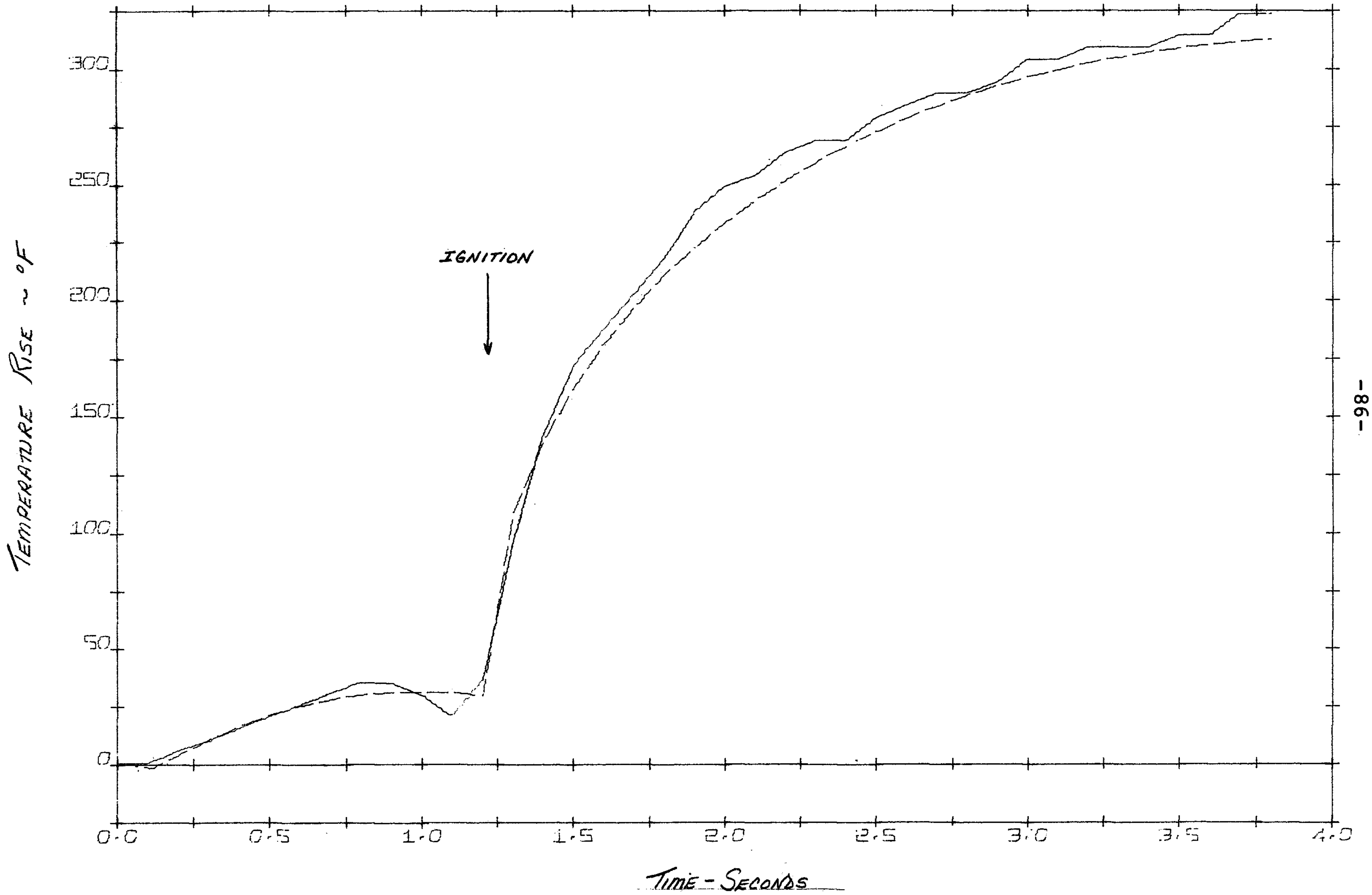

Figure 4.2. Typical Curve Fit of Calorimeter Temperature Response

proved to be an important consideration and has led to the realization that insufficient data was acquired to accurately determine the heat flux as the following considerations will bring out.

To make the following discussion meaningful it is necessary to review the events which took place in the tests prior to ignition. Following calibration, the case and motor block were heated to about 300°F. When the apparatus reached the operating temperature the chamber and sampling system was evacuated and then the sampling system hot helium purge was turned on. This purge was done in order to prevent the sampling system from being contaminated with air before the test.

There exists some doubt about the temperature of the helium purge gas due to the fact that temperature measurements made of the helium showed temperatures lower than the block temperature while a sensor mounted on one of the pneumatic valves heated by the gas registered temperatures significantly above the block temperature (see Section 6). Judging from the gage response the helium temperature was in the range of 350° (or about 30° to 50° hotter than the block temperature). At about 10 seconds before firing, the helium pressure was increased to 350 psia to prevent a surge of gases into the sampling circuit during the ignition transient and these jets of hot helium emminating from the sampling ports probably impinged on the gages. Also, about one to five seonds before ignition, the injector was purged with room temperature nitrogen. Depending upon the flow pattern in the motor, this purge gas may or may not have cooled the gages. In the ignition transient there was a short period (about 100 MS) when only oxidizer was injected into the chamber (oxidizer lead) and since the gages were at the bottom of the chamber, a significant cooling occurred as the oxidizer was vaporized by the hot surface.

Unfortunately the oscillograph recordings of the events started only shortly before the ignition transient so that just a portion of the foregoing effects on the gage temperature was obtained. The significance of this procedural error did not become apparent until the testing was completed. The difficulty comes about because the data reduction procedure (i.e., the application of the transform theory) presumes the slab (i.e., the calorimeter) is at a uniform temperature before heating begins. The situation is perhaps best explained with an illustration. Consider a one dimensional slab which represents the calorimeter as shown in the sketch of Figure 4.3. If this slab is subjected to a constant heat source it would at some later instant in time have a temperature distribution like that shown by the dashed line above the undisturbed temberature T_b. Now assuming that hot helium gas impinges on the calorimeter surface before the foregoing heating takes place, (because of the contact resistance between the calorimeter and the main mass of the motor at temperature T_b) the calorimeter would be heated above T_b as shown by the right hand portion of the solid line labeled "A". If following the gas heating, it were suddenly cooled by cold nitrogen gas, then a temperature profile "dip" would result as shown by the left portion of line "A". Application of the constant heat source would then cause the upward portion of the curve on the extreme left. (The temperature of the surface would be different of course than that from the first curve.) Yet another profile could be drawn if for some reason the calorimeter were chilled below T_b before the helium gas heating event took place. This is shown by the line labeled "B". The dashed-dotted lines show effectively what was done in the data reduction procedure. The temperature history started just before ignition when the calorimeter temperature was below T_b (the block temperature) and this implied as stated above, that the calorimeter was everywhere at this temperature at that instant. As the foregoing discussion makes clear--this probably was not the case. Since heat flux at the surface is given by:

$$q = k \left.\frac{dT}{dx}\right|_{x=0}$$

it is obvious that the three profiles "A" "B" and the one resulting from the technique used in the data reduction program will result in different heat flux being calculated.

The observations prompted a brief attempt at correlating the poor repeatability noted for runs 9, 27-30 which were all conducted at the same injector position and mixture ratio. A significant variation in

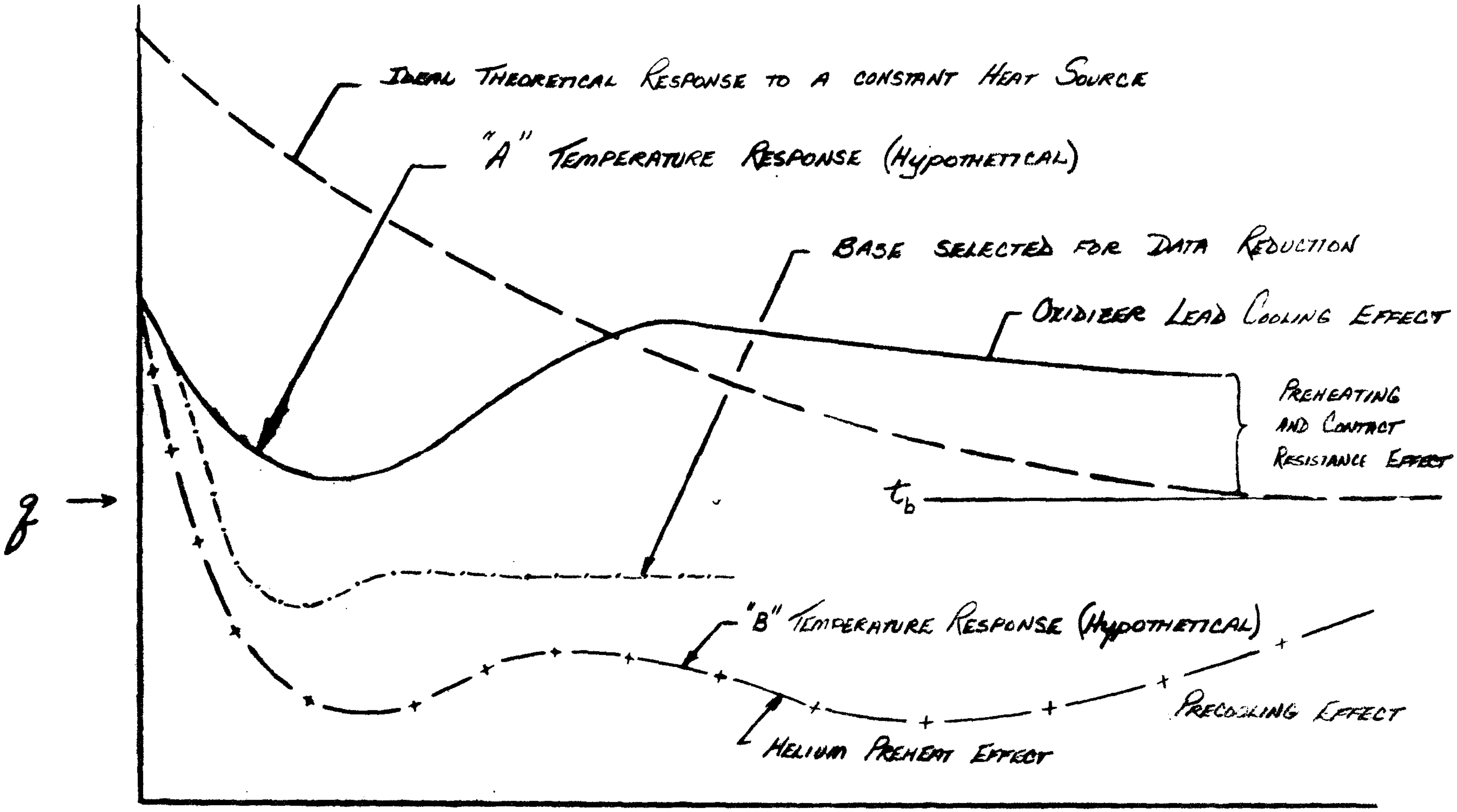

Figure 4.3. Temperature Response in a Slab to Various Heating Histories

the initial temperature of the calorimeters for the different runs was noted. Table 4.1 summarizes these initial temperatures for each gage for every run as well as the recorded block temperature. When the heat flux for these runs is plotted versus the difference between the block temperature and the gage initial temperature, an unmistakable trend emerges as shown in Figure 4.4. The higher the temperature difference the lower the heat flux. There also seems to be superimposed on this effect the absolute level of temperature since in this correlation, run 9, which had the lowest block temperature, also has the lowest heat flux. Note also in Figure 4.1-c the agreement between run 32 and runs 28-30 which had the same ΔT. The cause of the low initial temperature of the calorimeters is unknown. It could possibly be the result of slight leakage of the propellants or injector purge gas into the chamber.

From these results it seems apparent that the scatter in the redundant data is more probably due to the lack of precision in the data reduction than from variation in test stand parameters or instrumentation errors. Certainly it is clear that in future tests with this equipment, that calorimeter data should be acquired well in advance of the firing. It would also probably be wise to orient the chamber such that the gages are not on the bottom.

TABLE 4.1

CALORIMETER INITIAL TEMPERATURES*

RUN NO.	T_0	GAUGE NO.			TEMPERATURE DIFFERENCE		
		1	3	4	1	3	4
9	272	287	234	246	+15	-38	-26
10	324	260	255	279	-64	-69	-45
11	N/M	231	287	295			
12	342	224	279	289	-118	-63	-53
13	348	226	279	287	-122	-69	-61
14	336	225	309	289	-111	-27	-47
15	335	227	292	292	-108	-43	-43
16	337	234	302	296	-103	-35	-41
17	N/M	232	298	293			
18	336	236	296	294	-100	-40	-42
19	340	233	300	298	-107	-40	-42
20	356	240	316	312	-116	-38	-42
21	324	224	286	282	-100	-38	-42
22	333	232	299	295	-101	-34	-38
23	327	228	294	289	-99	-33	-38
24	298	228	295	291	-70	-3	-7
25	340	234	299	294	-106	-41	-46
26	336	220	285	290	-116	-51	-46
27	329	225	289	287	-104	-40	-42
28	335	283	286	246	-52	-99	-89
29	331	276	284	247	-55	-48	-84
30	332	278	272	247	-54	-60	-85
31	343	288	296	252	-55	-97	-91
32	333	287	295	251	-46	-38	-82

* TIME IS 0.1 SECONDS FROM THE OXIDIZER VALVE OPEN SIGNAL.

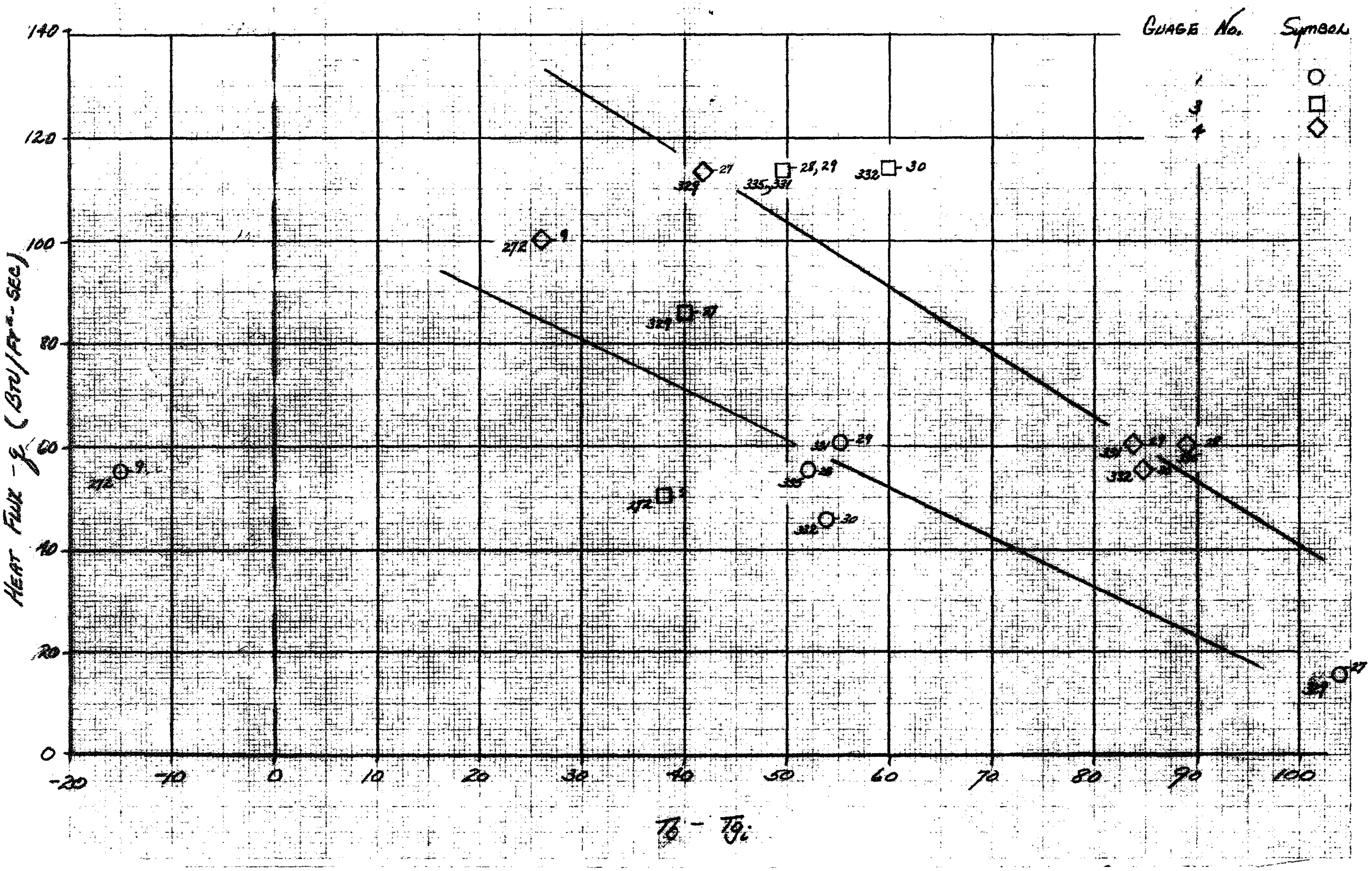

Figure 4.4. Effect of Initial Temperature Difference on Heat Flux Gage Response

SECTION 4.3

HEAT FLUX DATA UNCERTAINTIES

Several factors peculiar to the application of the foregoing techniques to the apparatus in this program should be considered. only qualitative remarks can be made at this point since circumstances do not permit a detailed analysis.

First, the boundary conditions in the actual test for each calorimeter depart from the uniform one dimensional ideal presumed in the underlying theory. Gradients in heat flux as high as 200 Btu/ft^2 sec/ft are evident in the data in the circumferential direction. High axial gradients occur in the throat region as well. The surface temperature gradients produced by these flux gradients in themselves cause heat flux in the copper in a nonradial direction. The significance of the effect on the heat flux data is unknown.

The flow in the chamber as noted above is principally radial and not one dimensional as required by the theory. The calorimeters were isolated from this effect by building an air gap between most of the calorimeter body and the surrounding chamber. The calorimeter does, however, contact the chamber at its rearmost portion. Because of the radial flow of heat this portion of the chamber will be cooler for a given flux level than a corresponding one-dimensional body. The effect on the calorimeter response is believed to be quite small. Since predicted chamber temperature distributions show very little temperature response at this distance from the inner surface (Refer to Part IV).

Another point of uncertainty exists because of manufacturing tolerances in the calorimeter construction. Particularly sensitive is the distance between the thermocouple "bead" and the surface. This distance was to be 0.01 inches to keep the criterion of R/E = 1. Allowance has to be made for manufacturing inaccuracies, because blind holes were drilled in the calorimeter body and the thermocouples were brazed in these blind holes.

The theoretical results of reference 2 can be used to estimate the error in surface temperature due to R/E being less than unity. Figure 2 in this reference plots the temperature difference as a function of R/E for parametric values of the plot numbers, $\alpha t/E^2$. For time greater than 0.05 seconds $\alpha t/E^2$ is very large (~70) so that as an approximation $\alpha t/E^2 = \infty$ can be justified. Fitting a straight line through these curves one finds that

$$\frac{T_c}{T_\infty} = \frac{1.4 q_o R}{KT}\left(\frac{R}{E} - 1\right) + 1$$

For a 10 percent error in R/E (i.e., R/E = 1.1)

$$\frac{T_c}{T_\infty} \simeq 1.04$$

or 4 percent error in temperature. More importantly, the large value for the Biot number means that for times greater than 0.05 seconds, the derivative:

$$\frac{dT_c}{d\tau} \simeq \frac{dT_\infty}{d\tau}$$

will be an even closer equality. It can be concluded that manufacturing tolerances will affect the absolute level of temperatures-- a 10 percent error in the distance E causing a 5 percent error in the predicted surface temperature. However, the temperature gradients $dT/d\tau$ are much more precise. The gages have not been sectioned, therefore the actual value for the distance E remains unknown.

SECTION 4.4

HEAT FLUX DATA IRREGULARITIES

It has been noted that particular problems exist with regard to heat flux gage number six--the gage located in the chamber converging section. In addition to the obvious nonrepeatability, the gage exhibited other data pecularities. These pecularities include:

1. An apparent increase in temperature and heat flux response between the first and last tests.
2. A rapid decrease in heat flux following the ignition transient.

Figure 4.5 presents a comparison of the data from the first firing (run 9) with one of the last which shows these data trends. Note that for the run 9 data the flux is nearly constant but for the other runs there is a significant decrease with time. This decrease is greater than the inferred increase in wall temperature would create as the following simple analysis points out.

The simple film analog equation for heat transfer in a boundary layer with no chemical reactions and equal diffusion is given by

$$q = \rho_e u_e C_H (h_{r_e} - h_w)$$

Differentiation of this equation with respect to time, presuming constant edge recovery enthalpy, h_{r_e}, yields

$$\frac{dq}{d\tau} = - \rho_e u_e C_H C_P \frac{dT}{d\tau}$$

Substituting in approximate values for the transfer coefficient

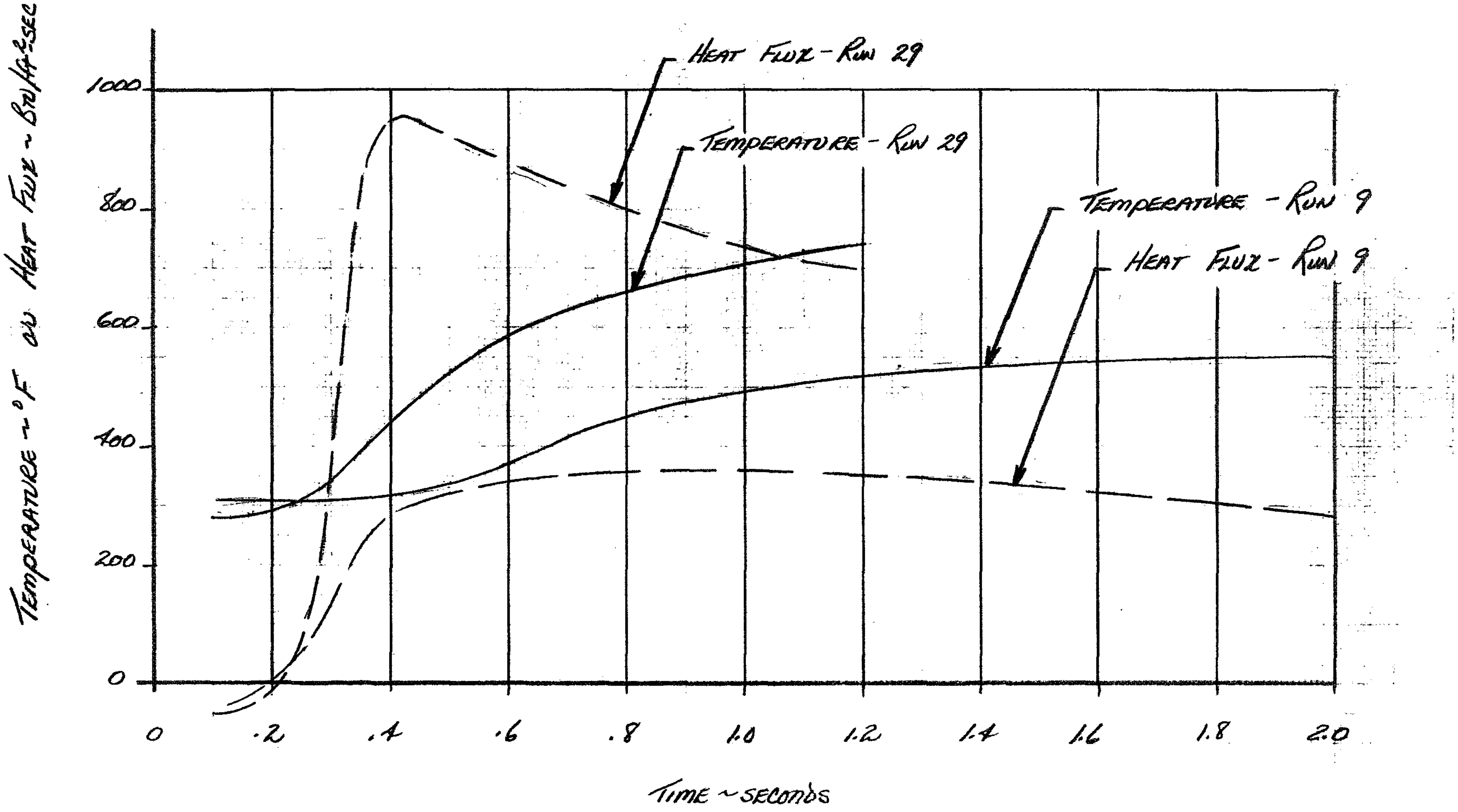

Figure 4.5. Typical Response of Gage Number 6

and the calculated gradients from the temperature and flux curves from Figure 4.5

$$\rho_e u_e C_H \simeq 0.2 \ ; \quad C_P \simeq 0.5 \ ; \quad \frac{dq}{d} \simeq -300 \ ; \ \frac{dT}{d} \simeq 150$$

yields

$$300 > 15$$

and the calculated heat flux decreases at a rate over a factor 10 greater than the measured temperature increase would lead one to expect.

This heat flux gage was removed from its chamber in order to examine the gage thoroughly. Visual examination of the gage and the region surrounding the gage location in the chamber converging section showed what appeared to be black globules attached to the surface. These globules appear to be copper oxide which apparently only formed on the hotter portions of the chamber (since the constant diameter section did not show such formations). As noted previously the portion of the calorimeter above the void is at a higher temperature than the surrounding mass and probably for this reason a globule was found in the very center of the calorimeter face. A photograph of the gage face magnified 300 times is presented in Figure 4.6, and the presence of the formation is clearly seen. It is suggested that the presence of these surface contaminants is responsible for the gage response, however, analysis to support this hypothesis have not been performed.

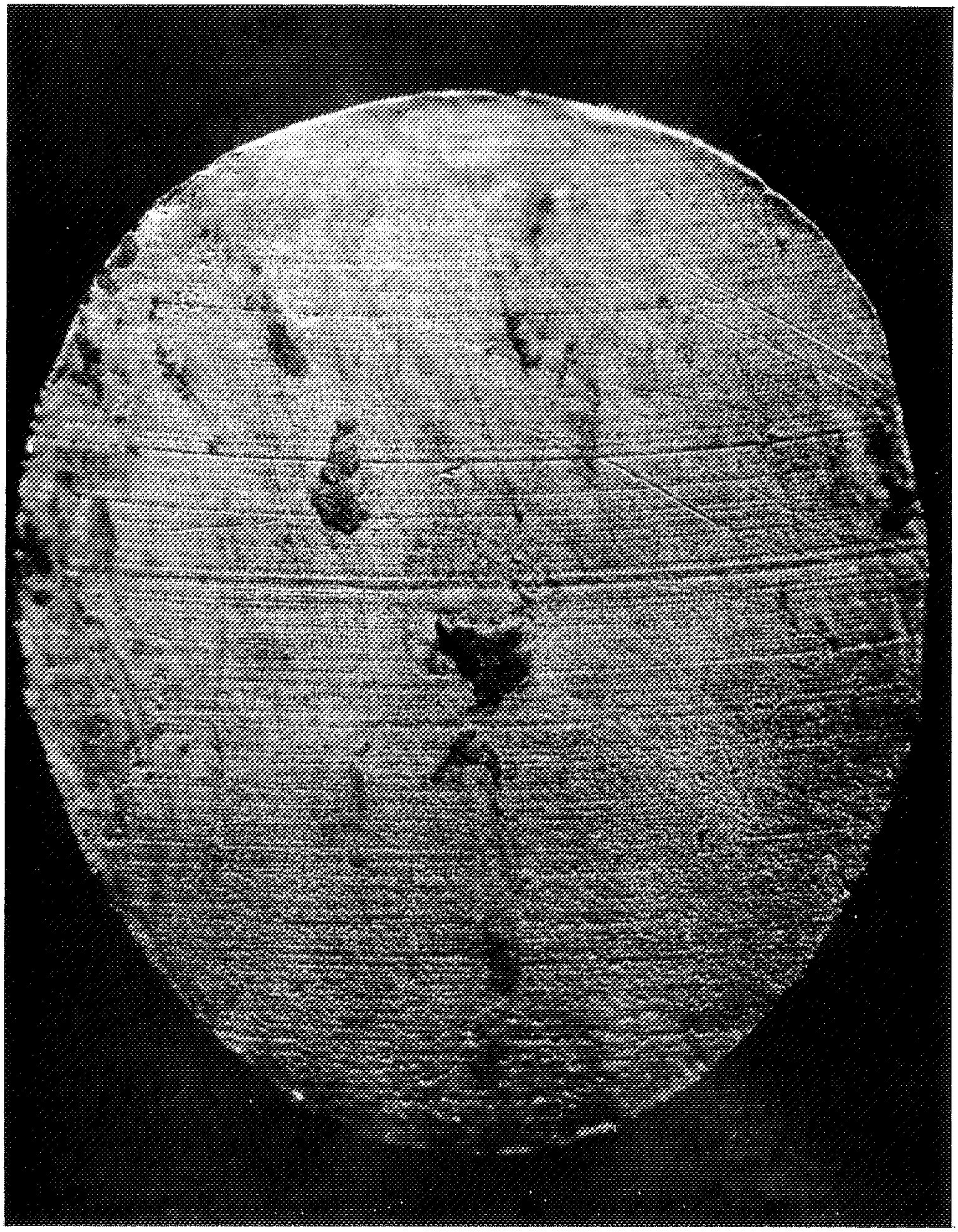

Figure 4.6. View of Heat Flux Gage No. 6 Surface Showing Surface Contaminate at Center

SECTION 5

MOTOR AND TEST STAND SYSTEM PERFORMANCE DATA

In this section brief discussion is given of the principal motor and test stand parameter data and what the effect of the variation of these parameters may have had on the data presented in the preceding sections. Within the range of each of the parameter studies, little or no consistent effect on the data is found.

5.1 DATA SUMMARY

A summary of the motor and test stand system parameter data is presented in Table 5.1. The complete data set is presented in the next section. For the most part the data is seen to be quite consistent and fairly constant. A percentage deviation study has not been performed on the data, however the fuel and oxidizer flow rates have been correlated with the JPL flow rate data and it is seen that the bulk of the flow rate data falls within a 2% tolerance. The oxidizer flow characteristic data is presented in Figure 5.1 and that for the fuel in Figure 5.2. This data was plotted without making density corrections. A casual examinatin of the fuel and oxidizer temperature data in Table 5.1 and comparison with the data in these figures leads to the conclusion that such a correction would not reduce the data scatter significantly. In at least one run, notably run 27, the significant departure from the mean can be noted (Figure 5.1). As previously noted, run 23 suffered from a loose fitting between the oxidizer connection and the injector. This resulted is an effective low O/F ratio. Run 31 was run with an intentionally low ratio.

The C^* efficiency for the motor is fairly good, runing about 95% of theoretical. In the last five runs, (28 through 32) the chamber pressure measurement was lost. For these runs chamber pressure and was inferred from the measured flow rate and the injector pressure drop characteristic.

TABLE 5.1

MOTOR AND TEST STAND SYSTEM DATA

Run No	O/F	C^*	C_{SR}	I_S	C_F	P_C	W_Φ	W_F	P_N/P_C	P_{OT}	P_O	P_{FT}	P_F	P_W	T_Φ	T_F	T_B	T_S	T_{V1}
9	1.3067	5479	.9499	204.76	1.2024	164.25	.2428	.1858	.0811	1048.16	528.39	932.40	477.62	–	50.61	30.57	272.32	276.95	291.37
10	1.2939	5444	.9434	202.42	1.1963	160.35	.2376	.1836	.0808	957.86	492.31	–	471.07	129.81	49.42	–	324.04	252.70	352.95
11	1.2527	5386	.9300	190.35	1.1370	158.65	.2342	.1869	.0834	969.11	491.52	938.41	467.29	183.02	45.13	38.66	–	296.92	350.12
12	1.2792	5486	.9491	192.11	1.1266	160.12	.2342	.1831	.0817	969.08	496.51	943.32	469.80	184.23	45.13	43.25	342.19	225.25	311.84
13	1.3083	5503	.9542	199.55	1.1666	160.12	.2358	.1802	.0817	964.06	500.27	938.38	468.53	186.71	51.55	45.54	348.49	267.41	360.19
14	1.2714	5538	.9576	195.13	1.1334	161.10	.2328	.1831	.0819	969.07	501.52	938.37	472.33	181.75	44.96	46.14	335.83	258.22	273.42
15	1.2846	5503	.9525	206.40	1.1773	160.85	.2350	.1829	.0830	962.22	491.16	945.38	470.37	215.60	52.03	39.20	335.09	230.37	265.01
16	1.2444	5498	.9489	203.02	1.1879	161.33	.2326	.1869	.0819	947.48	493.60	945.37	472.88	190.93	52.90	39.20	336.55	273.41	353.86
17	1.2467	5540	.9563	198.53	1.1528	162.30	.2324	.1864	.0806	952.38	504.59	940.44	471.61	190.92	53.77	44.63	–	289.87	282.60
18	1.2887	5576	.9654	196.77	1.1353	161.81	.2336	.1813	.0801	942.56	493.59	930.59	464.05	192.16	52.90	45.72	336.55	264.55	279.54
19	1.2811	5592	.9677	191.85	1.1030	162.11	.2328	.1817	.0820	770.09	501.84	937.15	472.16	206.64	54.22	50.28	340.37	320.50	331.69
20	1.2942	5586.	.9676	192.71	1.1098	163.09	.2355	.1819	.0815	778.25	520.62	937.15	470.89	214.80	53.03	50.28	356.39	323.71	341.98
21	1.2950	5627	.9746	236.37	1.3514	164.98	.2366	.1827	.0782	960.59	519.89	993.35	479.77	105.89	40.98	35.76	323.48	322.81	355.88
22	1.2838	5600	.9692	233.41	1.3408	162.51	.2332	.1817	.0779	955.50	526.23	933.74	469.63	108.38	42.17	38.09	333.10	259.20	340.62
23	1.1259	5655	.9708	237.05	1.3485	153.13	.2050	.1821	.0769	960.59	413.28	933.74	464.57	105.89	42.17	40.42	326.69	251.65	320.99
24	1.3088	5663	.9821	225.05	1.2784	166.48	.2383	.1820	.0776	965.68	522.44	943.68	478.51	100.90	43.37	49.75	297.83	252.73	333.38
25	1.2943	5652	.9790	223.27	1.2713	165.42	.2361	.1824	.0769	945.27	538.86	938.65	474.64	97.09	43.37	39.26	340.58	276.45	359.21
26	1.3101	5587	.9689	220.89	1.2720	165.33	.2400	.1831	.0779	965.52	514.66	943.52	480.89	170.63	40.89	39.45	335.49	259.84	355.61
27	1.3078	5509	.9552	216.43	1.2639	161.37	.2373	.1815	.0767	945.18	580.65	938.56	472.02	174.37	42.09	40.56	328.87	282.87	387.41
28	1.2901	5746	.9950	192.48	1.0776	167.45	.2347	.1819	.0786	959.64	500.90	929.26	472.03	172.30	53.21	35.09	335.20	270.86	385.26
29	1.2921	5950	1.0304	201.57	1.0899	173.94	.2356	.1823	.0742	964.62	509.63	934.27	477.08	174.74	54.39	39.33	330.82	286.07	379.57
30	1.3041	5774	1.0009	199.00	1.1088	168.92	.2367	.1815	.0763	959.61	512.11	924.21	472.00	171.04	53.21	36.41	331.91	303.46	375.77
31	1.1170	5674	.9739	190.87	1.0821	160.42	.2133	.1909	.0774	764.62	439.62	1014.68	497.35	174.74	54.39	39.06	342.86	294.76	363.41
32	1.2896	5812	1.0063	185.10	1.0246	169.43	.2348	.1820	.0754	954.61	518.36	934.26	474.53	173.50	54.39	52.26	333.01	323.01	350.30

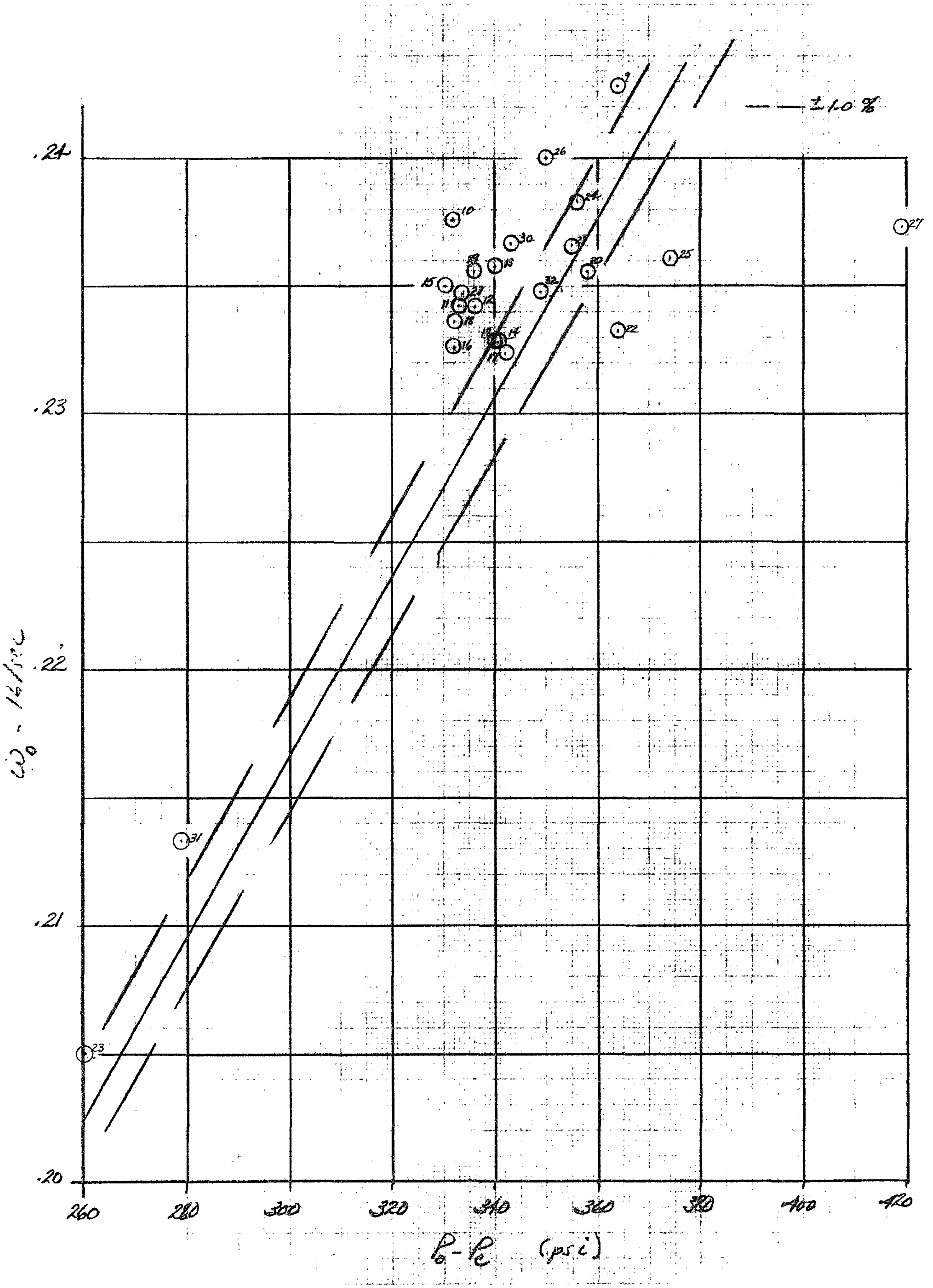

Figure 5.1. Injector Oxidizer Flow Characteristic

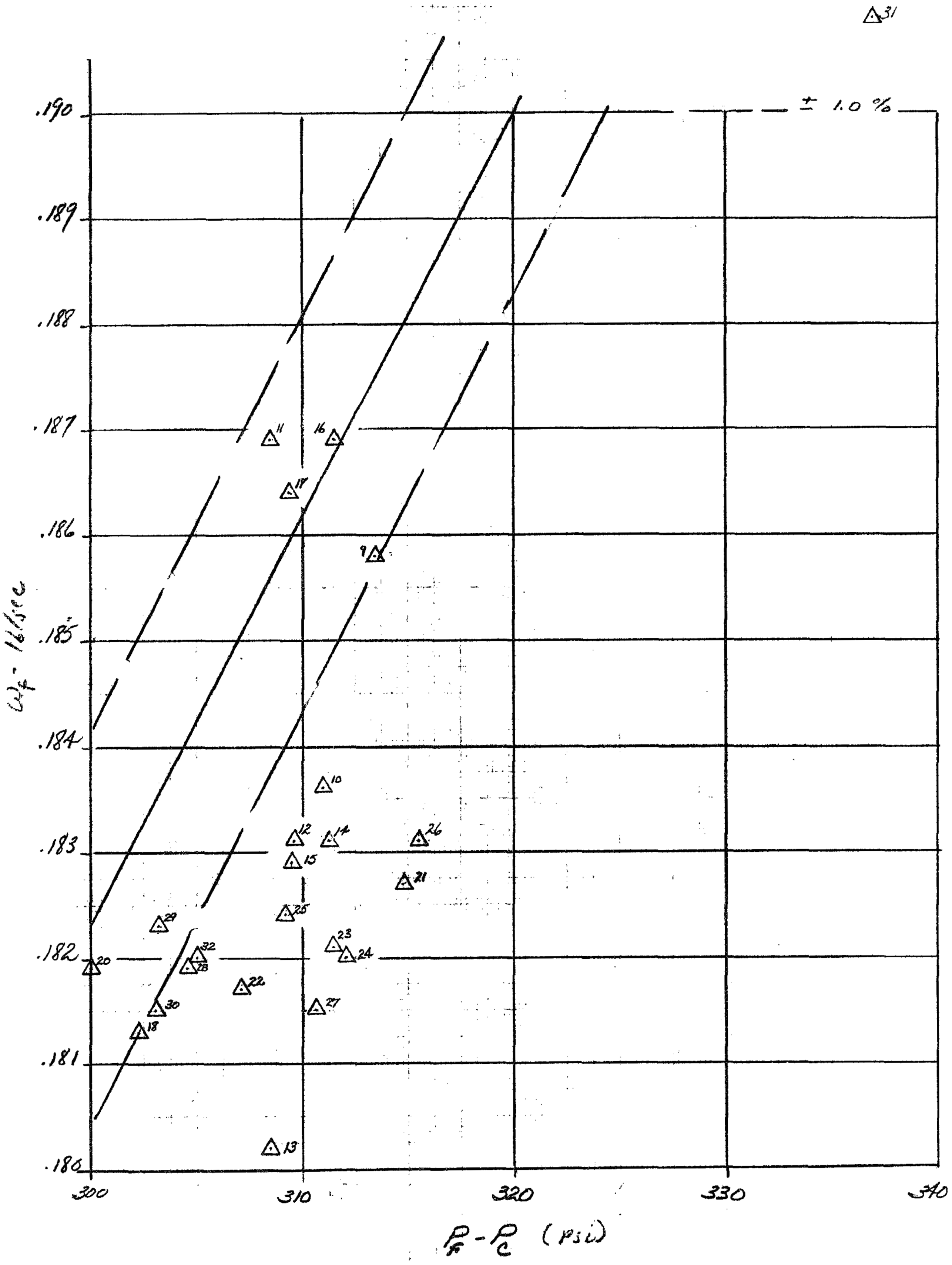

Figure 5.2. Injector Fuel Flow Characteristic

This procedure does not tend to be precisely accurate and probably accounts for the fact that the C^* efficiencies exceeded 100% for these runs

5.2 INFLUENCE OF PARAMETERS ON CHEMISTRY AND HEAT FLUX DATA

Since it was not possible to precisely control certain of the parameters, it was decided that a preliminary investigation should be made concerning the effect of these same parameters on the heat flux and chemistry data. The two parameters studied were oxidizer to fuel ratio and sampling duration. A third possibility for investigation, the effect of upstream sampling, was considered, however it's effect (as mentioned earlier) was found to be insignificant. The two parameters studied also appear to have little effect on the heat flux and chemistry data, however the data is ambiguous in this regard.

The effect of mixture ratio is presented in Figure 5.3. In the upper part of the figure the effect on the heat flux for the first station is shown. From 1.1 to 1.3 there is almost a factor of two increase (from 30 to about 55 Btu/ft^2-sec). However the lowest O/F in the test series (except for run 23) was 1.244 and it can be seen that the mixture ratio effect between 1.244 and 1.3 is less than the scatter in the data due to other unknown factors.* It can be seen from the heat flux figures (e.g., 4.-c) that any mixture ratio effect is even less apparent for stations further down the chamber.

The lower half of Figure 5.3 shows selected chemistry which ambiguously does and does not show a mixture ratio dependence. However, the data does show clearly that for upstream stations (open symbols),

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The only system parameter which has been found to possibly have a bearing is C which is highest for run 29. Run 28 and 30 have lower and nearly equal C*. However, this consideration is not conclusive due to the manner in which C* was obtained for these runs.

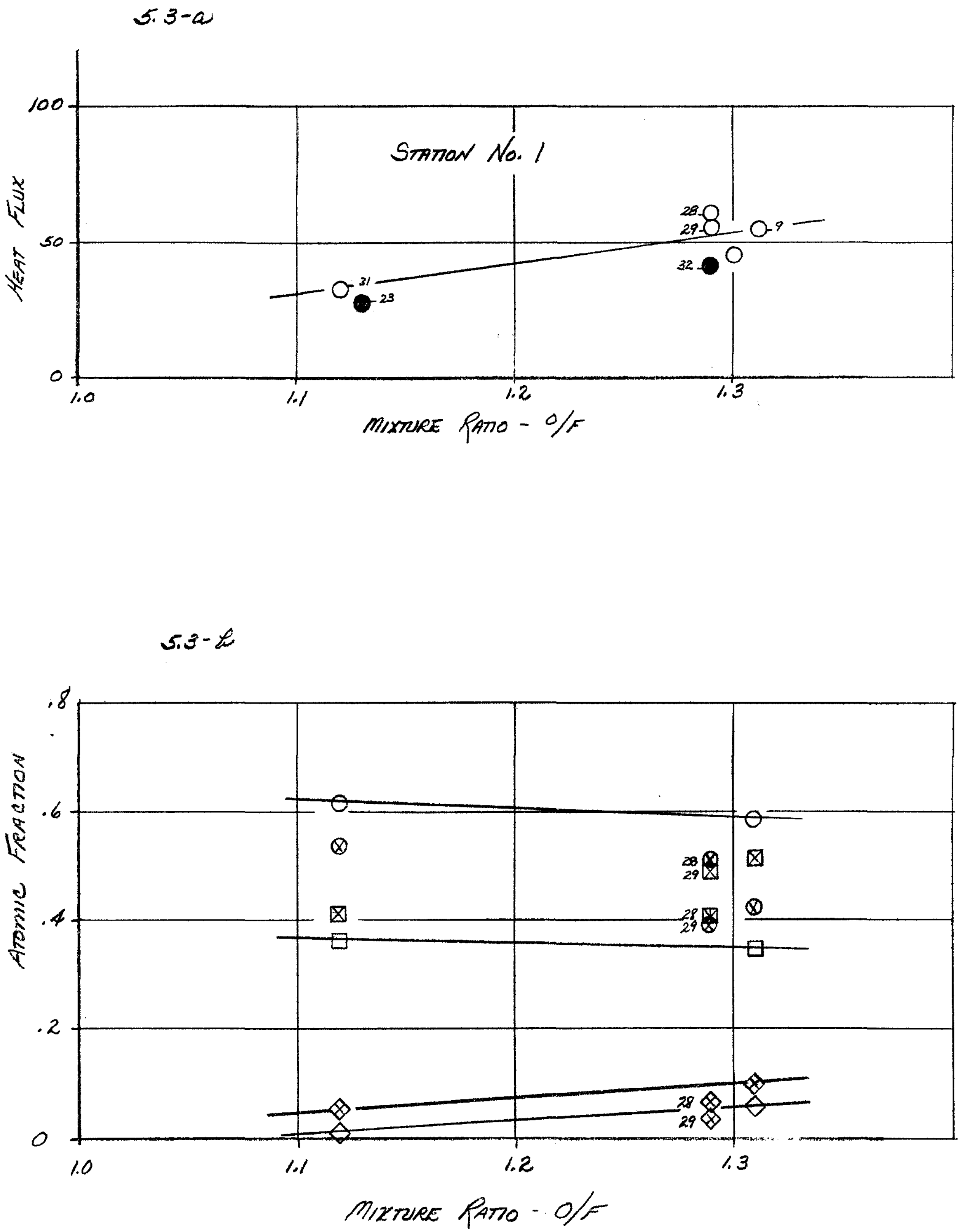

Figure 5.3. Effect of Mixture Ratio on Selected Chemical and Heat Flux Data

there is little or no effect on the hydrogen or nitrogen atomic fractions. Also, it clearly shows that for these stations there is some effect on the oxygen fraction as it gradually increases from .01 to .06 as O/F goes between 1.1 and 1.3. For the axial positions near the throat, the situation is not clear with runs 28 and 29 conflicting. Run 28 shows little or no effect and 29 shows significant effect on H and N (agreeing with run 9 in this regard) but no effect on O (disagreeing with 9). Again the net conclusion, as far as the data of this program is concerned, is the same as that for the heat flux. There is more uncertainty in the data due to other causes than there is due to mixture ratio.

Sampling duration was one of the less well controlled parameters as reference to Table 2.1 will show. Fluxuation in the sampling duration is due to certain malfunctions of the automatic sequencer controlling the test--certain channels being more adversely affected than others. Two tests were run to bracket this variation at one injector position. The results are presented in Figure 5.4 which compares the axial atom fraction distribution data for one injector position.

These results are quite interesting although inconclusive except for one fact. It appears that, along with mixture ratio, the atomic composition is largely uneffected by sampling duration for the stations nearest the injector. Beyond this the situation is not clear. The data presented in the figure shows that for a short sampling time (run 27) there is a crossover near the injector station and all downstream stations have high nitrogen and low hydrogen compared to data from sampling duration of about 1 second in length (run 9). In this later run the crossover doesn't occur until near the throat. For the long sampling time (run 28) no crossover at all occurs and hydrogen is everywhere higher than nitrogen. Now this trend could well be illusionary as the following considerations make clear. First the run 27 data is suspect because of its injector flow characteristic. Secondly, run 27 data appears quite like run 23 data (they are the only runs to show "early crossover") and the injector flow was known to be fouled up for run 23. The sampling durations for 27 and 23 were quite different. Thirdly--Run 31 data agrees with that from the long sampling time--Run 28 (see Figure 3.2-t and 3.2-w) and presumably,

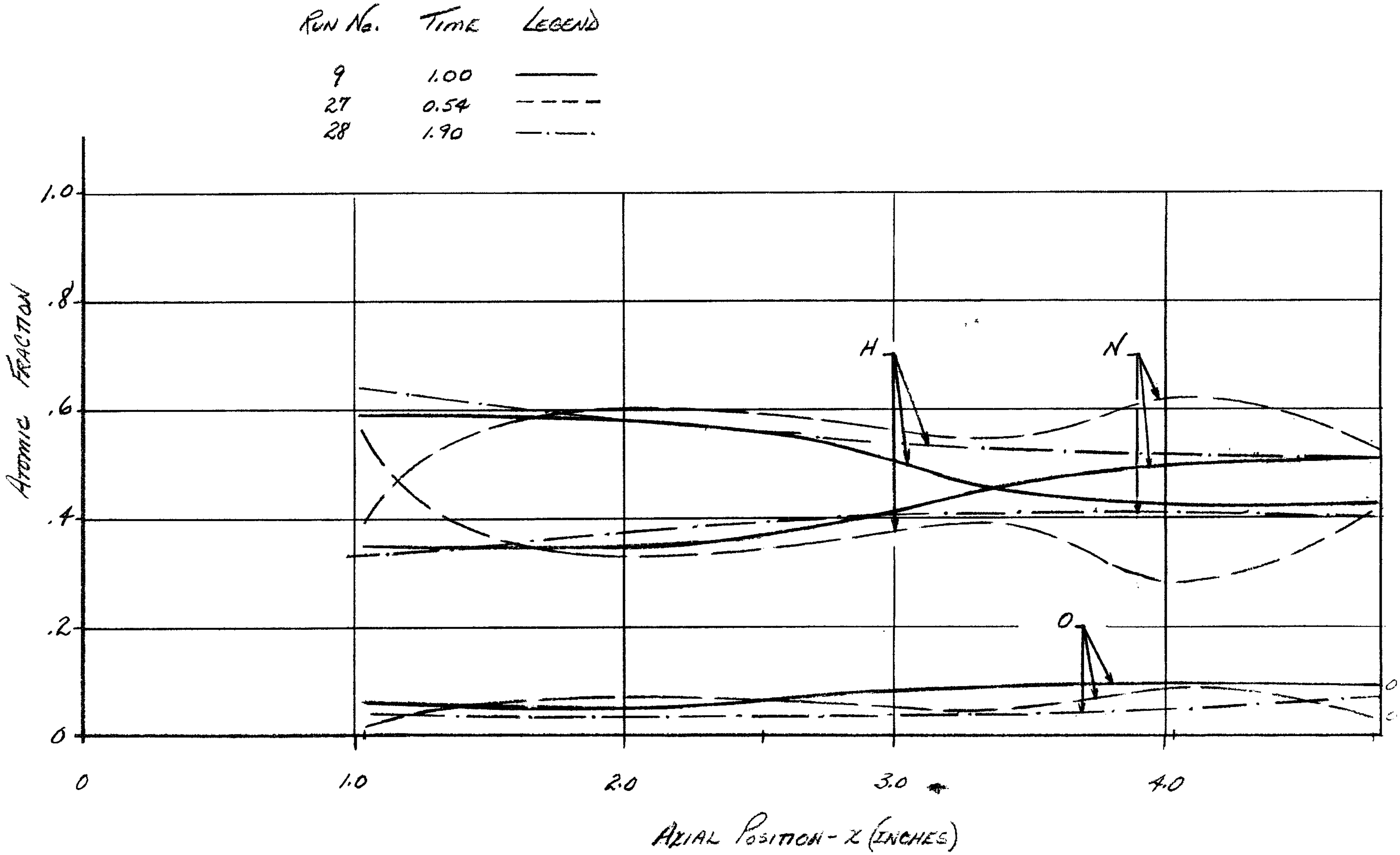

Figure 5.4. Effect of Sampling Duration on Atomic Composition

as shown previously, the low mixture ratio characteristic of run 31 is not significant. Now, as Table 2.1 shows, the sampling times for runs 9 and 31 are about the same. Thus, it is seen that the data are really inconsistent in somewhat of an uncertain way. No other system data variation has been found which can shed light on the inconsistency. If reliance is placed on the theoretical findings of Part II, which show little influence of sampling time between .6 and 1.0 seconds, then it would appear that the burden of proof favors the philosophy that sampling duration variation between .5 and 2.0 seconds has little or no effect on the measured composition.

SECTION 6

DATA COMPILATION

The formal tabulation for the data obtained in the program is presented in this section. This includes both the motor and test stand system data as well as the boundary flow composition and heat flux data. The heat flux is presented for a specific time. The full response of the calorimeter is presented in Appendix A.

The data presentation was performed by a computer so that some symbology compromise was required. A nomenclature section precedes the data. In the presentation, a page was reserved for each run which gives comments about the data reduction.

The composition data (determined by the mass spectrometer) shows the species that the least square curve fitting procedure required to arrive at the best fit for the data. Some of the species so obtained are subject to question. In particular this is true of the oxides of nitrogen--N_2O, NO, and NO_2. Equilibrium calculations show these species are present in only trace amounts, if at all. Further, high resolution studies by West Coast Technical showed that CO_2 and not N_2O is responsible for the 44 peak. As discussed in Part IV the source of the CO_2 contamination is unknown. Thus the presence of such species must be regarded with some suspicion. The oxides of nitrogen were used in the computation of O/F but not CO_2. The reason for omitting CO_2 is that the CO_2 is probably coming from some source external to the combustion chamber. The oxidizer to fuel ratio data that is presented in this section is discussed in Part II.

DATA PRINTOUT NOMENCLATURE

A. Gas Analysis - Engine Performance (page one)

CF - C_f - thrust coefficient

CSR - C*ratio - (c*/c* ideal)

CSTAR - C*

F - Thrust

IS - I_{s_1} - specific impulse (oscillograph)

ISB - I_{s_2} - specific impulse (ballistic analyzer)*

ISR - I_{s_r} - specific impulse ratio ($I_s/I_{s_{ideal}}$)

O/F - oxidizer - fuel ratio

PC - P_c - chamber pressure (oscillograph)

PF - P_f - fuel pressure at injector

PFT - $P_{f,t}$ - fuel tank pressure

PO - P_o - oxidizer pressure at injector

POT - $P_{o,t}$ - oxidizer tank pressure

PCB - P_c - chamber pressure (ballistic analyzer)*

PNPC - P_n/P_c - motor pressure ratio

PSR - P_s/P_o - shroud pressure ratio*

PW - P_w - water pressure at injector

TB - T_b - motor temperature during sampling

WF - $\dot{W}_f$ - fuel flow rate

WO - W_o - oxidizer flow rate

WW - W_o - water flow rate

FB - F_b - thrust (ballistic analyzer)*

TS - T_s - helium supply temperature (for case heating)

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*Not recorded for the runs presented.

TV1 - T_{v_1} - valve #1 temperature
TO - T_o - oxidizer temperature
TF - T_f - fuel temperature

B. Gas Analysis — (Page 2)

H - H - atomic hydrogen
H2 - H_2 - hydrogen
HO - HO - hydrogen peroxide
H2O - H_2O - water
HO2 - HO_2
HNO - HNO
HNO2 - HNO2 - nitrous acid
HNO3 - HNO3 - nitric acid
HN - HN
O - O - atomic oxygen
O2 - O_2 - oxygen
N - N - atomic nitrogen
N2 - N_2 - nitrogen
NO - NO - nitrous oxide
N2O - N_2O - nitrogen monoxide
NO2 - NO_2 - nitrogen tetroxide
NH3 - NH_3 - ammonia
A - A - argon
CO2 - CO_2 - carbon dioxide
N2H4 - N_2H_4 - hydrazine
HE - He - helium

C. Oscillograph Readings — (Page 3)

AT - A_t - throat area

CF - C_f - flow rate calibration

CSI - $C^*_{s(\text{ideal})}$ - ideal C*

FB - F - force (thrust) (ballistic analyzer)*

FD - ρ_f - fuel density

WF - $\dot{W}_f$ - fuel flow rate

WO - $\dot{W}_o$ - oxidizer flow rate

F - F - force

IS - $I_{s(\text{ideal})}$ - ideal specific impulse

OD - ρ_o - oxidizer density

PAM - P_a - ambient pressure

P1-P6 - $P_1 P_6$ - bottle pressures

PB - P_c - chamber pressure (ballistic analyzer)*

PC - P_c - chamber pressure

PF - P_f - fuel pressure at injector

PT - $P_{f,t}$ - fuel pressure at tank

PO - P_o - oxidizer pressure at injector

PV - $P_{o,t}$ - oxidizer pressure at tank

PN - P_n - nozzle exit pressure

PW - P_w - cooling water pressure

TB - T_b - motor temperature

PS - P_s - shroud pressure*

TS - T_s - supply temperature

TF - T_f - fuel temperature

TO - T_o - oxidizer temperature

T1 - T_{v_1} - valve temperature

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*Not recorded for the runs presented.

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                    ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

          JPL CONTRACT - NAS7-463                   AEROTHERM PROJECT 7009

          RUN NUMBER -  19                          INJECTOR POSITION -   0

          FIRING NUMBER -    17                     DATA OF FIRING - 12/24/68

--------------------------------------------------------------------------------


                             DATA REDUCTION RESULTS

          AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                           BTU/FT2-SEC

               1.0280                   0.3086                 107.0

               1.7780                   0.0000                   0.0

               2.5280                   0.2995                  79.7

               3.2780                   0.5310                  78.3

               4.0280                   0.0000                 103.3

               4.7780                   1.3200                 362.5

                          ENGINE PERFORMANCE PARAMETERS

          O/F   1.3069          CSTAR  5479. (FT/S)    CSR   0.9499

          ISR   0.8993          PNPC   0.0811          CF    1.2024

          IS    204.76 (SEC)    F      87.79 (LB)      PC    164.25 (PSIA)

          ISB     0.00 (SEC)    FB      0.00 (LB)      PCB    14.70 (PSIA)

          WO    0.2428 (LB/S)   WF     0.1858 (LB/S)   WW    0.0000 (LB/S)

          RSR   1.0000


                               SYSTEM DATA

              PRESSURE (PSIA)                  TEMPERATURE (DEG.F)

          PF     477.62    PFT    932.40      TF   272.32     TO    50.61

          PO     528.39    POT   1048.16      TS   276.95     TF    30.57

          PA      14.70                       TV1  291.37
```

```
          GAS COMPOSITION          RUN NUMBER  9

               ******************************************************************
               *
               *                       MOLE FRACTION
               *
               *
               *                       BOTTLE NUMBER
               *
GAS            *     1          2          3          4          5          6
               *
               *
H2             *   16.460     0.000     22.486      6.595      0.000      5.488
               *
H2O            *   16.407     0.000     14.903     22.258      0.000     18.955
               *
O2             *    0.193     0.000      0.000      0.000      0.000      0.000
               *
N2             *   32.929     0.000     35.312     48.801      0.000     46.090
               *
NO             *    0.000     0.000      0.000      0.000      0.000      0.478
               *
N2O            *    0.626     0.000      0.901      0.000      0.000      0.000
               *
NO2            *    0.000     0.000      0.000      0.000      0.000     11.666
               *
NH3            *   32.052     0.000     25.156     20.876      0.000     14.709
               *
N2H4           *    0.044     0.000      0.304      0.000      0.000      0.000
               *
A              *    0.058     0.000      0.060      0.111      0.000      0.252
               *
CO2            *    0.309     0.000      0.000      0.000      0.000      0.202
               *
HE             *    0.916     0.000      0.873      1.355      0.000      2.156
               *
               ******************************************************************

PRESSURE          41.44      35.84      39.07      36.81      50.15      33.91
 (PSIA)

H/N                1.63       0.00       1.54       1.01     ******       0.78

O/N                0.17       0.00       0.16       0.19     ******       0.35

H2O                6.33       0.00       9.70      31.45     ******      34.09
```

```
                              RUN NUMBER  9

                            OSCILLOGRAPH DATA

QUANTITY       READING    CAL        QUANTITY        READING      CAL
                (IN.)*                                (IN.)

                                 MOTOR

  WF             69.30   383.00         F               1.74      50.45

  PC              2.68    55.80         PO              4.13     124.38

  PF              3.53   131.14         PV              2.05     501.68

  PW              0.00   501.68         PN             -0.11      12.41

  PS              0.00    12.41         PT              1.89     485.55

  WO            166.70  1007.00         TB              1.06       4.34

  TS              1.15     4.16         TO             -0.83       4.13

  TF             -1.03     3.99         T1              1.29       4.12


                             BOTTLE PRESSURE

  P1              1.06    25.00         P2              0.85      24.97

  P3              0.97    25.12         P4              0.88      25.12

  P5              1.39    25.51         P6              0.77      24.63

                          BALLISTIC ANALYZER DATA

  PB            14.70(PSIA)                        FB            0.00(LB.

                           MISCELLANEOUS DATA

  PAM          14.700(PSIA)             IS          227.69(SEC)

  OD           91.599(LB/CUFT)          CSI        5767.65(FT/SEC)

  FD           64.120(LB/CUFT)          AT            0.44(SQIN)

                           * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 9

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

WATER PRESSURE WAS NOT RECORDED

NO BALLISTIC ANALYZER DATA

NOZZLE OVEREXPANDED - THRUST LOW

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

SAMPLING DURATION - 1.00 SECONDS

MEAN SAMPLING TIME - 1.9 SECONDS

BOTTLE 1 PEAK 16 OFF SCALE, PEAK 20 HIGH

BOTTLE 2 DISCARDED DUE TO EXCESSIVE OXYGEN CONTENT

BOTTLE 3 PEAK 15 OFF SCALE, PEAK 20 HIGH

BOTTLE 4 PEAK 16 OFF SCALE, PEAK 45 LOW

BOTTLE 5 NO DATA AVAILABLE

BOTTLE 6 PEAKS 20 AND 30 HIGH, PEAKS 15 AND 16 OFF SCALE

```
                                                                 PAGE 1 OF 4

                    ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

          JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

          RUN NUMBER -  10                        INJECTOR POSITION -  30

          FIRING NUMBER -   18                    DATE OF FIRING - 12/24/68

----------------------------------------------------------------------------


                              DATA REDUCTION RESULTS

          AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                            BTU/FT2-SEC

               1.0280                   0.4989                110.0

               1.7780                   0.4477                  0.0

               2.5280                   0.4436                140.2

               3.2780                   0.6679                151.0

               4.0280                   0.0000                125.4

               4.7780                   1.5042                391.8

                           ENGINE PERFORMANCE PARAMETERS

          O/F    1.2953            CSTAR  5446. (FT/S)   CSR    0.9434

          ISR    0.8887            PNPC   0.0808         CF     1.1963

          IS     202.52 (SEC)      F      85.26 (LB)     PC     160.35 (PSIA)

          ISB      0.00 (SEC)      FB      0.00 (LB)     PCB     14.70 (PSIA)

          WO     0.2376 (LB/S)     WF     0.1834 (LB/S)  WW     0.0000 (LB/S)

          PSR    1.0000


                                  SYSTEM DATA

               PRESSURE (PSIA)                        TEMPERATURE (DEG.F)

          PF     471.07     PFT    927.55            TB   324.04     TO    49.42

          PO     492.31     POT    957.86            TS   252.70     TF    30.57

          PW     129.81                              TV1  352.95
```

```
          GAS COMPOSITION          RUN NUMBER 10

          ***************************************************************
          *
          *                      MOLE FRACTION
          *
          *
          *                      BOTTLE NUMBER
          *
GAS       *      1         2         3         4         5         6
          *
          *
H2        *   37.332    23.700    38.497     8.699     0.000     4.536 ✓
          *
H2O       *   11.103    14.145    16.951    12.918     0.000    19.929 ✓
          *
O2        *    1.634     1.131     0.000     0.318     0.000     0.000 ✓
          *
N2        *   46.088    47.588    39.475    69.429     0.000    50.098 ✓
          *
NO        *    0.000     0.000     1.454     0.003     0.000     0.000
          *
N2O       *    2.460     0.719     0.000     0.000     0.000     0.000
          *
NO2       *    0.000     0.000     0.000     0.000     0.000    11.778
          *
NH3       *    0.000    11.377     2.738     4.985     0.000    11.356 ✓
          *
N2H4      *    0.000     0.000     0.000     0.021     0.000     0.000
          *
A         *    0.093     0.221     0.000     2.051     0.000     1.209
          *
HE        *    1.286     1.116     0.882     1.571     0.000     1.091
          *
          ***************************************************************

PRESSURE       31.44     38.82     39.82     35.55     44.29     33.66
 (PSIA)

H/N             0.99      1.01      1.43      0.40     -0.00      0.67

O/N             0.17      0.15      0.22      0.09     -0.00      0.35

H2O            26.83     29.67      9.58     71.98      0.00     40.05
```

```
                              RUN NUMBER 10

                            OSCILLOGRAPH DATA

QUANTITY     READING    CAL           QUANTITY      READING     CAL
              (IN.)*                                 (IN.)

                                 MOTOR

   WF         68.40    383.00            F            1.68     50.45

   PC          2.61     55.80            PO           3.84    124.38

   PF          3.48    131.14            PV           1.88    501.68

   PW          0.92    123.77            PN          -0.14     12.41

   PS          0.00     12.41            PT           1.87    485.55

   WO        162.90   1007.00            TB           1.53      4.34

   TS          0.92      4.16            TO          -0.84      4.13

   TF         -1.03      3.99            T1           1.88      4.12


                             BOTTLE PRESSURE

   P1          0.66     25.00            P2           0.96     24.87

   P3          1.00     25.12            P4           0.83     25.12

   P5          1.15     25.51            P6           0.76     24.63


                         BALLISTIC ANALYZER DATA

   PB         14.70(PSIA)                       FB           0.00(LB.)


                           MISCELLANEOUS DATA

   PAM       14.700(PSIA)                IS       227.86(SEC)

   OD        91.697(LB/CUFT)             CSI     5773.16(FT/SEC)

   FD        64.120(LB/CUFT)             AT         0.44(SQIN)

                           * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 10

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

NOZZLE OVEREXPANDED - THRUST LOW

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

SAMPLING DURATION - 1.00 SECONDS

MEAN SAMPLING TIME - 1.9 SECONDS

BOTTLE 1	PEAKS 17 AND 44 HIGH
BOTTLE 2	PEAKS 15, 28 AND 32 HIGH, PEAK 14 HIGHER THAN USUAL
BOTTLE 3	PEAKS 14, 15, 28, 32 AND 44 ALL HIGH
BOTTLE 4	PEAK 18 HIGH
BOTTLE 6	PEAKS 15, 17 AND 30 HIGH, PEAK 14 LOW AND PEAK 16 HIGH AND SLIGHTLY OFF SCALE

```
                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

      JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

      RUN NUMBER -  11                        INJECTOR POSITION -  60

      FIRING NUMBER -    19                   DATE OF FIRING -  1/10/69

-------------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

      AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER       HEAT FLUX
                                                        BTU/FT2-SEC

            1.0280                 0.2243                  74.1

            1.7780                 0.2945                   0.0

            2.5280                 0.2105                 132.3

            3.2780                 0.1756                 172.0

            4.0280                 0.4586                   0.0

            4.7780                 0.2796                 419.9

                       ENGINE PERFORMANCE PARAMETERS

      O/F   1.2527            CSTAR  5386. (FT/S)  CSR    0.9300

      ISR   0.8332            PNPC   0.0834        CF     1.1370

      IS    190.35 (SEC)      F      80.18 (LB)    PC     158.65 (PSIA)

      ISB     0.00 (SEC)      FB      0.00 (LB)    PCB     14.73 (PSIA)

      WO    0.2342 (LB/S)     WF     0.1869 (LB/S) WW     0.0000 (LB/S)

      PSR   1.0000


                               SYSTEM DATA

           PRESSURE (PSIA)                     TEMPERATURE (DEG.F)

      PF    467.29    PFT    938.41       TB   150.00    TO    45.13

      PO    491.52    POT    969.11       TS   296.92    TF    38.66

      PW    183.02                        TV1  350.12
```

```
GAS COMPOSITION              RUN NUMBER 11

           ******************************************************************
           *
           *                         MOLE FRACTION
           *
           *
           *                         BOTTLE NUMBER
           *
GAS        *      1          2          3          4          5          6
           *
           *
H2         *   24.020     19.416     23.332     19.517     23.785     24.570
           *
H2O        *    9.314     14.827      8.561      5.365      4.994      4.483
           *
O2         *    0.000      0.000      0.212      0.000      4.075      1.362
           *
N2         *   46.568     35.708     42.566     58.580     55.464     60.272
           *
N2O        *    0.165      0.248      0.694      0.444      0.376      0.656
           *
NH3        *   18.223     26.151     22.588     14.806      8.820      7.273
           *
C2H4       *    0.000      0.000      0.113      0.199      0.155      0.210
           *
A          *    1.004      0.785      0.839      0.717      1.780      0.192
           *
CO2        *    0.000      0.000      0.041      0.000      0.082      0.000
           *
HE         *    0.702      2.861      1.049      0.369      0.464      0.976
           *
           ******************************************************************

PRESSURE        15.47      22.69      24.22      23.43      23.77      22.65
 (PSIA)

H/N              1.08       1.49       1.20       0.71       0.70       0.62

O/N              0.08       0.15       0.08       0.04       0.11       0.06

H2O             30.85      11.37      25.66      55.23      47.82      56.82
```

```
                           RUN NUMBER 11

                         OSCILLOGRAPH DATA

QUANTITY     READING     CAL        QUANTITY      READING     CAL
              (IN.)*                               (IN.)

                              MOTOR

  WF          70.00    383.00          F             1.63     49.19

  PC           2.89     49.80          PO            3.79    125.47

  PF           3.55    127.12          PV            1.89    502.30

  PW           1.35    123.74          PN           -0.11     12.37

  PS           0.00      0.00          PT            1.86    493.95

  WO         160.00   1007.00          TB            0.00   1007.00

  TS           1.34      4.16          TO           -0.98      3.69

  TF          -0.97      3.96          T1            1.92      3.97
  (

                         BOTTLE PRESSURE

  P1           0.02     24.87          P2            0.31     24.87

  P3           0.37     25.00          P4            0.34     24.87

  P5           0.36     25.12          P6            0.31     24.75

                      BALLISTIC ANALYZER DATA

  PB          14.73(PSIA)                       FB              0.00(LB.)

                        MISCELLANEOUS DATA

  PAM        14.730(PSIA)              IS        228.44(SEC)

  OD         92.048(LB/CUFT)           CSI      5791.26(FT/SEC)

  FD         63.874(LB/CUFT)           AT           0.44(SQIN)

                        * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 11

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

BLOCK TEMPERATURE WAS NOT RECORDED

NO BALLISTIC ANALYZER DATA

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES IS NON-LINEAR

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

HEAT FLUX GAUGE 1 WENT OFF SCALE. READ PREMATURELY AT .68 SECONDS

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 0.6 SECONDS

MEAN SAMPLING TIME - 1.01 SECONDS

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                                                            PAGE 1 OF 4

                 ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

        RUN NUMBER -  12                        INJECTOR POSITION -  90

        FIRING NUMBER -   20                    DATE OF FIRING -  1/10/69

------------------------------------------------------------------------------

                          DATA REDUCTION RESULTS

        AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                          BTU/FT2-SEC

             1.0280                   0.1055                  72.8

             1.7780                   0.1321                   0.0

             2.5280                   0.1812                 132.4

             3.2780                   0.3128                 165.2

             4.0280                   0.2057                   0.0

             4.7780                   0.0000                 427.0

                      ENGINE PERFORMANCE PARAMETERS

        O/F     1.2792          CSTAR   5486. (FT/S)    CSR    0.9491

        ISR     0.8422          PNPC    0.0817          CF     1.1266

        IS      192.11 (SEC)    F       80.18 (LB)      PC     160.12 (PSIA)

        ISB       0.00 (SEC)    FB       0.00 (LB)      PCB     14.70 (PSIA)

        WO      0.2342 (LB/S)   WF      0.1831 (LB/S)   WW     0.0000 (LB/S)

        PSR     1.0000


                              SYSTEM DATA

            PRESSURE (PSIA)                     TEMPERATURE (DEG.F)

        PF      469.80     PFT     943.32           TB   342.19     TO     45.13

        PO      496.51     POT     969.08           TS   225.25     TF     43.25

        PW      184.23                              TV1  311.84
```

```
GAS COMPOSITION             RUN NUMBER 12

          ************************************************************
          *
          *                        MOLE FRACTION
          *
          *
          *                        BOTTLE NUMBER
          *
GAS       *     1         2         3         4         5         6
          *
          *
H2        *   15.127    10.408     8.612    19.177    29.862     0.000
          *
H2O       *    3.948     7.574    11.338    16.449     7.838     0.000
          *
O2        *    0.000     0.000     0.000     0.000     0.070     0.000
          *
N2        *   53.488    34.247    29.982    35.181    47.758     0.000
          *
N2O       *    0.327     0.527     0.485     0.293     0.227     0.000
          *
NH3       *   26.049    46.525    49.137    27.476    12.922     0.000
          *
N2H4      *    0.000     0.110     0.000     0.000     0.090     0.000
          *
A         *    0.167     0.067     0.022     0.676     0.168     0.000
          *
HF        *    0.889     0.538     0.421     0.745     1.060     0.000
          *
          ************************************************************

PRESSURE       32.36     42.56     47.69     47.53     46.35     44.89
 (PSIA)

H/N             0.86      1.51      1.70      1.56      1.05      0.00

O/N             0.03      0.06      0.10      0.17      0.07      0.00

H2O            48.92     16.16      7.00      8.81     31.80      0.00
```

RUN NUMBER 12

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
MOTOR					
WF	68.70	383.00	F	1.63	49.19
PC	2.92	49.80	PO	3.83	125.47
PF	3.58	127.12	PV	1.89	502.30
PW	1.37	123.74	PN	-0.13	12.37
PS	0.00	12.37	PT	1.87	493.95
WO	160.00	1007.00	TB	1.47	4.97
TS	0.66	4.16	TO	-0.98	3.69
TF	-0.93	3.96	T1	1.55	3.97
BOTTLE PRESSURE					
P1	0.70	24.87	P2	1.11	24.87
P3	1.31	25.00	P4	1.32	24.87
P5	1.25	25.12	P6	1.22	24.75

BALLISTIC ANALYZER DATA

PB	14.70(PSIA)	FB	0.00(LB.

MISCELLANEOUS DATA

PAM	14.700(PSIA)	IS	228.09(SEC)
OD	92.048(LB/CUFT)	CSI	5780.40(FT/SEC)
FD	63.735(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 12

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

CALIBRATION FRO CHROMEL CONSTANTAN THERMOCOUPLES IS NON-LINEAR

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

HEAT FLUX GAUGE 1 WENT OFF SCALE. READ PREMATURELY AT 0.65 SECONDS

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 1.2 SECONDS

MEAN SAMPLING TIME - 2.15 SECONDS

BOTTLE 1 -- PEAKS 12-16 RERUN AT END OF TRACE BUT PREVIOUS
VALUES FOR 14,15,16 WERE USED

BOTTLE 6 DISCARDED DUE TO EXCESSIVE OXYGEN CONTENT

```
              ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

JPL CONTRACT - NAS7-463                       AEROTHERM PROJECT 7009

RUN NUMBER -  13                              INJECTOR POSITION - 120

FIRING NUMBER -   21                          DATA OF FIRING -  1/10/69

------------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER        HEAT FLUX
                                                  BTU/FT2-SEC

     1.0280                  0.2887                     50.3

     1.7780                  0.2736                      0.0

     2.5280                  0.0000                    108.2

     3.2780                  0.3148                    151.0

     4.0280                  0.2279                      0.0

     4.7780                  0.2652                    449.2

                       ENGINE PERFORMANCE PARAMETERS

O/F     1.3093           CSTAR  5503. (FT/S)    CSR     0.9542

ISR     0.8765           PNPC   0.0817          CF      1.1666

IS      199.55 (SEC)     F      83.03 (LB)      PC      160.12 (PSIA)

ISB       0.00 (SEC)     FB      0.00 (LB)      PCB      14.70 (PSIA)

WO      0.2359 (LB/S)    WF     0.1802 (LB/S)   WW      0.0000 (LB/S)

RSR     1.0000


                             SYSTEM DATA

     PRESSURE (PSIA)                        TEMPERATURE (DEG.F)

PF      468.53     PFT    938.38          TB   348.49     TC    51.55

PO      500.27     POT    964.06          TS   267.41     TF    45.54

PW      186.71                            TV1  360.19
```

```
     GAS COMPOSITION            RUN NUMBER 13

          ******************************************************************
          *
          *                         MOLE FRACTION
          *
          *
          *                         BOTTLE NUMBER
          *
GAS       *      1          2          3          4          5          6
          *
          *
H2        *   26.708     26.412      0.000     26.903     30.891     25.432 ✓
          *
H2O       *   11.361     11.740      0.000     10.508      6.513      6.175 ✓
          *
O2        *    0.000      0.000      0.000      0.000      0.278      0.146 ✓
          *
N2        *   45.470     42.340      0.000     52.709     55.220     62.296 ✓
          *
N2O       *    0.765      0.546      0.000      0.196      0.149      0.363
          *
NH3       *   14.664     17.373      0.000      7.506      5.186      3.333 ✓
          *
N2H4      *    0.110      0.120      0.000      0.066      0.140      0.179
          *
A         *    0.202      0.419      0.000      1.211      0.600      0.627
          *
CO2       *    0.000      0.000      0.000      0.000      0.018      0.058
          *
HF        *    0.716      1.046      0.000      0.896      1.000      1.386
          *
          ******************************************************************

PRESSURE        50.52      57.73      63.94      61.46      61.43      61.23
 (PSIA)

H/N              1.12       1.24       0.00       0.86       0.78       0.57

O/N              0.11       0.11       0.00       0.09       0.06       0.05

H2O             27.33      21.85       0.00      39.52      44.75      59.08
```

```
                              RUN NUMBER 13

                            OSCILLOGRAPH DATA

QUANTITY       READING    CAL         QUANTITY       READING    CAL
                (IN.)*                                (IN.)

                                 MOTOR

 WF             67.70    383.00         F              1.63     50.94

 PC              2.92     49.80         PO             3.87    125.47

 PF              3.57    127.12         PV             1.89    502.30

 PW              1.39    123.74         PN            -0.13     12.37

 PS              0.00     12.37         PT             1.86    493.95

 WO            162.00   1007.00         TB             1.52      4.97

 TS              1.06      4.16         TO            -0.92      3.69

 TF             -0.90      3.96         T1             2.03      3.97
 $

                            BOTTLE PRESSURE

 P1              1.44     24.87         P2             1.73     24.87

 P3              1.96     25.00         P4             1.87     24.87

 P5              1.86     25.12         P6             1.88     24.75

                         BALLISTIC ANALYZER DATA

 PB             14.70(PSIA)                         FB              0.00(LB.

                          MISCELLANEOUS DATA

 PAM          14.700(PSIA)            IS         227.67(SEC)

 OD           91.522(LB/CUFT)         CSI       5766.99(FT/SEC)

 FD           63.665(LB/CUFT)         AT            0.44(SQIN)

                         * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 13

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES NON-LINEAR

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

OSCILLOGRAPH TRACE FOR HEAT FLUX GAGE 1 OFF SCALE. READ PREMATURELY AT 0.85 SECONDS

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION   1.7 SECONDS

MEAN SAMPLING TIME - 2.43 SECONDS

BOTTLE 3   REJECTED DUE TO EXCESSIVE OXYGEN CONTENT

BOTTLE 4   PEAKS 20 AND 40 SEEM HIGHER THAN USUAL

BOTTLE 5   CHANGED SENS ON PEAKS 16, 17 AND 18 TO EQUAL 10 - READING ERROR SUSPECTED

```
                                                              PAGE 1 OF 4

                 ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                    AEROTHERM PROJECT 7009

        RUN NUMBER -  14                           INJECTOR POSITION - 150

        FIRING NUMBER -   22                       DATE OF FIRING -  1/10/69

-------------------------------------------------------------------------------


                         DATA REDUCTION RESULTS

        AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                          BTU/FT2-SEC

             1.0280                    0.0000                 77.7

             1.7780                    0.3154                  0.0

             2.5280                    0.1368                133.4

             3.2780                    0.2225                155.8

             4.0280                    0.4646                  0.0

             4.7780                    0.3754                533.6

                      ENGINE PERFORMANCE PARAMETERS

        O/F    1.2714            CSTAR  5538. (FT/S)   CSR    0.9576

        ISR    0.8550            PNPC   0.0819         CF     1.1334

        IS     195.13 (SEC)      F      81.17 (LB)     PC     161.10 (PSIA)

        ISR      0.00 (SEC)      FB      0.00 (LB)     PCB     14.69 (PSIA)

        WO     0.2328 (LB/S)     WF     0.1831 (LB/S)  WW     0.0000 (LB/S)

        PSR    1.0000


                               SYSTEM DATA

            PRESSURE (PSIA)                       TEMPERATURE (DEG.F)

        PF     472.33    PFT    938.37            TB  335.83     TO    44.96

        PO     501.52    POT    969.07            TS  258.22     TF    46.14

        PW     181.75                             TV1 273.42
```

```
        GAS COMPOSITION          RUN NUMBER 14

        ***********************************************************
        *
        *                       MOLE FRACTION
        *
        *
        *                       BOTTLE NUMBER
        *
GAS     *        1         2         3         4         5         6
        *
        *
H2      *      0.000    26.209    17.833    26.229    26.235    22.395
        *
H2O     *      0.000    11.502     6.157     5.700    13.194     8.819
        *
O2      *      0.000     0.000     0.000     0.000     0.400     0.000
        *
N2      *      0.000    47.613    48.143    62.590    55.849    64.566
        *
N2O     *      0.000     0.683     0.000     0.234     0.176     0.311
        *
NH3     *      0.000    11.377    27.075     4.183     2.816     2.440
        *
N2H4    *      0.000     0.340     0.000     0.037     0.065     0.019
        *
A       *      0.000     1.210     0.043     0.044     0.113     0.020
        *
HE      *      0.000     1.062     0.747     0.980     1.148     1.426
        *
        ***********************************************************

PRESSURE         33.34     42.79     41.43     46.53     43.83     43.40
 (PSIA)

H/N              0.00      1.02      1.04      0.58      0.76      0.52

O/N              0.00      0.11      0.04      0.04      0.12      0.06

H2O              0.00     31.40     37.11     59.10     42.75     61.83
```

```
                              RUN NUMBER 14

                            OSCILLOGRAPH DATA

  QUANTITY      READING    CAL        QUANTITY      READING     CAL
                 (IN.)*                              (IN.)

                                  MOTOR

     WF          68.80   383.00          F             1.65    49.19

     PC           2.94    49.80          PO            3.87   125.47

     PF           3.59   127.12          PV            1.89   502.30

     PW           1.35   123.74          PN           -0.11    12.37

     PS           0.00    12.37          PT            1.86   493.95

     WO         159.00  1007.00          TB            1.34     5.27

     TS           0.80     5.00          TO           -1.10     3.26

     TF          -0.94     3.77          T1            1.53     3.01
     *

                            BOTTLE PRESSURE

     P1           0.74    24.87          P2            1.13    24.87

     P3           1.06    25.00          P4            1.28    24.87

     P5           1.15    25.12          P6            1.16    24.75

                         BALLISTIC ANALYZER DATA

     PB          14.69(PSIA)                     FB          0.00(LB.)

                          MISCELLANEOUS DATA

     PAM        14.690(PSIA)             IS        228.20(SEC)

     OD         92.062(LB/CUFT)          CSI      5783.77(FT/SEC)

     FD         63.647(LB/CUFT)          AT           0.44(SQIN)

                          * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 14

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES IS NON-LINEAR

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

HEAT FLUX GAUGE 1 WENT OFF SCALE READ PREMATURELY AT 0.75 SECONDS

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 1.2 SECONDS

MEAN SAMPLING TIME - 2.2 SECONDS

BOTTLE 1 BOTTLE DATA DISCARDED - MICRO TUBE LEAK

BOTTLE 6 PEAK 47 WAS CUT-OFF THE TRACE SO COULD NOT BE RECORDED

```
                                                                PAGE 1 OF 4

                     ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

          JPL CONTRACT - NAS7-463                    AEROTHERM PROJECT 7009

          RUN NUMBER -  15                           INJECTOR POSITION - 180

          FIRING NUMBER -   23                       DATE OF FIRING -  1/13/69

---------------------------------------------------------------------------


                             DATA REDUCTION RESULTS

          AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER       HEAT FLUX
                                                            BTU/FT2-SEC

               1.0280                  0.1482                 41.8

               1.7780                  0.0000                  0.0

               2.5280                  0.3007                125.5

               3.2780                  0.7157                105.0

               4.0280                  0.3326                  0.0

               4.7780                  0.4408                477.6

                          ENGINE PERFORMANCE PARAMETERS

          O/F    1.2846           CSTAR  5503. (FT/S)   CSR    0.9525

          ISR    0.8832           PNPC   0.0830         CF     1.1773

          IS     201.40 (SEC)     F      84.17 (LB)     PC     160.85 (PSIA)

          ISB      0.00 (SEC)     FB      0.00 (LB)     PCB     14.58 (PSIA)

          WO     0.2350 (LB/S)    WF     0.1829 (LB/S)  WW     0.0000 (LB/S)

          PSR    1.0000


                                 SYSTEM DATA

              PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

          PF     470.37    PFT    945.38         TB   335.09     TO    52.03

          PO     491.16    POT    962.22         TS   230.37     TF    39.20

          PW     215.61                          TV1  265.01
```

```
          GAS COMPOSITION          RUN NUMBER 15

          **************************************************************
          *
          *                        MOLE FRACTION
          *
          *
          *                        BOTTLE NUMBER
          *
GAS       *      1         2         3         4         5         6
          *
          *
H2        *   23.268     0.000    21.213    19.487    27.444    23.495 ✓
          *
H2O       *    6.903     0.000    13.362     6.917    10.456    15.797 ✓
          *
O2        *    0.000     0.000     0.000     5.603     1.048     0.000 ✓
          *
N2        *   36.512     0.000    36.907    51.176    43.852    45.216 ✓
          *
N2O       *    0.807     0.000     1.113     1.276     0.734     0.759
          *
NH3       *   28.870     0.000    21.702     7.765    12.446     9.346 ✓
          *
N2H4      *    0.591     0.000     0.986     0.428     0.389     0.301
          *
A         *    0.667     0.000     2.485     6.134     1.881     2.817
          *
HE        *    2.379     0.000     2.228     1.211     1.745     2.266
          *
          **************************************************************

PRESSURE        33.23     43.51     41.32     46.42     43.72     43.29
 (PSIA)

H/N              1.42      0.00      1.38      0.68      1.12      1.05

O/N              0.07      0.00      0.14      0.17      0.12      0.16

H2O             17.45      0.00     15.58     43.27     25.60     26.47
```

RUN NUMBER 15

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	68.50	383.00	F	1.67	50.40
PC	2.97	49.08	PO	3.90	122.20
PF	3.62	125.90	PV	1.93	491.00
PW	1.62	123.33	PN	-0.10	12.27
PS	0.00	12.27	PT	1.89	492.49
WO	161.50	1007.00	TB	1.23	5.76
TS	0.59	5.00	TO	-1.13	2.99
TF	-1.01	3.74	T1	1.43	3.01
+					

BOTTLE PRESSURE

P1	0.74	24.87	P2	1.13	25.38
P3	1.06	25.00	P4	1.28	24.87
P5	1.15	25.12	P6	1.16	24.75

BALLISTIC ANALYZER DATA

PB	14.58(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.580(PSIA)	IS	228.02(SEC)
OD	91.482(LB/CUFT)	CSI	5778.05(FT/SEC)
FD	63.858(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 15

C/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES NON-LINEAR

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION 1.1 SECONDS

MEAN SAMPLING TIME - 1.85 SECONDS

FOR LIB 23, RUN 15 - ALL THERMOCOUPLES WERE RECALIBRATED

ALL ENGINE DATA EG. PE, PVF, FORGE ETC WERE RECALIBRATED BUT NOT THE TEMPERATURES EG. TB, TSP, TSV1, TLO, TTF

BOTTLE 2 BOTTLE DATA DISCARDED DUE TO EXCESSIVE OXYGEN CONTENT

BOTTLE 4 -- PEAKS 32,40,44 LOOK HIGH

```
                                                        PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

       JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

       RUN NUMBER -  16                        INJECTOR POSITION - 190

       FIRING NUMBER -   24                    DATE OF FIRING -  1/13/69

---------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

       AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER      HEAT FLUX
                                                       BTU/FT2-SEC

            1.0280                 0.1275                  51.4

            1.7780                 0.1111                   0.0

            2.5280                 0.1194                 134.1

            3.2780                 0.1403                 133.5

            4.0280                 0.1824                   0.0

            4.7780                 0.2255                 547.7

                      ENGINE PERFORMANCE PARAMETERS

       O/F    1.2444          CSTAR  5498. (FT/S)    CSR    0.9489

       ISR    0.8883          PNPC   0.0819          CF     1.1879

       IS     203.02 (SEC)    F      85.18 (LB)      PC     161.33 (PSIA)

       ISB      0.00 (SEC)    FB      0.00 (LB)      PCB     14.57 (PSIA)

       WO     0.2326 (LB/S)   WF     0.1869 (LB/S)   WW     0.0000 (LB/S)

       PSR    1.0000


                               SYSTEM DATA

           PRESSURE (PSIA)                     TEMPERATURE (DEG.F)

       PF     472.88     PFT    945.37          TB   336.55     TO    52.90

       PO     493.60     POT    947.48          TS   273.41     TF    39.20

       PW     190.93                            TV1  353.86
```

```
                                                            PAGE 2 OF 4

          GAS COMPOSITION          RUN NUMBER 16

         ************************************************************
         *
         *                         MOLE FRACTION
         *
         *
         *                         BOTTLE NUMBER
         *
GAS      *       1         2         3         4         5         6
         *
         *
H2       *    20.642    18.732    19.191    21.535    23.555    22.016 ✓
         *
H2O      *     6.510     5.856     6.445     7.325     8.155     9.719 ✓
         *
O2       *     0.112     0.450     0.283     0.000     0.618     0.345 ✓
         *
N2       *    32.034    28.548    28.892    33.218    33.424    38.449 ✓
         *
N2O      *     0.472     0.064     0.218     0.340     0.157     0.244
         *
NH3      *    35.520    41.950    40.574    32.831    28.642    23.702 ✓
         *
N2H4     *     0.363     0.321     0.207     0.161     0.246     0.264
         *
A        *     2.096     1.445     2.020     3.283     3.862     3.425
         *
CO2      *     0.362     0.350     0.098     0.000     0.109     0.245
         *
HE       *     1.884     2.279     2.067     1.302     1.226     1.586
         *
         ************************************************************

PRESSURE      43.92     42.18     50.81     46.16     49.49     45.01
 (PSIA)

H/N            1.60      1.76      1.75      1.56      1.56      1.33

O/N            0.07      0.06      0.07      0.07      0.09      0.10

H2O           10.99      5.50      5.78     12.00     10.90     18.98
```

RUN NUMBER 16

OSCILLOGRAPH DATA

MOTOR

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
WF	70.00	383.00	F	1.69	50.40
PC	2.98	49.08	PO	3.91	122.20
PF	3.64	125.90	PV	1.90	491.00
PW	1.43	123.33	PN	-0.10	12.27
PS	0.00	12.27	PT	1.89	492.49
WO	160.00	1007.00	TB	1.24	5.76
TS	0.92	5.00	TO	-1.12	2.99
TF	-1.01	3.74	T1	1.70	4.57

+

BOTTLE PRESSURE

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
P1	1.17	24.87	P2	1.11	24.87
P3	1.45	25.00	P4	1.27	24.87
P5	1.39	25.12	P6	1.22	24.75

BALLISTIC ANALYZER DATA

PB	14.57(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.570(PSIA)	IS	228.54(SEC)
OD	91.411(LB/CUFT)	CSI	5794.41(FT/SEC)
FD	63.858(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 16

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

NO HEAT FLUX FOR STATIONS 2 AND 5

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES NON-LINEAR

MEAN SAMPLING TIME - 2.6 SECONDS

SAMPLING DURATION - 1.4 SECONDS

NOZZLE OVEREXPANDED - THRUST LOW

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                                                                PAGE 1 OF 4

                 ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                   AEROTHERM PROJECT 7009

        RUN NUMBER -  17                          INJECTOR POSITION - 200

        FIRING NUMBER -   25                      DATA OF FIRING - 1/13/69

--------------------------------------------------------------------------

                          DATA REDUCTION RESULTS

        AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER       HEAT FLUX
                                                          BTU/FT2-SEC

             1.0280                  0.1255                   63.6

             1.7780                  0.1503                    0.0

             2.5280                  0.2314                  143.3

             3.2780                  0.3018                  151.9

             4.0280                  0.0000                    0.0

             4.7780                  0.6132                  584.0

                       ENGINE PERFORMANCE PARAMETERS

        O/F    1.2467             CSTAR  5540. (FT/S)   CSR    0.9563

        ISR    0.8687             PNPC   0.0806         CF     1.1528

        IS     198.53 (SEC)       F      83.17 (LB)     PC     162.30 (PSIA)

        ISB      0.00 (SEC)       FB      0.00 (LB)     PCB     14.56 (PSIA)

        WO     0.2324 (LB/S)      WF     0.1864 (LB/S)  WW     0.0000 (LB/S)

        PSR    1.0000

                             SYSTEM DATA

            PRESSURE (PSIA)                      TEMPERATURE (DEG.F)

        PF     471.61     PFT    940.44          TB   150.00      TO    53.77

        PO     504.59     POT    952.38          TS   289.87      TF    44.63

        PL     190.92                            TV1  282.60
```

```
                                                              PAGE 2 OF 4

            GAS COMPOSITION          RUN NUMBER 17

            ****************************************************************
            *
            *                        MOLE FRACTION
            *
            *
            *                        BOTTLE NUMBER
            *
GAS         *        1          2          3          4          5          6
            *
            *
H2          *     20.206     20.241     23.009     20.707      0.000     12.104  ✓
            *
H2O         *      5.737      7.938     10.892     11.675      0.000     17.982  ✓
            *
O2          *      0.385      0.000      0.198      0.000      0.000      0.699  ✓
            *
N2          *     28.783     28.288     32.625     29.968      0.000     48.622  ✓
            *
N2O         *      0.290      0.325      0.174      0.286      0.000      1.307
            *
NO2         *      0.000      0.000      0.000      0.000      0.000      0.610
            *
NH3         *     34.309     33.721     24.489     16.134      0.000     12.875  ✓
            *
N2H4        *      0.150      0.074      0.232      0.158      0.000      0.946
            *
A           *      7.262      6.645      5.494      7.645      0.000      3.125
            *
CO2         *      0.055      0.000      0.104      0.000      0.000      0.000
            *
HE          *      2.820      2.764      2.778     13.424      0.000      1.726
            *
            ****************************************************************

PRESSURE          32.96      36.94      38.56      38.93      37.42      36.58
 (PSIA)

H/N                1.67       1.73       1.57       1.47     ******       0.89

O/N                0.07       0.09       0.12       0.15     ******       0.19

H2O                7.76       5.37       9.14       9.38     ******      35.32
```

```
                         RUN NUMBER 17

                       OSCILLOGRAPH DATA

QUANTITY      READING    CAL          QUANTITY       READING    CAL
               (IN.)*                                 (IN.)

                             MOTOR

   WF          70.00    383.00           F             1.65     50.40

   PC           3.01     49.08           PO            4.01    122.20

   PF           3.63    125.90           PV            1.91    491.00

   PW           1.43    123.33           PN           -0.11     12.27

   PS           0.00     12.27           PT            1.88    492.49

   WO         160.00   1007.00           TB            0.00   1007.00

   TS           1.05      5.00           TO           -1.10      2.99

   TF          -0.96      3.74           T1            1.66      3.01


                        BOTTLE PRESSURE

   P1           0.74     24.87           P2            0.89     24.87
   P3           0.96     25.00           P4            0.99     24.87
   P5           0.90     25.12           P6            0.88     24.75

                     BALLISTIC ANALYZER DATA

   PB          14.56(PSIA)                       FB             0.00(LB.)

                      MISCELLANEOUS DATA

   PAM        14.560(PSIA)               IS       228.51(SEC)
   OD         91.340(LB/CUFT)            CSI     5793.57(FT/SEC)
   FD         63.692(LB/CUFT)            AT         0.44(SQIN)

                      * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 17

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

NO BLOCK TEMPERATURE RECORDED

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES NON-LINEAR

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION 1.05 SECONDS

MEAN SAMPLING TIME - 1.8 SECONDS

BOTTLE 1 - PEAK 20 LOOKS HIGH

BOTTLE 5 NO BOTTLE DATA AVAILABLE

BOTTLES 4 AND 6 - PEAK 40 SEEMS HIGH

```
                                                        PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

      JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

      RUN NUMBER -  18                         INJECTOR POSITION - 210

      FIRING NUMBER -   26                     DATE OF FIRING -  1/13/69

--------------------------------------------------------------------------------

                         DATA REDUCTION RESULTS

      AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER       HEAT FLUX
                                                        BTU/FT2-SEC

            1.0280                  0.6124                  70.3

            1.7780                  0.2671                   0.0

            2.5280                  0.0000                 152.6

            3.2780                  0.2778                 160.4

            4.0280                  0.0000                   0.0

            4.7780                  1.4693                 603.4

                      ENGINE PERFORMANCE PARAMETERS

      O/F    1.2887           CSTAR  5576. (FT/S)   CSR    0.9654

      ISR    0.8631           PNPC   0.0801         CF     1.1353

      IS     196.77 (SEC)     F      81.65 (LB)     PC     161.81 (PSIA)

      ISB      0.00 (SEC)     FB      0.00 (LB)     PCB     14.56 (PSIA)

      WO     0.2336 (LB/S)    WF     0.1813 (LB/S)  WW     0.0000 (LB/S)

      PSR    1.0000


                              SYSTEM DATA

           PRESSURE (PSIA)                      TEMPERATURE (DEG.F)

      PF     464.05     PFT    930.59         TB   336.55     TO    52.90

      PO     493.59     POT    942.56         TS   264.55     TF    45.72

      PW     192.16                           TV1  279.54
```

```
                GAS COMPOSITION           RUN NUMBER 18

               ****************************************************************
               *
               *                     MOLE FRACTION
               *
               *
               *                     BOTTLE NUMBER
               *
GAS            *      1         2         3         4         5         6
               *
               *
H2             *   25.848    24.316     0.000    30.706     0.000    18.244 ✓
               *
H2O            *   11.221    10.108     0.000     9.040     0.000    11.419 ✓
               *
O2             *    3.060     0.964     0.000     0.000     0.000     0.000 ✓
               *
N2             *   53.458    38.383     0.000    51.501     0.000    52.251 ✓
               *
N2O            *    0.275     0.347     0.000     0.573     0.000     0.958
               *
NO2            *    0.000     0.000     0.000     0.000     0.000    10.461
               *
NH3            *    2.587    21.221     0.000     6.041     0.000     1.437 ✓
               *
N2H4           *    0.171     0.148     0.000     0.427     0.000     0.357
               *
A              *    1.718     2.173     0.000     0.689     0.000     1.447
               *
CO2            *    0.000     0.061     0.000     0.000     0.000     0.000
               *
HE             *    1.657     2.275     0.000     1.019     0.000     3.422
               *
               ****************************************************************

PRESSURE           46.64     42.17     48.30     43.41     42.95     39.56
 (PSIA)

H/N                 0.74      1.34      0.00      0.89      0.00      0.54

O/N                 0.15      0.12      0.00      0.08      0.00      0.27

H2O                40.19     17.48      0.00     37.71      0.00     46.56
```

```
                                                                    PAGE 3 OF 4
                                  RUN NUMBER 18

                                OSCILLOGRAPH DATA

      QUANTITY      READING    CAL        QUANTITY      READING     CAL
                     (IN.)*                              (IN.)

                                      MOTOR

        WF           68.10   383.00          F             1.61     50.40

        PC            3.00    49.08          PO            3.91    122.20

        PF            3.57   125.90          PV            1.89    491.00

        PW            1.44   123.33          PN           -0.13     12.27

        PS            0.00    12.27          PT            1.85    492.49

        WO          160.70  1007.00          TB            1.24      5.76

        TS            0.85     5.00          TO           -1.12      2.99

        TF           -0.95     3.74          T1            1.62      3.01
        $

                                 BOTTLE PRESSURE

        P1            1.28    24.87          P2            1.11     24.87

        P3            1.35    25.00          P4            1.16     24.87

        P5            1.12    25.12          P6            1.01     24.75

                             BALLISTIC ANALYZER DATA

        PB          14.56(PSIA)                         FB          0.00(LB.)

                               MISCELLANEOUS DATA

        PAM        14.560(PSIA)              IS         227.96(SEC)

        OD         91.411(LB/CUFT)           CSI       5776.20(FT/SEC)

        FD         63.659(LB/CUFT)           AT            0.44(SQIN)

                              * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 18

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

CALIBRATION FOR CHROMEL CONSTANTAN THERMOCOUPLES IS NON-LINEAR

POSSIBLE PROBLEM IN HEAT FLUX GAUGE SIX AND/OR IT S CALIBRATION

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION 1.4 SECONDS

MEAN SAMPLING TIME - 2.3 SECONDS

BOTTLE 1 - OXYGEN LOOKS HIGH

18-3-A REJECTED DUE TO EXCESSIVE OXYGEN CONTENT

ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

JPL CONTRACT - NAS7-463	AEROTHERM PROJECT 7009
RUN NUMBER - 19	INJECTOR POSITION - 220
FIRING NUMBER - 27	DATE OF FIRING - 1/22/69

DATA REDUCTION RESULTS

AXIAL STATION (IN.)	O/F IN BOUNDARY LAYER	HEAT FLUX BTU/FT2-SEC
1.0280	0.0000	92.6
1.7780	0.4721	0.0
2.5280	0.5735	134.8
3.2780	0.5439	158.9
4.0280	0.0000	0.0
4.7780	0.7207	574.0

ENGINE PERFORMANCE PARAMETERS

O/F	1.2811	CSTAR	5592. (FT/S)	CSR	0.9677
ISR	0.8407	PNPC	0.0820	CF	1.1030
IS	191.75 (SEC)	F	79.48 (LB)	PC	162.11 (PSIA)
ISB	0.00 (SEC)	FB	0.00 (LB)	PCB	14.78 (PSIA)
WO	0.2328 (LB/S)	WF	0.1817 (LB/S)	WW	0.0000 (LB/S)
PSR	1.0000				

SYSTEM DATA

PRESSURE (PSIA)				TEMPERATURE (DEG.F)			
PF	472.16	PFT	937.15	TB	340.37	TO	54.22
PO	501.84	POT	770.09	TS	320.50	TF	50.28
PW	206.64			TV1	331.69		

```
     GAS COMPOSITION          RUN NUMBER 19

     ***************************************************************
     *
     *                         MOLE FRACTION
     *
     *
     *                         BOTTLE NUMBER
     *
GAS  *       1         2         3         4         5         6
     *
     *
H2   *     0.000    24.049    23.411    22.850     0.000    21.577
     *
H2O  *     0.000    12.406    17.708    11.084     0.000    15.720
     *
O2   *     0.000     0.932     0.608     1.073     0.000     1.149
     *
N2   *     0.000    56.262    53.136    50.274     0.000    59.082
     *
N2O  *     0.000     0.292     0.220     0.272     0.000     0.706
     *
NH3  *     0.000     4.857     4.171     0.912     0.000     0.000
     *
N2H4 *     0.000     0.271     0.272     0.168     0.000     0.000
     *
A    *     0.000     0.351     0.080     0.057     0.000     0.099
     *
HE   *     0.000     0.575     0.389    13.305     0.000     1.664
     *
     ***************************************************************

PRESSURE       24.73     30.27     33.28     34.78     38.03     32.76
 (PSIA)

H/N            -0.00      0.74      0.86      0.69     -0.00      0.62

O/N            -0.00      0.12      0.17      0.13     -0.00      0.15

H2O             0.00     44.62     35.95     39.96    ******     48.61
```

RUN NUMBER 19

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	68.40	383.00	F	1.62	48.76
PC	2.98	49.43	PO	3.89	125.20
PF	3.61	126.69	PV	1.84	408.27
PW	1.41	136.07	PN	-0.11	12.29
PS	0.00	12.29	PT	1.85	495.90
WO	160.30	1007.00	TB	1.72	4.21
TS	1.54	4.22	TO	-0.80	4.13
6					
TF	-0.97	3.54	T1	1.71	4.06

BOTTLE PRESSURE

P1	0.39	24.87	P2	0.61	25.00
P3	0.74	25.00	P4	0.80	25.00
P5	0.93	25.00	P6	0.73	24.63

BALLISTIC ANALYZER DATA

PB	14.78(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.780(PSIA)	IS	228.07(SEC)
OD	91.303(LB/CUFT)	CSI	5779.57(FT/SEC)
FD	63.521(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 19

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

NOZZLE OVEREXPANDED - THRUST LOW

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

SAMPLING DURATION - .98 SECONDS

MEAN SAMPLING TIME - 1.08 SECONDS

BOTTLE 1 NO BOTTLE DATA AVAILABLE

BOTTLE 2 - PEAK 20 READ AT SENS 10 SINCE PEAK SMALL READING MAY BE INACCURATE

BOTTLE 5 CHANGED SENS ON PEAK 18 TO 1 -- READING ERROR SUSPECTED

```
                                                          PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

        RUN NUMBER -  20                        INJECTOR POSITION - 230

        FIRING NUMBER -   28                    DATE OF FIRING -  1/22/69

-------------------------------------------------------------------------

                        DATA REDUCTION RESULTS

        AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER      HEAT FLUX
                                                        BTU/FT2-SEC

             1.0280                  0.9568                  75.9

             1.7780                  0.8651                   0.0

             2.5280                  0.9356                 121.2

             3.2780                  0.9223                 148.9

             4.0280                  0.4369                   0.0

             4.7780                  1.4898                 552.5

                      ENGINE PERFORMANCE PARAMETERS

        O/F   1.2942             CSTAR  5586. (FT/S)   CSR   0.9676

        ISR   0.8456             PNPC   0.0815         CF    1.1098

        IS    192.71 (SEC)       F      80.46 (LB)     PC    163.09 (PSIA)

        ISB     0.00 (SEC)       FB      0.00 (LB)     PCB    14.78 (PSIA)

        WO    0.2355 (LB/S)      WF     0.1819 (LB/S)  WW    0.0000 (LB/S)

        PSR   1.0000

                            SYSTEM DATA

            PRESSURE (PSIA)                   TEMPERATURE (DEG.F)

        PF     470.89     PFT     937.15      TB   356.39     TO    53.03

        PO     520.62     POT     778.25      TS   323.71     TF    50.28

        PW     214.80                         TV1  341.98
```

```
                 GAS COMPOSITION          RUN NUMBER 20

                 ****************************************************************
                 *
                 *                        MOLE FRACTION
                 *
                 *
                 *                        BOTTLE NUMBER
                 *
      GAS        *       1          2          3          4          5          6
                 *
                 *
      H2         *    15.215     16.499     15.804     13.092      8.106      7.988
                 *
      H2O        *    15.369     16.257     27.559     18.706      8.607     37.137
                 *
      O2         *     2.446      1.670      0.460      0.207      0.000      0.000
                 *
      N2         *    64.592     62.977     54.451     64.836     72.837     47.083
                 *
      N2O        *     0.716      0.142      0.323      1.067      0.281      2.010
                 *
      NO2        *     0.000      0.000      0.000      0.121      0.000      3.842
                 *
      NH3        *     0.000      0.000      0.000      0.000      8.328      0.000
                 *
      N2H4       *     0.445      0.000      0.413      0.000      0.000      0.000
                 *
      A          *     0.102      0.165      0.013      0.782      0.245      0.269
                 *
      HE         *     1.111      2.285      0.974      1.185      1.593      1.668
                 *
                 ****************************************************************

      PRESSURE        15.02      16.77      18.53      19.27      18.03      17.73
       (PSIA)

      H/N              0.47       0.51       0.80       0.48       0.37       0.88

      O/N              0.15       0.15       0.26       0.15       0.05       0.45

      H2O             59.69      55.74      34.52      59.94      80.61      22.32
```

RUN NUMBER 20

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
MOTOR					
WF	68.50	383.00	F	1.64	48.76
PC	2.99	49.43	PO	4.03	125.20
PF	3.59	126.69	PV	1.87	408.27
PW	1.46	136.07	PN	-0.11	12.29
PS	0.00	12.29	PT	1.85	495.90
WO	162.00	1007.00	TB	1.87	4.21
TS	1.56	4.22	TO	-0.80	4.13
&					
TF	-0.97	3.54	T1	1.81	4.06
BOTTLE PRESSURE					
P1	0.00	24.87	P2	0.07	25.00
P3	0.15	25.00	P4	0.17	25.00
P5	0.13	25.00	P6	0.11	24.63

BALLISTIC ANALYZER DATA

PB	14.78(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.780(PSIA)	IS	227.88(SEC)
OD	91.401(LB/CUFT)	CSI	5773.67(FT/SEC)
FD	63.521(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 20

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

NOZZLE OVEREXPANDED - THRUST LOW

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

SAMPLING DURATION - .58 SECONDS

MEAN SAMPLING TIME - 1.62 SECONDS

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                                                                  PAGE 1 OF 4

                  ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

         JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

         RUN NUMBER -  21                         INJECTOR POSITION - 240

         FIRING NUMBER -    29                    DATE OF FIRING -  1/23/69

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                            DATA REDUCTION RESULTS

         AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER        HEAT FLUX
                                                            BTU/FT2-SEC

              1.0280                   1.2142                    66.2

              1.7780                   1.2243                     0.0

              2.5280                   1.1172                    78.0

              3.2780                   0.6410                   115.2

              4.0280                   0.5146                     0.0

              4.7780                   0.9236                   583.9

                         ENGINE PERFORMANCE PARAMETERS

         O/F    1.2950          CSTAR  5627. (FT/S)    CSR    0.9746

         ISR    1.0372          PNPC   0.0782          CF     1.3514

         IS     236.37 (SEC)    F      99.11 (LB)      PC     164.98 (PSIA)

         ISP      0.00 (SEC)    FB      0.00 (LB)      PCB     14.79 (PSIA)

         WO     0.2366 (LB/S)   WF     0.1827 (LB/S)   WW     0.0000 (LB/S)

         PSR    1.0000


                                SYSTEM DATA

             PRESSURE (PSIA)                        TEMPERATURE (DEG.F)

         PF     479.77     PFT    993.35          TB   323.48     TO    40.98

         PO     519.89     POT    960.59          TS   322.81     TF    35.76

         PW     105.89                            TV1  355.08
```

```
          GAS COMPOSITION          RUN NUMBER 21

          *************************************************************
          *
          *                        MOLE FRACTION
          *
          *
          *                        BOTTLE NUMBER
          *
GAS       *       1         2         3         4         5         6
          *
          *
H2        *     6.326    10.238    12.848    17.978    20.598    10.005
          *
H2O       *    14.979    31.234    34.795    12.433    12.975    19.676
          *
O2        *     0.000     1.756     0.000     0.296     0.211     0.000
          *
N2        *    72.466    54.817    49.690    67.373    61.591    66.292
          *
N2O       *     3.869     0.621     0.655     0.307     0.209     0.558
          *
NO2       *     0.000     0.000     0.813     0.220     0.000     0.168
          *
NH3       *     0.000     0.000     0.000     0.000     2.341     0.000
          *
N2H4      *     0.489     0.000     0.000     0.216     0.434     1.145
          *
A         *     0.250     0.165     0.115     0.000     0.482     0.332
          *
HE        *     1.617     1.165     1.081     1.174     1.155     1.820
          *
          *************************************************************

PRESSURE        18.02     21.53     23.79     23.79     21.54     21.68
 (PSIA)

H/N              0.29      0.74      0.93      0.45      0.59      0.46

O/N              0.12      0.31      0.36      0.10      0.10      0.15

H2O             81.29     34.48     23.54     65.52     54.70     62.60
```

8.4   11.3   17.5   15.1   5.6   9.2

```
                         RUN NUMBER 21

                       OSCILLOGRAPH DATA

QUANTITY    READING     CAL       QUANTITY     READING      CAL
             (IN.)*                             (IN.)

                            MOTOR

   WF        68.30     383.00        F           1.75      56.31

   PC         3.03      49.40        PO          3.98     126.91

   PF         3.67     126.69        PV          1.86     508.49

   PW         0.73     124.79        PN         -0.15      12.52

   PS         0.00      12.52        PT          1.97     496.73

   WO       161.00    1007.00        TB          1.57       4.22

   TS         1.55       4.25        TO         -0.90       4.13
   &
   TF        -0.97       4.02        T1          1.92       4.08


                       BOTTLE PRESSURE

   P1         0.12      24.87        P2          0.26      25.00

   P3         0.36      25.00        P4          0.36      25.00

   P5         0.27      25.00        P6          0.27      24.63

                    BALLISTIC ANALYZER DATA

   PB        14.79(PSIA)                   FB             0.00(LB.

                      MISCELLANEOUS DATA

   PAM     14.790(PSIA)              IS       227.87(SEC)

   OD      92.389(LB/CUFT)           CSI     5773.34(FT/SEC)

   FD      63.962(LB/CUFT)           AT         0.44(SQIN)

                      * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 21

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

NO HEAT FLUX FOR STATIONS 2 AND 5

SAMPLING DURATION - 0.67 SECONDS

MEAN SAMPLING TIME - 1.6 SECONDS

BOTTLE 1 - PEAKS 44, 45, 47 SEEM ABNORMALLY HIGH

BOTTLE 2 - OXYGEN PEAK ABOUT FIVE TIMES AS HIGH AS REST OF SERIES

BOTTLE 6 - PEAK 47 IS EXTREMELY HIGH

```
                                                          PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

     JPL CONTRACT - NAS7-463                    AEROTHERM PROJECT 7009

     RUN NUMBER -  22                           INJECTOR POSITION - 250

     FIRING NUMBER -   30                       DATE OF FIRING -  1/23/69

--------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

     AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER        HEAT FLUX
                                                        BTU/FT2-SEC

           1.0280                  0.3638                     41.0

           1.7780                  0.3389                      0.0

           2.5280                  0.5293                     47.5

           3.2780                  0.5180                     64.8

           4.0280                  0.0000                      0.0

           4.7780                  2.1348                    554.6

                       ENGINE PERFORMANCE PARAMETERS

     O/F    1.2838          CSTAR  5600. (FT/S)    CSR    0.9692

     ISR    1.0235          PNPC   0.0779          CF     1.3408

     IS     233.41 (SEC)    F      96.86 (LB)      PC     162.51 (PSIA)

     ISB      0.00 (SEC)    FB      0.00 (LB)      PCB     14.79 (PSIA)

     WO     0.2332 (LB/S)   WF     0.1817 (LB/S)   WW     0.0000 (LB/S)

     PSR    1.0000


                              SYSTEM DATA

          PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

     PF     469.63    PFT    933.74          TB  333.10     TO    42.17

     PO     526.23    POT    955.50          TS  259.20     TF    38.09

     PW     108.38                           TV1 340.62
```

```
     GAS COMPOSITION          RUN NUMBER 22

     ****************************************************************
     *
     *                           MOLE FRACTION
     *
     *
     *                           BOTTLE NUMBER
     *
GAS  *        1          2          3          4          5          6
     *
     *
H2   *     25.488     26.543     22.757     20.417      0.000      7.985 ✓
     *
H2O  *     11.611     12.051     15.153      7.444      0.000     17.311 ✓
     *
O2   *      0.000      0.000      0.000      1.453      0.000      0.000 ✓
     *
N2   *     52.328     49.068     53.563     64.182      0.000     60.399 ✓
     *
N2O  *      0.479      0.382      0.328      0.000      0.000      1.740
     *
NO2  *      0.000      0.000      0.000      0.733      0.000      9.283
     *
NH3  *      7.071      9.082      1.804      2.645      0.000      0.000 ✓
     *
N2H4 *      0.000      0.221      0.686      0.461      0.000      0.000
     *
A    *      0.479      0.202      0.357      0.083      0.000      0.398
     *
CO2  *      0.000      0.000      0.000      0.194      0.000      0.000
     *
HE   *      2.541      2.446      5.349      2.382      0.000      2.880
     *
     ****************************************************************

PRESSURE       28.22      27.78      29.79      29.54      26.54      28.09
 (PSIA)

H/N             0.84       0.97       0.75       0.49       0.00       0.37

O/N             0.10       0.11       0.13       0.08       0.00       0.28

H2O            39.29      33.03      40.82      62.66       0.00      59.63
```

```
                              RUN NUMBER 22

                            OSCILLOGRAPH DATA

   QUANTITY       READING     CAL          QUANTITY        READING      CAL
                   (IN.)*                                   (IN.)

                                  MOTOR

     WF            68.00    383.00            F              1.72     56.31

     PC             2.99     49.40            PO             4.03    126.91

     PF             3.59    126.69            PV             1.85    508.49

     PW             0.75    124.79            PN            -0.17     12.52

     PS             0.00     12.52            PT             1.85    496.73

     WO           158.90   1007.00            TB             1.66      4.22

     TS             0.96      4.25            TO            -0.90      4.13

     TF            -0.96      4.02            T1             1.79      4.08


                             BOTTLE PRESSURE

     P1             0.54     24.87            P2             0.51     25.00
     P3             0.60     25.00            P4             0.59     25.00
     P5             0.47     25.00            P6             0.53     24.63

                          BALLISTIC ANALYZER DATA

     PB           14.79(PSIA)                        FB            0.00(LB

                            MISCELLANEOUS DATA

     PAM         14.790(PSIA)            IS           228.03(SEC)
     OD          92.291(LB/CUFT)         CSI         5778.42(FT/SEC)
     FD          63.891(LB/CUFT)         AT             0.44(SQIN)
                           * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 22

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION 0.92 SECONDS

MEAN SAMPLING TIME - 2.24 SECONDS

BOTTLE 1 - PEAKS 45 AND 47 SEEM MORE THAN NORMALLY HIGH

BOTTLE 3 - PEAK 20 READ AT A SENS OF 10 SMALL PEAK

BOTTLE 4 NOTE READ 15-16-17-18-20 AT GAIN 10 ALTHOUGH TRACE WAS MARKED AT 100, SINCE IT LOOKED AS THOUGH THERE WAS A POSSIBLE READING ERROR BY WEST COAST TECHNICAL

BOTTLE 5 NO BOTTLE DATA AVAILABLE

BOTTLE 6 - PEAK 44 HIGH

```
                                                           PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

      JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

      RUN NUMBER -  23                         INJECTOR POSITION - 260

      FIRING NUMBER -   31                     DATE OF FIRING -  1/23/69

--------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

      AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                        BTU/FT2-SEC

           1.0280                  1.1195                   43.5

           1.7780                  0.8725                    0.0

           2.5280                  1.0590                   26.4

           3.2780                  0.4696                   26.9

           4.0280                  0.0000                    0.0

           4.7780                  0.0000                  425.3

                      ENGINE PERFORMANCE PARAMETERS

      O/F    1.1259             CSTAR  5655. (FT/S)   CSR    0.9708

      ISR    1.0329             PNPC   0.0769         CF     1.3485

      IS     237.05 (SEC)       F      91.79 (LB)     PC     153.13 (PSIA)

      ISB      0.00 (SEC)       FB      0.00 (LB)     PCB     14.79 (PSIA)

      WO     0.2050 (LB/S)      WF     0.1821 (LB/S)  WW     0.0000 (LB/S)

      PSR    1.0000


                              SYSTEM DATA

           PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

      PF     464.57    PFT    933.74          TB   326.69     TO    42.17

      PO     413.28    POT    960.59          TS   251.65     TF    40.42

      PW     105.89                           TV1  320.99
```

```
          GAS COMPOSITION          RUN NUMBER 23

          ***************************************************************
          *
          *                       MOLE FRACTION
          *
          *
          *                       BOTTLE NUMBER
          *
GAS       *       1         2         3         4         5         6
          *
          *
H2        *     6.515    15.769    11.434    20.480     0.000     0.000  ✓
          *
H2O       *    64.526     6.302    23.778    13.145     0.000     0.000  ✓
          *
O2        *     0.000     6.256     3.708     0.000     0.000     0.000  ✓
          *
N2        *    17.244    62.447    50.095    56.770     0.000     0.000  ✓
          *
N2O       *     0.726     0.105     0.398     0.336     0.000     0.000
          *
NH3       *     8.420     4.918     4.868     5.027     0.000     0.000  ✓
          *
N2H4      *     0.000     0.839     0.156     0.020     0.000     0.000
          *
A         *     0.000     0.648     0.257     0.059     0.000     0.000
          *
CO2       *     0.000     1.169     0.242     0.000     0.000     0.000
          *
HE        *     2.566     1.541     5.059     4.159     0.000     0.000
          *
          ***************************************************************

PRESSURE        22.75     22.79     25.54     25.79     26.29     24.64
 (PSIA)

H/N              3.77      0.47      0.80      0.69    ******      0.00

O/N              1.47      0.14      0.29      0.11    ******      0.00

H2O            -47.95     60.74     31.69     47.55    ******    ******
```

```
                          RUN NUMBER 23

                        OSCILLOGRAPH DATA

QUANTITY      READING     CAL        QUANTITY      READING     CAL
               (IN.)*                               (IN.)

                              MOTOR

   WF          68.24    383.00          F            1.62     56.31

   PC           2.79     49.40          PO           3.13    126.91

   PF           3.55    126.69          PV           1.86    508.49

   PW           0.73    124.79          PN          -0.24     12.52

   PS           0.00     12.52          PT           1.85    496.73

   WO         139.70   1007.00          TB           1.60      4.22

   TS           0.88      4.25          TO          -0.90      4.13

   TF          -0.93      4.02          T1           1.59      4.08


                         BOTTLE PRESSURE

   P1           0.31     24.87          P2           0.31     25.00

   P3           0.43     25.00          P4           0.44     25.00

   P5           0.46     25.00          P6           0.39     24.63

                     BALLISTIC ANALYZER DATA

   PB          14.79(PSIA)                      FB            0.00(LB.)

                       MISCELLANEOUS DATA

   PAM        14.790(PSIA)           IS        229.50(SEC)

   OD         92.291(LB/CUFT)        CSI      5825.10(FT/SEC)

   FD         63.820(LB/CUFT)        AT           0.44(SQIN)

                      * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 23

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

THE RECORDED DATA FOR HEAT FLUX STATION 6 WAS WAVY AND IMPOSSIBLE TO READ

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 0.86 SECONDS

MEAN SAMPLING TIME - 2.0 SECONDS

FIRST RUN OF A SERIES -- THERE MAY BE A WATER PROBLEM IN THE BACKGROUND DATA FROM UTC

BOTTLE 1 - PEAKS 17, 18, 44, 45 SEEM HIGH. PEAKS 18 AND 44 ARE OFF SCALE, I.E. ARE READ AT GALVO 4 WITH A HEIGHT GREATER THAN 75

BOTTLE 2 - PEAKS 32, 34, 47 HIGH. PEAK 18 MUCH LOWER THAN ON REST OF SERIES

BOTTLE 3 - PEAK 14 ABOUT 1.5 TIMES AS HIGH AS REST OF SERIES, PEAK 34 ALSO HIGH

BOTTLE 4 - PEAK 31 ABOUT HALF AS HIGH AS REST OF SERIES.

BOTTLE 5 - REJECTED DUE TO EXCESSIVE OXYGEN CONTENT

BOTTLE 6 - REJECTED DUE TO EXCESSIVE OXYGEN CONTENT

```
                                                    PAGE 1 OF 4

            ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

RUN NUMBER -  24                        INJECTOR POSITION - 270

FIRING NUMBER -   32                    DATE OF FIRING -  1/23/69

------------------------------------------------------------------

                     DATA REDUCTION RESULTS

AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER      HEAT FLUX
                                                 BTU/FT2-SEC

     1.0280                  0.8069                  60.5

     1.7780                  1.1993                   0.0

     2.5280                  0.8013                  48.7

     3.2780                  1.2625                  94.1

     4.0280                  2.1198                   0.0

     4.7780                  4.2427                 595.0

                 ENGINE PERFORMANCE PARAMETERS

O/F   1.3088          CSTAR  5663. (FT/S)   CSR   0.9821

ISR   0.9885          PNPC   0.0776         CF    1.2784

IS    225.05 (SEC)    F      94.60 (LB)     PC    166.48 (PSIA)

ISB     0.00 (SEC)    FB      0.00 (LB)     PCB    14.80 (PSIA)

WO    0.2383 (LB/S)   WF     0.1820 (LB/S)  WW    0.0000 (LB/S)

PSR   1.0000


                         SYSTEM DATA

     PRESSURE (PSIA)                  TEMPERATURE (DEG.F)

PF    478.51    PFT    943.68         TB   297.83     TO    43.37

PO    522.44    POT    965.68         TS   252.73     TF    49.75

PW    100.90                          TV1  333.38
```

```
GAS COMPOSITION             RUN NUMBER 24

            *****************************************************************
            *
            *                       MOLE FRACTION
            *
            *
            *                       BOTTLE NUMBER
            *
GAS         *     1         2         3         4          5         6
            *
            *
H2          *   11.793    11.495    14.728     6.597     3.458     2.116
            *
H2O         *   14.243    13.738    17.212    15.198     8.945     8.556
            *
O2          *    1.358     5.613     0.000     1.428     3.777    10.637
            *
N2          *   65.012    61.519    58.021    71.893    77.266    73.313
            *
N2O         *    0.281     0.269     1.733     1.112     1.815     2.247
            *
NO2         *    0.000     0.000     0.000     0.000     0.000     0.383
            *
NH3         *    2.960     2.526     1.332     0.000     0.000     0.000
            *
N2H4        *    0.098     0.590     0.000     0.000     0.000     0.220
            *
A           *    0.708     1.108     3.602     0.511     1.735     1.006
            *
CO2         *    0.088     0.899     0.000     0.000     0.000     0.000
            *
HE          *    3.454     2.240     3.368     3.258     2.999     1.517
            *
            *****************************************************************

PRESSURE        16.04     17.29     18.80     19.55     23.30     18.98
 (PSIA)

H/N              0.45      0.47      0.56      0.29      0.15      0.14

O/N              0.12      0.19      0.15      0.13      0.11      0.21

H2O             62.96     56.30     51.61     76.42     91.06     82.93
```

```
                                  RUN NUMBER 24

                               OSCILLOGRAPH DATA

    QUANTITY      READING    CAL         QUANTITY       READING     CAL
                   (IN.)*                                (IN.)

                                     MOTOR

     WF            68.52   383.00           F             1.68     56.31

     PC             3.07    49.40           PO            4.00    126.91

     PF             3.65   126.69           PV            1.86    508.49

     PW             0.69   124.79           PN           -0.15     12.52

     PS             0.00    12.52           PT            1.86    496.73

     WO           162.50  1007.00           TB            1.33      4.22

     TS             0.89     4.25           TO           -0.89      4.13

     TF            -0.85     4.02           T1            1.71      4.08


                               BOTTLE PRESSURE

     P1             0.04    24.87           P2            0.09     25.00
     P3             0.16    25.00           P4            0.19     25.00
     P5             0.34    25.00           P6            0.16     24.63

                           BALLISTIC ANALYZER DATA

     PB            14.80(PSIA)                      FB            0.00(LB.)

                             MISCELLANEOUS DATA

     PAM          14.800(PSIA)             IS       227.66(SEC)
     OD           92.193(LB/CUFT)          CSI     5766.76(FT/SEC)
     FD           63.537(LB/CUFT)          AT         0.44(SQIN)
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 24

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 0.62 SECONDS

MEAN SAMPLING TIME - 1.70 SECONDS

BOTTLE 1 - PEAK 18 OFF SCALE

BOTTLE 2 - PEAKS 31, 34, 47 ABNORMALLY HIGH

BOTTLE 3 - PEAKS 28, 32 LOWER THAN USUAL, PEAK 20 TWICE AS HIGH AS REST OF SERIES, PEAKS 18 AND 40 OFF SCALE

BOTTLE 4 - PEAK 47 ABOUT TWICE AS HIGH AS REST IN SERIES EXCEPT BOTTLE 2

BOTTLE 5 - PEAK 34 IS HIGHER THAN USUAL EXCEPT 24-3

BOTTLE 6 - PEAK 30 IS ABOUT 7 TIMES HIGHER THAN REST IN SERIES, PEAK 32 IS HIGH AND PEAK 34 IS EXTRAORDINARILY LARGE, PEAKS 34 AND 44 ARE FAIRLY HIGH ON THIS SERIES

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                                                              PAGE 1 OF 4

                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

        RUN NUMBER -  25                         INJECTOR POSITION - 300

        FIRING NUMBER -   33                     DATE OF FIRING -  1/23/69

--------------------------------------------------------------------------


                         DATA REDUCTION RESULTS

        AXIAL STATION (IN.)      O/F IN BOUNDARY LAYER        HEAT FLUX
                                                             BTU/FT2-SEC

             1.0280                    0.2018                    61.4

             1.7780                    0.3020                     0.0

             2.5280                    0.2273                   115.2

             3.2780                    0.3389                   142.0

             4.0280                    0.6822                     0.0

             4.7780                    0.5903                   606.0

                       ENGINE PERFORMANCE PARAMETERS

        O/F    1.2943           CSTAR  5652. (FT/S)    CSR    0.9790

        ISR    0.9802           PNPC   0.0769          CF     1.2713

        IS     223.37 (SEC)     F      93.48 (LB)      PC     165.42 (PSIA)

        ISB      0.00 (SEC)     FB      0.00 (LB)      PCB     14.73 (PSIA)

        WO     0.2361 (LB/S)    WF     0.1824 (LB/S)   WW     0.0000 (LB/S)

        PSR    1.0000


                             SYSTEM DATA

            PRESSURE (PSIA)                   TEMPERATURE (DEG.F)

        PF     474.64    PFT    938.65         TB   340.58    TO    43.37

        PO     538.86    POT    945.27         TS   276.45    TF    39.26

        PW      97.09                          TV1  359.21
```

```
          GAS COMPOSITION          RUN NUMBER 25

               ******************************************************************
               *
               *                           MOLE FRACTION
               *
               *
               *                           BOTTLE NUMBER
               *
GAS            *      1          2          3          4          5          6
               *
               *
H2             *    17.065     16.280     24.276     26.704     19.027     21.152
               *
H2O            *     5.256      5.313     10.029     11.719     12.728      8.385
               *
O2             *     2.570      4.227      0.486      0.529      2.864      4.644
               *
N2             *    36.527     41.726     38.983     48.110     55.862     52.570
               *
N2O            *     0.229      0.171      0.119      0.060      0.359      0.166
               *
NH3            *    34.817     29.146     23.276      9.963      5.039      8.330
               *
N2H4           *     0.521      0.473      0.510      0.501      0.139      0.675
               *
A              *     1.381      0.388      0.788      0.693      1.847      2.017
               *
CO2            *     0.440      0.456      0.050      0.103      0.515      0.541
               *
HE             *     1.189      1.816      1.477      1.613      1.616      1.515
               *
               ******************************************************************

PRESSURE            34.13      29.22      32.23      32.48      34.73      31.23
 (PSIA)

H/N                  1.38       1.16       1.37       1.01       0.67       0.75

O/N                  0.09       0.12       0.10       0.11       0.15       0.15

H2O                 18.98      27.10      17.79      31.01      45.84      41.90
```

```
                         RUN NUMBER 25

                       OSCILLOGRAPH DATA

QUANTITY     READING    CAL          QUANTITY      READING     CAL
              (IN.)*                                 (IN.)

                             MOTOR

   WF          68.30    383.00          F             1.66     56.31

   PC           3.04     49.40          PO            4.13    126.91

   PF           3.63    126.69          PV            1.82    508.49

   PW           0.65    124.79          PN           -0.16     12.52

   PS           0.00     12.52          PT            1.85    496.73

   WO         161.00   1007.00          TB            1.73      4.22

   TS           1.12      4.25          TO           -0.89      4.13

   TF          -0.94      4.02          T1            1.96      4.08
   +

                        BOTTLE PRESSURE

   P1           0.77     24.87          P2            0.57     25.00

   P3           0.70     25.00          P4            0.71     25.00

   P5           0.80     25.00          P6            0.66     24.63

                     BALLISTIC ANALYZER DATA

   PB          14.73(PSIA)                     FB            0.00(LB.)

                      MISCELLANEOUS DATA

   PAM        14.730(PSIA)          IS       227.88(SEC)

   OD         92.193(LB/CUFT)       CSI     5773.62(FT/SEC)

   FD         63.856(LB/CUFT)       AT          0.44(SQIN)
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 25

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 1.0 SECONDS

MEAN SAMPLING TIME - 2.10 SECONDS

BOTTLE 2 - PEAK 20 ABOUT HALF AS HIGH AS USUAL

BOTTLE 3 - PEAK 29 READ ON GALVO 1. MAY BE INACCURATE SINCE PEAK IS SMALL

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                                                          PAGE 1 OF 4

                 ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

         JPL CONTRACT - NAS7-463                 AEROTHERM PROJECT 7009

         RUN NUMBER -  26                        INJECTOR POSITION - 330

         FIRING NUMBER -   34                    DATE OF FIRING -  1/24/69

---------------------------------------------------------------------------


                          DATA REDUCTION RESULTS

         AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                           BTU/FT2-SEC

             1.0280                    0.4160                  87.6

             1.7780                    0.2921                   0.0

             2.5280                    0.3418                 139.4

             3.2780                    0.3700                 154.0

             4.0280                    0.4838                   0.0

             4.7780                    0.6278                 630.6

                       ENGINE PERFORMANCE PARAMETERS

         O/F    1.3101           CSTAR  5587. (FT/S)   CSR    0.9689

         ISR    0.9703           PNPC   0.0779         CF     1.2720

         IS     220.89 (SEC)     F      93.48 (LB)     PC     165.33 (PSIA)

         ISB      0.00 (SEC)     FB      0.00 (LB)     PCB     14.64 (PSIA)

         WO     0.2400 (LB/S)    WF     0.1831 (LB/S)  WW     0.0000 (LB/S)

         PSR    1.0000


                              SYSTEM DATA

             PRESSURE (PSIA)                      TEMPERATURE (DEG.F)

         PF     480.89    PFT    943.52          TB  335.49     TO    40.89

         PO     514.66    POT    965.52          TS  259.84     TF    39.45

         PW     170.63                           TV1 355.61
```

```
          GAS COMPOSITION           RUN NUMBER 26

         *****************************************************************
         *
         *                         MOLE FRACTION
         *
         *
         *                         BOTTLE NUMBER
         *
GAS      *       1         2         3         4         5         6
         *
         *
H2       *     27.828    20.604    22.506    23.929    23.643    22.133
         *
H2O      *      8.911    11.470    13.827    12.224    12.355    14.849
         *
O2       *      1.309     0.593     0.245     0.513     0.516     2.289
         *
N2       *     54.197    42.638    41.725    47.547    52.016    52.127
         *
N2O      *      0.000     0.000     0.002     0.000     0.076     0.232
         *
NH3      *      0.000    20.001    15.731     9.922     2.238     4.399
         *
N2H4     *      1.523     0.063     0.103     0.185     0.297     0.688
         *
A        *      3.214     2.362     3.545     3.281     5.819     0.647
         *
CO2      *      0.213     0.000     0.000     0.000     0.000     0.268
         *
HE       *      2.801     2.265     2.310     2.394     3.035     2.363
         *
         *****************************************************************

PRESSURE       22.35     22.13     26.64     25.89     24.14     26.21
 (PSIA)

H/N             0.71      1.18      1.21      0.97      0.74      0.81

O/N             0.10      0.12      0.14      0.12      0.12      0.17

H2O            43.92     24.58     21.39     31.56     40.22     37.13
```

```
                              RUN NUMBER 26

                            OSCILLOGRAPH DATA

QUANTITY      READING     CAL          QUANTITY      READING      CAL
               (IN.)*                                 (IN.)

                                  MOTOR

  WF           68.60     383.00          F            1.66       56.31

  PC            3.04      49.40          PO           3.94      126.91

  PF            3.68     126.69          PV           1.86      508.49

  PW            1.25     124.79          PN          -0.14       12.52

  PS            0.00      12.52          PT           1.86      496.73

  WO          163.30    1007.00          TB           1.63        4.35

  TS            0.94       4.33          TO          -0.90        4.13
   6
  TF           -1.00       3.81          T1           1.91        4.11
  +

                            BOTTLE PRESSURE

  P1            0.31      24.87          P2           0.30       25.00
  P3            0.48      25.00          P4           0.45       25.00
  P5            0.38      25.00          P6           0.46       24.63

                        BALLISTIC ANALYZER DATA

  PB          14.64(PSIA)                        FB             0.00(LB.

                        MISCELLANEOUS DATA

  PAM         14.640(PSIA)               IS         227.64(SEC)
  OD          92.396(LB/CUFT)            CSI       5766.10(FT/SEC)
  FD          63.850(LB/CUFT)            AT           0.44(SQIN)

                           * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 26

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - 0.8 SECONDS

MEAN SAMPLING TIME - 2.0 SECONDS

BOTTLE 1 - PEAKS 31, 32, 34 HIGH. PEAK 16 ONE TENTH AS HIGH AS REST, PEAK 17 ALSO LOWER, PEAKS 45 AND 47 ARE VERY HIGH

BOTTLE 5 - PEAK 15 LOWER THAN REST-ABOUT HALF AS HIGH

BOTTLE 6 - PEAK 20 LOW BY ABOUT FACTOR OF TEN, PEAKS 40 AND 47 ARE LOW

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                                                                PAGE 1 OF 4
                  ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION
       JPL CONTRACT - NAS7-463                     AEROTHERM PROJECT 7009
       RUN NUMBER -  27                            INJECTOR POSITION -   0.
       FIRING NUMBER -   35                        DATE OF FIRING -  1/24/69

-------------------------------------------------------------------------------

                             DATA REDUCTION RESULTS

       AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER        HEAT FLUX
                                                          BTU/FT2-SEC

            1.0280                    0.1282                   40.0
            1.7780                    0.5818                    0.0
            2.5280                    0.0000                   53.9
            3.2780                    0.3576                  100.6
            4.0280                    0.9509                    0.0
            4.7780                    0.2789                  605.4

                          ENGINE PERFORMANCE PARAMETERS

       O/F    1.3078            CSTAR   5509. (FT/S)   CSR    0.9552
       ISR    0.9505            PNPC    0.0767         CF     1.2639
       IS     216.43 (SEC)      F       90.66 (LB)     PC     161.37 (PSIA)
       ISR      0.00 (SEC)      FB       0.00 (LB)     PCB     14.64 (PSIA)
       WO     0.2373 (LB/S)     WF      0.1815 (LB/S)  WW     0.0000 (LB/S)
       PSR    1.0000

                                  SYSTEM DATA

           PRESSURE (PSIA)                          TEMPERATURE (DEG.F)

       PF     472.02    PFT    938.56               TB   328.87     TO    42.09
       PO     580.65    POT    945.18               TS   282.87     TF    40.56
       PW     174.37                                TV1  387.41
```

```
          GAS COMPOSITION          RUN NUMBER 27

          ***************************************************************
          *
          *                        MOLE FRACTION
          *
          *
          *                        BOTTLE NUMBER
          *
GAS       *      1         2         3         4         5         6
          *
          *
H2        *   19.000    10.206     0.000    20.815    15.544    29.916
          *
H2O       *    6.402     2.804     0.000     8.912     6.783     7.314
          *
O2        *    0.000     6.513     0.000     0.891     6.090     0.000
          *
N2        *   34.828    59.647     0.000    55.007    62.516    50.544
          *
N2O       *    0.701     0.223     0.000     0.309     0.250     0.546
          *
NH3       *   34.436    17.682     0.000     9.440     4.329     1.689
          *
N2H4      *    1.237     0.037     0.000     0.146     0.091     0.349
          *
A         *    0.459     0.809     0.000     1.243     1.405     5.091
          *
HE        *    2.933     2.074     0.000     3.232     2.987     4.547
          *
          ***************************************************************

PRESSURE        19.36     18.13     18.64     18.39     17.13     19.07
 (PSIA)

H/N              1.47      0.57    ******      0.73      0.44      0.77

O/N              0.06      0.11    ******      0.09      0.14      0.07

H2O             16.59     59.90     -0.00     47.12     60.95     40.11
```

```
                                                                        PAGE 3 OF
                                  RUN NUMBER 27

                                 OSCILLOGRAPH DATA

  QUANTITY      READING     CAL          QUANTITY       READING      CAL
                 (IN.)*                                  (IN.)

                                       MOTOR

    WF            68.01    383.00          F               1.60       56.31

    PC             2.96     49.40          PO              4.46      126.91

    PF             3.61    126.69          PV              1.82      508.49

    PW             1.28    124.79          PN             -0.18       12.52

    PS             0.00     12.52          PT              1.85      496.73

    WO           161.70   1007.00          TB              1.56        4.35

    TS             1.16      4.33          TO             -0.90        4.13

    TF            -0.98      3.81          T1              2.23        4.11


                                  BOTTLE PRESSURE

    P1             0.18     24.87          P2              0.13       25.00
    P3             0.16     25.00          P4              0.15       25.00
    P5             0.09     25.00          P6              0.17       24.63

                               BALLISTIC ANALYZER DATA

    PB           14.64(PSIA)                       FB                0.00(LB.

                                MISCELLANEOUS DATA

    PAM         14.640(PSIA)             IS         227.68(SEC)
    OD          92.297(LB/CUFT)          CSI       5767.22(FT/SEC)
    FD          63.816(LB/CUFT)          AT           0.44(SQIN)
                             * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 27

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATIONS 2 AND 5

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - .54 SECONDS

MEAN SAMPLING TIME - 1.9 SECONDS

PEAK 34 HIGH IN THIS GROUP OF MASS SPEC DATA

PEAKS 14, 15, 20, 29, 40 AND 45 ARE ALSO HIGHER THAN USUAL IN THIS GROUP

BOTTLE 1 - PEAKS 30, 31, 45 AND 47 HIGH

BOTTLE 2 - PEAK 32 HIGH

BOTTLE 3 - NO BOTTLE DATA AVAILABLE

BOTTLE 4 - PEAK 14 OFF SCALE AND HIGH, PEAK 16 HIGH

BOTTLE 5 - PEAKS 32 AND 40 HIGH

BOTTLE 6 - PEAK 20 HIGH

```
                                                              PAGE 1 OF 4

                  ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

       JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

       RUN NUMBER -  28                         INJECTOR POSITION -   0

       FIRING NUMBER -   36                     DATE OF FIRING -  2/11/69

-----------------------------------------------------------------------------

                          DATA REDUCTION RESULTS

       AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER       HEAT FLUX
                                                         BTU/FT2-SEC

             1.0280                   0.1621                 65.5

             1.7780                   0.1596                  0.0

             2.5280                   0.2136                 98.3

             3.2780                   0.2644                 66.5

             4.0280                   0.0000                 84.2

             4.7780                   0.4092                612.0

                       ENGINE PERFORMANCE PARAMETERS

       O/F    1.2901          CSTAR  5746. (FT/S)    CSR    0.9950

       ISR    0.8444          PNPC   0.0786          CF     1.0776

       IS     192.48 (SEC)    F      80.21 (LB)      PC     167.45 (PSIA)

       ISB      0.00 (SEC)    FB      0.00 (LB)      PCB     14.65 (PSIA)

       WO     0.2347 (LB/S)   WF     0.1819 (LB/S)   WW     0.0000 (LB/S)

       PSR    1.0000

                              SYSTEM DATA

            PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

       PF     472.03     PFT    929.26         TB  335.20     TO    53.21

       PO     500.90     POT    959.64         TS  270.86     TF    35.09

       PW     172.30                           TV1 385.26
```

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                                                                  PAGE 2 OF 4

              GAS COMPOSITION          RUN NUMBER 28

              ***************************************************************
              *
              *                        MOLE FRACTION
              *
              *
              *                        BOTTLE NUMBER
              *
    GAS       *        1         2         3         4         5         6
              *
              *
    H2        *     18.661    19.704    24.068    26.485     0.000    22.935
              *
    H2O       *     10.273     9.597    10.645    12.216     0.000    17.701
              *
    N2        *     27.411    30.703    39.178    41.166     0.000    43.020
              *
    N2O       *      0.171     0.118     0.045     0.085     0.000     0.321
              *
    NH3       *     42.346    38.691    24.758    18.715     0.000    15.060
              *
    A         *      0.590     0.410     0.529     0.424     0.000     0.054
              *
    HE        *      0.544     0.774     0.773     0.906     0.000     0.904
              *
              ***************************************************************

    PRESSURE        68.44     54.40     63.62     52.90     53.88     58.95
     (PSIA)

    H/N              1.89      1.74      1.39      1.31     -0.00      1.24

    O/N              0.10      0.09      0.10      0.12     -0.00      0.17

    H2O             -0.11      5.42     17.33     18.86      0.00     19.66
```

RUN NUMBER 28

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	68.00	383.00	F	1.58	50.76
PC	3.05	50.10	PO	3.89	125.00
PF	3.61	126.69	PV	1.89	499.99
PW	1.27	123.16	PN	-0.11	12.27
PS	0.00	12.27	PT	1.81	502.53
WO	161.50	1007.00	TB	1.63	4.32
TS	1.06	4.29	TO	-0.81	4.07
TF	-0.87	4.55	T1	2.28	3.98
		BOTTLE PRESSURE			
P1	2.26	23.69	P2	1.59	25.00
P3	1.92	25.51	P4	1.53	25.00
P5	1.53	25.64	P6	1.78	24.75

BALLISTIC ANALYZER DATA.

PB	14.65(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.650(PSIA)	IS	227.94(SEC)
OD	91.386(LB/CUFT)	CSI	5775.55(FT/SEC)
FD	63.982(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 28

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION 1.9 SECONDS

MEAN SAMPLING TIME - 2.1 SECONDS

PEAK 34 HIGH IN THIS GROUP OF MASS SPEC DATA

PEAKS 14, 15, 20,29, 40 AND 45 ARE ALSO HIGHER THAN USUAL IN THIS GROUP

BOTTLE 3 - PEAKS 28, 32, AND 40 HIGH

BOTTLE 4 - PEAK 34 HIGH

BOTTLE 5 NO BOTTLE DATA AVAILABLE

BOTTLE 6 - PEAK 14 HIGH, PEAK 40 LOW AND PEAK 15 SLIGHTLY OFF SCALE

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                                                              PAGE 1 OF 4
                ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION
    JPL CONTRACT - NAS7-463                    AEROTHERM PROJECT 7009
    RUN NUMBER -  29                           INJECTOR POSITION -   0
    FIRING NUMBER -   37                       DATE OF FIRING -  2/11/69
----------------------------------------------------------------------------

                        DATA REDUCTION RESULTS
    AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER      HEAT FLUX
                                                     BTU/FT2-SEC
         1.0280                  0.0000                   76.1
         1.7780                  0.1783                    0.0
         2.5280                  0.0000                  100.0
         3.2780                  0.0000                   68.7
         4.0280                  0.0000                   86.5
         4.7780                  0.9239                  741.9
                    ENGINE PERFORMANCE PARAMETERS
    O/F    1.2921            CSTAR  5950. (FT/S)   CSR    1.0304
    ISR    0.8844            PNPC   0.0742         CF     1.0899
    IS    201.57 (SEC)       F       84.27 (LB)    PC    173.94 (PSIA)
    ISP     0.00 (SEC)       FB       0.00 (LB)    PCB    14.63 (PSIA)
    WO     0.2356 (LB/S)     WF     0.1823 (LB/S)  W[illegible]   0.0000 (LB/S)
    PSR    1.0000

                           SYSTEM DATA
      PRESSURE (PSIA)                       TEMPERATURE (DEG.F)
    PF     477.08    PFT   934.27          TB  330.82    TO   54.39
    PO     509.63    POT   964.62          TS  286.07    TF   39.33
    P[illegible]     174.74                            TV1 379.57
```

```
          GAS COMPOSITION           RUN NUMBER 29

          ***************************************************************
          *
          *                       MOLE FRACTION
          *
          *
          *                       BOTTLE NUMBER
          *
GAS       *      1         2         3         4         5         6
          *
          *
H2        *    0.000    18.571     0.000     0.000     0.000    23.401
          *
H2O       *    0.000     8.343     0.000     0.000     0.000     4.693
          *
O2        *    0.000     0.491     0.000     0.000     0.000     0.000
          *
N2        *    0.000    35.971     0.000     0.000     0.000    50.099
          *
N2O       *    0.000     0.398     0.000     0.000     0.000     1.786
          *
NO2       *    0.000     0.000     0.000     0.000     0.000     7.255
          *
NH3       *    0.000    34.225     0.000     0.000     0.000     3.013
          *
A         *    0.000     0.676     0.000     0.000     0.000     5.383
          *
HE        *    0.000     1.321     0.000     0.000     0.000     4.366
          *
          ***************************************************************

PRESSURE        14.86     26.38     14.11     14.63     14.63     28.24
 (PSIA)

H/N              0.00      1.46      0.00    ******     -0.00      0.57

O/N              0.00      0.09      0.00    ******     -0.00      0.18

H2O              0.00     15.89      0.00    ******      0.00     47.28
```

RUN NUMBER 29

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	68.30	383.00	F	1.66	50.76
PC	3.18	50.10	PO	3.96	125.00
PF	3.65	126.69	PV	1.90	499.99
PW	1.30	123.16	PN	-0.14	12.27
PS	0.00	12.27	PT	1.83	502.53
WO	162.30	1007.00	TB	1.60	4.32
TS	1.20	4.29	TO	-0.81	4.07
TF	-0.84	4.54	T1	2.22	3.98

+

BOTTLE PRESSURE

P1	0.00	23.69	P2	0.47	25.00
P3	-0.01	25.51	P4	0.00	25.00
P5	0.00	25.64	P6	0.54	24.75

BALLISTIC ANALYZER DATA

PB	14.63(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.630(PSIA)	IS	227.91(SEC)
CD	91.289(LB/CUFT)	CSI	5774.67(FT/SEC)
FD	63.854(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 29

C/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - .9 SECONDS

MEAN SAMPLING TIME - 1.56 SECONDS

BOTTLE 2 - PEAKS 15 AND 32 HIGH

BOTTLE 6 MASS SPEC PRESSURE LOW, 8.4 BOTTLE DATA SUSPECT

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                                                                   PAGE 1 OF 4

                    ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

          JPL CONTRACT - NAS7-463                      AEROTHERM PROJECT 7009

          RUN NUMBER -  30                             INJECTOR POSITION -   0

          FIRING NUMBER -   38                         DATE OF FIRING -  2/11/69

----------------------------------------------------------------------------


                              DATA REDUCTION RESULTS

          AXIAL STATION (IN.)    O/F IN BOUNDARY LAYER       HEAT FLUX
                                                          BTU/FT2-SEC

               1.0280                  0.0000                  74.2

               1.7780                  0.0000                   0.0

               2.5280                  0.2045                  94.4

               3.2780                  0.0000                  69.4

               4.0280                  0.0000                  87.5

               4.7780                  0.0000                 702.3

                         ENGINE PERFORMANCE PARAMETERS

          O/F    1.3041            CSTAR  5774. (FT/S)    CSR    1.0009

          ISR    0.8738            PNPC   0.0763          CF     1.1088

          IS     199.00 (SEC)      F      83.25 (LB)      PC     168.92 (PSIA)

          ISB      0.00 (SEC)      FB      0.00 (LB)      PCB     14.62 (PSIA)

          WO     0.2367 (LB/S)     WF     0.1815 (LB/S)   WW     0.0000 (LB/S)

          PSR    1.0000


                              SYSTEM DATA

              PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

          PF      472.00     PFT     924.21        TB   331.91     TO     53.21

          PO      512.11     POT     959.61        TS   303.46     TF     36.41

          PW      171.04                           TV1  375.77
```

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                                                                  PAGE 2 OF 4

               GAS COMPOSITION          RUN NUMBER 30

              **************************************************************
              *
              *                       MOLE FRACTION
              *
              *
              *                       BOTTLE NUMBER
              *
     GAS      *      1         2         3         4         5         6
              *
              *
     H2       *    0.000     0.000    22.801     0.000     0.000     0.000
              *
     H2O      *    0.000     0.000    10.489     0.000     0.000     0.000
              *
     N2       *    0.000     0.000    34.316     0.000     0.000     0.000
              *
     N2O      *    0.000     0.000     0.083     0.000     0.000     0.000
              *
     NH3      *    0.000     0.000    27.279     0.000     0.000     0.000
              *
     A        *    0.000     0.000     2.162     0.000     0.000     0.000
              *
     HE       *    0.000     0.000     2.867     0.000     0.000     0.000
              *
              **************************************************************

     PRESSURE      15.33     15.11     26.86     15.61     14.62     28.23
      (PSIA)

     H/N           0.00      0.00      1.54     ******    -0.00     -0.00

     O/N           0.00      0.00      0.11     ******    -0.00     -0.00

     H2O           0.00     ******    11.05     ******     0.00      0.00
```

RUN NUMBER 30

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	67.90	383.00	F	1.64	50.76
PC	3.07	50.10	PO	3.97	125.00
PF	3.61	126.69	PV	1.89	499.99
PW	1.27	123.16	PN	-0.14	12.27
PS	0.00	12.27	PT	1.80	502.53
WO	162.90	1007.00	TB	1.61	4.32
TS	1.35	4.29	TO	-0.81	4.07
TF	-0.85	4.55	T1	2.17	3.98
O					
		BOTTLE PRESSURE			
P1	0.02	23.69	P2	0.01	25.00
P3	0.48	25.51	P4	0.03	25.00
P5	0.00	25.64	P6	0.54	24.75

BALLISTIC ANALYZER DATA

PB	14.62(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.620(PSIA)	IS	227.73(SEC)
OD	91.386(LB/CUFT)	CSI	5769.04(FT/SEC)
FD	63.942(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 30

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - .92 SECONDS

MEAN SAMPLING TIME - 1.57 SECONDS

BOTTLE 3 - THIS IS THE ONLY BOTTLE FOR THIS RUN

PEAKS 14, 15, 16, 20, 34, AND 40 ALL HIGH

```
                                                                    PAGE 1 OF 4

                       ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

            JPL CONTRACT - NAS7-463                    AEROTHERM PROJECT 7009

            RUN NUMBER -  31                           INJECTOR POSITION -   0

            FIRING NUMBER -   39                       DATE OF FIRING -  2/11/69

----------------------------------------------------------------------------


                                DATA REDUCTION RESULTS

            AXIAL STATION (IN.)      O/F IN BOUNDARY LAYER         HEAT FLUX
                                                                BTU/FT2-SEC

                  1.0280                    0.0982                    65.8

                  1.7780                    0.1342                     0.0

                  2.5280                    0.2471                   105.4

                  3.2780                    0.0000                    62.4

                  4.0280                    0.2786                    76.7

                  4.7780                    0.2733                   771.8

                             ENGINE PERFORMANCE PARAMETERS

            O/F    1.1170              CSTAR   5674. (FT/S)     CSR    0.9739

            ISR    0.8315              PNPC    0.0774           CF     1.0821

            IS     190.87 (SEC)        F       77.16 (LB)       PC     160.42 (PSIA)

            ISB      0.00 (SEC)        FB       0.00 (LB)       PCB     14.63 (PSIA)

            WO     0.2133 (LB/S)       WF      0.1909 (LB/S)    WW     0.0000 (LB/S)

            PSR    1.0000


                                     SYSTEM DATA

                 PRESSURE (PSIA)                       TEMPERATURE (DEG.F)

            PF      497.35     PFT   1014.68          TB   342.86      TO     54.39

            PO      439.62     POT    764.62          TS   294.76      TF     39.06

            PW      174.74                            TV1  363.41
```

```
          GAS COMPOSITION          RUN NUMBER 31

         ****************************************************************
         *
         *                        MOLE FRACTION
         *
         *
         *                        BOTTLE NUMBER
         *
GAS      *       1         2         3         4         5         6
         *
         *
H2       *    28.051    21.703    23.705     0.000    27.740    26.207
         *
H2O      *     4.203     7.279    11.806     0.000    10.284    10.674
         *
O2       *     0.042     0.000     0.000     0.000     0.660     0.279
         *
N2       *    31.514    33.156    37.953     0.000    42.391    39.075
         *
N2O      *     0.000     0.070     0.137     0.000     0.114     0.441
         *
NO2      *     0.581     0.000     0.000     0.000     0.000     0.000
         *
NH3      *    31.616    33.091    22.587     0.000    14.906    16.284
         *
A        *     0.095     0.072     0.048     0.000     1.046     1.044
         *
CO2      *     0.162     0.000     0.000     0.000     0.000     0.000
         *
HE       *     3.732     4.625     3.760     0.000     2.855     5.991
         *
         ****************************************************************

PRESSURE      32.16     26.12     25.34     24.87     23.86     25.27
 (PSIA)

H/N            1.67      1.57      1.40    ******      1.20      1.28

O/N            0.05      0.07      0.12    ******      0.11      0.12

H2O            8.54     11.49     15.60    ******     22.44     18.78
```

```
                         RUN NUMBER 31

                       OSCILLOGRAPH DATA

QUANTITY      READING   CAL        QUANTITY      READING    CAL
               (IN.)*                             (IN.)

                            MOTOR

  WF          71.50    383.00         F            1.52     50.76

  PC           2.90     50.10         PO           3.39    125.00

  PF           3.80    126.69         PV           1.49    499.99

  PW           1.30    123.16         PN          -0.18     12.27

  PS           0.00     12.27         PT           1.99    502.53

  WO         146.90   1007.00         TB           1.70      4.32

  TS           1.27      4.29         TO          -0.81      4.07

  TF          -0.84      4.55         T1           2.06      3.98
  +

                        BOTTLE PRESSURE

  P1           0.74     23.69         P2           0.45     25.00
  P3           0.42     25.51         P4           0.40     25.00
  P5           0.36     25.64         P6           0.42     24.75

                    BALLISTIC ANALYZER DATA

  PB          14.63(PSIA)                    FB            0.00(LB.)

                     MISCELLANEOUS DATA

  PAM        14.630(PSIA)             IS      229.54(SEC)
  OD         91.289(LB/CUFT)          CSI    5826.36(FT/SEC)
  FD         63.862(LB/CUFT)          AT        0.44(SQIN)

                      * CPS FOR WF AND WO
```

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER= 31

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION .92 SECONDS

MEAN SAMPLING TIME 1.58 SECONDS

BOTTLE 3 - PEAKS 16 AND 17 HIGH

NO BOTTLE 4 DATA AVAILABLE

BOTTLE 5 - PEAKS 4, 20 AND 40 HIGH

BOTTLE 6 - PEAKS 20 AND 30 HIGH

```
                    ROCKET MOTOR BOUNDARY FLOW DATA REDUCTION

        JPL CONTRACT - NAS7-463                  AEROTHERM PROJECT 7009

        RUN NUMBER -  32                         INJECTOR POSITION - 260

        FIRING NUMBER -   40                     DATE OF FIRING -  2/11/69

------------------------------------------------------------------------------


                            DATA REDUCTION RESULTS

        AXIAL STATION (IN.)     O/F IN BOUNDARY LAYER      HEAT FLUX
                                                          BTU/FT2-SEC

              1.0280                  0.4404                  67.4

              1.7780                  0.0000                   0.0

              2.5280                  0.5413                  49.4

              3.2780                  4.6317                  39.1

              4.0280                  3.1929                  69.5

              4.7780                  3.8893                 726.8

                         ENGINE PERFORMANCE PARAMETERS

        O/F   1.2896            CSTAR  5812. (FT/S)    CSR   1.0063

        ISR   0.8120            PNPC   0.0754          CF    1.0246

        IS    185.10 (SEC)      F      77.16 (LB)      PC    169.43 (PSIA)

        ISB     0.00 (SEC)      FB      0.00 (LB)      PCB    14.62 (PSIA)

        WO    0.2348 (LB/S)     WF     0.1820 (LB/S)   WW    0.0000 (LB/S)

        PSR   1.0000


                                 SYSTEM DATA

             PRESSURE (PSIA)                    TEMPERATURE (DEG.F)

        PF    474.53    PFT    934.26          TB   333.01     TO    54.39

        PO    518.36    POT    954.61          TS   323.01     TF    52.26

        PW    173.50                           TV1  350.30
```

```
          GAS COMPOSITION         RUN NUMBER 32

          ***************************************************************
          *
          *                    MOLE FRACTION
          *
          *
          *                    BOTTLE NUMBER
          *
GAS       *      1          2          3          4          5          6
          *
          *
H2        *    22.991     0.000     20.608      2.877      8.704      5.370
          *
H2O       *    14.744     0.000     14.187     22.609     13.828     13.568
          *
N2        *    51.636     0.000     58.266     11.067     38.250     38.690
          *
N2O       *     0.016     0.000      0.122     62.311     36.462     37.913
          *
NH3       *     6.920     0.000      2.084      0.347      0.000      0.000
          *
N2H4      *     0.000     0.000      0.011      0.156      0.039      0.032
          *
A         *     0.755     0.000      0.505      0.225      0.497      1.025
          *
HE        *     2.935     0.000      4.213      0.404      2.217      3.399
          *
          ***************************************************************

PRESSURE       22.20      21.11      22.78      24.12      21.79      23.77
 (PSIA)

H/N             0.87       0.00       0.63       0.35       0.30       0.24

O/N             0.13       0.00       0.12       0.57       0.33       0.33

H2O            36.48     ******      49.18      52.42      67.83      72.35
```

RUN NUMBER 32

OSCILLOGRAPH DATA

QUANTITY	READING (IN.)*	CAL	QUANTITY	READING (IN.)	CAL
		MOTOR			
WF	68.60	383.00	F	1.52	50.76
PC	3.09	50.10	PO	4.02	125.00
PF	3.63	126.69	PV	1.87	499.99
PW	1.29	123.16	PN	-0.14	12.27
PS	0.00	12.27	PT	1.83	502.53
WO	161.70	1007.00	TB	1.61	4.32
TS	1.54	4.29	TO	-0.81	4.07
&A TF	-0.73	4.55	T1	1.92	3.98
		BOTTLE PRESSURE			
P1	0.31	23.69	P2	0.26	25.00
P3	0.32	25.51	P4	0.38	25.00
P5	0.28	25.64	P6	0.36	24.75

BALLISTIC ANALYZER DATA

PB	14.62(PSIA)	FB	0.00(LB.)

MISCELLANEOUS DATA

PAM	14.620(PSIA)	IS	227.95(SEC)
OD	91.289(LB/CUFT)	CSI	5775.80(FT/SEC)
FD	63.461(LB/CUFT)	AT	0.44(SQIN)

* CPS FOR WF AND WO

COMMENTS ON DATA AND DATA REDUCTION

RUN NUMBER- 32

O/F ANALYZED BY ELEMENTAL COMPOSITION

NO SHROUD PRESSURE PS MEASUREMENT

INJECTOR COOLING WATER WW FLOW RATE NOT MEASURED

NO BALLISTIC ANALYZER DATA

HEAT FLUX VALUES WERE DETERMINED AT 1 SECOND FROM OXIDIZER LEAD-IN

NO HEAT FLUX FOR STATION 2

NOZZLE OVEREXPANDED - THRUST LOW

SAMPLING DURATION - .92 SECONDS

MEAN SAMPLING TIME - 1.42 SECONDS

BOTTLE 1 - PEAK 15 HIGH

BOTTLE 2 BOTTLE DATA DISCARDED DUE TO EXCESSIVE OXYGEN CONTENT

BOTTLE 3 - PEAK 16 HIGH

BOTTLE 4 MASS SPEC PRESSURE 56.4 ABOUT 4 TIMES HIGHER THAN
BOTTLE PRESSURE -- DATA SUSPECT

BOTTLE 6 - PEAK 44 HIGH

APPENDIX A

(intentionally omitted)

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