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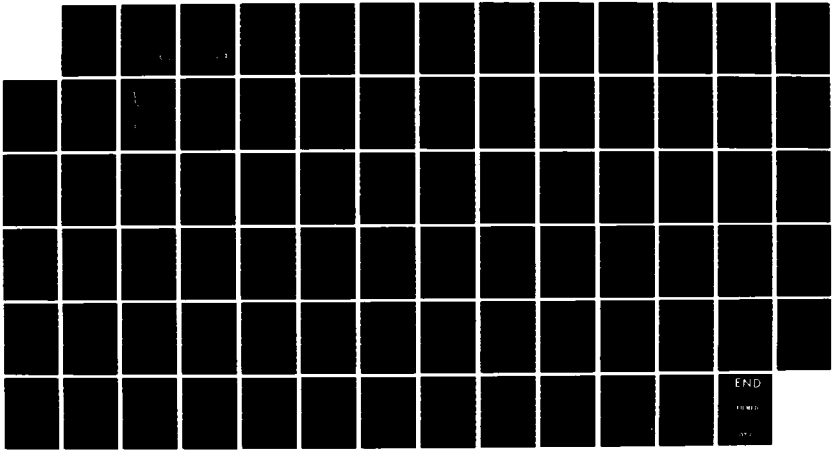

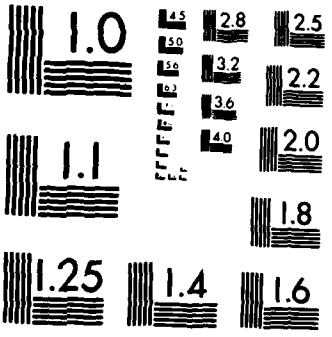

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SSBAUER SPECTROMETRY: TESTING OF A NEW COMPUTER BASED SYSTEM AND ITS APPLICATION TO A STUDY OF AN ALUMINUM-IRON-CERIUM ALLOY

THESIS

Joseph F. Harmon Jr.
Second Lieutenant, USAF
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AFIT/GNE/PH/84M -6

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THESIS

Presented to the Faculty of the School of Engineering of the Air Force Institute of Technology Air University In Partial Fulfillment of the Requirements for the Degree of Master of Science

by

Joseph F. Harmon Jr., B.S.
Second Lieutenant, USAF

Graduate Nuclear Engineering

March 1984

Preface

This thesis is the product of my efforts to interface a new Mossbauer spectrometer to a PDP 11/03 microcomputer, which has the capabilities of analyzing Mossbauer data, and also to determine microstructure changes of an Al-Fe-Ce alloy due to various processing stages. This thesis will describe both the hardware and software changes made to assemble the new system, the system's limitations, and a complete operating procedure. For the alloy studied, a literature review and spectra for each processing stage is included.

I would like to thank Don Elworth of the Physics Department for his technical assistance throughout the project, and Doug Barker of the Air Force Materials Laboratory for supplying the alloy samples. I especially want to thank my advisor, Dr. George John, for his continuous support and guidance during this project.

Finally, I want to thank my wife, Rosie, for her constant support and understanding.

Joseph F. Harmon Jr.

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Abstract

In this study, a computer based Mossbauer spectrometer was built using a new MS-900 spectrometer, an APPLE 2+ computer system, and a PDP 11/03 computer system. The APPLE was used as the link between the spectrometer and the PDP, which is used to analyze the Mossbauer spectra. In addition to minor hardware connections, software changes were made to the analysis program so that it could accept the data format produced by the new spectrometer. Due to equipment failure, only preliminary tests were made of the new system, however the tests were positive. Originally, an Al-Fe-Ce alloy was chosen to be studied by the new system. Instead, the alloy, chosen because of its excellent high temperature properties, was studied by the original Mossbauer spectrometer system. The goal was to follow and identify changes in the microstructure of the alloy due to different processing stages. Although changes in the spectra were identified with processing stages, it is still unclear as to what compounds are related to the observed spectra.

MOSSBAUER SPECTROMETRY: TESTING OF A NEW COMPUTER BASED SYSTEM AND ITS APPLICATION TO A STUDY OF AN ALUMINUM-IRON-CERIUM ALLOY

I. Introduction

Mossbauer spectrometry is becoming an increasingly important tool for the field of physical metallurgy. The goal of this study consisted of assembling and testing a computer based mossbauer spectrometer and its application to examining an alloy consisting of 88% Al, 8% Fe, and 4% Ce by weight. This alloy was chosen to be studied by the Air Force Materials Laboratory because of its attractive elevated temperature and creep resistance properties.

Background

In previous years, students have studied mossbauer spectrometry and its application to materials technology. These studies included: 1) the monitoring of chemical changes which occur during the manufacture of rare earth-cobalt magnets, 2) the determination of chemical changes in the bonding surface between a coating and its substate, and 3) the physical characteristics of amorphous metallic materials. The equipment used for these studies, including the software for data analysis, involved tedious manual transfer of data to a computer. In 1981 Pate succesfully completed the programing for a DEC LSI-11/03 computer which permits rapid analysis of mossbauer spectra without the need for a central processor at

The Air Force Institute of Technology. With this completed, it was desired to replace the aging and bulky spectrometer with a new one which could be interfaced with the DEC, resulting in rapid easy collection and analysis of data.

The alloy to be studied and used as a test for the newly built system was chosen by the Materials Laboratory at Wright Patterson Air Force Base. This organization has been involved in the study of powder metallurgy aluminum base alloys in order to improve elevated temperature strength and creep resistance properties. Initially, a total of 21 binary and ternary alloys fabricated from atomized powders, hot pressed to full density, were chosen to evaluate the effect of alloy composition and fabrication parameters on mechanical properties up to 405 - 650 F. From this study, the Al-Fe-Ce alloy was most promising and demonstrated that powder metallurgy was feasible for producing a new generation of elevated temperature aluminum alloys. However, it is still unclear as to the exact mechanism surrounding Ce. Also, it is realized that the type of processing will definitely influence the final product. Thus it is desirable to better understand the microstructure and how the microstructure is affected by changes in the processing parameters.

Problem

The problem investigated in this study was twofold. First, an interface between the new spectrometer and the DEC was to be accomplished. Second, the new system was to be used for

studying the aluminum-iron-cerium alloy. In particular, the alloy was to be analyzed at each stage of processing to follow and identify changes in the microstructure. The processing stages include: 1) gas atomization, 2) cold isostatic pressing, 3) hot vacuum degassing, and 4) hot isostatic pressing followed by hot vacuum degassing.

Scope

The interfacing achieved in this study was only a temporary solution. Instead of a direct link between the new spectrometer and the DEC, an APPLE 2 Plus computer was used to link the two devices. Appendix B contains a brief discussion of how a direct interface could be accomplished. Also, due to equipment failure, the alloy tests had to be accomplished on the original equipment. However, it was possible to test the new equipment using a known source. In addition to these limitations, the testing of all samples was taken at room temperature and all samples were fabricated based on theoretical calculations to optimize the spectra obtained. A literature search was done and included sources at the Air Force Institute of Technology, School of Engineering, an Air Force Wright Aeronautical Laboratories technical report and a search by the Mossbauer Effect Data Center in North Carolina on binary and ternary alloys containing Al, Fe, and Ce.

Review of the Literature

The literature review contains information found

pertaining to the Al-Fe-Ce alloy and the possible intermetallic compounds formed. Most of this information comes from the Air Force Materials Laboratory Technical Report. In order to better understand their results, it is necessary to explain how the test alloy was fabricated. First, the alloying elements Ce and Fe were added to 99.5% pure superheated aluminum and the alloy was then gas atomized in a low-oxygen flue gas to generate a fine, irregular powder (1:3). The low-oxygen flue gas was necessary to prevent violent oxidation (1:3). Following atomization, the powder was screened through a 325 mesh sieve and cold compacted at 414 MPa (60 Ksi) to form compacts with a density of about 80% of theoretical (1:4,47). Next, the compacts were heated to temperature in argon, transferred in air to a die and hot pressed to 100% density at 600 F or 700 F (1:48). Finally, the fully dense hot compacted billets were machined into forging preforms and hot forged at 600 F or 700 F.

The study by the Air Force Materials Laboratory indicated that this and the other alloys considered were likely to produce unknown metastable compounds due to the rapid solidification resulting from atomization. In order to try and identify the metastable intermetallic phases in the alloy, X-ray and thermal analysis, as well as optical metallography and scanning transmission electron microscopy (STEM), were used to study both the atomized powders and the forgings. Guinier-deWolf X-ray analysis revealed small amounts of $FeAl_6$ and an unidentified phase. The same structure was seen in both the powder and the forging samples (1:55). Thermal analysis,

differential scanning calorimetry (DSC), also showed a lack of structural differences between the forgings upset at 600 F and 700 F and the atomized powders. Optical metallography revealed a very fine and uniform microstructure (1:11). Within a single particle, areas of fine, dense precipitates were interspersed with areas that appeared almost featureless at magnifications up to 1000X (1:103). It is believed that the featureless areas impart high strength while the precipitated areas contribute to increased ductility (1:164). In further efforts to identify the precipitated intermetallic phases present, a foil of the alloy was examined by STEM. The results indicated that some areas contain no Fe or Ce in the matrix while the intermetallics contained 90.5 at.% Al, 7.4 at.% Fe and 2.0 at.% Ce (1:103). These results however do not correspond to either of the ternary phases Al_8 Ce Fe_4 and Al_{10} Fe_2 Ce stated to be possible formations in Al-Fe-Ce alloys (1:55).

When searching for information on ternary phases containing Al, Fe and Ce, only one other study was found. The study by Felner and Nowik shows Mossbauer spectra of an Fe57 probe replacing the Cu ion in the compound Ce Cu_4Al_8 (2:1040). Their spectra, taken at temperatures from -452.29 F to room temperature, show a single quadrupole doublet with an isomer shift of +0.23 mm/s relative to Fe metal.

Finally, the most likely binary compounds formed, from the ratio of elements present, include Fe Al , Fe Al_3, Fe Al_6, Fe_4Al_{13} (3:299), and Fe_2Ce (4). Of these compounds, only information on Fe Al_6, Fe_4Al_{13}, and Fe_2Ce was found. The spectra

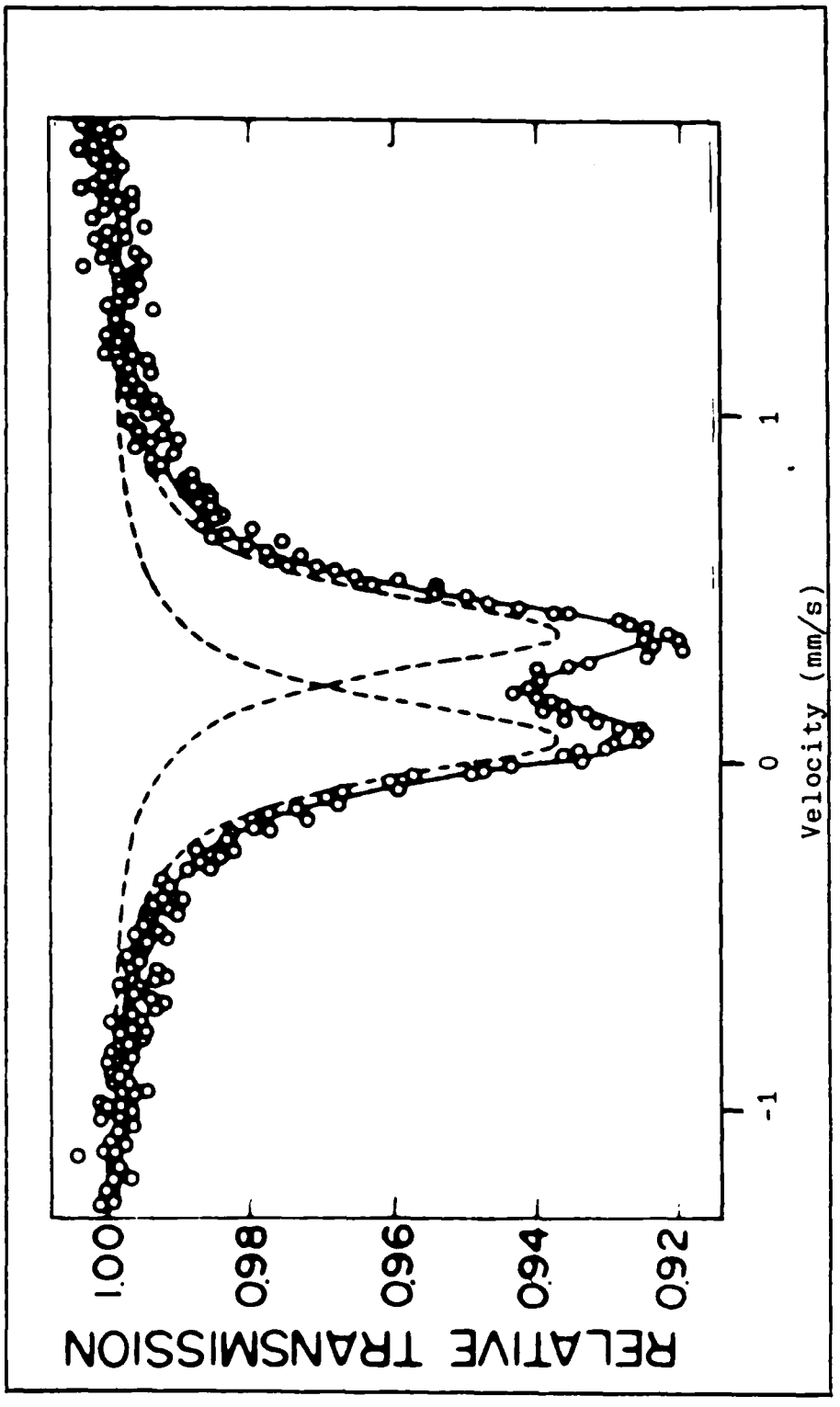


Figure 1. Spectra of $FeAl_6$ with respect to NFE.

of $Fe\ Al_6$ (Figure 1) is that of a quadrupole doublet with an isomer shift of +0.25 mm/s with respect to natural iron (3:301). The Fe_4Al_{13} spectra is the result of five different quadrupole doublets representing five different iron sites (5:1521). This spectra appears as a closely spaced triplet centered at 0.2 mm/s relative to natural iron foil (5:1522). The $Ce\ Fe_2$ spectra is a symmetric six line pattern and the curie temperature for this compound is reported to be -32.8 F (4:762).

II. Theory

Mossbauer Effect

The theory of the Mossbauer Effect has been well developed and thus will not be covered here in detail. For a detailed discussion the reader is referred to reference 6. Instead, a general description of the Mossbauer Effect will be given through the following example. Consider a nucleus of an atom bound in some type of lattice such as is the case of a metal. The nucleus may interact with its environment in three ways. First, the nuclear charge may interact electrostatically with the electrons present at the nucleus. A change in the electron density at the nucleus, from perhaps a change in the lattice structure, results in a shift of the nuclear energy levels. Second, the nuclear quadrupole moment of a nucleus can interact with an electric field gradient which is usually a result of the charge distribution of the ions in the lattice. An interaction of this type will cause splitting of the nuclear energy levels. For the case of an iron nucleus, the splitting will result in two nuclear energy levels. Finally, the magnetic dipole moment of a nucleus can interact with a magnetic field produced externally or due to ions in the lattice. This interaction also causes splitting of nuclear energy levels and for the case of an iron nucleus, six energy levels are produced.

In 1957, Rudolph Mossbauer noticed that by moving a radioactive source, the energy of a photon emitted by the nucleus was changed by a small amount. Mossbauer spectrometry takes advantage of this fact by using photons of a spectrum of

energies, produced by accelerating a radioactive source, to probe the nuclear energy levels of a nucleus in its lattice. If the emitted photon, from a source, has the correct energy needed to excite the nucleus in a lattice, or absorber, then the photon may be absorbed and re-emitted isotropically resulting in a resonant effect. This effect will take place if the source and absorber both contain the same atom. Commonly, the source contains iron in an excited state and the absorber contains iron in the ground state. If the absorber is placed between the velocity modulated source and a detector, a spectrum containing dips, or lines, will be seen where each dip is a result of the resonant absorption. Each dip is related to a particular source velocity, and thus a particular photon energy, which is characteristic of the absorbing nuclei. From studying these spectra, a great deal can be learned about the environment of the iron nucleus. In this study, the alloy being tested contains an iron nucleus which will be used as a probe to uncover information about the alloy's lattice structure.

Absorber Parameters

A Mossbauer spectrum can be optimized by choosing the proper absorber thickness. A method by Shimony (7) enables one to find the best absorber thickness for maximizing the relative intensity of the absoption lines. This method is based on maximizing a single line, but can be extended to cases where there are several lines of equal intensity (7:350).

If an absorber is made very thick, there will be a

large number of active nuclei in the path of an incident photon, resulting in a strong resonant effect. However, if the absorber is too thick, the non-resonant radiation emerging from the absorber will be very weak. Because of this, the resonance lines will appear very slowly due to statistics involved and the background noise will tend to mask it out (7:348). If the absorber is too thin, the emerging non-resonant beam will be increased but the resonance effect will be reduced because of fewer active nuclei present in the path of the incident photon. The method to be described below enables one to calculate an intermediate thickness which will result in maximum absorption peaks.

Initially, one assumes that the shape of the resonant line(s) is Lorentzian, which is true unless perturbed by the system (8:3,5). If this is the case, then the magnitude of the Lorentzian peaks, according to Shimony, can be expressed as (7:349):

$$q(d)=N_0 f_s(1-\exp(-1/2u_r d)J_0(1/2iu_r d))\exp(-u_a d) \qquad (1)$$

where,

d = actual absorber thickness

N_0 = number of photons striking the absorber

f_s = recoil free fraction of the source

u_r = coefficient of resonant absorption

u_a = coefficient of non-resonant absorption

J_0 = zero-order Bessel function

If equation (1) is examined closely, it is noticed that for d = 0 and as $d \rightarrow \infty$, q (d) vanishes. By setting the derivative of q (d) with respect to d equal to zero and using the identity

$$(dJ_0(x))/dx = -J_1(x) \tag{2}$$

the following relation is found:

$$\frac{u_r}{2u_a} = \frac{(\exp(1/2u_r d_0) - J_0(1/2iu_r d_0))}{(J_0(1/2iu_r d_0) + J_1(1/2iu_r d_0))} \tag{3}$$

which yields Table 1 (7:349). If one can find the value of the dimensionless quantity $u_r/2u_a$, one can use table 1 to find the value of $1/2u_r d_0$ and thus d_0.

The value of u_r can be found through the relation

$$u_r = f_a n s_0 / M \tag{4}$$

where

f_a = recoiless traction of the absorber

n = number density of active nuclei in absorber

M = number of equal intensity peaks

s_0 = maximum average cross section for resonant absorption per active nucleus

Table 1.

$1/2\ u_r d_0$ as a Function of $u_r/(2u_a)$

$1/2\ u_r d_0$	$u_r/(2u_a)$	$1/2\ u_r d_0$	$u_r/(2u_a)$	$1/2\ u_r d_0$	$u_r/(2u_a)$
0.0	0.0000	2.2	8.946	5.8	53.88
0.1	0.1078	2.3	9.760	6.0	57.08
0.2	0.2324	2.4	10.620	6.2	60.33
0.3	0.3758	2.5	11.50	6.4	63.67
0.4	0.5397	2.6	12.42	6.6	67.02
0.5	0.7264	2.7	13.36	6.8	70.42
0.6	0.9379	2.8	14.36	7.0	73.94
0.7	1.176	2.9	15.36	7.2	77.47
0.8	1.445	3.0	16.40	7.4	81.05
0.9	1.741	3.2	18.55	7.6	84.73
1.0	2.072	3.4	20.79	7.8	88.46
1.1	2.438	3.6	23.13	8.0	92.18
1.2	2.837	3.8	25.55	8.2	95.87
1.3	3.276	4.0	28.06	8.4	100.1
1.4	3.749	4.2	30.78	8.6	103.8
1.5	4.261	4.4	33.39	8.8	107.9
1.6	4.839	4.6	36.05	9.0	113.3
1.7	5.404	4.8	38.87	9.2	115.9
1.8	6.039	5.0	41.71	9.4	120.6
1.9	6.703	5.2	44.65	9.6	124.6
2.0	7.416	5.4	47.62	9.8	128.7
2.1	8.160	5.6	50.72	10.0	132.5

For the alloy being studied, no data was available on the recoil free fraction. However, a value of 0.5 was assumed which is typical of many absorbers. For an iron atom, the value of S_0 is given as 2.38E-18 cm^2/Fe atom (9). The value for n was calculated to be 1.88E+19 atoms/g and from initial spectra, two peaks appeared with nearly equal intensities, thus a value of 2 will be given to M. These constants lead to a value of 11.208 cm^2/g for u_r.

The value for u_a in cm^2/g was found by assuming the relation

$$u_{a_t} = \sum_i w_i u_{a_i} \qquad (5)$$

holds true (10:69). The values of each u_a lead to a final value of 17.3 cm^2/g for the alloy. By using the values of u_r and u_a and table I, a value of 0.047 g/cm^2 was calculated for the optimum absorber thickness. As will be shown later, this value differs from the experimentally found optimal value by approximately 50%. However, this method was useful for finding an initial value which was able to be refined experimentally.

III. Equipment and Procedures

In this section, the Mossbauer spectrometry equipment and procedures for data aquisition will be discussed. The equipment for the original system will simply be listed while the equipment and installation procedure will be included for the new system. Also discussed will be the method of absorber preparation, the experimental method for finding the optimum absorber thickness, and the experimental geometry.

Original Mossbauer System

The major components of the original Mossbauer spectrometer include a velocity transducer (motor), a motor control unit (MCU) to drive the motor at a constant acceleration, a linear amplifier/single channel analyzer, a Krypton-filled proportional counter with a preamplifier, and a high voltage supply for the detector. All of the above equipment, with exception for the detector, was manufactured by Ranger Electronics. Other equipment included a RIDL 400 multichannel analyzer (MCA) operated in a time-sequential scaling mode and driven by a RIDL time base oscillator.

New Mossbauer System

The new Mossbauer spectrometer system consists of a single unit (MS-900) which contains the Mossbauer control unit, the linear amplifier/single channel analyzer, a time base oscillator and a 1024 multichannel analyzer. This unit, built by Ranger Scientific, Incorporated, was designed to be operated

with the assistance of an APPLE 2+ or 2e computer. Other equipment used in conjunction with this unit included a velocity transducer (VT-900) also built by Ranger Scientific, Incorporated, a detector/preamplifier, and a high voltage supply. In order to transfer and display data, an APPLE 2+ computer was connected to the MS-900 via an MS-900-100 interface card inserted in the computer.

For both the new and original system, the operation is basically the same. The source is connected to the shaft of the velocity transducer, which is accelerated by the control unit. This unit is driven by the channel address ramp from the multichannel analyzer, which is driven by the time base oscillator. The pulses produced by the detector are sent through the preamplifier, linear amplifier and single channel analyzer respectively. The single channel analyzer windows are set such that only pulses resulting from the 14.4 kiloelectron volt (keV) photons are passed through the remaining circuitry. As each channel in the MCA is opened for a time specified by the time base oscillator, pulses from the SCA enter this channel and thus a spectrum of counts versus channel number is produced. Each channel is related to a particular velocity of the source and thus the spectrum is also that of counts versus velocity. How the velocity scale is assigned to the spectrum during data analysis will be discussed later. The velocity scale on this spectrum depends on whether the motor is driven in the triangular mode or flyback mode. In either case, the maximum velocity (VMAX) of the source is set and the source is moved at

a constant linear acceleration between +VMAX and -VMAX. For the flyback mode, the source velocity is varied from -VMAX to +VMAX and generates a single spectrum. For the triangular mode, the source velocity is varied from +VMAX to -VMAX and back to +VMAX. In this case, two identical spectra are seen. One spectrum is generated when accelerating from +VMAX to -VMAX and a mirror image spectra is generated when accelerating from -VMAX to +VMAX. Due to limitations in the data analysis program, to be discussed later, only the flyback mode was used in this study.

Computer System

The computer system used for data analysis with both the new and original Mossbauer spectrometers consists of a PDP 11/03 microcomputer with 64 kilobytes of memory, an RX-02 dual 8-inch floppy disk drive, and a VT-100 terminal, all manufactured by Digital Equipment Corporation. Additionally, an MX-80 F/T dot matrix printer by Epson is serially connected to provide a printout of results.

The PDP 11/03 is a 16 bit word computer consisting of an LSI 11/02 microprocessor with a KEV-11 floating point chip, a BDV-11 bootstrap and diagnostic board, a DLV-11 4 port serial interface board, and a DRV-11 parallel interface board (8:9). All programming is in FORTRAN IV version 2.5 and all FORTRAN software was provided by Digital Equipment Corporation (8:9).

The computer system used for interfacing the MS-900 unit with the PDP 11/03 consists of an APPLE 2+ with 48 kilobytes of memory, an APPLE monitor III, 5 1/4-inch floppy

disk drive, and an APPLE Super Serial Card. Also, a joystick and a Sylentype thermal printer was used for manipulating data and printing results respectively. The software for data manipulation was a Mossbauer Master program supplied by Ranger Scientific, Incorporated for an APPLE 2+ or 2e computer. This software enables one to do several things with the data obtained. The options include acquiring data, storing data on a disk, retrieving data from a disk, printing the data on a printer, and displaying the spectrum. Changes made to this software, as part of the new Mossbauer spectrometer installation, are included in later sections.

MOSFUN Program

Whether one is using the new or original spectrometer system, the data must somehow be analyzed. The computer program used for spectrum analysis in this study is MOSFUN, originally written by E.W. Muller and modified by B.E. Pate in 1981 as a thesis project. Pate modified the console version of MOSFUN, designed to run on mainframe computers using terminals, to a size and format which could fit into the PDP 11/03. By extensive use of subroutines, an overlaying technique was able to be used to fit the program into the smaller memory of the PDP 11/03. The final version allows up to 32 fit parameters, 24 lines, and 1024 data points (8:15). The parameters used by MOSFUN to fit a spectrum include intensity, position, half-width and possibly form. These parameters are used in one of four possible models provided by MOSFUN. Two models use Lorentzian lineshapes, one

using line intensity and one using line area. The other two models use Voigt lineshapes and again, one uses line intensity and one uses line area. Only when using the Voigt theory is the fourth parameter, form, used. This parameter determines whether the lineshape is more Gaussian or Lorentzian.

There are two iterative methods, Newton and Gradient, provided for correcting the initially calculated theoretical spectrum in MOSFUN. Both are equally accurate. However, Newton's method is much faster if it does not diverge. For this study, the Lorentzian - intensity and Voigt-intensity theories were used with the gradient method. Details of the parameters used and theory applied to each spectra are discussed in chapter 4 (results/discussion). For a detailed description of the modified MOSFUN program, the reader is referred to reference 8.

New Spectrometer Insallation

In order to assemble a new system so that data could be sent directly to the PDP 11/03 for anaylysis from the new spectrometer, software and hardware changes had to be made. The software changes included modifications made to both MOSFUN and the Mossbauer Master program.

MOSFUN Changes . Basically, the changes made to MOSFUN include altering the DATI and DRIVE subroutines to allow a 1024 data point spectrum with no velocity data included, instead of a 400 point spectrum with velocity data every 10 channels. Additionally, the read statements for the time base data also had to be changed. Originally, the first 14 channels contained

time base data and the remaining 386 channels contained Mossbauer data, with velocity data every ten channels, starting with channel 19. The new spectrometer does not contain a moire system and thus the spectrum contains no velocity data. The first two channels contain time base data while the remaining channels contain Mossbauer data. The first step taken was to allow subroutine DATI to accept the new spectrum format by reading in the first two data points as time base data, instead of the first 14. These points were then set equal to zero as originally done for the first 14 points. Next, a GOTO statement was added to bypass the velocity extraction portion of DATI. Normally, velocity points are stored in an array called VCON(I) and a linear least squares fit is done on the velocity data. Since the new system does not produce velocity data, the velocity values in mm/s and peak positions of a known spectrum were entered. The velocity values and channel positions for each peak of a natural iron spectrum were inserted into subroutine DATI. The velocity values, taken from reference 9, are those with respect to sodium nitroprusside. Thus, all spectra will be analyzed with respect to sodium nitroprusside. As before, a linear least squares fit will be done on the VCON(I) array and the channel numbers for each velocity point are set equal to zero. Finally, no changes had to be made to allow a 1024 point spectra instead of a 400 point one, because MOSFUN was originally equipped to handle this option.

The changes made to subroutine DRIVE include altering arrays X(I) and XY(I). Array X(I) contains the channel number

corresponding to each velocity point and was originally assigned a value in subroutine DRIVE since velocity points were evenly spaced throughout the data. The array values are now assigned by entering them into subroutine DRIVE (see appendix A for procedure), where each channel number corresponds to a peak from the natural iron calibration run. Array XY(I) is an array containing values of VCON(I) which have been converted to mm/s. This conversion has been omitted since VCON(I) is entered as mm/s in subroutine DATI. The velocity values for each peak are from published calibration data and thus do not need to be changed. However, the channel locations for each peak, which must be entered into subroutines DRIVE and DATI, must be updated periodically to insure an accurately calibrated system. The present values are a result of a 25 micron thick natural iron absorber run at room temperature for 4.25 hours (*figure 2*).

Mossbauer Master Changes . The changes made to the Mossbauer Master program permit data to be sent to the PDP 11/03, in addition to a printer or a disk. Also, once the hardware connections were made between the APPLE and the PDP, to be discussed later, the format in which the program transmitted or printed data had to be changed. Appendix C contains a listing of the Mossbauer Master program with the changes added. The format changes include using one line for the spectrum name, a second line for specifying the format in which MOSFUN reads the data, and a third line for listing the number of time base overflows, data overflows, number of data points total, number of data points in a full period, and the drive mode.

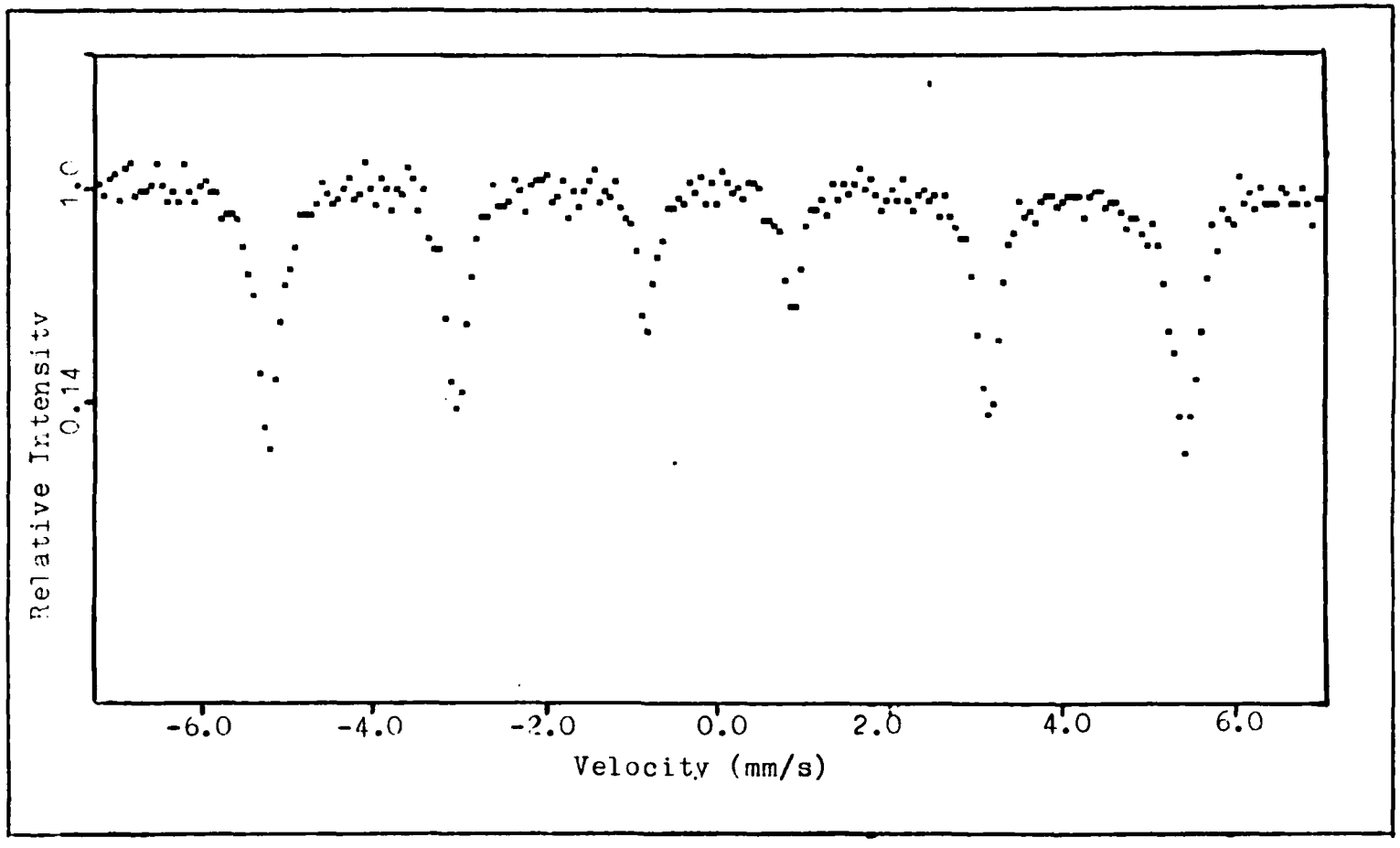


Fig 2. Natural Iron Calibration Results From MS-900
(With respect to Sodium Nitroprusside)

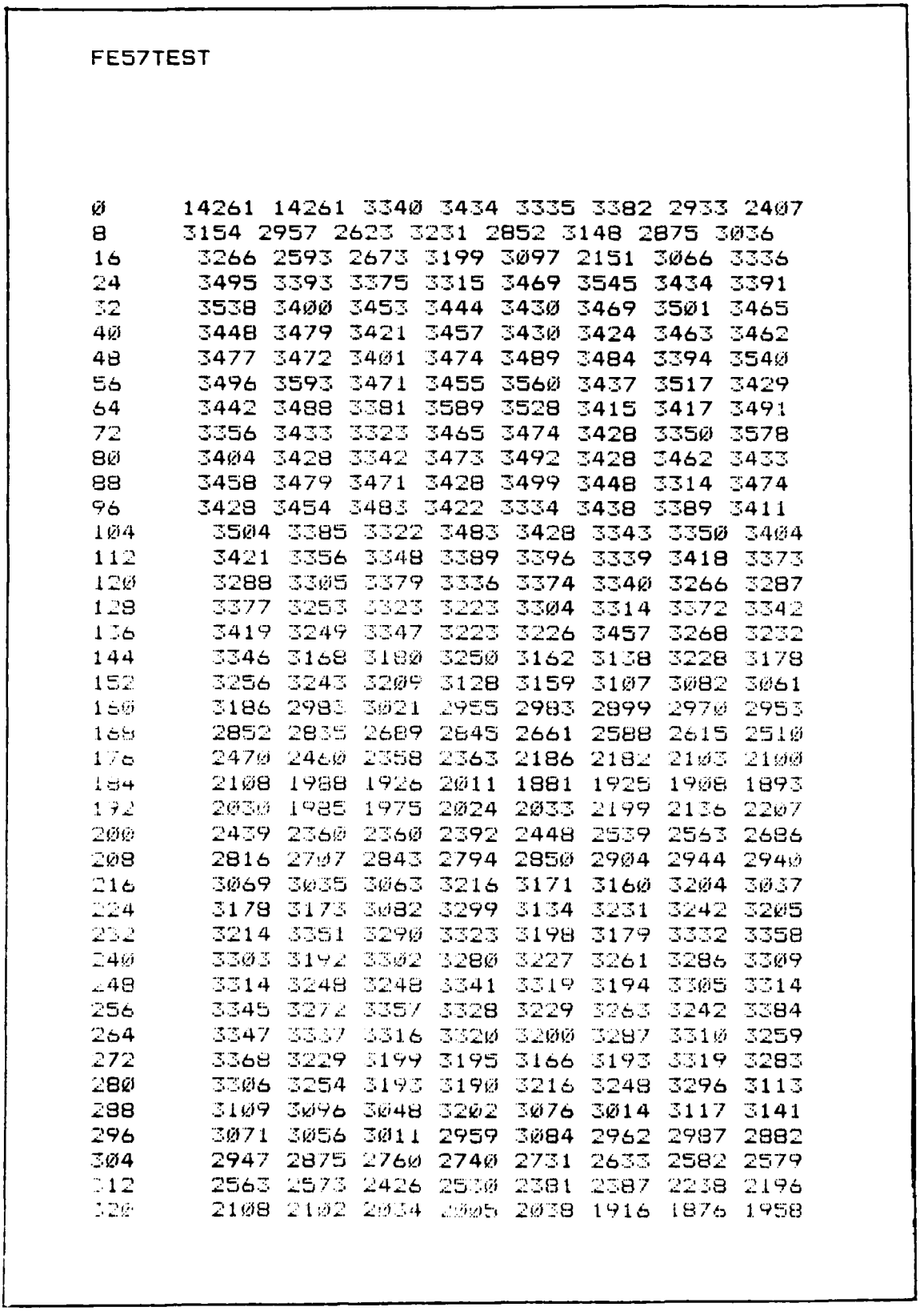


Figure 3. Old Data Format

```
NFECAL.EXT
( 8F9.0)
0,0,1024,2048, 3
    89207    89207    14447    14200    14128    14457    14255    13091
    14337    14412    13433    14315    14301    13872    14443    13843
    14220    14578    13507    13989    14232    14095    13076    14087
    14521    14302    14656    14412    14348    14175    14344    14342
    14485    14357    14446    14509    14304    14374    14488    14313
    14524    14476    14269    14369    14409    14484    14407    14462
    14509    14670    14573    14608    14255    14479    14499    14659
    14441    14530    14372    14351    14401    14107    14310    14428
    14314    14328    14414    14627    14473    14472    14612    14585
    14506    14332    14487    14537    14270    14531    14363    14356
    14563    14421    14271    14434    14595    14438    14409    14584
    14334    14384    14569    14317    14376    14555    14684    14503
    14392    14293    14367    14299    14412    14396    14329    14386
    14610    14420    14400    14451    14441    14447    14487    14240
    14290    14516    14282    14449    14358    14384    14471    14396
    14300    14187    14457    14474    14655    14474    14399    14133
    14357    14273    14598    14344    14299    14260    14650    14362
    14412    14405    14369    14428    14486    14385    14420    14476
    14394    14465    14375    14309    14370    14533    14402    14309
    14080    14236    14172    14143    14193    13973    14242    14262
    14198    14115    14081    14201    14141    14162    13972    13853
    13835    13849    13698    13622    13570    13516    13494    13314
    13427    13135    13044    12732    12609    12607    12306    12054
    12145    11995    12047    12239    11928    12205    12320    12441
    12565    12660    12985    13036    13147    13488    13386    13627
    13482    13604    13800    13688    13640    13864    13917    14024
    13848    13921    14019    14031    14197    14156    14176    13849
    14184    14171    14193    14130    14168    14186    14192    14240
    14284    14420    14246    14389    14476    14341    14493    14285
```

Figure 4. New Data Format

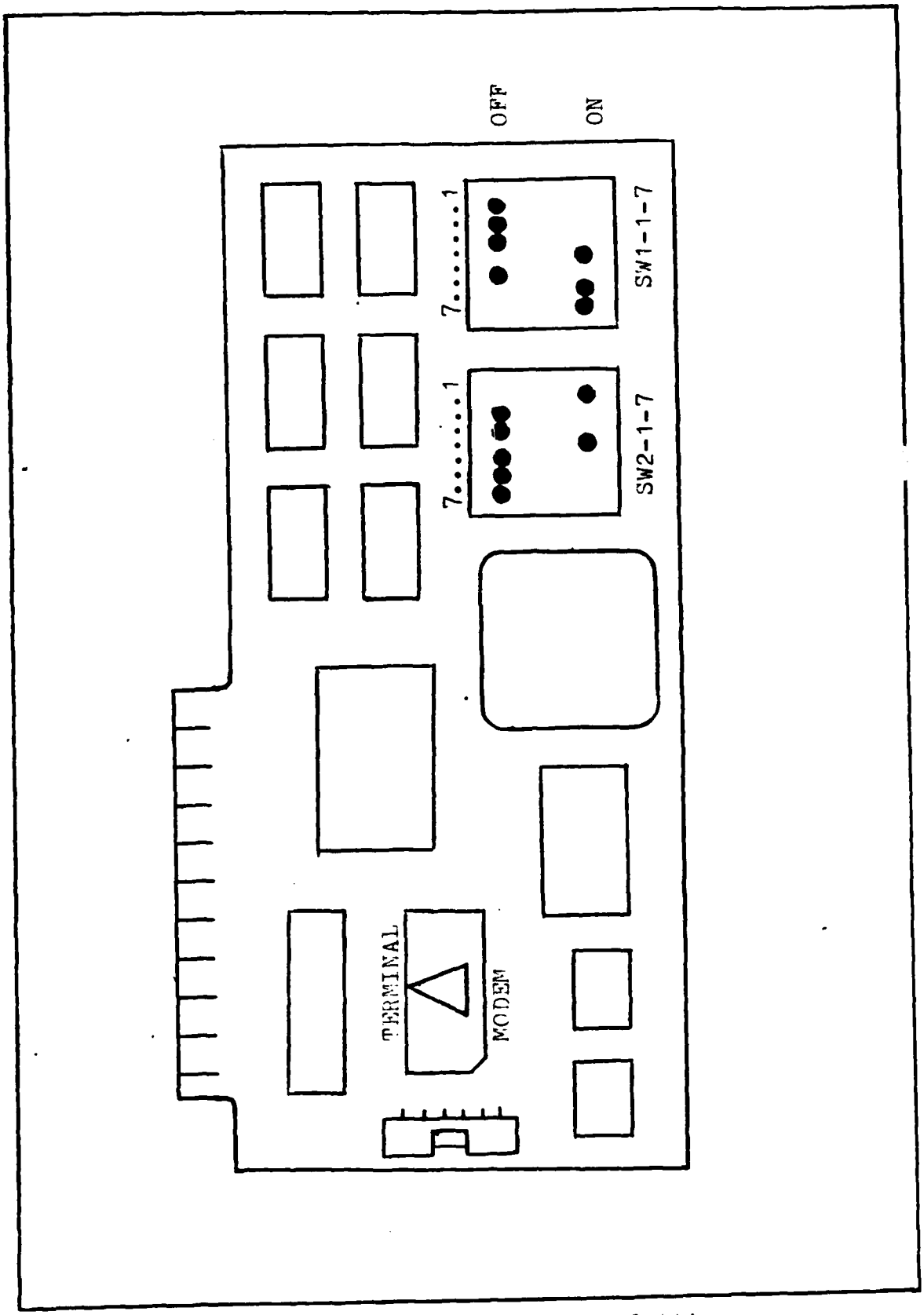


FIGURE 5. Cuper Serial Card Settings

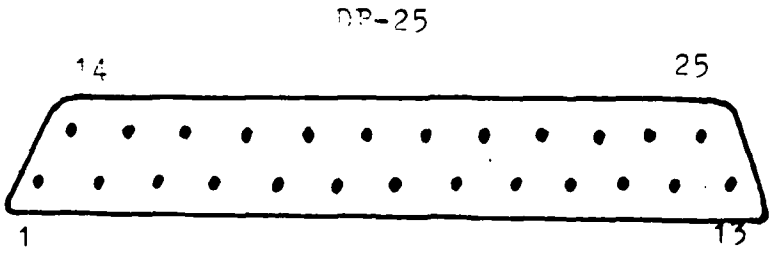
Additionally, the data was made to be listed in an 8F9.0 format. In other words, there are 8 values per row with each value containing up to 9 characters. All of the changes mentioned above were made to conform to the format MOSFUN expects. Examples of the original and new formats are shown in figures 3 and 4.

Hardware Changes . The connection between the APPLE 2+ and the PDP 11/03 was made with an APPLE Super Serial card and a modified 10 wire connector cable. The card was inserted into slot number two of the APPLE and a series of switches on the card were set to match the connecting device which, in this case, was the PDP. The switch settings, shown in figure 5, control the baud rate, number of stop bits, carriage return delay, line width, and linefeed. Switches SW1-1 through SW1-4 control the baud rate and were set for a value of 9600 to match the PDP. Switches SW1-5 and SW1-6 control the operating mode of which the printer mode was used. This mode is used when sending data to a printer, a terminal, or in this case, another computer without the use of a modem. The number of stop bits sent to signal the end of a character is controlled by SW2-1 and was set for one stop bit. The carriage return delay, controlled by SW2-2, was set equal to zero since the PDP can accept data much quicker than a printer, which normally needs a small delay. Switches SW2-3 and SW2-4 control the linewidth and were set to produce 80 characters per line. Switch SW2-5 controls linefeed generation and was set to not produce a linefeed since the PDP does this automatically. Switches SW2-6, SW2-7, and SW1-7 were

TABLE 2.

DB-25 Pin Connections For Connector Cable Exiting APPLE 2+

10-pin header	DB-25 connector	Signal Name
1	1	Frame Ground
2	2	Transmit Data
3	3	Recieve Data
4	4	Request To Send
5	5	Clear To Send
6	6	Data Set Ready
7	19	Secondary Clear To Send
8	7	Signal Ground
9	20	Data Terminal Ready
10	8	Data Carrier Detect



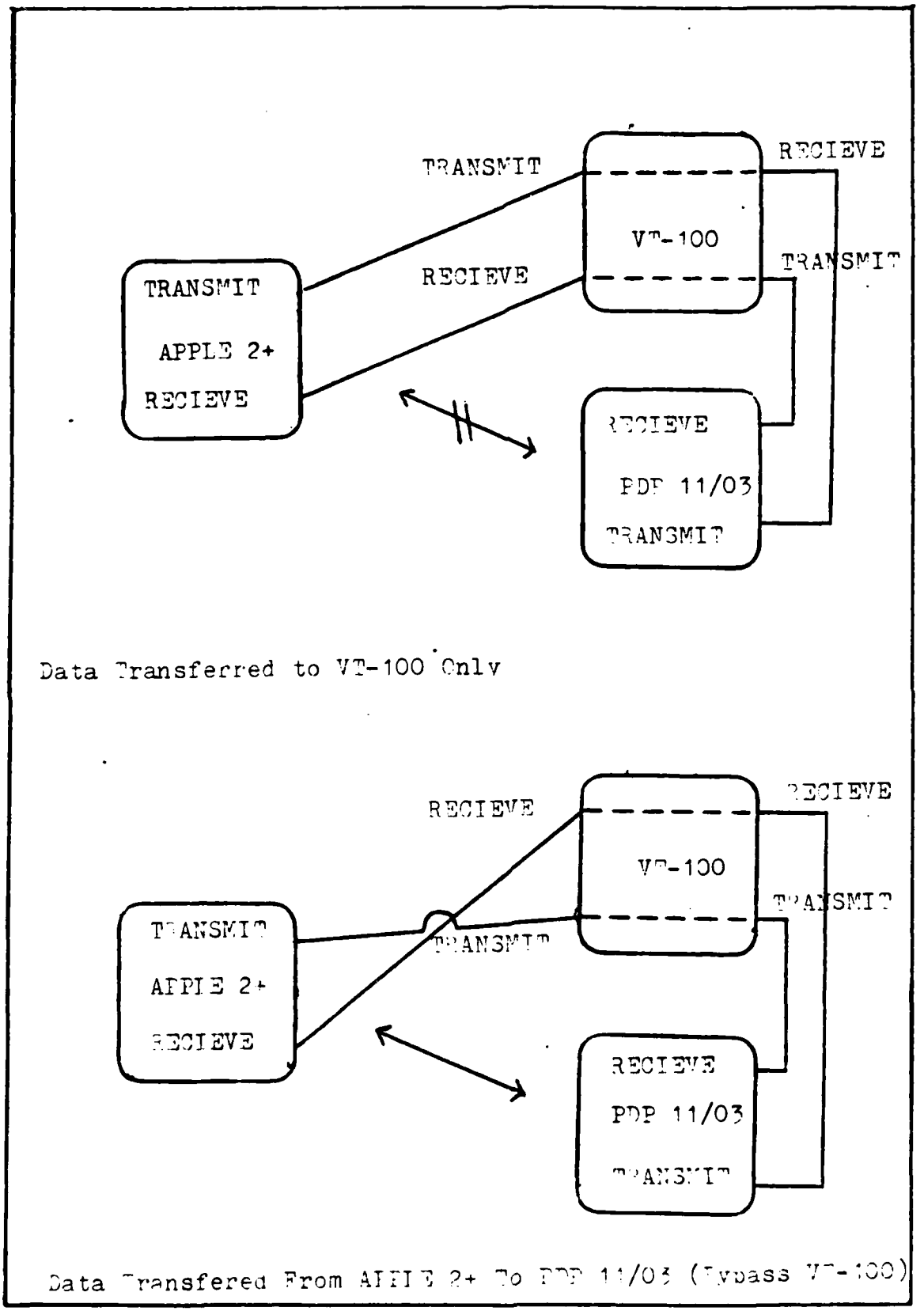


FIGURE 6. Transmit/recieve Data Connection

set at the default settings specified by the card manual. These switches are used for special cases and do not apply in this situation. The only other adjustment made was to put the card into printer, or terminal mode. This was accomplished by extracting and reinserting the jumper block on the card such that the triangle pointed towards terminal. This is also illustrated in figure 5.

The connecting cable between the PDP and the Super Serial card was the final step in the installation of the system. A ten strand flat cable and two male DB-25 connectors were used to make the connecting cable. The connector pin assignments for the ten pin header on the card and the corresponding pins on the DB-25 connector are shown in table 2. The opposite end of the cable, which connects to the PDP, has the same pin assignments except for the switching of pins two and three. These connections are those for transmitting and receiving data respectively. This switch is illustrated in figure 6. In the printer or terminal mode, the transmit pin of the Super Serial card is connected to the recieve pin of the terminal and visa versa. This same relationship exists between the PDP and the VT-100 terminal. Thus, in order for the APPLE to communicate directly with the PDP, the transmit and recieve cables were switched on one end of the connecting cable. The connection to the PDP was made by disconnecting the female end cable at the VT-100 terminal and reconnecting this end to the male end of the modified connector cable mentioned above. Now, data from the APPLE can be sent directly to the PDP to be put on

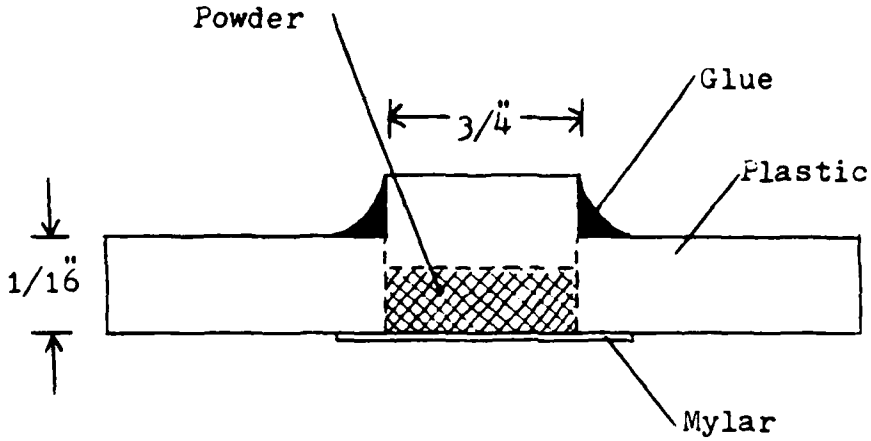


Figure 7. Powder Sample Preparation

a disk. The procedure for setting up and operating this system is included in appendix A.

Absorber Parameters

The form of the alloy samples tested in this study include: 1) atomized powder, 2) cold compacted wafers, and 3) cold compacted-hot vacuum degassed wafers. All of the above absorber forms were fabricated to have the optimum grams per square centimeter as determined experimentally. By starting near the theoretically calculated optimum value, an improved value was found through succesive trial runs with powder absorbers of different g/cm^2. Each trial run was compared with the others by the relative intensity of the lines present. The range of values tested were between 0.05 g/cm^2 and 0.15 g/cm^2. From these tests, a value of 0.1 g/cm^2 was chosen and applied to all other forms of the alloy samples.

The fabrication method of the powder test samples was chosen to provide a uniform density of powder across the area of the absorber. Of all the methods tried, only one was successful. This method consisted of putting a specific amount of powder into a 3/4 inch diameter hole which is in the center of a 1/16 inch thick , 2 inch square piece of plastic. One side of the hole was sealed with a piece of mylar bonded to the plastic with rubber cement. The other side was sealed with a 3/4 inch diameter 1/16 inch thick plastic disk resulting from the hole in the plastic sheet. This plug was lightly pressed into place with uniform pressure and the small space around the plug was then

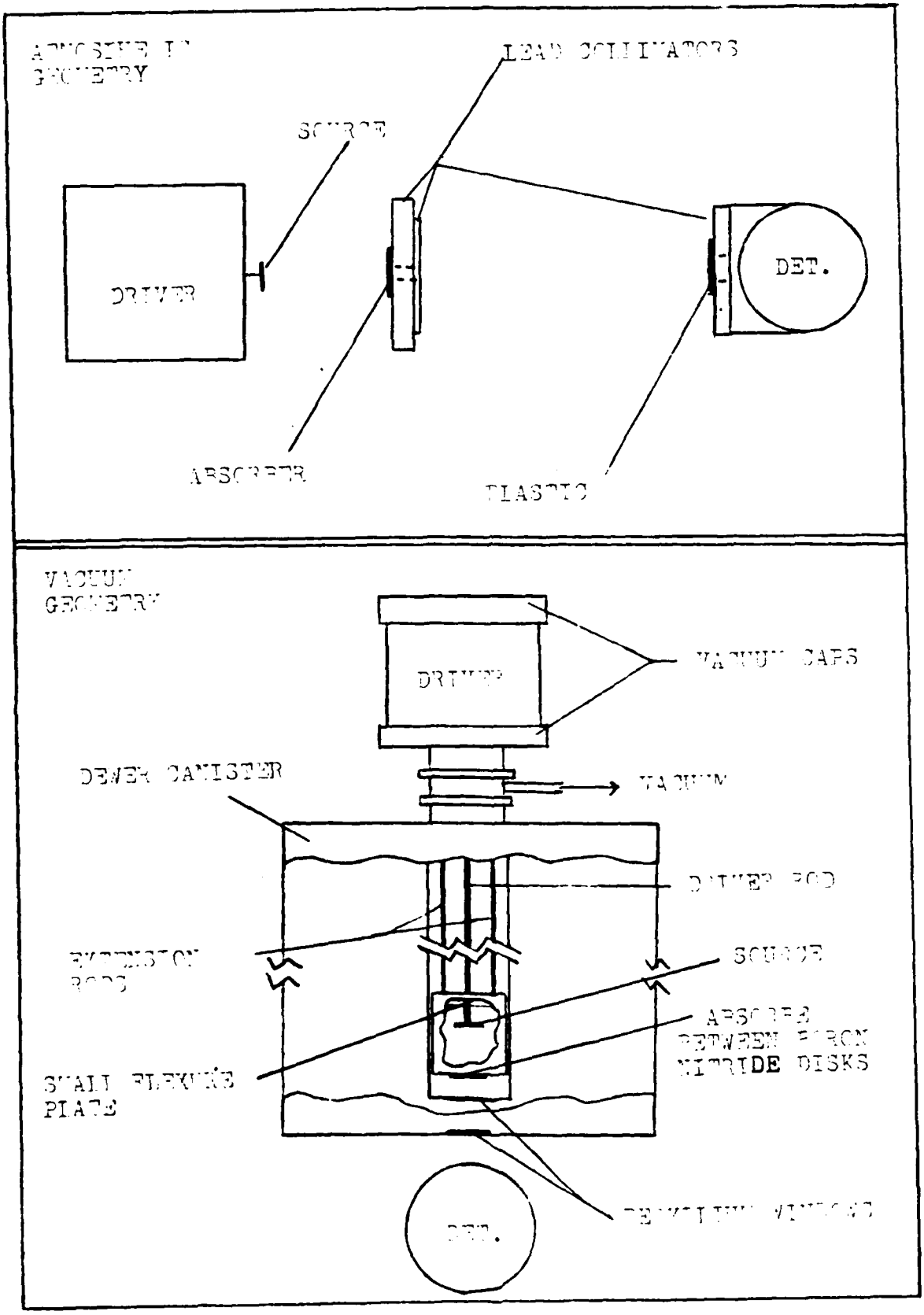


FIGURE 8. Experimental Geometry

sealed with DUCO cement. With this method, the thickness in g/cm^2 was determined by dividing the weight of the powder inserted into the hole by the area of the hole.

The fabrication of the other samples was accomplished by the High Temperature Materials Branch at the Air Force Materials Laboratory. The cold compacted absorber was made by first putting a known amount of powder into a 1/16 inch thick cardboard die with a 1/2 inch diameter hole. The die and powder were then subjected to 24,000 pounds per square inch for approximately 15 seconds with a hydraulic hand press. The thickness in g/cm^2 was then determined by dividing the weight of the wafer by its area. By trial and error, a value of 0.102 g/cm^2 was obtained. The cold compacted-hot vacuum degassed samples were made by first repeating the above procedure to obtain a pressed wafer. These wafers were then placed in a vacuum chamber for two hours where a vacuum of 3E-05 Torr was reached. Next, still under vacuum, the samples were heated for 30 minutes at approximately 860 F. The samples were then cooled to 212 F in a period of about 1.5 hours with a final vacuum of 1.5E-05 Torr being reached. The samples were then removed from vacuum and were exposed to atmospheric conditions for 15 minutes before being placed in a vacuum dessicator at room temperature.

Experimental Geometry

Due to component failure in the MS-900, all data for the alloy samples was obtained using the original Mossbauer system. The source used was 50 mCi cobalt-57 (date:5 June 1981)

diffused into a six micron thick rhodium matrix (8:8). The source was prepared by Amersham-Searle and produces, among other radiations, the 14.4 keV gamma ray of interest for this study. For the powder and cold compacted absorbers, the source-to-detector distance was 11.5 inches. A lead collimator with a 3/8 inch opening was placed 4 inches in front of the source, centered between the source and detector. The absorber was then placed on the front face of the collimator, centered over the hole. An additional lead collimator with a 7/8 inch opening was placed directly in front of the detector window and a plastic plate was placed over this hole to reduce the detection of 6.4keV X-rays emitted from the source.

For the cold compacted-hot vacuum degassed absorber, a vacuum system was used while aquiring data to insure that no properties of the hot vacuum degassing stage were changed by exposure to atmospheric conditions. The vacuum system was achieved by using a cylindrical dewar with a forepump and produced a vacuum of 2.79E-03 Torr. As can be seen in figure 8, the source to detector distance was reduced (to 6 inches) as well as the source to absorber distance (to 0.69 inches). Additionally, the plastic plate in front of the detector was removed because the new set-up has two berylium windows between the absorber and detector which is sufficient to absorb the 6.4 keV X-rays. For all three types of absorbers, the flyback mode was used and a run time of 48 hours was chosen to minimize statistical fluctuations in the spectra.

IV. Results and Discussion

In this section, the capabilities of the new computer based Mossbauer Spectrometer, as well as the results of all spectrum analysis will be presented. The spectra presented include calibration runs for both the new and original systems in addition to the spectra for each stage of alloy processing.

System Capabilities

The capabilities of the new computer based Mossbauer spectrometer include simplified operation, a larger memory for data storage, and quicker data analysis. Unlike the original system, there is not an extensive network of cables connecting many separate system components, thus resulting in a simplified assembly. Also, in addition to a simplified assembly, the number of operating controls are reduced, so setting the system for operation is much easier and faster. Once the system is operating, the data can be manipulated with a joystick and by commands entered on the keyboard. Then, at any time during data acquisition, the APPLE 2+ can be used for normal functions totally independent of the MS-900. This is possible since the MS-900 has its own random access memory (RAM) of 1024 channels with 24 bits (16 million counts) each (11). Once all data needed is obtained, it can be stored on a 5 1/4 inch floppy disk, printed out, and/or sent to the PDP to be stored on an 8 inch floppy disk and analyzed. The time it takes to send the 1024 data points to the PDP is only 1 1/2 minutes whereas it took over an hour to manually type in the 400 point spectrum of the

original system. Once the data is available to the MOSFUN program on the PDP, the same commands are used for analysis. However, with 1024 data points instead of 400, all operations take longer.

An example of a spectrum obtained by the new system and analyzed by MOSFUN is shown in figure 2. This figure is that of natural iron foil with respect to sodium nitroprusside. The spectrum is shifted 0.243 $\pm$ 0.006 mm/s with respect to sodium nitroprusside instead of the standard value of 0.26 $\pm$ 0.002 mm/s (9). The calibration of this spectrum could be corrected by acquiring data for natural iron foil for a longer period of time than done previously and inserting the more accurate peak channel locations into the DATI and DRIVE subroutines discussed earlier. The current natural iron foil spectrum was obtained in only 4.25 hours and thus the peak locations were subject to statistical fluctuations. For a step by step guide for setting up and operating the new system, see appendix A.

Alloy Results

The results for the natural iron calibration run and those for each stage of alloy proccessing are shown in table 3. All isomer shifts in this table were adjusted to be relative to natural iron. The spectra of the calibration run and those of the alloy samples were obtained on the original Mossbauer spectrometer as mentioned earlier, and are shown in figures 9-13. Thus, the velocity scale on all of these figures is relative to cobalt 57 in a rhodium matrix.

Table 3.

MOSFUN Results for Calibration and Alloy Samples With Respect to NFE

Sample	Run Time (hrs)	Isomer Shift (mm/s)	Relative Peak Intensity (%)	Half Width (mm/s)	Peak Location (mm/s)
NFE Calibration (Original System)	21.9	0.000			
Peak # 1			26.2±4.7	0.144±0.011	-5.280±0.037
2			21.9±5.2	0.140±0.012	-3.056±0.027
3			13.2±10.6	0.132±0.020	-0.832±0.025
4			13.2±10.6	0.132±0.020	00.832±0.023
5			21.9±5.2	0.140±0.012	3.056±0.018
6			26.2±4.7	0.144±0.011	5.280±0.024
NFE Calibration (MS-900 System)	4.25	0.000			
Peak # 1			15.99±3.3	0.180±0.009	-5.316±0.026
2			14.68±4.0	0.149±0.009	-3.077±0.018
3			8.32±7.5	0.144±0.016	-0.844±0.013
4			8.32±7.5	0.144±0.016	0.844±0.017
5			14.68±4.0	0.149±0.009	3.077±0.013
6			15.99±3.3	0.180±0.009	5.316±0.018

Table 3. (Continued)

Sample	Run Time (hrs)	Isomer Shift (mm/s)	Relative Peak Intensity (%)	Half Width (mm/s)	Peak Location (mm/s)
Alloy Samples:					
Powdered	48	0.181±0.025			
Peak # 1			19.78±3.2	0.193±0.047	-0.032±0.039
2			20.90±3.3	0.189±0.037	0.395±0.069
Cold Compacted	48	0.181±0.031			
Peak # 1			19.46±3.5	0.193±0.064	-0.029±0.049
2			21.10±3.7	0.181±0.048	0.390±0.091
Cold Compacted/ Hot Vacuum Degassed (Gaussian)	48	0.204±0.029			
Peak # 1			17.88±2.5	0.271±0.057	-0.007±0.03
2			20.36±3.9	0.183±0.031	0.416±0.067
Cold Compacted/ Hot Vacuum Degassed (Lorentzian)	48	0.206±0.078			
Peak # 1			13.12±6.4	0.173±0.029	-0.109±0.050
2			12.05±6.4	0.173±0.029	0.115±0.019
3			19.91±2.4	0.173±0.029	0.411±0.058

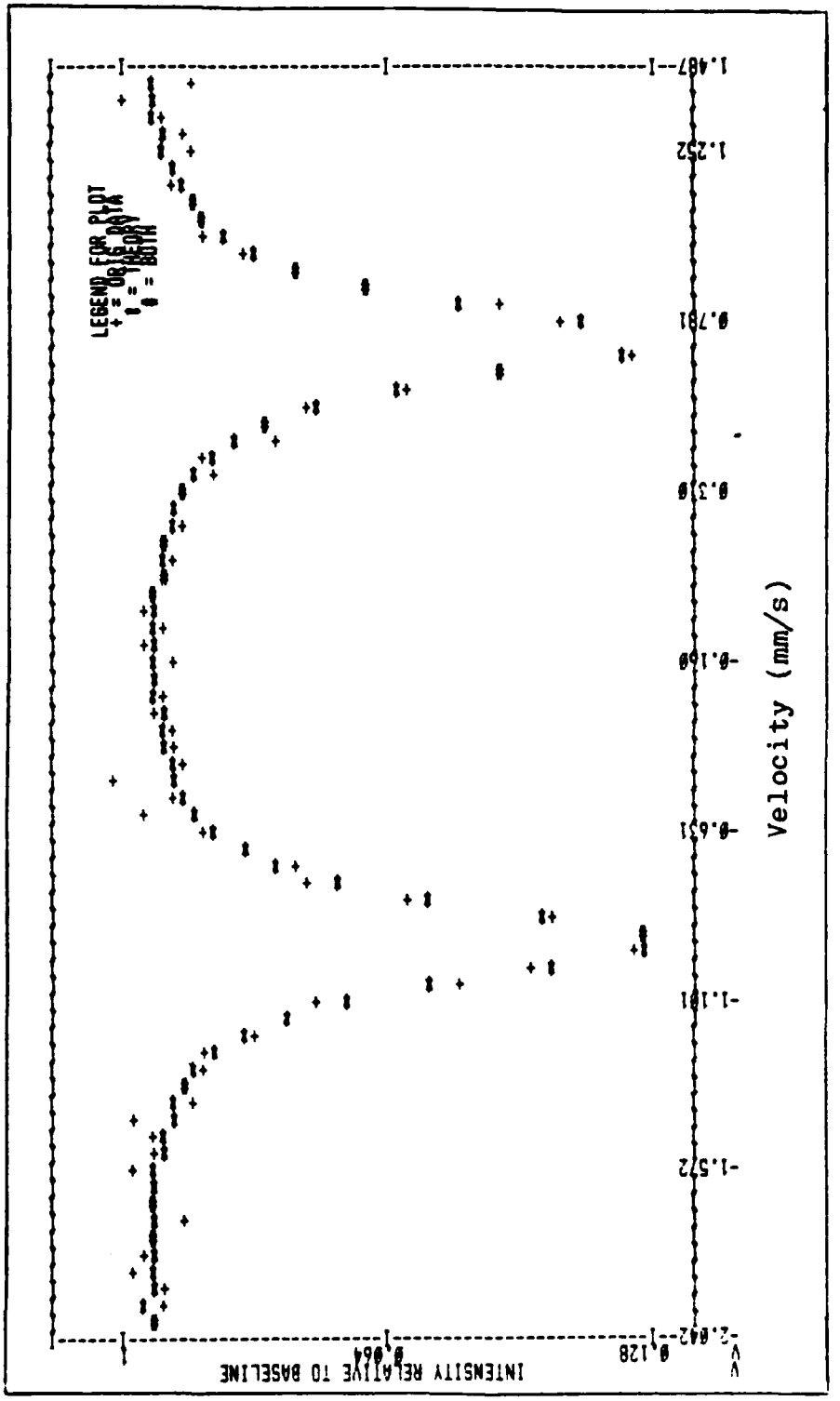


Figure 9. Natural Iron Results for Peaks 3 and 4 from Original Mossbauer Spectrometer (with respect to Co57 Source)

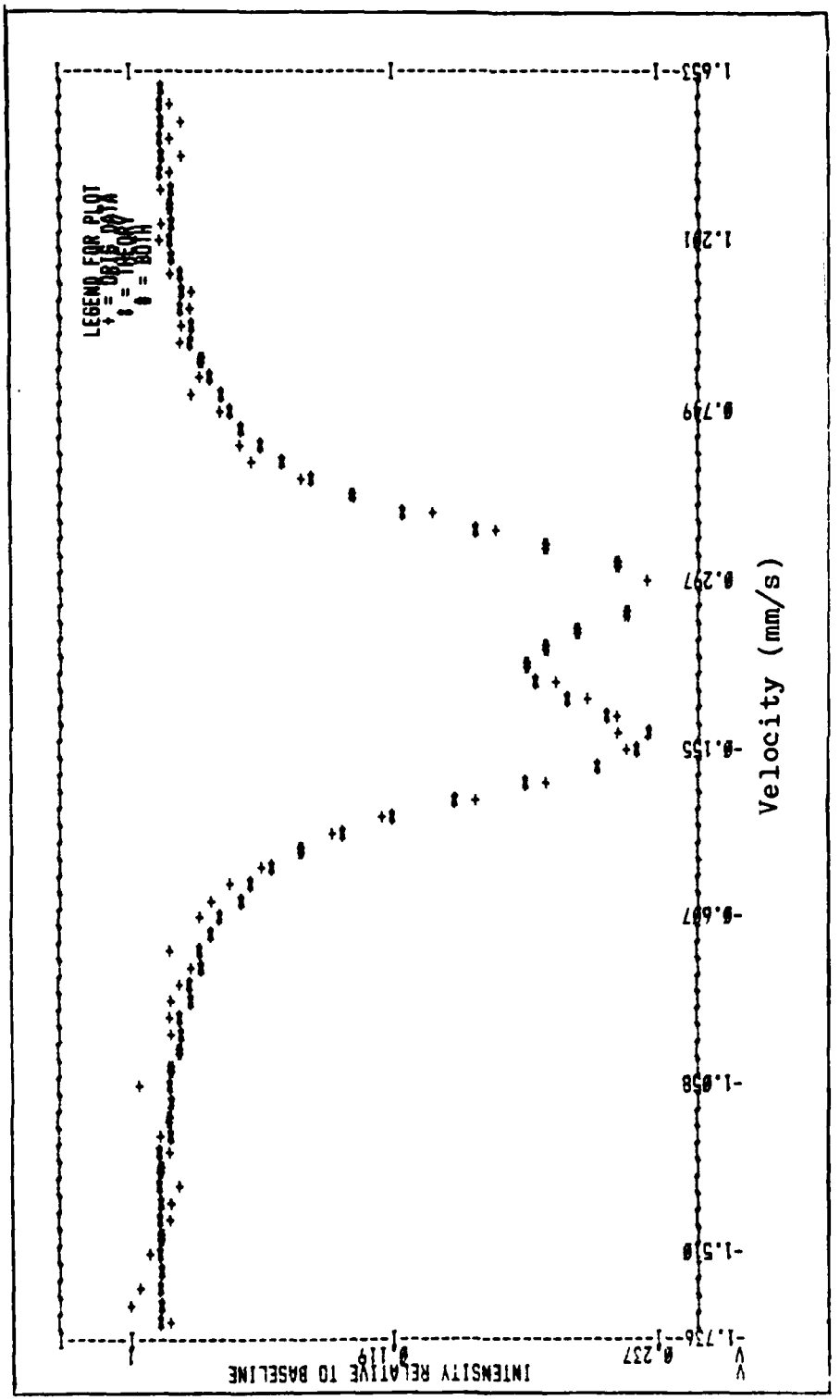


Figure 10. Results for Alloy Powder
(With respect to Co57 Source)

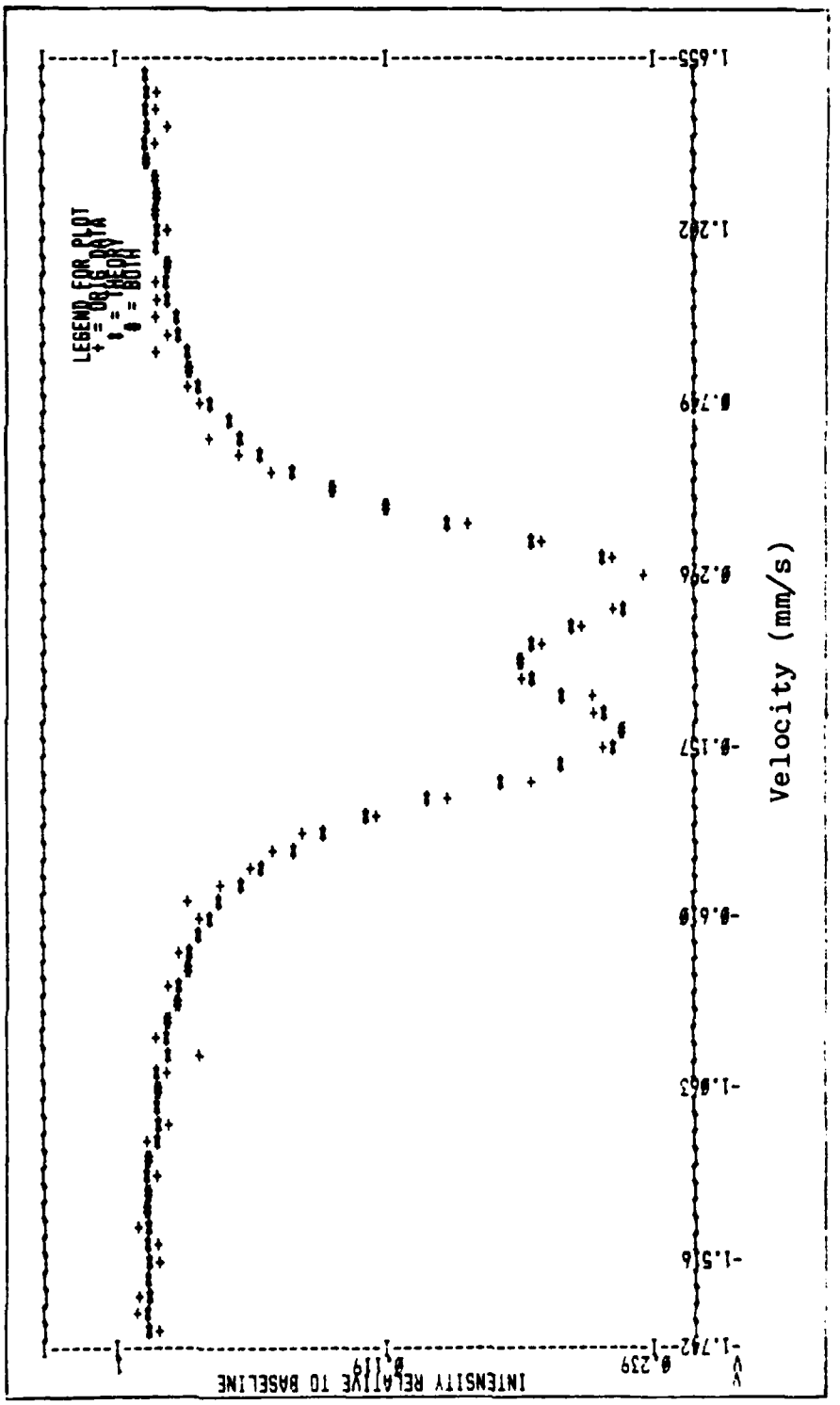


Figure 11. Results for Cold Compacted Alloy (With respect to Co57 source)

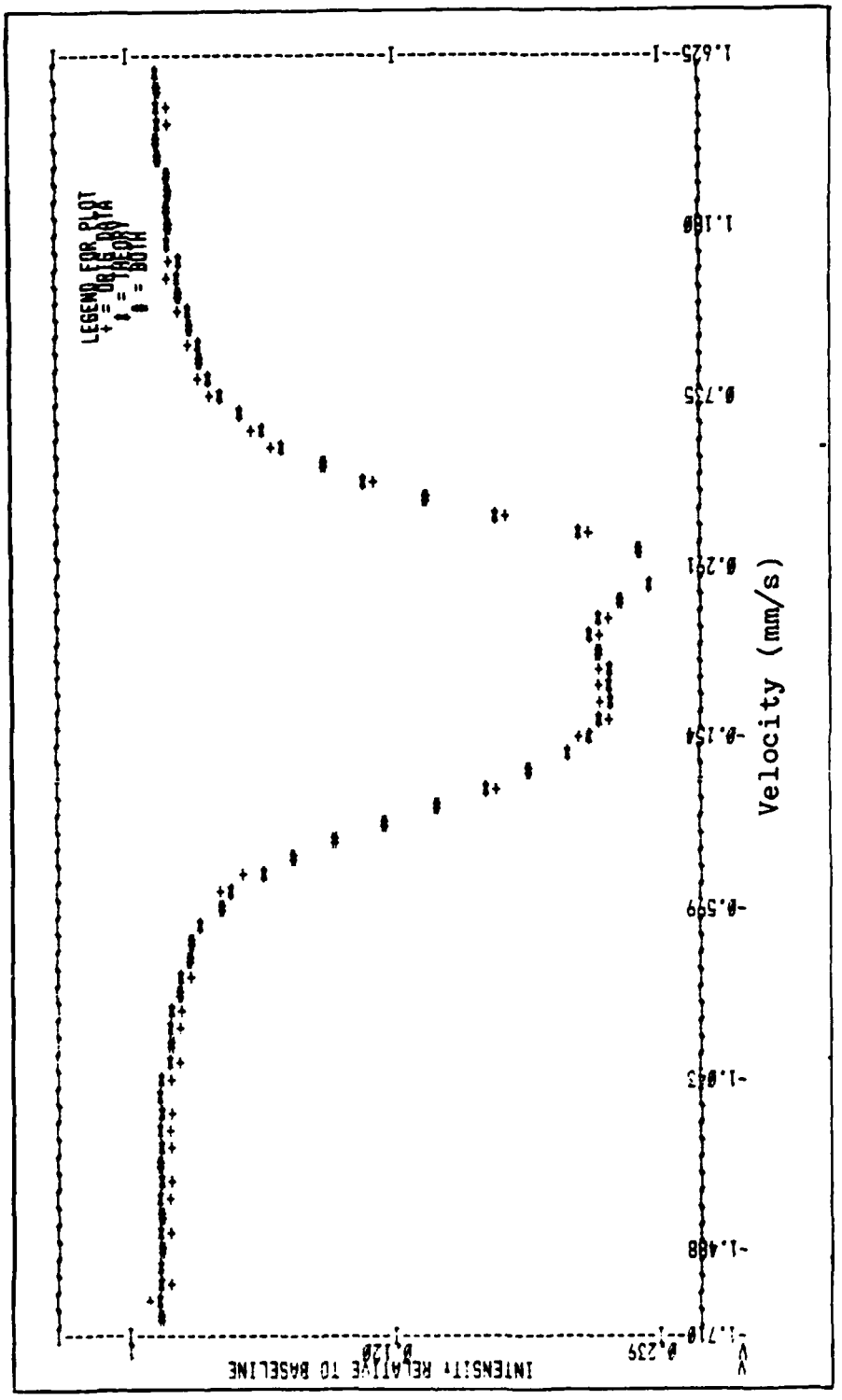


Figure 12. Results for Cold Compacted/Hot Vacuum Degassed Alloy (with respect to Co57 source)(2 line Gaussian fit)

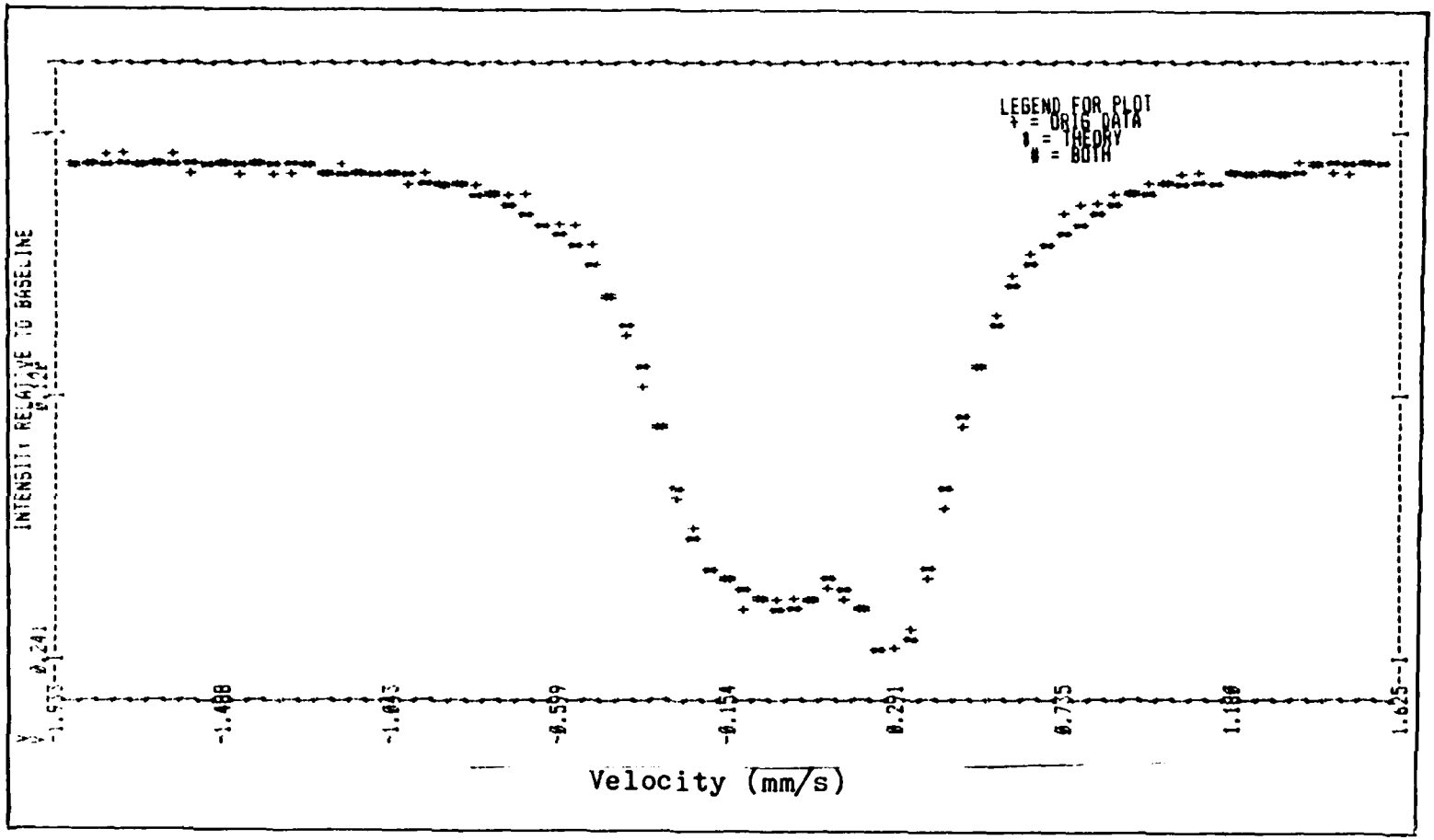


Figure 13. Results for Cold Compacted/Hot Vacuum Degassed Alloy (with respect to Co57 source) (3 line Lorentzian fit)

All of the spectra shown here were fitted by MOSFUN using the Lorentzian-intensity theory with a gradient iteration refinement. The only exception was that of figure 12. This spectrum was fitted using the Voigt-Intensity theory for better results. The parameters varied to fit the spectra included: 1) baseline, 2) geometry factor (a measure of the amount of baseline curvature), 3) line intensity (each line independent of the other), 4) isomer shift, 5) quadrupole splitting (separation of doublet lines), and 6) half width at half maximum. In addition to these, an additional parameter, form, was assigned to each line of the Voigt fitted spectrum.

Figure 10 shows the spectrum of the atomized powder form of the alloy. As can be seen, the spectrum is that of a nearly symetric doublet. From this spectrum, it is not clear as to whether the doublet is a result of quadrupole splitting or two different compounds formed in the lattice. However, it is obvious that there is no hyperfine splitting present which indicates that agglomeration of iron atoms is unlikely. The cold compacted alloy results are shown in figure 11. Basically, the spectrum is identical to the powder alloy spectrum except for a slight decrease in the left peak intensity. However, due to the statistical errors of the parameter values, the peak intensities overlap and thus nothing conclusive can yet be stated as to whether quadrupole splitting is the mechanism present or whether a decrease in one of the two compounds occured. The results for the cold compacted-hot vacuum degassed samples are shown in figures 12 and 13. Due to the broadening of the left line, a new

theory was needed to obtain a good fit. From figure 12 and table 3, it can be seen that the left peak has reduced in intensity and become more Gaussian shaped as opposed to Lorentzian. Even with statistical errors involved, the peak intensities are significantly different. In order to determine the cause of the left peak broadening and decrease in intensity, a new theory was considered. A spectra fit was attempted using three lines, letting each line's intensity and position vary independently. The results, shown in figure 13 and Table 3, indicate that the spectra is that of a quadrupole doublet (left two peaks) and a single line (right peak). Thus the left peak broadening is most probably due to quadrupole splitting. These results indicate that the two compound theory is the mechanism present. If this is the case, then only the third processing stage, which involved hot vacuum degassing, significantly changed the lattice structure. Although it is believed that two different compounds are present in the alloy, it is still not known what they are. The Fe Al_6 compound, which was expected to be seen, was not. Unfortunately, all efforts to match the peaks of this spectra to previous work on Al-Fe-Ce compounds has been unsuccesful.

V. Conclusions and Recomendations

Conclusions

With the new system completed, Mossbauer spectra can easily be obtained, displayed, and analyzed. In addition, the system eliminates time normally wasted transferring data manually. The only problems observed, other than the system breaking down, were minor. These include poorly made front panel switches and rear panel sockets, slow response from joystick commands, and an incomplete instruction manual.

The spectra of the alloy samples show that two compounds are formed in the gas atomization stage and remain unchanged until the hot vacuum degassing stage. No spectra were obtained for further processing stages due to a lack of prepared samples. However, it is clear that Mossbauer spectrometry is useful for following changes in the lattice structure due to mechanical processing.

Recommendations

There are several changes or additions possible which would make the new system more valuable of a tool. First of all, the MS-900 and VT-900 (motor) should be equipped with a Moire interferometer to produce velocity data as the old system does. If this is done, Pate's modified version of MOSFUN could be used with minor changes. Secondly, the problems mentioned above concerning faulty switches and sockets should be resolved by replacing them. Thirdly, since the Physics Department of the Air Force Institute of Technology has limited access to an APPLE 2+

or 2e computer, it is recomended that the MS-900 be directly interfaced with the PDP 11/03. A brief discussion of the problems for this interfacing is included in appendix B. Fourth, it is recomended that the MOSFUN program be modified to accept triangular mode spectra.

As for the alloy studied, it is recomended that hot compacted-hot vacuum degassed and extruded samples be studied to follow the changes in the spectra due to these processing stages. Lastly, it is recomended that all samples be run at liquid nitrogen temperatures. This may result in new lines being revealed or sharpening of the present lines.

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APPENDIX A

Assembly and Operating Instructons

Assembly

1. It is assumed that an APPLE 2+ Or 2e computer with a monitor is set up with a disk drive in slot #6, a printer (optional) in slot #1, and a joystick connected according to its specific instructions. Slots #2 and #4 should be vacant.
2. Remove the top of the computer and place the Mossbauer interface card, MS-900-100, into slot #4 and bring the ribbon cable through the rear panel of the computer.
3. Place the Super Serial Card, with the switch settings set as discussed earlier, into slot #2 of the computer and mount the female DB-25 connector into the rear panel of the computer.
4. Place the cover back on the computer and connect the computer's power cord into the upper 115 VAC OUT power outlet on the rear panel of the MS-900. Plug the monitor's power cord into the lower 115 VAC OUT outlet.
5. Making sure that the power on the MS-900 is OFF, connect the ribbon cable from computer slot #4 to the rear panel connector of the MS-900 labeled COMPUTER.
6. Connect a mini-coax cable from the rear panel of the MS-900, marked 24V, to the connector marked POWER on the preamplifier.
7. Connect a second mini-coax cable from the rear panel of the

MS-900, marked ANALOG IN, to the connector marked OUTPUT on the preamplifier.

8. Connect a high voltage supply (not from MS-900) to the preamplifier/detector assembly.
9. Make sure that the three toggle switces marked EXT/INT are in the DOWN internal position and then connect the Mossbauer drive cable with the BLUE hexagonal connectors to the rear panel mating connector of the MS-900, labeled VT-900, and to the VT-900.
10. Connect the power cord to the female receptacle marked 115 VAC and plug the other end into the wall (power source).
11. Finally, connect one end of the 10 wire flat ribbon to the DB-25 connector of the Super Serial Card.
12. Refer to figure 14 for a block diagram of the system set-up.

Operation

1. With the power switch for the APPLE and monitor in the ON position, turn on the power switch on the front panel of the MS-900. The MS-900 controls the power system now.
2. Press the start button and the YELLOW light should come on.
3. Load the Mossbauer Master program into the disk drive and boot the program by typing PR#6 on the keyboard. The program menu should appear on the monitor.
4. Set the sampling time (time that a channel is open to receive data) to the desired value. The first two digits give the sampling time in microseconds, and the third digit is the multiplier in exponents of 10. A value of 200

microseconds is currently used.

5. The lower level and upper level discriminators of the SCA are set in a modified pulse height analysis mode. This mode is engaged by pressing the PHA button ONCE. With the LLD set at the lowest value and the ULD set at the highest value, press the GREEN button marked STORE. Now press the A key to start data acquisition. The CLEAR button may be used to erase the spectrum at any time. The scale of the spectra can be increased or decreased by moving the joystick up or down. Once a spectrum is seen, identify the 14.4keV peak and adjust the gain until this peak is centered on the screen. At this point one should see a pulse-height spectrum with three numbers on the bottom of the screen. From left to right, these numbers are the channel number, number of counts in that channel, and the full scale number of counts displayed. To select the 14.4keV peak only, move the vertical line cursor to the left edge of the peak and increase the LLD until no more counts are seen on the left side of the cursor. The cursor is controlled by moving the joystick left or right. Now move the cursor to the right edge of the peak and decrease the ULD until no more counts are seen on the right side of the cursor. To stop acquiring data, press the STORE button again and the light should go out. Now press CLEAR to erase the memory. If the PHA button is pressed again, the light will still be on and the normal PHA mode is engaged.

6. To obtain a Mossbauer spectrum, first press the ESC button

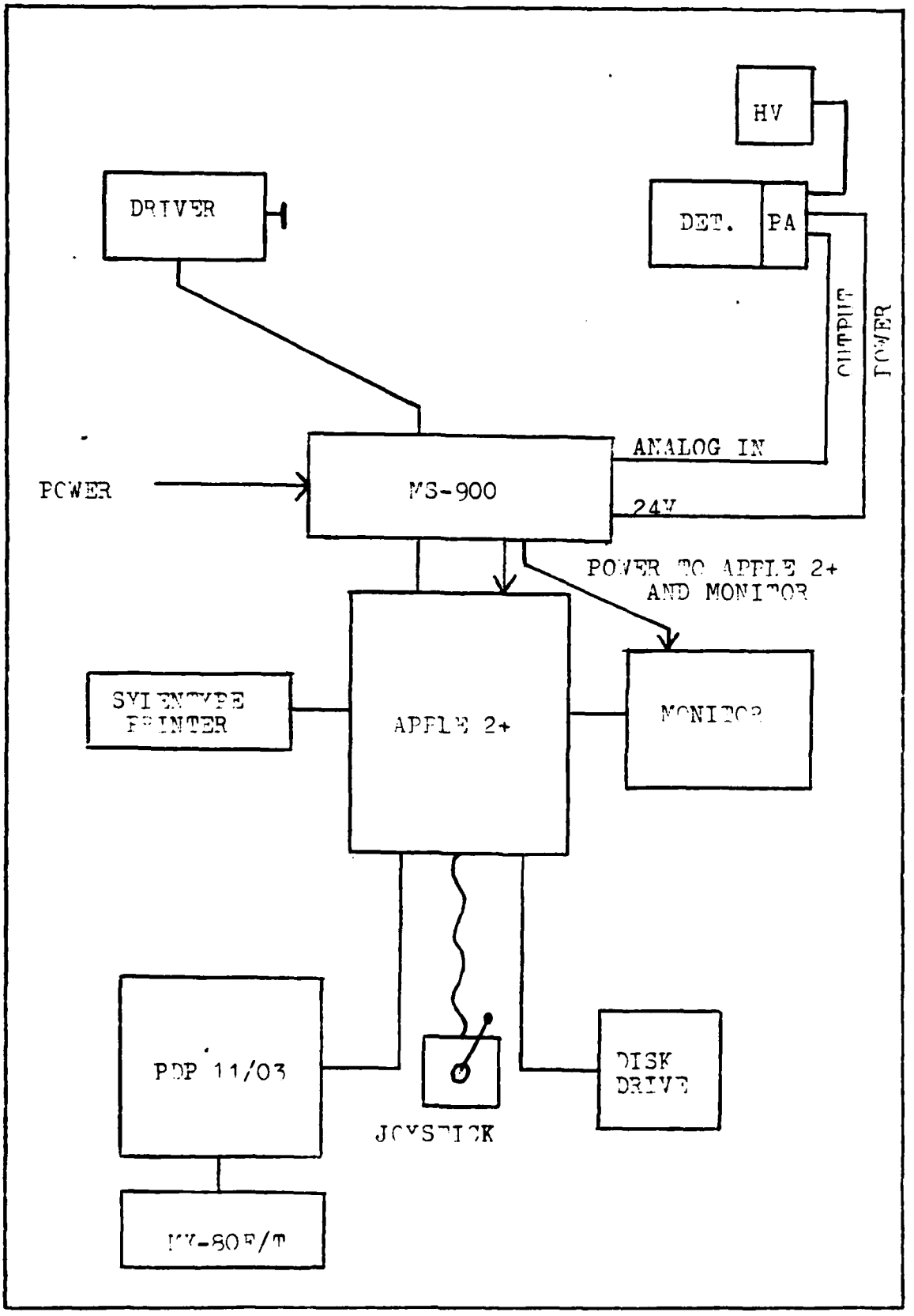

FIGURE 14. New Spectrometer Set-Up

on the keyboard to return to the menu. Next, adjust the velocity values on the thumbwheel switches. For a full spectra, set the MAX VELOCITY to zero and the MIN VELOCITY to 6.0. Unlike the original spectrometer, these settings can be varied to produce a window though which only a part of the spectrum is acquired. Now press either the flyback or triangular mode button. The VT-900 driver should begin oscillating. The symmetry is now set by turning the symmetry potentiometer until the equilibrium position of the flexure plate is centered. Now, by pressing the STORE button and entering A on the keyboard, a Mossbauer spectrum should be seen.

7. Other buttons on the front panel include SUB, SINGLE, TIME, and an unmarked blue button. The SUB button is used to subtract, instead of add, counts from the spectrum. With the STORE button OFF, a single subtraction scan can be executed by activating the SINGLE button and pressing the START button. The TIME button is activated to store the number of pulses from the crystal controlled clock. When not activated, the number of sweeps are recorded. In either case, this data is stored in the first two channels. The blue button is pressed to activate the acquiring of velocity data if a Moire interferometer is installed.
8. At any time during operation, one can return to the menu by pressing the ESC key. This will not affect data acquisition at all. To use the APPLE for other purposes while data is being collected, return to the menu and type D for

displaying data. Then use CTRL-C to stop the program. Finally, type TEXT to exit from the graphics mode.

9. Once all data needed is acquired, simply deactivate the STORE button. Next, return to the menu and follow the diections given. To send the data to the PDP, choose the "print spectral data option". Before entering all the information requested by the program, boot the PDP and type EDIT FILENAME.EXT/C on the PDP terminal. Then disconnect the DB-25 connector from the back of the VT-100 and connect it to the male DB-25 at the other end of the 10 wire ribbon coming from the Super Serial Card. Now enter all information about the spectrum as prompted by the program. One should then have to wait 90 seconds until all data is transferred. Now one should reconnect the VT-100 to the PDP and save the file by using the GOLD 7-EXIT command of the keyboard editor.

10. Before the file can be analyzed, one defect in the file must be eliminated. When the data is sent over, an extra line is placed at the beginning of the file. This line must be deleted before the file can be analyzed.

11. If the data is that of a calibration spectra, the peak channel locations (a total of 6) should be entered into the DATI and DRIVE subroutines of MOSFUN. The peak locations can be found by printing the data file and manually searching for them. Once found, follow the directions at the beginning of the MOSFUN program for editing MOSFUN subroutines. A more detailed description is provided in appendix A of Pate's

thesis.

12. Finally, to obtain a printout of the spectrum, the printer connected to the Apple should be used. The spectra printed by the MOSFUN program is very spread out since 1024 data points are plotted instead of 400. The ZOOM GRAPHICS program donated for use with an APPLE computer system is capable of printing spectra or parts of spectra in many different sizes and formats.

APPENDIX B

Interfacing the MS-900 Directly to the PDP 11/03

An interfacing of the MS-900 directly to the PDP would result in a simplified operation and eliminate the need for an APPLE computer system. Once completed, the PDP would perform all of the functions previously done by the APPLE and there would not be a need to connect/disconnect cables in order to send data to the PDP.

The work involved for this interfacing involves both hardware connections and software changes. From discussions with Captain Paul Bailar, U.S.A.F, who had previously worked on a spectrometer - computer interfacing, a basic outline of the problem was obtained (12). First, the interface card for the MS-900 should be studied to understand exactly what functions it performs. This would enable one to build a similar interface for joining the MS-900 and the PDP. Second, once a hardware connection is made, software will have to be written for the PDP so that it may understand the signals sent from the MS-900. Third, the Mossbauer Master program will have to be studied so that it may be re-written for the PDP. The current version is written in BASIC for an APPLE computer and uses machine specific commands. Thus, a simple translation to FORTRAN is not possible. Finally, in order for the spectra to be displayed on a terminal as it is currently done, graphics capability will have to be added to the VT-100 or the VT-100 can be replaced with a VT-55

terminal. In either case, the FORTRAN version of the Mossbauer Master program should permit the joystick functions to be replaced by keyboard commands.

APPENDIX C

Listings For:

Mossbauer Master program

Subroutine DATI

Subroutine DRIVE

```
2  HIMEM: 34300
6  TEXT
7  POKE 961,0: POKE 962,0: POKE 975,5
10 D$ =  CHR$ (13) +  CHR$ (4)
20  TEXT : HOME
30  PRINT "          MS-900": PRINT
40  PRINT "MOSSBAUER SYSTEM"
50  PRINT : PRINT : PRINT
60  PRINT "(A)QUIRE SPECTRAL DATA": PRINT
70  PRINT "(S)TORE  SPECTRAL DATA ON DISK": PRINT
80  PRINT "(R)ETRIEVE SPECTRAL DATA FROM DISK": PRINT
90  PRINT "(P)RINT SPECTRAL DATA": PRINT
100  PRINT "(T)RANSMIT SPECTRAL DATA": PRINT
105  PRINT "(D)ISPLAY SPECTRAL DATA": PRINT : PRINT
110  PRINT : PRINT "PLEASE SELECT ONE OF THE ABOVE"
120  PRINT : GET A$
125  HOME
130  IF A$ = "A" THEN 1010
140  IF A$ = "R" THEN 3000
150  IF A$ = "S" THEN 2008
160  IF A$ = "D" THEN 4000
170  IF A$ = "P" THEN 4500
250  GOTO 20
1010  IF  PEEK (34688) = 8 THEN  GOTO 2004
1030  GOTO 2003
1900  PRINT "1111111111111111111111111111111111111111111111111111111111111111
     1111111111111111111111111111111111111111111111111111111111111111
     11111111111111111111111111111111111111111111"
2000  PRINT "2222222222222222222222222222222222222222222222222222222222222222
     2222222222222222222222222222222222222222222222222222222222222222"
2001  PRINT "3333333333333333333333333333333333333333333333333333333333333333
     3333333333333333333333333333333333333333333333333333333333333333
     3333333333333333333333333333333333333333333333333333"
2003  PRINT D$;"BLOAD HISPDDATAGRAB"
2004  CALL 34688
2005  GOSUB 5000
2006  GOTO 2004
2008  PRINT "WHAT IS THE NAME OF THE DATA"
2010  PRINT "TO BE SAVED ON THE DISK ?": PRINT : PRINT
2020  INPUT " ";A$
2030  PRINT : PRINT : PRINT : PRINT "DATA GOING OUT TO DISK"
2040  PRINT D$;"BSAVE ";A$;",A$8900,L$C00"
2050  GOTO 20
3000  PRINT "WHAT IS THE NAME OF THE DATA"
3005 D$ =  CHR$ (4)
3010  PRINT "TO BE RETRIEVED FROM                                    THE DISK ?": PRINT
     : PRINT
3020  INPUT " ";A$
3025  PRINT : PRINT : PRINT : PRINT "DATA COMING IN FROM DISK"
3030  PRINT D$;"BLOAD ";A$
3050  GOSUB 5000
3060  GOTO 3050
4000  GOSUB 5000
4010  GOTO 4000
4500  TEXT : PRINT "WHAT IS THE NAME OF THE SPECTRUM ?"
4510  INPUT " ";A$
```

```
4511  INPUT "ENTER TOVR,NOVR,N,PERI,NORV SEPARATED BY COMAS.";TV,NO,N,PE,N
    O
4512  INPUT "FORMAT? (EX. 8F9.0) ";F$
4520  INPUT "SEND DATA TO SILENTYPE OR PDP-11? (1 OR 2):";Z
4521  PR# Z
4530  PRINT : PRINT A$
4531  PRINT F$
4532  PRINT TV;",";NO;",";N;",";PE;",";NO;",";MP;",";NS
4540 BASE = 35072
4550  FOR T = 0 TO 3048 STEP 24
4570  FOR S = 0 TO 21 STEP 3
4580 X =  PEEK (BASE + T + S) +  PEEK (BASE + T + S + 1) * 256 +  PEEK (BA
    SE + T + S + 2) * 65536
4581  IF X < 10000000 THEN Q = 3
4582  IF X < 1000000 THEN Q = 4
4583  IF X < 100000 THEN Q = 5
4585  IF X < 10000 THEN Q = 6
4586  IF X < 1000 THEN Q = 7
4587  PRINT  SPC( Q - 1)X;
4590  NEXT S
4600  PRINT
4605  IF  PEEK (49152) = 155 THEN 4620
4607 Q = 0
4610  NEXT T
4620  PR# 0
4630  GOTO 20
5000  REM  DISPLAY SUBROUTINE
5005  IF  PEEK (2783) <  > 160 THEN  GOSUB 6000
5010  IF  PEEK (34304) = 162 THEN 5030
5020  PRINT : PRINT D$;"BLOAD JOYSTICK"
5030  CALL 34304
5040 BASE = 35072
5042 CH =  PEEK (961) +  PEEK (962) * 256
5045 C3 = CH * 3
5050 COUNT =  PEEK (C3 + BASE) +  PEEK (C3 + BASE + 1) * 256 +  PEEK (C3 +
    2 + BASE) * 65536
5055  VTAB (21)
5057  PRINT "                    ";: HTAB (27): PRINT "          ";
5058  HTAB (1)
5060  PRINT CH;: HTAB (10): PRINT COUNT;: HTAB (24): PRINT 2 ^ (24 -  PEEK
    (975));"  FS"
5070  FOR T = 0 TO 39
5080  POKE 2640 + T, PEEK (1616 + T)
5090  NEXT
5100 A =  PEEK (49152)
5110  IF A <  > 155 THEN  RETURN
5120  GOTO 20
6000 T = 2640:U = 2768:V = 2896:W = 3024
6010  FOR S = 0 TO 39
6020  POKE (S + T),160
6030  POKE (S + U),160
6040  POKE (S + V),160
6050  POKE (S + W),160
6060  NEXT S
6070  RETURN
```

```
      SUBROUTINE DATI (N1,N2,N3)
C
      COMMON /UNIT/ NRD,NWR,NCR,LPR,LFD,NFL,NVS,MAXN,MAXM,MAXF,NV(121)
      COMMON /DAT/  VMAX,PERI,Y(1024),ID(40),NDRV,N,NF,VEL(10)
      COMMON /THEO/ F,P(32),DF(32),NTEO,M,MF,KTEO(20),KP(32)
      COMMON /FLD/  P3,B,V,VCON(65),V1,V2,GEO,B0,C0,NFLD,MSH,MPLEX,IHH
      COMMON /TRA/  IN(81),OUT(16)
C
      DIMENSION KFRM(8),IFRM(8),INST(4)
      DATA IFRM/2H(1,2H0F,2H8.,2H0),2H  ,2H  ,2H  ,2H  /
      DATA INST(1)/1HL/,INST(2)/1HZ/,INST(3)/1HH/,INST(4)/1H*/
      DATA NY/1HY/
C
C     N1 = INPUT UNIT
C     N2 = FACTOR FOR SEARCHING DROPPED CHANNELS
C     N3.NE.0 ERROR RETURN
C
      N9=N2
      IF(N1.EQ.0) GOTO 285
      READ(N1,5200,END=202)(ID(I),I=1,40)
      READ(N1,5200,END=202)(KFRM(I),I=1,8)
      READ(N1,5210,END=202)(IN(I),I=1,80)
      GOTO 203
C
C     EOF
C
  202 WRITE(NWR,6205) N1
      N=0
      N3=1
      RETURN
  203 CALL TRANS(NN)
      IOVR=OUT(1)
      NOVF=OUT(2)
      N=OUT(3)
      PERI=OUT(4)
      NDRV=OUT(5)
C     MPLEX=OUT(6)
C     NST=OUT(7)
      NST=189
  205 IF (N.EQ.0) N=1024
C
C     MORE THAN MAXN POINTS
C
      IF(N.LE.MAXN) GOTO 220
      N=0
      N3=1
      WRITE(NWR,6200) MAXN
      RETURN
  220 IF(NDRV.EQ.0) NDRV=3
      IF(PERI.EQ.0.) PERI=N*2.
C     IF(NST.EQ.0) NST=189
      P3=PERI * .5 + .5
  230 IF(IFRM(1).NE.IFRM(8)) GOTO 240
      DO 231 I=1,8
  231 IFRM(I)=IFRM(I)
```

```
 240     WRITE(NWR,6230) (ID(I),I=1,39)
         WRITE(NWR,6240) TOVR,NOVF,N,PERI,NDRV,KFRM
         DO 241 I=1,MAXN
 241     Y(I)=0.
         READ(N1,KFRM,END=250) (Y(I),I=1,N)
C
C        CALCULATE AVERAGE TIME OSC. COUNTS
C
  99     TIME=0.
         DO 100 I=1,2
         TIME=TIME+Y(I)+16777216.*TOVR
 100     Y(I)=0.
         TIME=TIME/2
C
C        Fe57 peaks 1 thru 6 (mm/sec) w/respect to SNP.
         VCON(2)=-5.0494
         VCON(3)=-2.8167
         VCON(4)=-0.5800
         VCON(5)=1.1007
         VCON(6)=3.3376
         VCON(7)=5.5754
C
C        Y(I) where I=channel numbers for above peaks. From NFECAL.EXT
C        18-NOV-83 on MS-900.
         Y(189)=0.
         Y(331)=0.
         Y(476)=0.
         Y(582)=0.
         Y(733)=0.
         Y(878)=0.
C
C        Use GOTO statement to by-pass normal velocity extraction from
C        data.
         GOTO 107
C
C        EXTRACT VELOCITY DATA, ACCOUNT FOR
C        OVERFLOWS AND ZERO AFTER PUTTING IN VCON.
C
         IIII=0
         III=0
         NEND=PERI/2
         DO 101 I=19,NEND,MPLEX
         VJMP=Y(I+MPLEX)-Y(I)
         IF(VJMP.GE.500000.) III=III+1
 101     CONTINUE
         J=1
         DO 102 I=NST,NEND,MPLEX
         J=J+1
         IF(III.EQ.0) GOTO 105
         VJMP=Y(I+MPLEX)-Y(I)
         IF(J.GT.65) GOTO 102
         VCON(J)=Y(I)+FLOAT(III)*16777216.
         IF (VJMP.GE.500000.) III=III-1
```

```
      GOTO 102
105   VJMP=Y(I)-Y(I+MPLEX)
      IF(J.GT.65) GOTO 102
      VCON(J)=Y(I)+FLOAT(IIII)*16777216.
      IF(VJMP.GE.500000.) IIII=IIII+1
102   Y(I)=0.
      Y(399)=0.
      III=-1
      DO 106 I=3,J-1
      VJMP=ABS(VCON(I-1))-VCON(I)
      IF(ABS(VCON(I)-VCON(I+1)).GT.(2.*VJMP)) III=1
      VCON(I)=VCON(I)*FLOAT(III)
106   CONTINUE
      VCON(2)=-VCON(2)



107   VCON(1)=7
      NN=N1
      NK=N2
      N1=0
      N2=NST
      CALL DRIVE(N1,N2)
      N1=NN
      N2=NK
      GOTO 260
C
C     LESS THAN N DATA IN PARTITION N1
C
250   WRITE(NWR,6210) I,N
      DO 255 J=I,N
255   Y(J)=0.
      GOTO 99
C
C     ADD OVERFLOWS, ZERO CHANNELS OUT OF RANGE
C
260   IF(N1.NE.NCR) REWIND N1
      MSH=0
      G4=16777216.*FLOAT(NOVF)
      IF(NOVF.LT.0) G4=-1048576.*FLOAT(NOVF)
      IF(N9.EQ.0) GOTO 264
      DO 262 I=3,N
      IF(Y(I).NE.0.) GOTO 263
262   CONTINUE
263   G2=N9
      G3=Y(I)+G4
      G2=SQRT(G3+G4)*G2
264   DO 280 I=1,N
      IF(Y(I).EQ.0.) GOTO 280
      Y(I)=Y(I)+G4
      IF(N9.EQ.0) GOTO 280
      IF(ABS(Y(I)-G3).LE.G2) GOTO 275
```

```
      WRITE(NWR,6220) I,Y(I)
      IF(NVS.EQ.0) GOTO 270
265   WRITE(NWR,9000)
      READ(NRD,5210,END=265)JJ
      IF(JJ.NE.NY) GOTO 280
270   Y(I)=0.
      GOTO 280
275   G3=Y(I)
280   CONTINUE
C
C     ZERO CHANNELS, FIT INTERVALS, GENERATE HALF SPECTRA
C
285   DO 286 I=1,N
286   Y(I)=ABS(Y(I))
290   IF(NVS.EQ.0) GOTO 287
      WRITE(NWR,9210)
      NN=PERI
      IF(N.LT.NN) GOTO 287
      WRITE(NWR,9215)
287   READ(NRD,5210,END=290) NN
      DO 291 K=1,4
      IF(NN.EQ.INST(K)) GOTO 294
291   CONTINUE
C
C     INVALID INPUT
C
      IF(NVS.EQ.1) GOTO 290
292   WRITE(NWR,6275)
      N3=1
      RETURN
294   GOTO (295,295,320,340),K
295   IF(NVS.EQ.1) WRITE(NWR,9220)
      READ(NRD,5210,END=295) (IN(J),J=1,NPL)
      IF(IN(1).EQ.INST(4)) GOTO 290
      CALL TRANS(NN)
      IF(NN.EQ.0) GOTO 290
      K1=ABS(OUT(1))
      K2=ABS(OUT(2))
      IF(K2-K1) 300,302,302
300   NN=K1
      K1=K2
      K2=NN
302   IF(K2.GT.N) GOTO 295
      IF(K1.EQ.0) K1=K2
      IF(K1.EQ.0) GOTO 295
      KK=K-2
      IF(KK.EQ.-1) WRITE(NWR,6250) K1,K2
      IF(KK.EQ.0)  WRITE(NWR,6260) K1,K2
      DO 304 J=K1,K2
304   Y(J)=FLOAT(KK)*ABS(Y(J))
      GOTO 295
320   NN=PERI
      IF(N.LT.NN) GOTO 290
```

```
      IF(NVS.EQ.1) WRITE(NWR,9240)
      KP(3)=0
      READ(NRD,5210) KK
      IF(KK.EQ.INST(1)) GOTO 330
      NN=N/2
      DO 325 I=1,NN
      G1=Y(I)
      II=N-I+1
      Y(I)=Y(II)
325   Y(II)=G1
330   N=N/2
      WRITE(NWR,6270) N
      GOTO 290
340   NF=N
      DO 350 I=1,N
      IF(Y(I)) 345,345,346
345   NF=NF-1
      GOTO 350
346   B=Y(I)
350   CONTINUE
      NFLD=0
      RETURN
C     ****************************************************************
5200  FORMAT(40A2)
5210  FORMAT(80A1)
C     ****************************************************************
9000  FORMAT(1H0,'ZERO Y/N'/)
9200  FORMAT(1H0,F5.0,' TIME OVERFLOWS',',',I5,' DATA OVERFLOWS'/)
9210  FORMAT(1H0,'* = END'/' Z = ZERO CHANNELS'/' L = SET FIT LIMITS'/)
9215  FORMAT(1H ,'H = GENERATE HALF PERIOD SPECTRUM'/)
9220  FORMAT(1H ,'CHANNEL 1, CHANNEL 2'/)
9240  FORMAT(1H ,'L = LEFT, R = RIGHT HALF'/)
C
6200  FORMAT(1H0,'***** ERROR ***** MORE THAN',I5,' POINTS')

6205  FORMAT(1H0,'***** ERROR ***** EOF ON UNIT',I3)
6210  FORMAT(1H0,'**** WARNING **** POINTS',I5,' TO',I5,' ZEROED')
6220  FORMAT(1H0,'**** WARNING **** POINT',I4,' OUT OF RANGE',F10.0)
6225  FORMAT(1H0,'**** WARNING **** VELOCITY OVERFLOW PROBLEM')
6230  FORMAT(1H0,1H ,39A2)
6240  FORMAT(1H0,4X,'TIME OVERFLOWS',F6.0,/5X,'DATA
      1 OVERFLOWS',I5/5X,'CHANNELS',7X,I5/5X,
      2'PERIOD',7X,F10.3/5X,'DRIVE MODE',6X,I3/5X,
      3'INPUT FORMAT    ',8A2)
6250  FORMAT(1H0,I4,' -',I4,' NOT FITTED')
6260  FORMAT(1H ,I4,' -',I4,'ZEROED')
6270  FORMAT(1H ,'HALF PERIOD SPECTRUM ',I5,' CHANNELS')
6275  FORMAT(1H ,'***** ERROR ***** INVALID INPUT')
      END
```

```
      SUBROUTINE DRIVE (N1,N2)
      COMMON /UNIT/ NRD,NWR,NCR,LPR,LFD,NPL,NVS,MAXN,MAXM,MAXF,NV(121)
      COMMON /DAT/  VMAX,PERI,Y(1024),ID(40),NDRV,N,NF,VEL(10)
      COMMON /THEO/ F,P(32),DF(32),NTEO,M,MF,KTEO(20),KP(32)
      COMMON /FLD/  P3,B,V,VCON(65),V1,V2,GEO,B0,C0,NFLD,MSH,MPLEX,TIME
      COMMON /TRA/  IN(81),OUT(16)
      COMMON /LIN/  BB(32),A(32,32)
C
      DIMENSION X(65),XY(65),XDP(10),XYDP(10)
C
C     N1 = 0  CALCULATE VELOCITY COEFF.
C     N1 = 1  VELOCITY V FROM CHANNEL NUMBER XX
C     N1 = 2  V,GEO
C     N1 = 3  DERIVATIVES P(1)-P(3)
C     N1 = 4  DERIVATIVES P(1)-P(2)
C
C     N2 = 1st CHANNEL CONTAINING VELOCITY (N1=0)
C     N2 = CHANNEL NUMBER   (FOR N1 = 1-4)
C     N2 = 0  ERROR RETURN
C
C     NDRV = 1  TRIANGULAR WAVE MODE
C     NDRV = 2  SINE WAVE MODE
C     NDRV = 3  FLYBACK WAVE MODE**
C
      IF(N1.NE.0) GOTO 1000
      NST=N2
      NFN=VCON(1)
      GOTO (1,2,3), NDRV
    1 WRITE(NWR,6000)
      RETURN
    2 WRITE(NWR,6200)
      VCON(1)=0.
      RETURN
    3 WRITE(NWR,6300)

C     Channel numbers for NFECAL.EXT peaks 1 thru 6.

      X(2)=NST
      X(3)=331.0
      X(4)=476.0
      X(5)=582.0
      X(6)=733.0
      X(7)=878.0
C     XY(2)=VCON(2)*156.25/TIME
      XY(2)=VCON(2)
      DO 401 I=3,NFN
C     X(I)=X(I-1)+MPLEX
C401  XY(I)=VCON(I)*156.25/TIME
 401  XY(I)=VCON(I)
      L=2
      K=1
```

```
C
C       FIND MIN AND MAX VALUES FOR X
C
        XMIN=X(2)
        XMAX=X(2)
        DO 402 I=3,NFN
        XMIN=AMIN1(XMIN,X(I))
 402    XMAX=AMAX1(XMAX,X(I))
C
C       ZERO ARRAYS FOR SUMMING
C
        MM=2*K+1
        DO 403 I=1,MM
        XDP(I)=0.
        XYDP(I)=0.
 403    CONTINUE
C
C       TRANSFORM RANGE OF X TO (-1,1) AND COMPUTE SUMS OF
C       POWERS OF X AND SUMS OF XY TIMES POWERS OF X.
C
        C1=2.0/(XMAX-XMIN)
        C2=(XMAX+XMIN)/(XMAX-XMIN)
        LU=2*K+1
        LL=K+2
        DO 404 II=2,NFN
        XP=1.
        XI=C1*X(II)-C2
        DO 405 I=1,L
        XDP(I)=XDP(I)+XP
        XYDP(I)=XYDP(I)+XP*XY(II)
 405    XP=XP*XI
        DO 404 I=LL,LU
        XDP(I)=XDP(I)+XP
 404    XP=XP*XI
        DO 406 I=1,L
        BB(I)=XYDP(I)
        DO 406 J=1,L
        A(I,J)=XDP(I+J-1)
 406    CONTINUE
C
C       CALL LINEQ AND FIT VELOCITY DATA
C
        N1=0
        N2=2
        CALL LINEQ(N1,N2)
C
C       MOVE VELOCITY CALIB. TO VEL ARRAY
C
        DO 407 I=1,L
        JK=K-1+2
 407    VEL(JK)=BB(I)
C
C       ADJUST COEFF. TO ORIGINAL RANGE OF X
C
```

```
      DO 408 I=1,K
      DO 408 J=1,I
 408  VEL(J)=VEL(J)*C1
      C1=(XMAX+XMIN)/2.0
      DO 409 I=1,K
      MM=L-I+1
      DO 409 J=2,MM
 409  VEL(J)=-C1*VEL(J-1)+VEL(J)
C
C     COMPUTE MAXIMUM AND ROOT MEAN SQUARE
C     ERRORS AND OUTPUT ERROR ANALYSIS
C
      WRITE(NWR,6400)
      EMAX=0.
      SUM=0.
      VMAX=0.
      DO 410 I=2,NFN

      YC=VEL(1)
      DO 411 J=1,K
 411  YC=YC*X(I)+VEL(J+1)
      VMAX=AMAX1(VMAX,ABS(YC))
      DIFF=YC-XY(I)
      IF (I-1.GT.L) GOTO 413
      WRITE(NWR,6410) I,X(I),XY(I),YC,DIFF,VEL(I-1)
      GOTO 412
 413  WRITE(NWR,6420) I,X(I),XY(I),YC,DIFF
 412  EMAX=AMAX1(EMAX,ABS(DIFF))
 410  SUM=SUM+DIFF**2
      ERMS=SQRT(SUM/FLOAT(NFN-1))
      WRITE(NWR,6430) EMAX,ERMS
      RETURN
C
 1000 GOTO (10,100,200),NDRV
C
C     FLYBACK MODE
C
 200  IF(N1.GE.3) GOTO 250
      XX=N2
      PER=PERI/4.
      IF(XX.LE.PERI/2.) GOTO 232
      XX=XX-PERI
      C1=P3-PER-XX
      S=1.
      GOTO 240
 232  C1=P3+PER-XX
      S=-1.
 240  C4=S*VMAX/PER
      V=VEL(1)*XX+VEL(2)
      IF(N1.EQ.1) RETURN
      CX=V/VMAX
      C2=S*(CX*CX-1.)
      C5=1.+P(2)*C2
      GEO=1./C5/C5
      RETURN
```

```
C
C         DERIVATIVES
C
 250      MM=KP(1)
          IF(MM.GT.Ø) DF(1)=GEO
          MM=KP(2)
          IF(MM.GT.Ø) DF(MM)=-2.*GEO*BØ*C2/C5
          IF(N1.EQ.4) RETURN
          MM=KP(3)
          IF(MM.GT.Ø) DF(MM)=GEO*((V/XX)*CØ-BØ*P(2)*V*4./C5/VMAX/PER)
          RETURN
C
C         TRIANGULAR MODE
C
   1Ø     WRITE(NWR,6ØØØ)
          RETURN
C
C         SINE WAVE NOT AVAILABLE
C
 1ØØ      WRITE(NWR,62ØØ)
          RETURN
C
 5ØØØ     FORMAT(8ØA1)
 6ØØØ     FORMAT(1H ,4X,'DRIVE MODE TRIANGULAR WAVE NOT AVAILABLE')

 62ØØ     FORMAT(1H ,4X,'DRIVE MODE SINE WAVE NOT AVAILABLE')
 63ØØ     FORMAT(1H ,4X,'DRIVE MODE FLYBACK WAVE')
 64ØØ     FORMAT(1H ,//,1ØX,36HPOLYNOMIAL LEAST SQUARE FIT
          1ANALYSIS,//,4H    I,6X,7HX-GIVEN,7X,7HY-GIVEN,6X,
          28HY-FITTED,8X,5HERROR,1ØX,6HVEL(I),//)
 6411     FORMAT(1H ,I3,4X,4(1PE1Ø.3,4X),1PE13.6)
 6421     FORMAT(1H ,I3,4X,4(1PE1Ø.3,4X))
 6431     FORMAT(1H ,9X,5HEMAX=,1PE15.6,9X,5HERMS=,1PE15.6)
          END
```

VITA

Joseph Freddie Harmon Jr. was born on July 27, 1960, in Charleston, South Carolina and is the son of Joseph F. Harmon Sr. and Peggy V. Harmon. He graduated from R.B. Stall High School in Charleston, South Carolina in June, 1978. He attended The Citadel from August, 1978 until May, 1982 and was enrolled in Air Force R.O.T.C. during this period. In May of 1982 he graduated with a Bachelor of Science in Physics and recieved a commission in the United States Air Force. He and his wife Rosie have a daughter, Ashley.

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In this study, a computer based Mossbauer spectrometer was built using a new MS-900 spectrometer, an Apple 2+ computer system, and a PDP 11/03 computer system. The APPLE was used as the link between the spectrometer and the PDP, which is used to analyze the Mossbauer spectra. In addition to minor hardware connections, software changes were made to the analysis program so that it could accept the data format

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produced by the new spectrometer. Due to equipment failure, only preliminary tests were made of the new system, however the tests were positive. Orginally, an Al-Fe-Ce alloy was chosen to be studied by the new system. Instead, the alloy, chosen because of its excellent high temperature properties, was studied by the original Mossbauer spectromemter system. The goal was to follow and identify changes in the microstructure of the alloy due to different processing stages. Although changes in the spectra were identified with processing stages, it is still unclear as to what compounds are related to the observed spectra.

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