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UNITED STATES AIR FORCE

SUMMER RESEARCH PROGRAM -- 1993

FINAL REPORTS

VOLUME 13

PHILLIPS LABORATORY

RESEARCH & DEVELOPMENT LABORATORIES

5800 UPLANDER WAY

CULVER CITY, CA 90230-6608

SUBMITTED TO:

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AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

BOLLING AIR FORCE BASE

WASHINGTON, D.C.

DECEMBER 1993

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The Presence of Sulfuric Acid in the Stratosphere
and Its Effect on High Altitude Aircraft

Andrea B. Bowlby

Final Report for:
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The Presence of Sulfuric Acid in the Stratosphere
and Its Effect on High Altitude Aircraft

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Abstract

The effect of sulfuric acid in the stratosphere on high altitude aircraft was studied. After conducting research on the properties of sulfuric acid aerosols and the materials used to construct airframes and engines as well as discussing the topic with meteorologists and aircraft engineers, the data indicated that any impact H_2SO_4 may have on aircraft is negligible. The results of the investigation suggest that sulfuric acid does not cause significant structural damage to a plane nor does it impede performance. Nevertheless, the sulfuric acid content of the stratosphere is a threat to the environment because it has been linked with ozone depletion, climactic changes, and acid rain.

The Presence of Sulfuric Acid in the Stratosphere

And Its Effect on High-Altitude Aircraft

Andrea B. Bowlby

Introduction

Many people are familiar with the destruction a volcanic eruption can wreak on neighboring cities and towns, but few people are aware of the world-wide implications of such an incident. In March and April 1982, the residents of southern Mexico experienced first-hand the wrath of Mother Nature when the nearby volcano, El Chichón, violently erupted. After volcanic ash rained down on the vicinity, meteorologists realized the stratosphere would suffer harmful, long-term effects as a result of the El Chichón eruption. Scientists D.J. Hofmann and J.M. Rosen[1] determined that El Chichón's two eruptions spewed 10^7 metric tons of sulfuric acid (H_2SO_4) into the stratosphere. Previous studies showed that sulfuric acid is deleterious to this delicate second layer of the atmosphere, so naturally, Hofmann and Rosen worried about how the increased presence of sulfuric acid would affect the composition of the stratosphere in years to come.

The sulfuric acid content of the stratosphere has long been a concern to scientists. First, sulfuric acid plays a role in the dehydration of the atmosphere. H_2SO_4 is called a superacid because it is so acidic that materials that do not normally chemically bond with other materials are forced into acid-base relationships with sulfuric acid. Therefore it is no surprise that sulfuric acid combines readily, in fact, violently with water. Consequently, H_2SO_4 acts as a strong dehydrating agent, taking moisture from the air and other substances.[2] Additionally, sulfuric acid is extremely corrosive, and its presence in the stratosphere has also been linked to climactic changes and ozone depletion.[3]

Although major volcanic eruptions are the dominant source of sulfuric acid in the stratosphere, twenty-five percent of H_2SO_4 pollution results from the by-products of biomass burning, fossil fuel burning, petroleum refining, and other anthropogenic processes. Decaying, organic matter releases H_2SO_4 also, and scientists have measured low, background levels of sulfuric acid that continually persist in the atmosphere.[4] To researchers' dismay, data obtained by balloons from Laramie, Wyoming indicate background levels of H_2SO_4 have increased steadily 3-7% at northern mid-latitudes since 1981.[5] These high levels pose a serious threat to the future condition of the stratosphere. In the past, environmental authorities have been quick to point out the damaging effects aircraft and rocket emissions can have on the atmosphere, but the question arises whether or not the deteriorating quality of the stratosphere caused by the presence of sulfuric acid can be detrimental to the ***aircraft*** that fly through the stratosphere.

Problem

Airplanes routinely fly through the stratosphere. Military fighter aircraft such as the F-4 Phantom or the F-16 are built for combat purposes and require a high ceiling,[6] and commercial airliners often cruise at altitudes as high as seven miles (13 km).[7] Because these planes are repeatedly exposed to the impurities of the stratosphere, the presence of sulfuric acid warrants an investigation of possible "side effects." Various materials are used to construct aircraft -- aluminum, steel, glass, rubber, acrylic, and composites -- many of which could be vulnerable to the sulfuric acid contained in the stratosphere. In order to engineer safe and durable airplanes, it is necessary to determine whether or not the H_2SO_4 content of the air is significant enough to cause damage to the aircraft and/or its components and thus impede performance. The specter of a pollutant damaging aircraft raises several questions:

1. Could the sulfuric acid corrode the exterior of the airplane?
2. Would the dehydration of the stratosphere prevent jet engines from functioning properly?

3. Acknowledging the fact that H_2SO_4 combining with water produces an exothermic reaction, could the relatively large amount of heat that is released cause harm to the aircraft?

Methodology

In order to ascertain the effects sulfuric acid has on aircraft, it is necessary to gain a better understanding of the properties of the stratosphere and what occurs when sulfuric acid is released into the stratosphere. The stratosphere is the second layer of the atmosphere -- between the troposphere, where we live, and the mesosphere -- occupying a band of sky six to nineteen miles in altitude. The stratosphere is essentially isothermal meaning temperatures are fairly constant with height, and the airflow is horizontal. Therefore, there are no significant weather fluctuations. The air is composed of seventy-eight percent nitrogen and twenty-one percent oxygen. Argon, water vapor, and carbon dioxide are the major constituents of the remaining one percent.[8]

Preservation of the stratosphere is particularly important because of one other characteristic -- the ozone layer exists here about sixteen miles (thirty km) above the ground. Ozone shields the earth from harmful ultraviolet (UV) rays by absorbing them and preventing them from penetrating the troposphere. Ozone is actually oxygen (normally O_2) in a very rare form -- O_3. Creation of ozone occurs when UV rays strike the stratosphere and split O_2 molecules into individual oxygen atoms. The atoms combine with the remaining intact O_2 molecules to form O_3.[9] Unfortunately, sulfur dioxides and sulfur trioxides (released into the atmosphere after a volcanic eruption or from industrial by-products) attack the ozone's molecular bonds in order to combine with the oxygen atoms to make H_2SO_4.[10] Because this production of sulfuric acid depletes ozone, could aircraft equipment then malfunction because of exposure to excess amounts of UV radiation?

When sulfuric acid enters the air, whether from a volcanic eruption or industrial processing, it is distributed in the form of an aerosol. An aerosol is a system of liquid or solid particles evenly distributed throughout a gas -- fog and clouds. for example. The sulfuric acid aerosol in the stratosphere maintains a highly layered structure (with each layer containing varying concentration of the aerosol) indicating the vertical mixing of the air is very slow. Within a few months, winds distribute the layered aerosol both horizontally and vertically, and it is replaced by a homogeneous aerosol. The aerosol will eventually decay and fall to the earth after remaining in the atmosphere for at least two years.[11]

The air is often supersaturated with sulfuric acid after major volcanic eruptions because of the large amount of H_2SO_4 injected into the stratosphere.[12] Supersaturation occurs when the fully saturated solution cools. This temperature decrease enables the solution to contain more of the vapor substance (H_2SO_4) than normal. A supersaturated solution, however, is unstable, so the addition of even one more molecule of H_2SO_4 may induce condensation. Condensation causes an increase in the smaller particles. Coagulation of these new particles (droplets) soon occurs, so the smallest particles are depleted, and there is an increase in the number of large droplets. Consequently, the process results in a maximum particle size distribution. So although there is a rapid creation of new particles after condensation, the complete process maintains an equilibrium.[13]

There are many hazards associated with the presence of a sulfuric acid aerosol in the atmosphere including the risk of dehydration of the stratosphere and ozone depletion as mentioned before. Drastic climactic changes might also result. Sulfuric acid droplets continuously absorb sunlight, warming the surrounding air.[14] Hofmann and Rosen observed a 3°-5°C increase in the average stratospheric temperature above the equator following the El Chichón eruptions.[15] Animal life and vegetation on earth are extremely sensitive to temperature changes, so is it also likely that airplane engines may be adversely affected by heat? Researching sulfuric acid and the stratosphere only leads to more questions concerning whether or not the aerosol would affect flight, so in order to satisfactorily answer them. some knowledge of how much stress aircraft can endure must be obtained.

Results

After interviewing meteorologists and engineers employed by airline manufacturers in addition to conducting in-house research at Phillips Laboratory Geophysics Directorate, it is obvious that although sulfuric acid has some effect on airplanes, its impact on structural integrity is negligible. First, jet engines are designed to withstand tremendous heat because temperatures within a jet engine may reach 2500 Kelvin during any given cycle of a turbine. Metals and alloys would normally melt at similar temperatures, so aircraft engines are built using composites. The exothermic reaction that occurs when sulfuric acid combines with water produces temperatures ranging from 140°-170°C[16] and therefore will not damage the engine. Airplane manufacturers already construct aircraft with an exterior that is also made of composites to guard against heat damage because when airplanes fly at speeds of Mach 2 and greater, the friction between the airplane's surface and the air can produce very high temperatures. At Mach 6, the skin of the airplane can reach 1000°F.[17]

The presence of sulfuric acid may increase the metal fatigue of an airplane, however, this is still not a major concern because airplane manufacturers take precaution s to prevent an airplane from succumbing to metal fatigue. Metal fatigue occurs when airplanes are subjected to stress. Under normal conditions, the ductile metals of the airframe may stretch and bend, but as soon as the stress is removed, the metal returns to its normal shape and condition. On the other hand, if the airplane is placed under an extraordinary amount of stress, the damage can be permanent. Stress on some metals can result in a fracture. High temperatures and corrosion increase metal fatigue and the airplane's chance of fracturing. However, since it was discovered that metal fatigue can cause fractures, great pains have been taken to fatigue test all aircraft and give them a "safe Life" -- an amount of time that they are safe to fly.[18] It is also important to remember that H_2SO_4 is not the only factor that would cause high temperatures and corrosion and thus hasten metal fatigue. Severe weather such as turbulence is much more common and more likely than H_2SO_4 to damage an airplane.

Furthermore, dehydration of the stratosphere caused by sulfuric acid's tendency to combine with water would not prevent airplane engines from providing thrust. There are only two types of airplane engines -- air-breathing engines and rocket engines. Neither of them draw on any moisture in the atmosphere. Air-breathing engines rely on their ability to combine oxygen in the atmosphere with fuel, and in a rocket engine the fuel and oxidizer are self-contained.[19] Despite the fact that sulfur dioxides and sulfur trioxides bond with oxygen in the atmosphere, air-breathing engines would still not be affected because of the insignificant amount of sulfuric acid in the air. Even after the El Chichón eruption, initially called a once in a century event because of the amount of ash and H_2SO_4 released, measurements indicated that sulfuric acid aerosol levels constituted only one part per billion of the stratosphere.[20] Here again, any inefficiency of an air-breathing engine would be minimal.

According to R.F. Schleh, Public Relations Manager for Boeing Commercial Airplane Group, sulfuric acid in the stratosphere "is not a safety issue but a nuisance."[21] The aerosol causes a film to form on the acrylic passenger windows of commercial airliners thus obscuring the view. The engineering division at Boeing has termed this phenomenon crazing. The cockpit windows are made of glass , so it is not an issue for the crew. Mr. Schleh added that Boeing is exploring several ways to amend the situation. "Several solutions are being considered, including a reformulation of the passenger window material or possibly a special coating."[22]

Conclusion

In summation, sulfuric acid's impact on aircraft in the stratosphere is insignificant. An accident attributed to the presence of sulfuric acid is unheard of. High altitude aircraft have been successfully flying for years. The U-2, ER-2 and the F-4 Phantom are good examples. When McDonnell Douglas began manufacturing the F-4 in the 1960s, they proved so invaluable in combat that two branches of the military purchased them, and many foreign countries followed suit.[23]

Researching the effects sulfuric acid has on aircraft proved difficult because no investigation of the topic had ever been pursued. This lack of previous research corroborates the conclusion that any effect is negligible. Judging from the list of topics in the CD ROM database, scientists seem more preoccupied with the ways aircraft emissions harm the atmosphere than vice versa. The articles that concern sulfuric acid aerosols in the stratosphere never mention damage to aircraft or space vehicles, and aerospace-oriented articles never discuss the presence of sulfuric acid in the atmosphere as a consideration for design nor a cause of accidents. While sulfuric acid may cause environmental problems including ozone depletion, climactic changes, and acid rain, the amount contained in the stratosphere is certainly not significant enough to cause structural damage to high altitude aircraft.

Footnotes

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THE AURORAS AND THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM

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THE AURORA BOREALIS AND THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM

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ABSTRACT

The Aurora Borealis and Aurora Australis are phenomena in the space environment resulting from the flowing current of the sun's plasma through the stored plasma and atmospheric gases already present in the Earth's atmosphere. The position and color of the Northern and Southern Lights depends on the activity level in the ionosphere. This activity is monitored under the Defense Meteorological Satellite Program.

THE AURORAS AND THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM

Tiffany J. Jost

INTRODUCTION

The Aurora Borealis and the Aurora Australis are very mysterious in their hue and activity. The aurora and their physical environment are constantly being observed and studied in order for us to have more knowledge of these phenomena. The location, frequency, intensity, and the origins of these majestic northern and southern lights are the major focal points of study for both scientists and students. With resources ranging from ancient myths to the most complex technology, questions are beginning to be answered.

DISCUSSION

What is the cause of these wondrous auroral displays? Exhaustive research has discovered the main cause is the sun. The surface of the sun has sunspots; dark spots which appear on the sun's surface. Occasionally these sunspots churn up an abundant amount of energy which causes them to explode. This explosion, called a solar flare, forms an immense mass of charged and heated gas particles which bursts forward into space. These flares can reach a temperature as high as 20 million degrees celsius as they expand out 40-60 degrees from the sun's surface.[1] A coronal hole also allows gas to escape from the sun and to then flow into space, yet it is slightly different from a solar flare. It is most commonly found during the minimum of the eleven year sunspot cycle whereas a flare occurs at the maximum of this cycle. The hole is essentially caused by a diminished, or even a lack of, magnetic field in the sun's corona over certain parts of the sun's surface. With the lack of a magnetic force, the gas molecules (mostly electrons and fragments of hydrogen and helium atoms) of the sun's lower atmosphere float upwards and into space. In either case, this mass of charged particles enlarges the steady outward flow of gas from the sun which is called the solar wind. The solar wind is always present in the space environment but the solar flares can enhance the solar wind's force and magnitude. This plasma flows throughout space and causes geomagnetic disturbances on and around the Earth.

The Earth is a magnetized dipole planet. Therefore, the area above each of the polar caps is particularly vulnerable to foreign charged particles and ionized gases. This assailable region is called the cusp, see Figure 1. As the solar wind flows around the earth's magnetosphere, the high altitude ends of the magnetic field lines bend, or "blow" away from the Earth. However, some of the wind's plasma penetrates through the cusp region. This trapped plasma flows like an electrical current through the upper atmosphere, called the ionosphere. Located approximately 100 to

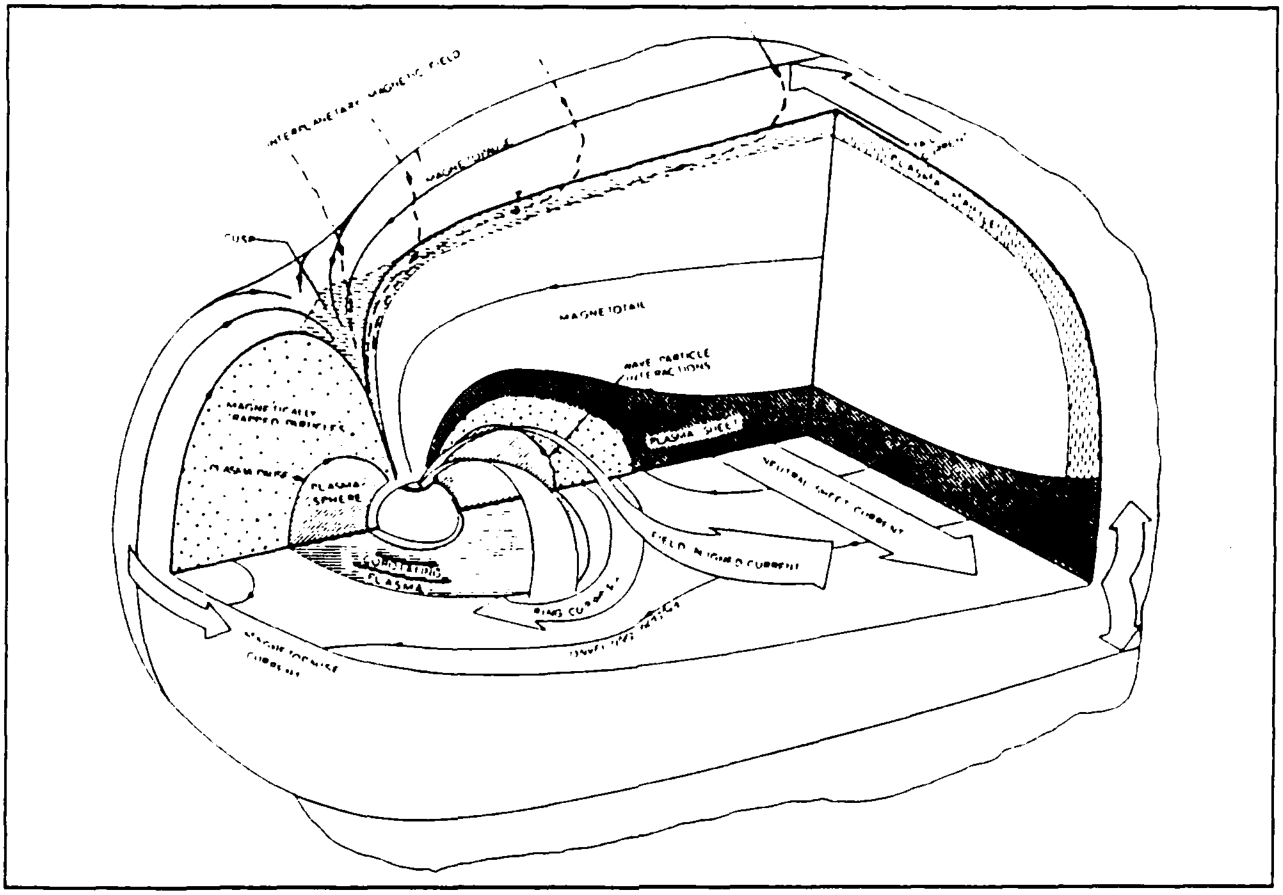


Figure 1 The high altitude ends of the magnetic field lines, or the magnetopause, bend away from the earth as the solar wind flows around the earth.

1000 km above the Earth, the ionosphere contains ionized atoms of nitrogen and oxygen gases. These ionized atoms allow this electrical current to flow. Meanwhile, as the magnetic field lines are being stretched outwards, the lines are gaining potential energy. As the solar wind diminishes, this potential energy transfers into kinetic energy. The kinetic energy, or the "snapping back" motion, adds energy to the stored plasma, also called cold plasma. The cold plasma gets heated as it is accelerated and these plasmatic and atmospheric molecules gain so much charge that they emit light. The nitrogen molecules emit a blue-violet light and they also form the red ridge often seen along the bottom of the curtain. The atomic oxygen molecules glow with a green-yellow hue. This light emission is seen as the Northern and Southern Lights.

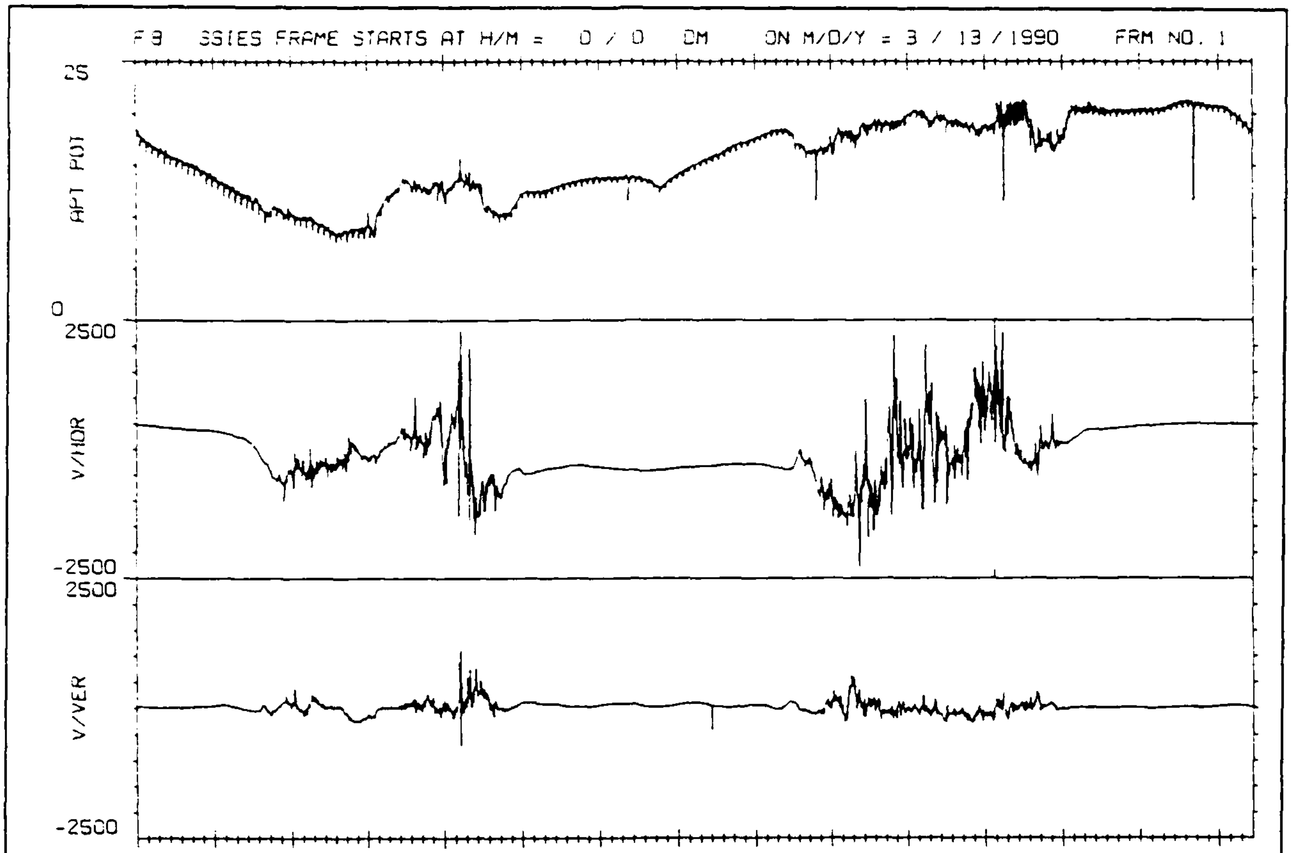
The Northern and Southern Lights take on many different shapes, including the aforementioned curtain effect. Resembling a curtain blowing in the wind, this particular auroral display ripples and flows. Some auroral displays show the individual streaks of light, called rays, as the plasma flows along the magnetic lines. Some can also become very chaotic. These chaotic forms are called instabilities and are caused by an overwhelming surge of energy. The glowing aurora can be flowing gently when suddenly this trickle of energy becomes a downpour and the aurora then becomes splotchy as it quickly brightens then dissipates. One interesting note is that the Earth faces the same side of the sun approximately every 27 days. Therefore, under normal conditions on and near the surface of the sun, the Earth can witness similar auroral displays every 27 to 54 days![2] A normal substorm can occur for 20 minutes every two to three hours over a 10 to 50 hour period. A big storm is a series of many substorms, each lasting for 20 minutes, but the frequency of these substorms is approximately every five minutes in a one hour duration; therefore, the energy gets piled up and the instabilities appear more frequently.

These dancing lights form a ring around the geomagnetic poles called the auroral oval. This oval zone covers, geographically, northern Norway, Iceland, and southern Greenland.[3] The oval shape, with a diameter of 4000 kilometers, is formed as the particles are flowing through the "snapped back" magnetosphere field lines. These intense shifts in the magnetosphere can be devastating for the mechanical and electrical life on Earth and in the satellites floating in the atmosphere. A fine example of the conflict between the aurora and the flow of electricity on the Earth was the major magnetic storm on March 13, 1989. The entire province of Quebec, Canada suffered a nine hour power outage. The electricity of an auroral storm should not be confused with the lightning of a thunderstorm. Lightning occurs in the lower levels of the atmosphere, up to 20 kilometers from the Earth's surface, along with the weather systems. On the contrary, the aurora appears one to three hundred kilometers above the Earth. Also, the aurora can occur without clouds in the sky, but the clouds are necessary for the lightning. Radio waves can also be affected by these distorted magnetic field lines which can be crucial for both commercial and military radio systems. These effects are all examples of Faraday's law which states that a change in the surrounding magnetic fields of a conductor will affect the flow of current in these electric conductors. Therefore, power lines are conductors which are vulnerable to such a drastic change in the magnetic field.[4]

It is important, then, to try to predict when such a destructive magnetic storm will occur in order to prepare and protect the vulnerable electrical systems. The Defense Meteorological Satellite Program, DMSP, has a series of satellites floating in a circular orbit 840 kilometers above the Earth. It takes 101 minutes for the satellites to complete one revolution around the Earth. In relation to the equator, these satellites are at a 98.8 degree inclination, slightly larger than a 90 degree polar inclination which would be directly over the poles. Relative to the sun, the satellites are stationary, a condition called sun synchronous. The life of a satellite depends upon the altitude at which it is located. The lowest point at which a satellite is safe from drag is about 250 kilometers. This can stay up for approximately two months. At 350 kilometers it can stay up for a year, et cetera. We worked primarily with data received from satellites F8, F9, F10, and F11.

These satellites have many instruments for observing the weather on the ground and the conditions in the ionosphere. SSIES is the ionospheric plasma monitoring instrument which measures the temperature and energy of the ions. OLS is the operational line scanner which takes pictures of the clouds. We worked closely with the driftmeter data from the SSIES instrument this summer. The driftmeter detects movement of ionospheric ions which are being pushed by the magnetic fields as the surges of plasma push past the magnetosphere. The data it produces goes through a three step process before it is recorded on Earth. First, it is recorded in the spacecraft's data formatter and is then sent through the transmitter to the geosynchronous tracking station on the Earth. This station is often automated with a directional antenna that can pick up the satellite's signal 800-3000 kilometers away. There can be, however, problems with the system being automated. If the satellites in the lower atmosphere become slowed down by drag, the antenna will continue to be activated to point where the satellite should be, and therefore it is moving ahead of the transmitter and data can be lost. Also, some clouds of charged particles on the sun side of the satellite can charge up to 1000 volts of electricity on the surface of the satellite. This uneven amount of charge on the surface will cause sparks to fly between the sun side and the dark side of the satellite. These sparks can cause severe damage to the electronics of the satellite.

The data plot shown in Figure 2 is an example of the data we analyzed this summer. This is a 101 minute plot from the drift-meter instrument on the F8 satellite on March 13, 1990. The top grid measures the aperture potential of the ions. The center grid is measuring the velocity of the ions which are moving horizontally against the satellite whereas the bottom grid shows their vertical velocity. From the time 0103 to 0125, there appears to be some turbulent ion activity - the graph is darkened and quite staggered as compared to the smooth flow from 0030 to 0100. These two graphs are the important ones that the scientists want to monitor because from them, they can detect if there is an abundant amount of



GMT-SEC	0	420	840	1260	1680	2100	2520	2940	3360	3780	4200	4620	5040	5460	5880
GMT-HM	0000	0007	0014	0021	0028	0035	0042	0049	0056	0103	0110	0117	0124	0131	0138
GLAT	-21.8	-46.1	-69.6	-79.2	-58.0	-33.9	-9.3	15.2	39.6	63.5	81.2	64.5	40.7	16.3	-8.2
GLNG	269.9	262.5	245.4	142.8	100.8	90.7	84.5	78.9	72.2	59.7	349.2	273.1	260.1	253.3	247.7
MLATSS	-11.5	-34.6	-58.7	-83.4	-71.6	-46.4	-20.2	7.1	34.3	58.7	79.7	75.5	50.9	24.0	-1.8
MLT110	17.9	18.0	18.1	18.4	5.8	6.0	6.0	5.9	5.6	5.1	3.6	18.9	18.0	17.8	17.8
MLAT110	-21.7	-38.9	-60.8	-84.0	-72.3	-48.8	-26.9	19.9	38.1	60.1	80.4	76.0	53.3	30.4	-18.9
ALT(KM)	855.6	861.2	864.9	864.9	859.3	850.1	844.5	846.4	853.8	863.0	868.6	868.6	861.2	855.6	853.8

Figure 2

turbulence in the space environment.

CONCLUSION

Though the research of years past have answered many questions, the scientists of the present are working diligently to answer many more. In the years to come, interest in the Aurora Borealis and the Aurora Australis will continue to grow as more people begin to realize that these phenomena can possibly affect their lives as well as the world they live in.

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** Information on DMSP and other details in discussion with Dr. Frederick Rich of the Phillips Geophysics Laboratory, Hanscom Air Force Base, Bedford, MA. August 11, 1993.

A STUDY OF IONOSPHERE

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A STUDY OF THE IONOSPHERE

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Abstract

The ionosphere is a partly ionized region of the upper atmosphere. It is important to the Air Force because anything that is (radio) signal passing through the ionosphere will be effected by it. The Air Force has both communications and radars that are effected by the ionosphere. At Phillips Laboratory, GPS (Global Positioning System) satellite signals are used to study the ionosphere. Phillips Laboratory has operated stations to receive the signals from the GPS satellites in Shetland ,United Kingdom, Shemya, Alaska, Hanscom Air Force Base, Massachusetts, and Thule, Greenland. The stations at Shemya are being run currently.

A STUDY OF THE IONOSPHERE

Min Shao

Introduction

We have known that the ionosphere can effect the electromagnetic material, like radio signal. Obviously the ionosphere can produce significant effects on RF propagation for Space Surveillance, such as range error due to ionospheric Total Electron Content (TEC) and variations in RF signal strength and phase. In order to avoid having errors in scientific, military, and civic electromagnetic applications, it is important to understand and anticipate the ionosphere will. In this paper, it talks about the ionosphere itself, like where is it; what does it look like; what's in there' why can it exist, and so on. Also, it talks about how the systems work to calculate the TEC which is a standard to determine the ionosphere and the GPS satellites.

Ionosphere

The ionosphere is partly ionized region of the upper atmosphere. Typical ionization levels are on the order of five percent. The majority of the ionospheric effects are due to contributions from the region near the altitude where the density of ions is at a peak. This altitude varies but is generally at 300-350 km. Above this altitude (see figure 1), the density of atmosphere is so low that there are fewer ions and charged particles. Below 300 km altitude, the atmospheric density is so high that the recombination of ions with electrons is fast. There is not much ions and electrons, either. The peak density of the ions is about $5 * 10^{11} /M^3$. Actually, electrons are the contributors to the RF effects. The ions are too heavy to interact substantially. That is why we use total electron content (TEC) to determine the ionosphere. The majority of the electron content of the ionosphere comes from the region within about 50 km of the peak ionization density.

The origin of the ionosphere in general is ionizing solar ultraviolet radiation, but other factors can contribute to the local ionosphere that can be observed from a particular location. Charged particles precipitation, like solar rain (usually in auroral regions), effects the ionosphere. Sometimes, part of ionization can be transported from one place to another place, which causes the ionosphere.

The ionosphere keeps changing all the time. Many factors can influence the ionosphere greatly. Magnetic storms, different geographic regions, sunspot, different time in a year, in a month, even in a day, all of these are major factors. It is easy to understand why the ionosphere changes daily. The reason is that the ionization is generated by solar radiation. At night, there is not enough solar radiation. The ionization goes up in the morning. It reaches the peak in the early afternoon. At that time, the Total Electron Content (TEC) reaches the maximum also. As we can the figure 2, the maximum point usually appears at 2pm-3pm. The altitude of the ionization peak changes daily, too. At night, it rises higher because of the recombination in the lower altitude. The ionosphere changes a lot even in one day. Obviously, the change of the ionosphere depends on the sun greatly. The unusually behaviors of the ionosphere occurs at the same time when the sun is unusually active. Difference in latitude can cause the difference in the ionosphere markedly. The reason is the same. For instance, the solar radiation in the auroral region is very active so that the ionosphere is also active.

Systems and Operation

Global Positioning System (GPS) is used to determine the ionosphere. There are more than 20 this kind of satellites running around the earth. Each satellite sends two different signals to the ground. The signals were effected by the ionosphere. Many factors of the signals can be changed by the it, such as the time of the signal needs to reach the ground, which can be delayed. The receivers receive the signals and determine how much the signals are changed by the ionosphere. The data can be translated to the TEC. Computers are used to calculate and plot. See figure 3 and figure 4.

The receiver we use has four channels. The receiver can track four satellites simultaneously throughout the day. When we make the plots of the TEC vs. Time, we need the location of the satellites. Each location file contains 7 days' information of the satellites as a period. So, the plots overplotted contains 7 days. The behavior of the ionosphere is different in different latitude regions. In order to show this, the data are separated into three latitude regions. They are the north, overhead, and the south, with respect to the receiving station. Each directional plot contains all four channels' information. As the plots shown, the station used in the plots is at Shemya, Alaska.

Channel's plots are shown as "tracker". There four tracers' plot with respect to the four channels. The trackers' time is universal time (Greenwich time). Greenwich time is 12 hours ahead of the local time at Shemya. On the plots, the peak of TEC is seen around midnight universal time which is noon at Shemya. This is the time that the ionosphere is the most active. The directional plots' time is the universal time directly below the ionospheric penetration point (local time at IPP). The IPP the point where the line of site from the receiver to the satellite is at altitude of 350 km.

Summer Accomplishments

In addition to learning about the ionospheric research being done, an increase in knowledge of computers was gained. Fortran programs are used to process the data. They are run in the DOS environment. The DOS version is 5.0. Batch files are set up so that the processing of data can be automatic.

Six months of data from Shemya, Alaska have been processed. In the figures 3 and 4, several days of data are overplotted. The data are collected by the receivers on four channels, or trackers. The same data are also sorted according to latitude and plotted as north, overhead, and south relative to the receiver location.

The plots are studied to determine the behavior of the ionosphere. These plots sometimes contain traces that are uncharacteristic of ionospheric data. These are usually processing artifacts. Each unusual trace is marked, and a list of them is made so that they can be carefully reviewed and their origins determined.

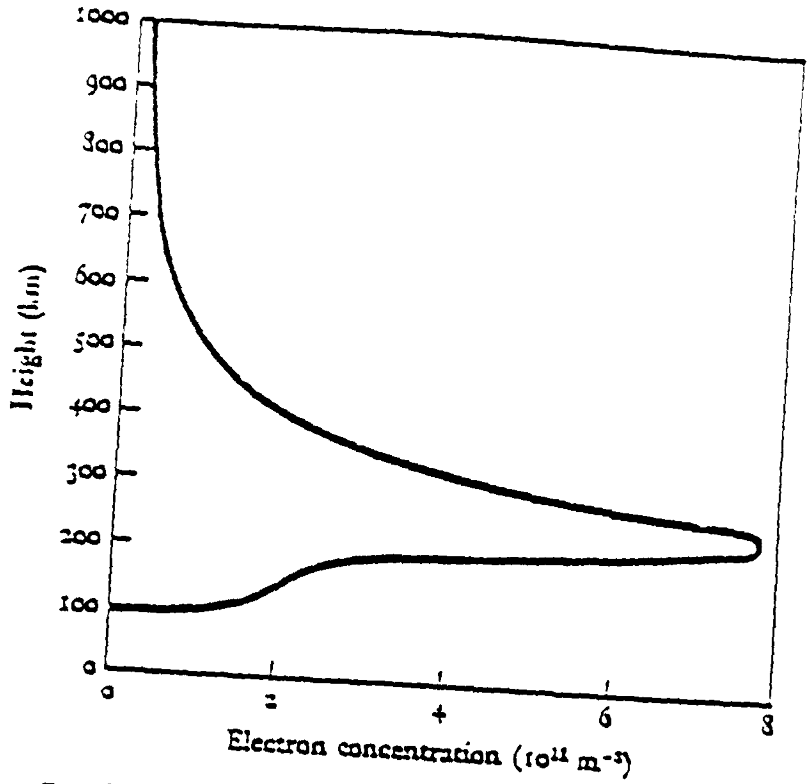


FIGURE 1

Typical Electron Density Profile of the Ionosphere

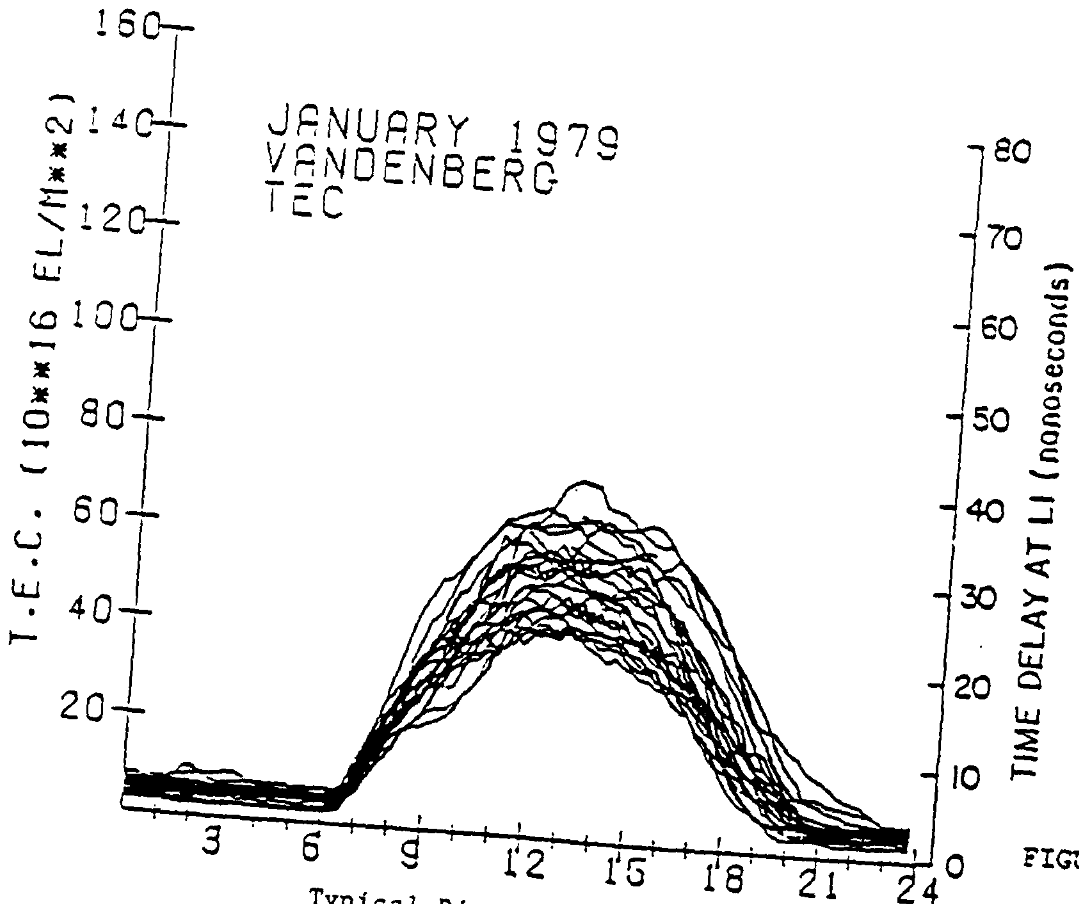


FIGURE 2

Typical Diurnal Variation

FIGURE 3

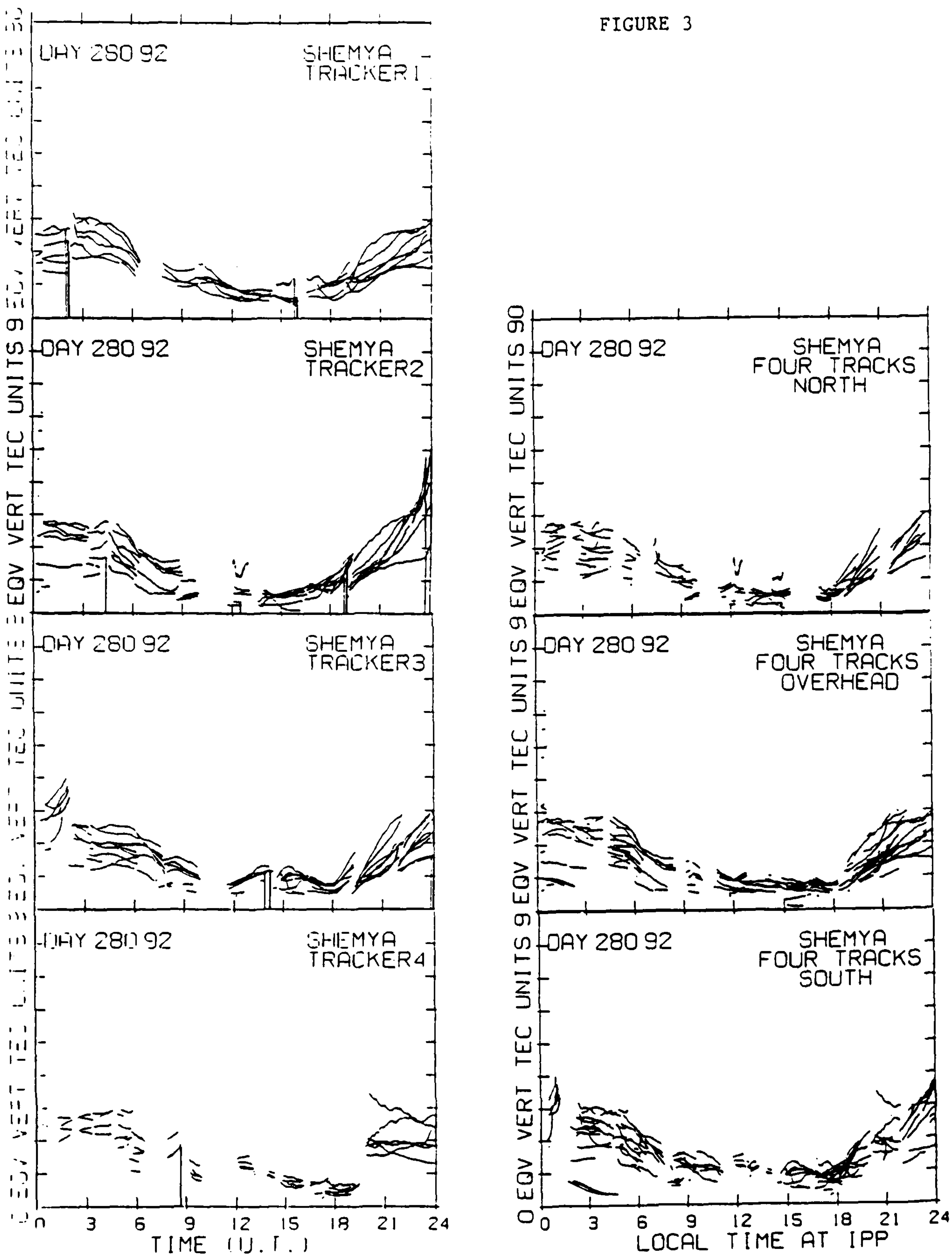
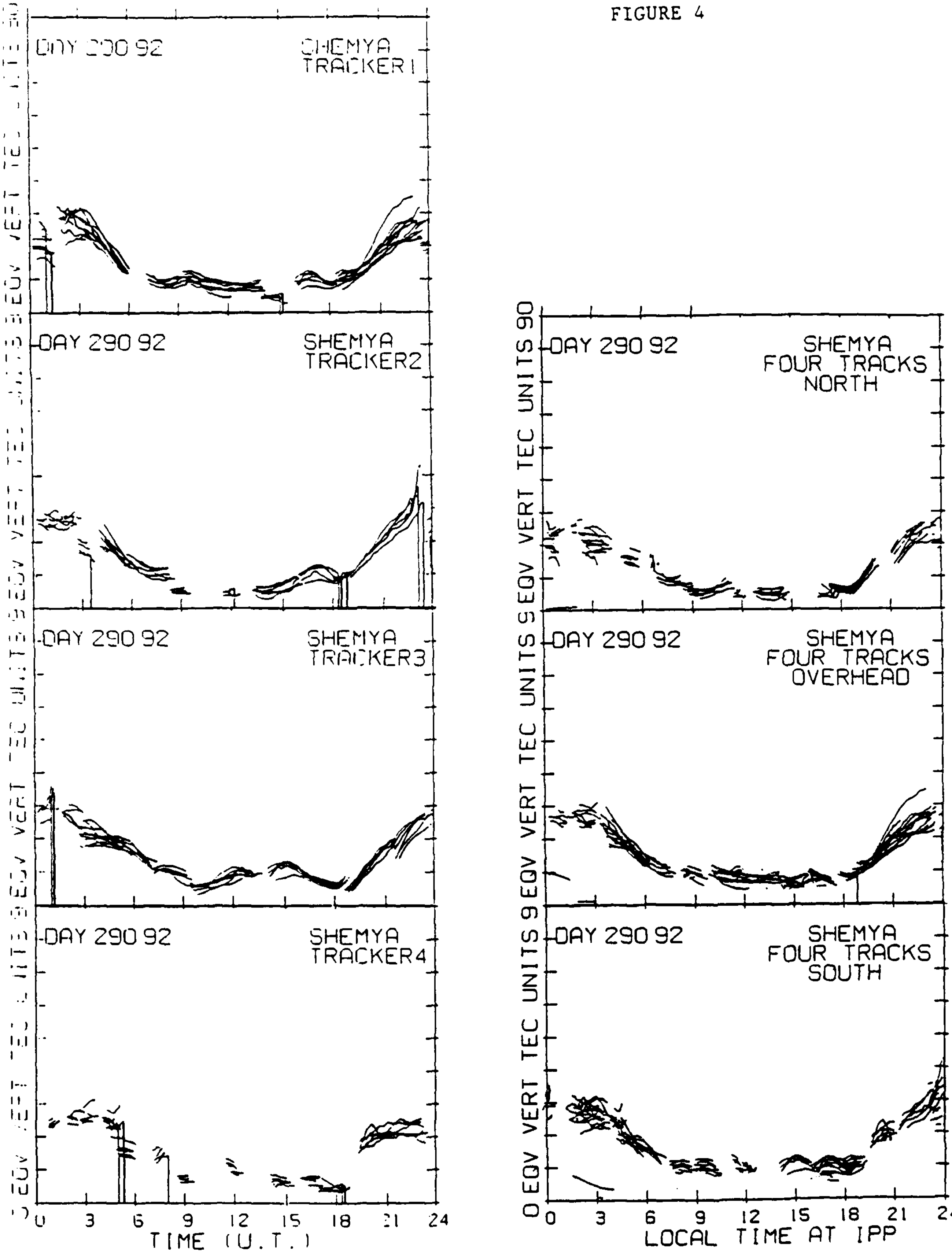

DAY 280 92
SHEMYA
TRACKER1
DAY 280 92
SHEMYA
TRACKER2
DAY 280 92
SHEMYA
TRACKER3
DAY 280 92
SHEMYA
TRACKER4
EQV VERT TEC UNITS
0
3
6
9
12
15
18
21
24
TIME (U.T.)
DAY 280 92
SHEMYA
FOUR TRACKS
NORTH
DAY 280 92
SHEMYA
FOUR TRACKS
OVERHEAD
DAY 280 92
SHEMYA
FOUR TRACKS
SOUTH
0 EQV VERT TEC UNITS 90
LOCAL TIME AT IPP

FIGURE 4


DAY 290 92
SHEMYA TRACKER1
DAY 290 92
SHEMYA TRACKER2
DAY 290 92
SHEMYA TRACKER3
DAY 290 92
SHEMYA TRACKER4
EQV VERT TEC UNITS
0 3 6 9 12 15 18 21 24
TIME (U.T.)
DAY 290 92
SHEMYA FOUR TRACKS NORTH
DAY 290 92
SHEMYA FOUR TRACKS OVERHEAD
DAY 290 92
SHEMYA FOUR TRACKS SOUTH
0 EQV VERT TEC UNITS 90
0 3 6 9 12 15 18 21 24
LOCAL TIME AT IPP

A VERIFICATION OF THE NGM- AND LFM-MOS FORECASTING MODELS' CLOUD AMOUNTS FORECASTS

Adam Smith
Summer Research Intern

Final Report for:
AFOSR Summer Research Program
Phillips Laboratory

Sponsored By:
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Bolling Air Force Base, Washington, D.C.

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A VERIFICATION OF THE NGM-
AND LFM-MOS FORECASTING MODELS'
CLOUD AMOUNTS FORECASTS

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Abstract

This project was intended to test the relative accuracies of the LFM MOS and NGM MOS forecasting model's cloud coverage forecasts. These models are used to forecast several variables, including cloud coverage amounts, twice per day (0Z and 12Z). Data from thirty stations was gathered over a period of five weeks, three days per week. Each data set consisted of the NGM and LFM predictions for that station over 36 hours and the actual observed cloud cover amounts over the same period, as well as a "persistence" forecast which predicts that the conditions present at the beginning of the period will remain present throughout the entire period. This data was then analyzed by comparing each of the NGM, LFM, and persistence forecasts with the actual conditions observed later. The LFM and NGM models both performed well, and both better than the persistence-based forecast, as expected.

A VERIFICATION OF THE NGM- AND LFM-MOS FORECASTING MODELS' CLOUD AMOUNTS FORECASTS

Adam Smith

-Introduction-

The LFM and NGM atmospheric models forecast several variables, including cloud amounts, twice per day (0Z and 12Z). Cloud coverage amounts are classified into four categories: clear, scattered, broken, and overcast, numerically represented as the numbers 1-4, respectively. Data from thirty stations was gathered over a period of five weeks, three days per week. Each data set consisted of the NGM and LFM predictions for that station over 36 hours and the actual observed cloud cover amounts over the same period, as well as a "persistence" forecast which predicts that the conditions present at the beginning of the period will remain present throughout the entire period. This data can be analyzed by comparing each of the NGM, LFM, and persistence forecasts with the actual conditions observed later. Compiled over time, these comparisons provide a database of the number of correct, nearly-correct, and far-from-correct predictions made by the three different methods (NGM, LFM, persistence).

-Methodology-

The data for the comparisons was drawn from services of the local computer network providing the LFM and NGM output for various stations as well as the reported observations (and therefor the persistence predictions). Data was gathered three times per week during the five weeks of the project. Each data set covered 36 hours: the +6, +12, +18, and +24 hour forecasts starting at 0Z and 12Z. Persistence values were taken from the time of the forecasts themselves (+0 hours): i.e. 0Z and 12Z. This data was initially recorded on paper, and latei entered into a computer file. Rather than tallying the almost 500 data sets by hand, it was decided that the compilation of statistics should be done by computer. As there was no existing computer program for such a task, a new program was written specific to the purpose, which could take the data from a file and perform all the necessary calculations, outputting to a file several tables comparing the LFM, NGM, and persistence forecasts to the actual observed conditions (see Figures). Each of these tables compares the output of one of the models with observed conditions by charting the number of predictions of each cloud coverage level as compared to the actual level.

Towards the end of the five week period, a program was written to automatically call up the one day's worth of data and output it for use with the first program, (which would end the task of calling up and writing down this information by hand) but this second program was not finished before the end of the five weeks. If the data collection is continued or repeated in the future, however, this facility will be available.

-Result-

Overall, the LFM model performed slightly better then the NGM, and both outperformed the persisten:: ıethod by a fairly large margin. The exception to this to this statement :omes with the 4/4 category: accurate predictions of level 4 (overcast) conditions, where a persistence forecast often does as well as or better than the LFM and NGM models.

This tendency may be the result of the relative infrequence of overcast conditions, and it should be noted that the persistence method simply predicts overcast skies much more often (nearly two times as frequently) than the NGM or LFM models. Therefor this is not necessarily a fault in the models: it is not beneficial to make a few more correct predictions at the price of many more added incorrect forecasts.

-Conclusions-

The LFM's slightly better overall performance was well within the margins of error for this experiment, so the two forecasting models should be evaluated as roughly equally accurate. Both outperformed the slightly educated guess of the persistence prediction, so this experiment certainly serves as a validation of both models to a workable degree. The two models were very close in their overall patterns, with a slight trend for the LFM to get more near-misses than wild guesses. The NGM was, conversely, slightly more spread out over the range of choices, but it did seem to do a little better at forecasting overcasts.

From the hour-by-hour breakdown, it becomes apparent that the NGM does a slightly better job of forecasting the near future (the +6 hours forecast) while the LFM takes the upper hand at forecasting results farther from the present, improving its lead from +12 hours out to +24 hours. The models' forecasts actually cover several days, going past the time range used in this experiment. These more extended forecasts might be an interesting subject for a similar study in the future. Both models tend toward the climatological norms for a given date as the forecast time gets farther from the valid time, which causes the two models to converge at longer time periods. It would be interesting and valuable to know which model held out longer with its short-term predictions, and whether these predictions stayed accurate at longer time periods. For the short-term forecasts, however, the models have shown their effectiveness as well as a tendency toward slightly different predictions. This provides meteorologists with a comparison between the two which, given this information about the relative merits of each model, can be ever more informative about the coming conditions than either model alone.

Database for:
0-sum:0 1993
+6 hours forecast.

OBS

		1	2	3	4
L	1	111	46	20	9
F	2	36	90	55	25
M	3	3	25	49	45
	4	2	3	25	63

lfm miss/bad: 14

OBS

		1	2	3	4
N	1	111	50	20	5
G	2	34	80	46	27
M	3	3	32	52	24
	4	1	6	32	89

ngm miss/bad: 10
Obs missing/bad: 29

OBS

		1	2	3	4
P	1	87	38	8	4
E	2	49	62	40	17
R	3	13	45	52	40
	4	2	23	51	82

per miss/bad: 21

Database for:
0-um::0 1993
+12 hours forecast.

OBS

		1	2	3	4
L	1	106	29	15	2
F	2	43	99	78	36
M	3	5	23	46	60
	4	1	7	15	82

lfm miss/bad: 15

OBS

		1	2	3	4
N	1	97	32	18	2
G	2	42	90	70	34
M	3	4	26	47	61
	4	2	5	16	79

ngm miss/bad: 34
Obs missing/bad: 21

OBS

		1	2	3	4
P	1	89	29	14	17
E	2	33	67	45	35
R	3	19	33	49	56
	4	14	33	49	71

per miss/bad: 21

Database for:
0-um::0 1993
+18 hours forecast.

OBS

		1	2	3	4
L	1	128	34	18	7
F	2	36	91	50	27
M	3	8	24	42	55
	4	3	9	16	54

lfm miss/bad: 11

OBS

		1	2	3	4
N	1	120	29	17	8
G	2	38	93	60	34
M	3	2	20	33	49
	4	4	9	13	48

ngm miss/bad: 33
Obs missing/bad: 55

OBS

		1	2	3	4
P	1	96	15	17	13
E	2	41	69	30	26
R	3	20	42	36	49
	4	21	33	45	54

per miss/bad: 20

Database for:
0-um::0 1993
+24 hours forecast.

OBS

		1	2	3	4
L	1	103	29	11	6
F	2	49	85	70	29
M	3	5	27	45	47
	4	3	5	19	58

lfm miss/bad: 15

OBS

		1	2	3	4
N	1	95	31	15	6
G	2	44	82	75	35
M	3	3	28	43	53
	4	3	4	10	42

ngm miss/bad: 34
Obs missing/bad: 20

OBS

		1	2	3	4
P	1	85	31	16	9
E	2	44	52	44	21
R	3	14	34	47	52
	4	15	35	43	58

per miss/bad: 18

Database for:
0-sum:0 1993
+0 hours forecast.

OBS

		1	2	3	4
L	1	427	132	61	23
F	2	154	346	245	112
M	3	21	99	177	202
	4	9	23	75	255

lfm miss/bad: 58

OBS

		1	2	3	4
N	1	426	142	70	21
G	2	158	345	251	130
M	3	12	106	175	187
	4	10	24	71	258

ngm miss/bad: 34
Obs missing/bad: 121

OBS

		1	2	3	4
P	1	338	107	52	41
E	2	161	239	151	98
R	3	63	152	180	194
	4	49	117	187	258

per miss/bad: 77

HYPERSPECTRAL IMAGING: FIELD EXPERIMENTS

Laura C. Ackermann

Final Report for:
AFOSR Summer Research Program
Phillips Laboratory
Kirtland Air Force Base, New Mexico

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Research and Development Laboratories
Culver City, California

August 1993

HYPERSPECTRAL IMAGING: FIELD EXPERIMENTS

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Abstract

The application of hyperspectral techniques to the imaging and identification of space objects was investigated during a series of field experiments at the Starfire Optical Range. Prior modeling and simulation efforts indicated that the increased target object information obtainable through hyperspectrometry should significantly enhance the ability to perform Space Object Identification (SOI). During the test series, many satellite targets were acquired and tracked, and data was recorded for subsequent analysis and evolution. The concept of hyperspectrometry is described in general terms, and aspects of the field tests are described. Technical performance of this long-term research is under the direction of Capt. Susan Durham, Ph.D. of the Phillips Laboratory's Imaging Technology Branch (PL/LIMI).

HYPERSPECTRAL IMAGING: FIELD EXPERIMENTS

Laura C. Ackermann

Introduction

With the recent proliferation of satellites, the identification of these objects in near- and deep-space orbits has taken on increased importance for the Air Force. Not only is it important to be able to track the satellites and thus determine their orbital element sets, but with more and more countries joining the "space club," it is essential for the United States to be able to assess the purpose of the satellites. This part of the program is known as Space Object Identification (SOI). For decades, the primary technology for accomplishing this has been based on radar. More recently, advances in optical technology have been used to increase the amount of information available to the analyst in trying to determine the function of an unknown satellite. These optical systems worked predominantly in the visible and infra-red regions of the spectrum. Current investigation is based on the premise that much more target object information can be obtained than is now available. Simulation and modeling have shown that hyperspectrometry should be able to provide this. Tests in a controlled laboratory environment have demonstrated that hyperspectrometry is able to provide both spectral and spatial information, and will, after the establishment of a sufficient data base, provide material composition information on the observed target. During this phase of the program, field experiments in a realistic environment were conducted to establish the capability of hyperspectral imaging in supporting the Air Force SOI mission.

Discussion

I was very fortunate to be selected to participate in an experimental program which was still in its beginning phases when I began my research. This program in hyperspectral imaging directly supports the mission of the Lasers and Imaging Directorate, to one of whose divisions I was assigned. Our mission was "to ascertain if hyperspectrometry has a place in Space Object Identification." In order to do this, the start of our effort consisted solely of identifying deep-space objects; that is, we tried to establish whether or not deep-space objects possess unique spectral signatures which we could detect and analyze.

It was understood that this experiment was not intended to advance state-of-the-art technology, but rather to use existing hyperspectral devices and configure them to our requirements. The necessary software for data reduction also existed, had been tested, and was thoroughly understood.

The process of implementation was to be the standard scientific method. Laboratory investigations and modeling were followed by production of the data-analysis software and the building and testing of hyperspectrometers.

A description of hyperspectrometry is best begun with a brief explanation of the concept of the spectrum, which can be described as "the characteristic distribution of energy of a physical system or phenomenon," and with the observation that standard spectrometry can provide very high resolution spectral data, but does not provide any spatial information about the target object. That is, one can determine the wavelength information from the target to high accuracy, but nothing about the target's size or spatial characteristics (see Figure #1).

A method between conventional spectrometry and hyperspectrometry known as multi-spectrometry is able to provide a degree of spectral and spatial information. It does not, however, have the excellent resolution possible with conventional spectrometry. To provide this information, it utilizes several distinct spectral band corresponding to certain spatial elements (see Figure #2). Hyperspectrometry, in comparison, is able to provide information relating to hundreds of spatial elements. This simultaneously available information would allow for a greater number of data elements to be used for a higher certainty of identifying the observed target (see Figure #3).

The immediate use of hyperspectrometry will be to contribute to the SOI mission in the essential area of obtaining satellite spectral signatures, which will help in reducing misidentification. Later, the intent is to add the ability to characterize material composition of satellites and establish a database of signatures.

I became associated with the program during the Field Experiment phase. Preliminary modeling and analysis and laboratory experiments for equipment characterization had already been performed, and some interesting results had been obtained. It was noted, for example, that solar light reflecting off a metal produced linearly polarized light, while a reflection off a dielectric and onto a metal produced circularly polarized light. Additional modeling efforts concentrated on signatures of unresolved satellites in geosynchronous orbits and what would result if several distinct material signatures would overlap. A very important question was whether enough light would be reflected from a distant satellite to produce an adequate signature above the background noise level. Results of all these early investigations were sufficiently positive to provide encouragement for continued work.

It was realized from the beginning that the true test of hyperspectral imaging program was to take place in the form of field experiments. During this test series in a realistic environment, the hyperspectral equipment was installed at the Starfire Optical Range on Kirtland Air Force Base, New Mexico, and was used to collect data on many space objects. Supplied with satellite orbital element sets which define the orbit in terms of time and space, we acquired and tracked targets and recorded the signature data for later analysis.

Methodology

Since the hyperspectral imaging program is a long-term project, I was primarily involved with the field experiment and data collection phase of the program during my research. Preliminary theoretical and experimental work had already established that the proposed imaging method should lead to the acquisition of additional information about the observed targets, but the final validation of the concept was to occur during the field experiments and subsequent data analysis.

Hyperspectrometers and detector assemblies were installed at the optical site, telescope time was scheduled, arrangements were made to obtain up-to-date satellite orbital data sets at the appropriate times, and crews were scheduled for night work. Upon reporting for duty, the crew chief briefed the night's activities, announcing any changes in data collection procedures, safety concerns, and any operating limitations affecting the test, and also giving information on the satellites we were going to track.

Successful performance required close cooperation between crew members since the satellite had to be acquired as soon as possible to allow the maximum time for data collection on each pass. I directly supported this team effort by operating the dome. In order to perform my duties, I had to learn about meteorology and astronomy. I was personally responsible for the safety of the telescope, as I was the only one with access to weather conditions. In addition, efforts continued during the daytime hours, when I assisted with mission planning. After becoming familiar with my mentor's software, I contributed to the establishment of a system for organizing and storing the log in a format compatible with data analysis.

Results

The results of the hyperspectral field experiment are currently being analyzed and evaluated. Unfortunately, all members of the hyperspectral imaging team are in Hawaii, continuing their research at the AMOS Optical Range, and I have no access to the data. To date, however, simulations and modeling efforts have indicated that hyperspectrometry is a viable concept for obtaining additional information about space objects, and laboratory experiments support this conclusion. The field tests that we performed this summer indicate that deep-space objects can be observed by this method, but the analysis and evaluation will be the final determinant of the method's value to the SOI community. The field tests performed at the Starfire Optical Range will later be supplemented by an additional test series as equipment is modified and optimized for this mission.

Conclusion

The field test phase of the hyperspectral program must be considered the most important part of the total effort. While simulations and models might give the indication that a conceptual system will perform to a certain level of capability and should be able to provide expected results, and while controlled laboratory experiments might give confidence that a system will perform, it is the field experiment which is the final judge of whether the system meets performance requirements.

The field tests conducted in July resulted in a large amount of hyperspectral data from numerous different satellites that had different orbits, elevation angles from the horizon, and atmospheric conditions. This phase of the program concerned itself primarily with data collection efforts and to a *much lesser extent* with system operation procedure improvements, and it met those objectives. Program success at this time can be strongly inferred based on the system's ability to obtain data from deep space objects, but final success, and the degree of this success must wait until completion of data analysis. Only then will we know to what extent hyperspectral imaging technology enhances our capability to identify space objects.

Figure #1

(Conventional Spectrometry)

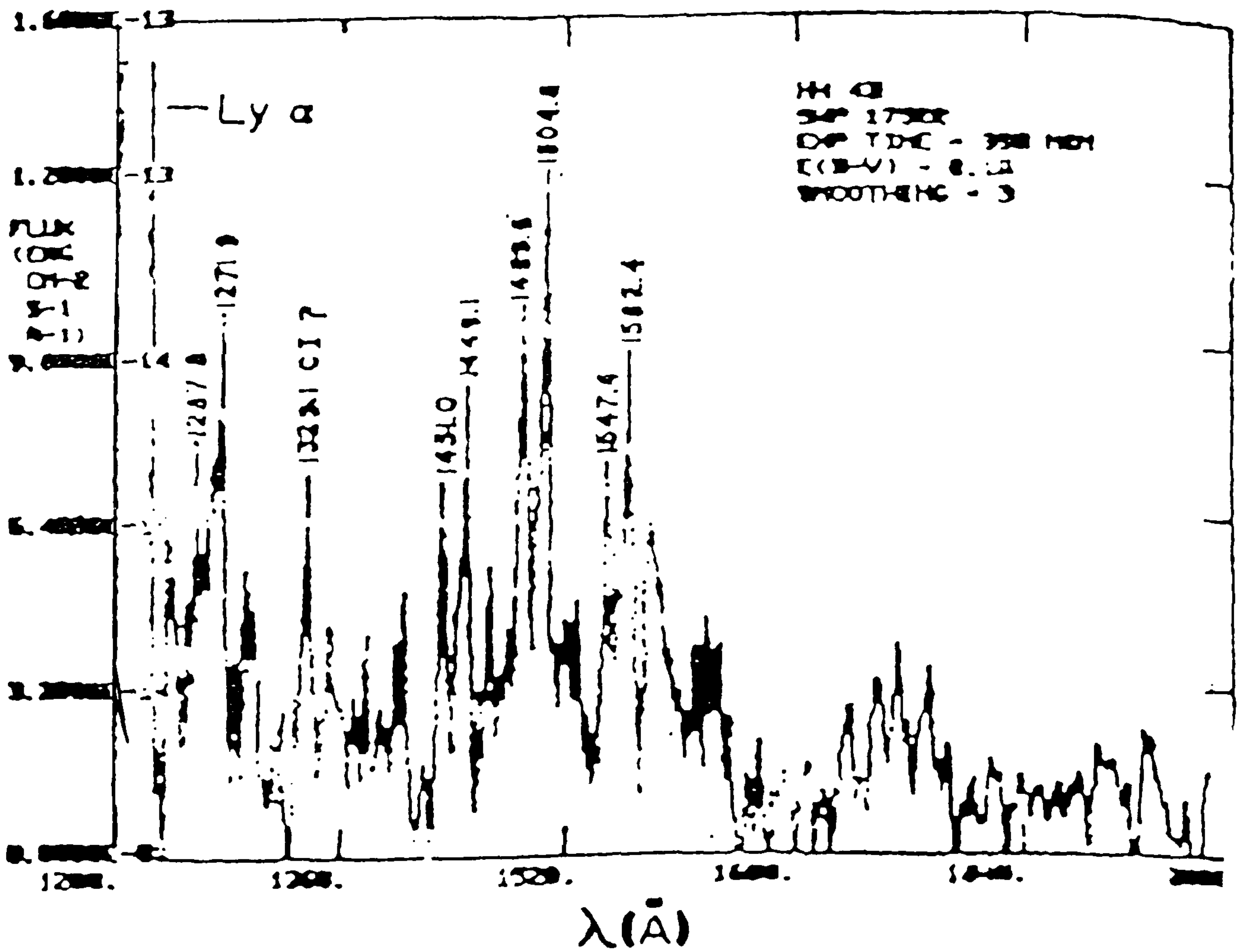


Figure #2

(Multi-Spectrometry)

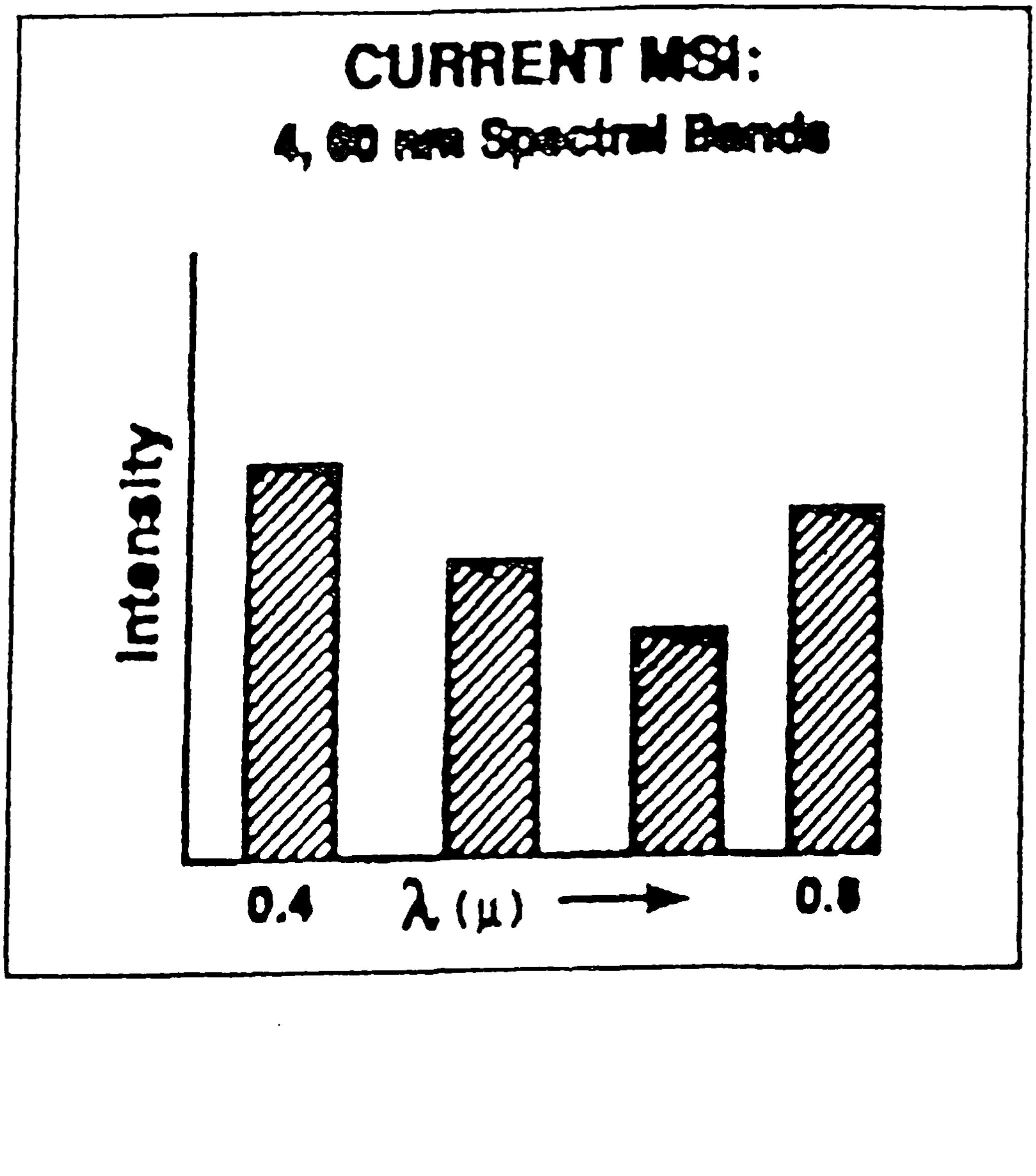
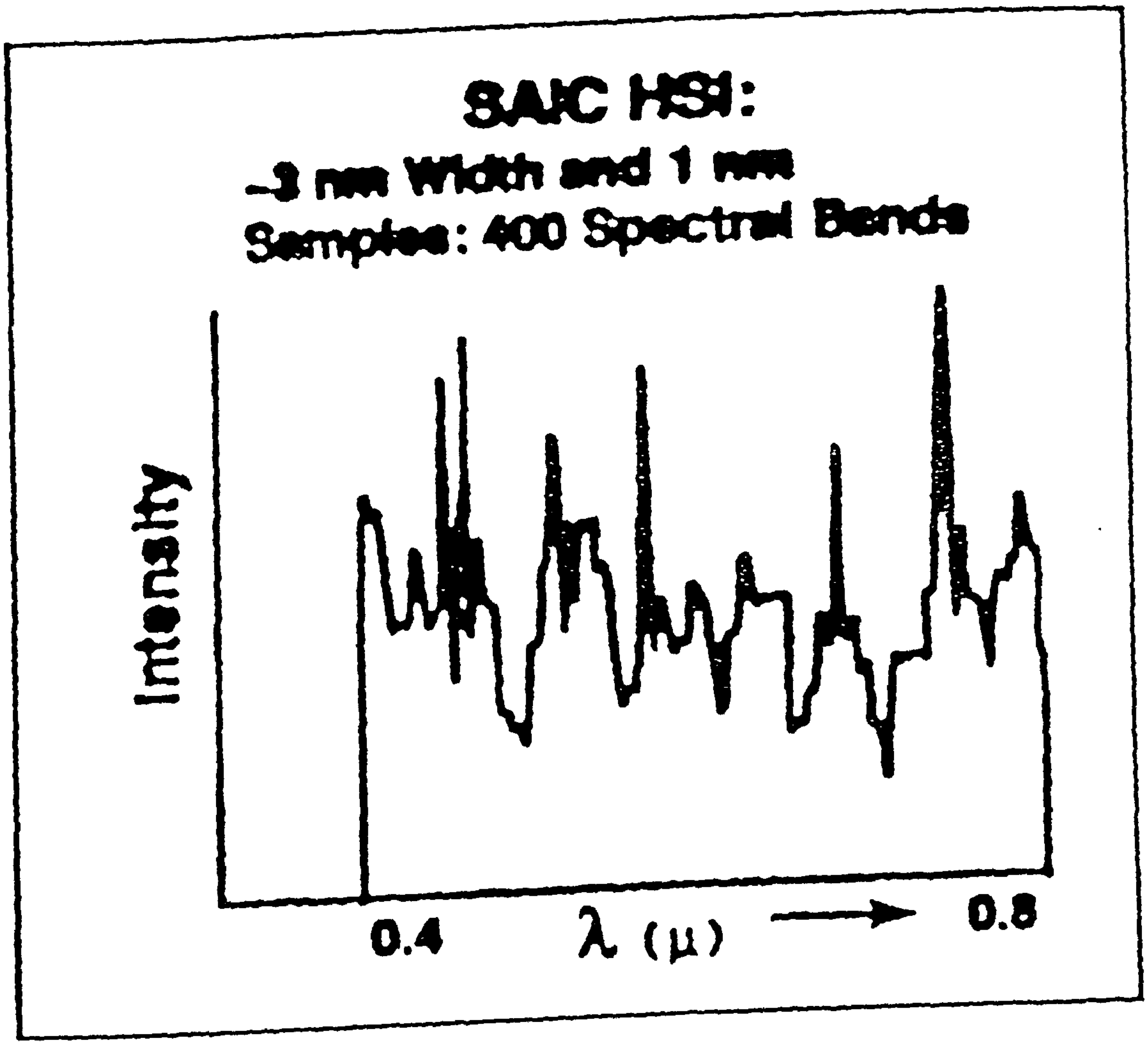


Figure #3

(Hyperspectrometry)



General Optics

(The Clueless Summer hires Guide to
life at Phillips Laboratory)

Blake Ethridge

Final Report for:
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General Optics

(The Clueless Summerhires Guide to
life at Phillips Laboratory)

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1.0 Introduction

Hello. My name is Blake Ethridge, but I guess you figured that out from the title page and from that little heading at the top of this page. Well I guess you have also seen the title of this paper. Let me explain. I have worked at Phillips for two summers and over that time I have picked up some helpful hints on optics and general survival, and I would like to pass them on to you, the new clueless summerhire, apprentice, internist or any other person who basically does not know what they are doing or why they are doing it.

Actually I know very little about optics. I know what I have learned by trial and error or what some annoyed scientist has told me after I made a blundering stupid mistake (this happened a lot but the scientists that I worked with were pretty patient). Believe me when I say this it really isn't that hard to pick up how to work with optics, you could probably train a blind monkey to do it, it just takes many hours of working at the optics table and fiddling with the equipment. And if you are ever interested I am sure that you could get a grant from the government to try and train a blind monkey to work with optics, but I would prefer to stay away from the monkey training field, entirely.

Anyway to tell you a little bit more about myself, I just graduated from La Cueva High School in Albuquerque, New Mexico; and I am going to be attending Goucher College, a small liberal arts school in Baltimore, Maryland in the fall. I plan on majoring in Biochemistry, and I them hope to go onto medical school and specialize in Orthopedic Surgery. Now I know what you are probably thinking and if you aren't thinking it you probably should be. Yes, optics don't have much to do with biochemistry and the association of imaging and lasers to some areas of the medical field is barely enough to warrant a job working in Lasers and Imaging. Well if you were thinking that, you are probably right, and if you were to ask me why I was working here, I probably couldn't come up with a good answer. I would just say that this is a good job and although it is not what I want to do "when I grow up" it is at times very interesting and it looks great on a resume. I did think that this might be what I wanted to go into two years ago when I first applied for the job, but since then I have found that I have found a great enthusiasm and curiosity for the field of medicine. Anyway that is enough about me and I'll get on with the paper.

2.0 Day One

2.1 The Beginning

You are probably kind of nervous and you don't really know what to do, when to do it, or where you should do it. On my first day I didn't know where to go or what to do and whenever I walked up to a door it said, "PHILLIPS LAB BADGE REQUIERD BEYOND THIS POINT." I quickly figured out that I should get a badge of some sort so I could go into the building where I was supposed to meet my boss. This seemed very simple, but I didn't know where to get a badge until I found the Visitor Control Center (now there is a ominous sounding military name for a building). In there I found the badge office and managed to get a visitor badge (I was getting somewhere), but that was not all I had to do the gut working at the office told me that I had to go to personnel and get in processed. Now there is an adventure, In-processing.

2.2 In Processing

Ok, this is actually very simple and everybody has to do it so don't complain and just hurry up and get it done. As a summer hire first off you need to talk to the supervisor of the program that you are on or your boss and get a paper which has your name on it and all of the in processing info too. This piece of paper should have a list of places where you have to go and check in or get registered or something. Go to all these places be patient and do what the people there ask you to do. Don't be afraid to ask for directions to the places on the list and I found that it was quickest if you get directions from place on the list that you are at to get to the next place on the list. An example would be if you were at the orderly room, and the next place that was on your list was the tech library, then you would ask the person in the orderly room how to get to the tech library. I know it sounds simple and idiotic, but I wish that I had some sort of guide on my first day. Now in processing may take you more than one day to do, but don't take too long and try to get the paper back to the person who gave it to you as soon as possible.

2.2 The end of the day

Make sure that you stay for your eight hours or however long you plan to work every day and remember that it doesn't hurt to stay a little bit longer if you need to. Also, and this is very important, as you are introduced to and meet people remember their names and try to remember where they work and what they do. This can be very hard, but if you spend some time with it at the beginning of the summer than you will save a lot of time when you actually start working on something. There is not a whole lot that you can do on the first day or the first week really, but just try to catch on to how things work and who you can get help from when you need it.

3.0 Optics

3.1 What are Optics?

This is a simple enough question. Guess what, though, optics are made up of whole lot of different kinds of equipment, and there are probably too many different things to list them all in this paper.

The main components of optics are mirrors, lenses, lasers, cameras, the mounts for all of those things, screws (lots and lots of screws), screwdrivers, optics tables, and of course computers lots of computers.

Optics tables 3.1.1

And of course most of all of these things are all put on to a special table called an optics table. You ask what is and optics table? It is a big heavy table that some company has painstakingly drilled hundreds of little holes, that are all usually one centimeter apart, into the table. This company usually turns around and sells this table to the government for much more money than you will make while you work for the government. Anyway they are pretty nice and they are usually up on some sort of shock absorbing stand and a large percent of them have little cages built on top of them. These cages are made out of a roof and doors around the sides, and they can be light tight, when the stuff the cage is made out of is a dark solid which allows no light to pass or they can be made out of clear plexiglass. There are also little say miniature boards that are made similarly to the table, but they are not as big and you can use then either on the table or as an independent stand. These are called breadboards. Optics tables are great things and without them it would be darn near impossible to align and projects in under several weeks.

3.1.2 Mirrors

These are simple little things you all know what they are and what they do. Almost everybody has one in their home and most peoples personal hygiene would go down the tubes without them. Most of the time mirrors are flat surfaced mirrors which means they reflect an image that is exactly the same as the one being projected onto the mirror. The only time I have ever seen a mirror that is not flat is at the fun house at the state fair. I guess a non-flat mirror could be used in imaging, and I am sure it is but I have never seen one used. Now mirrors are not just mirrors, they come in all different sizes, but their shape is usually round. It is best to use a large mirror when setting up an optical system because it gives you freedom in mounting it and when you have to have a beam hitting a mirror right in the middle it turns out to be a real pain when you align your system. So if you have a beam, a laser beam, that is two inches in diameter then you want to have a three inch mirror at the minimum. Also, when you are trying to decide on which mirror to use, look at the surfaces of the mirrors that you have and see which ones have the least amount of scratches, nicks, or dust on them. The imperfections in the mirrors can potentially misshape you beam when it hits it and make it so that is no longer in phase or alignment. Mirrors are also very fragile and remember if you break one not only will you have bad luck for seven years, but you will also have some pretty upset scientists on you case.

3.1.3 Lenses

Lenses are very simply a type of glass or clear solid that is shaped in a certain way as to give or take away certain characteristics of a beam. Some lenses will cause the beam to expand, some lenses will make a beam collapse and some lenses will make a beam stop expanding or collapsing. Other types of lenses can split a beam into two different beams, this is called a beam splitter. These can also be used to combine two beams together, and this can be very important. I don't think that there is any superstition about breaking lenses or beam splitters, but if I were you I would still be very careful as to not breaking any.

3.1.4 Lasers

Lasers are wonderful things which create an in phase intensified beam of light. This is about all I know about them, well actually with the assistance of a book I could probably go into exactly how they work, but I am no going to. Anyway the big thing to remember with these things is don't look into the laser, don't let the beam touch your eyes, always wear the safety goggles that should be supplied to you, and never let anyone else do any of the above. If goggles are not made available to you don't be afraid to ask for them. Just be careful and don't play around with the lasers because they can cause plenty of damage.

3.1.5 Cameras

These are basically very similar to any type camcorder that you may see at any electronics store, but the difference here is that they are much more complex they are most often hooked up to a computer. These are used to collect information of position and characteristics of a beam in a much more exact technique than visual observation.

3.1.5 Mounts

There are what seems like hundreds of different ways to mount just one mirror or lenses. There are mounts which allow for little if any movement and there are mounts that have a lot of freedom and both of these have their good and bad points. At first when I started working on optics I thought that I didn't need and range of movement at all and that fixed mounts were the key to creating o good system, but now I think that I was wrong. Some people may agree with the old me, but I do not. Mounts with a large range of movement are usually a little harder to find, a little harder to put together, and a little more difficult to mount to the table; but when it comes to aligning a system after it is all set up it is almost impossible without range of movement. The different kinds of ranges of movement would be side-to-side, forward and backward, tip, tilt, height, horizontal, and vertical. These are all very important when it comes to aligning a beam through a system of mirrors and lenses to a target. When you start working with the equipment you will quickly pick up on which equipment does what and what is best for what application. Also, after you mount your lens or mirror then you need to somehow attach it to the table. Personally I have come to find that a magnetic platform is best because it allows for movement of the base in-between where the holes are in the table. Anyway the art of mounting can not be taught on paper you just need to go out there and play around with the stuff to learn how to use it.

3.1.5 Screws and Screwdrivers

Actually what most optical labs use are balldriven screws and balldriving screwdrivers. These type screws have a hole in the top of the screw in the shape of a hexagon or some other polygonal shape which matches the drivers which fit into the top of the screw. These are actually much easier to use because of this fact. Also the screws and drivers usually come in all different lengths, thicknesses, and colors; and it can actually be very difficult to match the right size screw to the right size driver.

3.1.6 Computers

Our society is constantly moving toward the use of more and more computers. Computer literacy and competence is an essential factor is succeeding in the world of today. I can not stress that last statement enough. You as a person working in a scientific field need to be able to work on several different kinds of machines and in several different programs to be able to survive. Also you need to acquire the ability to adapt to new systems and learn them as fast as possible. It is simply essential for survival.

3.1.7 General Hints

Ok, don't drop or brake anything. Don't touch the surfaces of the lenses or mirrors. Always ask questions if you are not sure about something. Don't ever let a laser beam get near your eye, never put you eyes on the same plane as the beam, and always wear your safety equipment. Oh, and did I say Don't Break Anything.

3.2 Working With Optics

Well most of what you need to I have already mentioned here or there in this paper already. There are just a few more things that I feel I should mention. First, always map out what you are building, make sure you have the equipment to build it and make sure you have the space on a table or wherever you are going to build you system. Second, be careful with the equipment when you start to work with it because most of it is fragile. Third, be patient when putting together a mount or building a system it takes time and believe it or not but a lot of energy. If you do all these things and remember to be safe you will always be fine.

3.3 Aligning Optics

This can be so very frustrating and take a long time or it can be very simple and quick. Aligning is when you have set up all the equipment where it needs to be and you need to make sure that the beam will get from point A, the origin, to Point Z, the destination, and hit all the other points along the way. This is a process of fine tuning all the adjustments that you a installed on you mounts so that the beams path is exactly where you want it. First of all, unless you need the beam to be rising or falling, I believe that it is best to align the beam vertically. The best way to do this is to set up a piece of paper on a stand and draw a target with a dot in the center, a horizontal line and a vertical line. Next make sure that the beam is at the exact same height all along its path from beginning to end. Do this by starting at the beginning of the system and making sure the beam coming out of the laser is straight by putting the target up close to it and then far away from it. Then adjust the tilt of the laser so that it is on target all the way in-between the two points far and near. Go through this process with every of equipment in the system. After that is accomplished the horizontal needs to be aligned and this is much more difficult in certain situations, and in some situations it doesn't really need to be done as long as the beam gets to where it is supposed to be. In the difficult situations which is most often when multiple beams are being used I have found that it is best to try to try to align the separate beams on mirrors or lenses that only that beam is using. If that is not possible though then the best way to align the beams together is to align one beam, then the other beam, then align the first beam again because it was probably messed up by the aligning of the second beam, then align the second beam again, and then keep aligning them over and over again until you have the best compromise between the two beams. Again be patient when aligning and sometimes you just have to fiddle around and try different things until something works.

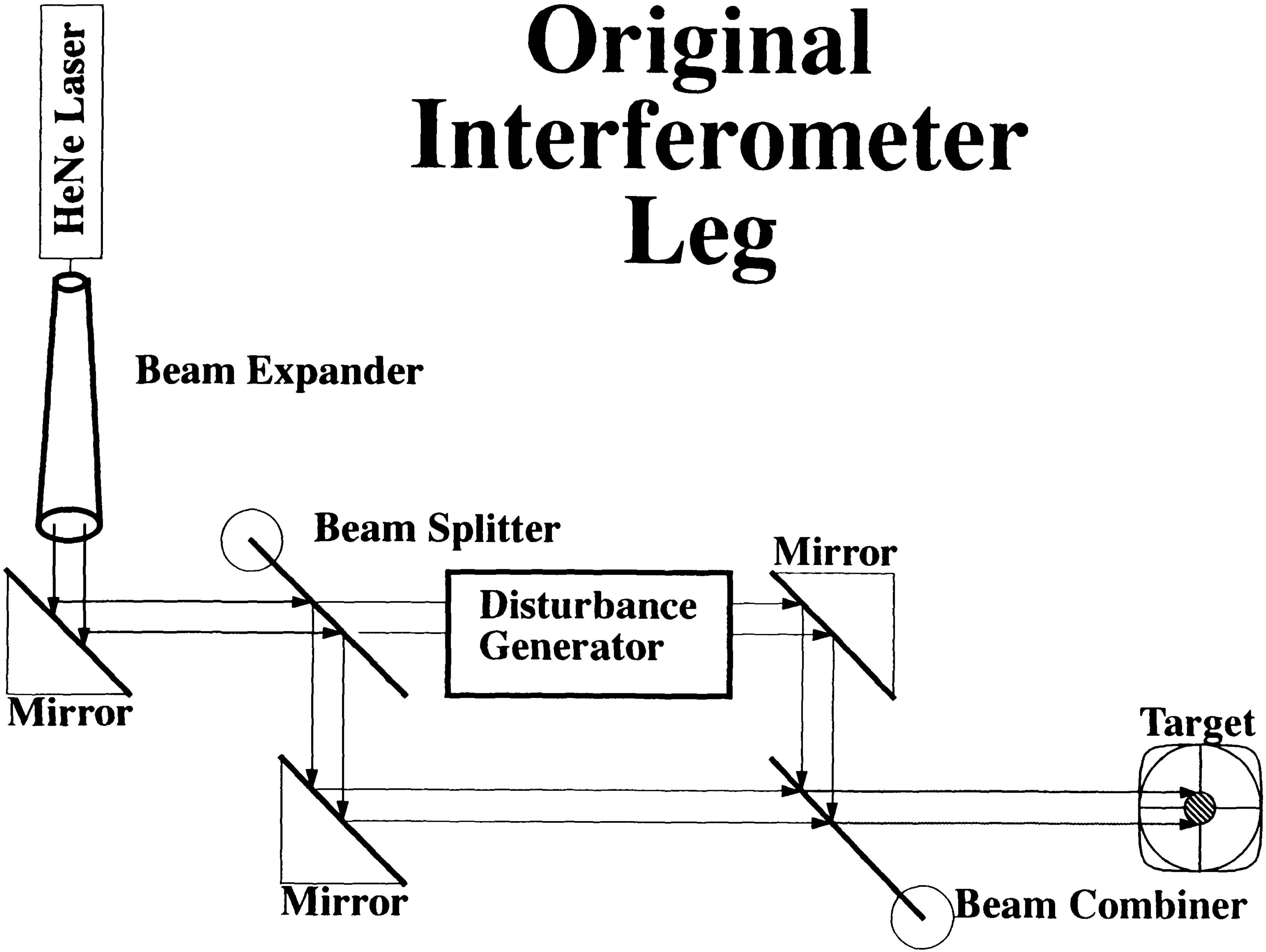
4.0 What I Did With What I Know

I didn't just play with the optical equipment while I was here I actually did something that was productive. What I did was build a Mach-Zehnder Interferometer with one leg going through a tunnel where certain atmospheric disturbances were injected. The tunnel consisted of four heating elements on the bottom of the tunnel and two fans on the top of the tunnel. I then studied the effect of heat and wind on the fringe patterns of the interferometer. I studied at three different heat levels and with the fans on and off at each level. The levels consisted of 0 Hz, 36 Hz, and 144 Hz. I studied each of these six setting at five different areas of the tunnel. I found that the original two fringes became approximately thirty to forty when the heat was turned up and that when the fans were on that the fringes shook back and forth very rapidly. I then added on another leg to the disturbance leg in which the beam was diverted and sent through a phase plate which was also supposed to simulate a atmospheric disturbance. Then I added that beam back to the interferometer. Next I added on another leg in which the phase plate leg did not recombine to the interferometer and sent it to a camera attached to a computer with software to read and display it. Later, I also added a leg to the interferometer which went to the same camera. I took several pictures of this completed system and have added them to this report at the end. They appear to be nothing more than a bunch of junk on a table, but it actually is a system. I also have added a diagram of the system on the end of this report.

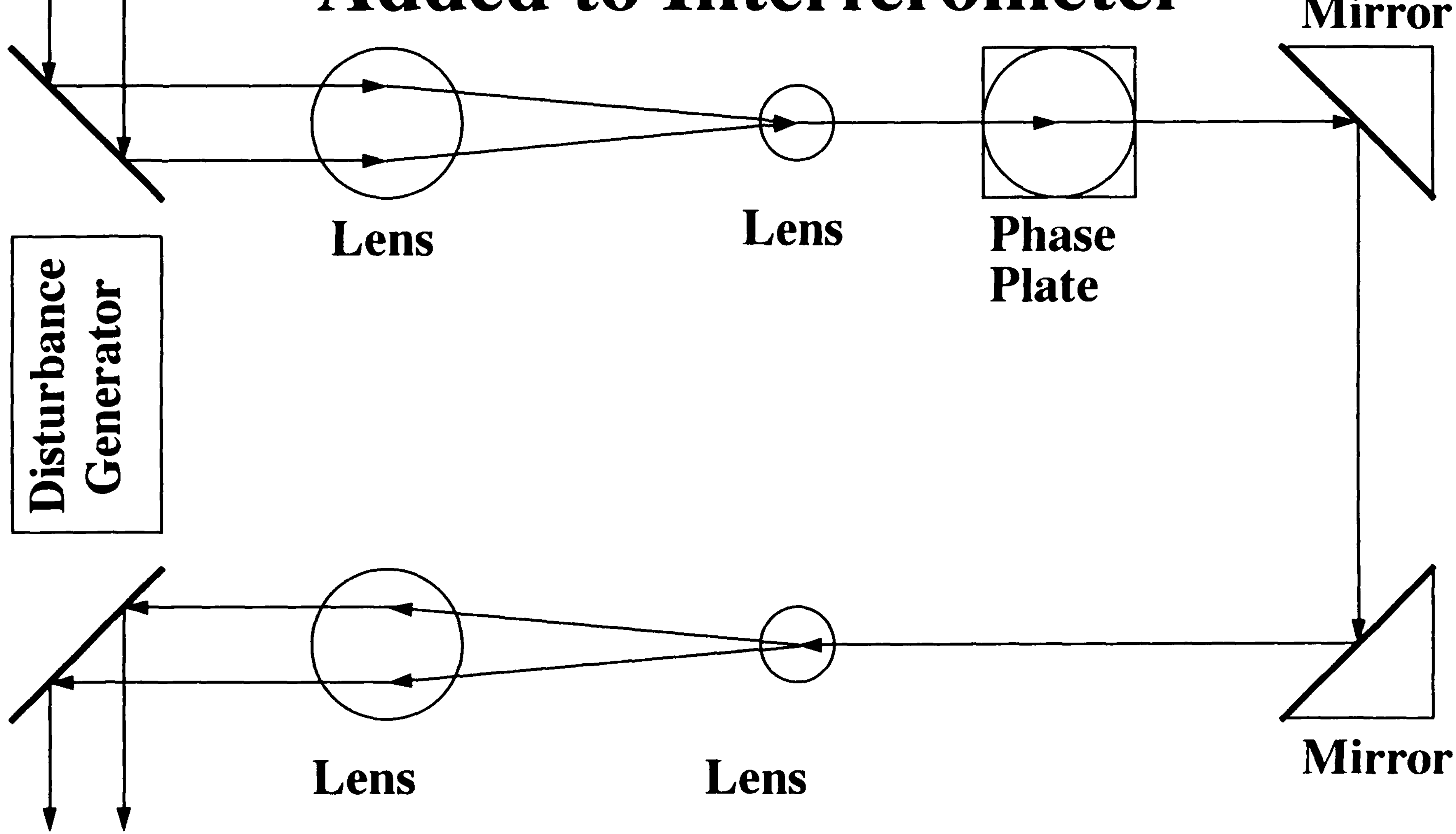
5.0 Conclusion

Overall during the past two summers I have learned so much about computers and optical technology. Last year I wrote a report of a Fuzzy-C Optical Tracker which I had a great time working with and learning about. This summer unfortunately I did not have the opportunity to work on a major project. I did set up the tracker again, but due to other projects I was not given anything to do with it, and I was not given the upgraded software which was used on it during the school year. I did have the chance to work with a Sun system which this report was written on. I also used a 386 PC and a NEXT machine. I learned a lot about the Windows programs and about computer hardware. Overall I have had a wonderful time working at Phillips Laboratory. It was a wonderful opportunity!

Original Interferometer Leg



Phase Plate Leg
Added to Interferometer



Benjamin Ortiz's report not available at time of publication.

EXPERIMENTS IN THE NONLINEAR OPTICS BRANCH OF THE PHILLIPS LABORATORY

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FINAL REPORT FOR:

AFOSR SUMMER RESEARCH PROGRAM

PHILLIPS LABORATORY

AFOSR SPONSORSHIP

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This summer at Phillips Laboratories I had the opportunity to assist others on some very interesting experiments. One of these experiments was making electronic circuits. I assisted in the making of a digital peak detector and a filter circuit. The peak detector was built to detect peak light intensity. In simpler terms, this circuit could be used to measure the intensity of lasers, sunlight, or any other source of light in which the intensity is unknown. The filter circuit was the more complicated of the two circuits on which I assisted. The goal of this project was to make a frequency selective network which illuminates LED's (Light Emitting Diodes) according to a certain frequency input. This project breaks the audible frequency into three different bands; low-band (0-5 kHz), mid-band (5-10 kHz), and high-band (10-20 kHz). The concept of this was to use filters to identify frequency. For example, if a certain filter passed a signal, one could indicate which frequency band that signal was in by simply turning on a LED. These filters would also eliminate the use of inductors and if needed, could amplify the signal. There are many practical uses for this circuit. For instance, controlling the intensity of an air conditioner in a house or automated light for a concert or light show.

The other task I was involved in is the sodium dye-laser experiment. The experiment worked on in the laboratory is only a small part of a larger experiment. The whole experiment involves shooting a laser beam at the sodium resonance wavelength to the mesosphere where there is a layer of sodium. The beam interacts with sodium particles and causes them to fluoresce. Some of the scattered light comes back down to earth, and is used to measure the aberrations caused by the turbulence in the atmosphere. The purpose of the experiment in the laboratory is to amplify the earthbound fluorescent light to enable measurement of higher-order aberrations.

All in all the program which I was involved in was set up pretty well. This job was different from other jobs because there was no daily routine. Whatever needed to be done at a certain time got done at that time. It was interesting working with people older than myself because it matured me more and made me more self-dependent. The AFOSR program also helped me narrow down what I want to study in college and perhaps choose a career in. This program is a good learning experience and should be offered to more young people so that we have a direction in life and to help us make important decisions about college and careers.

EMISSION SPECTROSCOPY OF A 30kW AMMONIA ARCJET RUN AT 16kW

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Final Report for:
AFOSR Summer Research Program
Phillips Laboratory

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27 August 1993

EMISSION SPECTROSCOPY OF A 30kW AMMONIA ARCJET RUN AT 16kW

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Abstract

Emission spectroscopy of an arcjet plume was studied. The object was to determine the electron temperature of the ionized propellant. An arcjet, spectrometer, and optics array were used to gather the data. Results found the temperatures to be within expected ranges and compared well to documented experimental data.

EMISSION SPECTROSCOPY OF A 30kW AMMONIA ARCJET RUN AT 16kW

Brandon J. Ellena

Introduction

Recently, much attention throughout the world has shifted to the use of electric propulsion as a means for powering spacecraft. Electric propulsion deals with using electricity to ionize a propellant, which is then funnelled out of a thruster. One type of electric propulsion thruster is called an arcjet. The major advantages of electric propulsion are low cost, and high fuel economy. Right now, many scientists are engaged in research to determine the impacts of using electric propulsion concepts on spacecraft. Through emission spectroscopy, it is possible to analyze just how the gas is being excited, what species exists in the plume, and what the temperatures are, to better understand how the arcjet works, and how it is effecting the gas.

Methodology

The analysis of the arcjet plume was performed through the use of emission spectroscopy. Emission spectroscopy is advantageous due to several factors. The most important factor being that emission spectroscopy is a non-intrusive method of measurement. Therefore, the arcjet plume is not disturbed. Also, emission spectroscopy is a relatively simple method to apply.

In this test, an arcjet was placed in a vacuum chamber. Light from the plume was then directed through a series of mirrors and lenses and focused onto the entrance slit of a spectrometer. The spectrometer and a photo-diode array were used subsequently to analyze the first eight lines of the hydrogen Balmer series. The relative intensities of the

Balmer lines were then used to compute the integrated electron temperature at the center of the exit plane of the plume through the use of a Boltzmann plot.

Apparatus

The thruster used was a 30kW class arcjet running on ammonia at 16kW. The vacuum chamber used was a cylinder 3 meters wide by 5 meters long. It was capable of sustaining pressures as low as 80 millitorr with the thruster firing. The power system was an arc-welding power supply producing 100 amperes and 160 volts. The spectrometer used was Spex Model 1269, with a 1.26 meter focal length. The detector used was a Princeton Instruments 512 element photo-diode array. The data acquisition system consisted of a 386DX IBM compatible personal computer. The optics consisted of a periscoping mirror system to gather the light from the arcjet plume. A 50 millimeter diameter lens with a 400 millimeter focal length was used to focus an image of the arcjet plume onto a variable diameter pinhole which provided spatial resolution, and blocked unwanted light. Then, a 50 millimeter diameter lens with a 100 millimeter focal length collimated the signal. The signal was then focused onto the spectrometer slit by a 25 millimeter diameter lens with a 385 millimeter focal length.

Analysis

The portion of the project with which I was associated, concerned itself with determining the integrated electron temperature at the center of the arcjet plume exit plane. The first eight lines of the hydrogen Balmer series were sampled. The intensity was then used to create a Boltzmann plot from which the electron temperature was computed. Figure (9-3) shows the Boltzmann plot. The X-axis of the plot is the energy of each transition in electron volts. (Notice how the energy levels lie closer to one another as the energy increases toward ionization.) The Y-axis is the natural log of the product of the intensity and wavelength divided by the product of the transition probability and the degeneracy of the upper energy level. The Boltzmann plot comes from the equation

$$\log_e\left(\frac{I\lambda}{Ag}\right) = \frac{-1}{KT} + C$$

K = Boltzmanns Constant
A = transition probability
g = degeneracy
λ = wavelength

which is similar to using relative line intensities but since four or more lines are generally used, the Boltzmann plot results in a more accurate temperature measurement. From the equation above, it can be seen that the temperature is proportional to the slope of the plot. As seen in Fig. (9-3), the computed temperature was found to be 0.11 electron volts or 1230 Kelvin.

Conclusion

The temperatures that were found in this experiment were satisfactory with the expected results and fit with documented experimental data. Follow up research could be conducted to include other portions of the plume, and perhaps it will be possible one day to check inside the arcjet itself.

References

Diagnostic Techniques in Thermal Plasma Processing. U.S Department of Energy. February 1986.

Boltzmann Plot of Lines 3 Through 8 of the Hydrogen Balmer Series

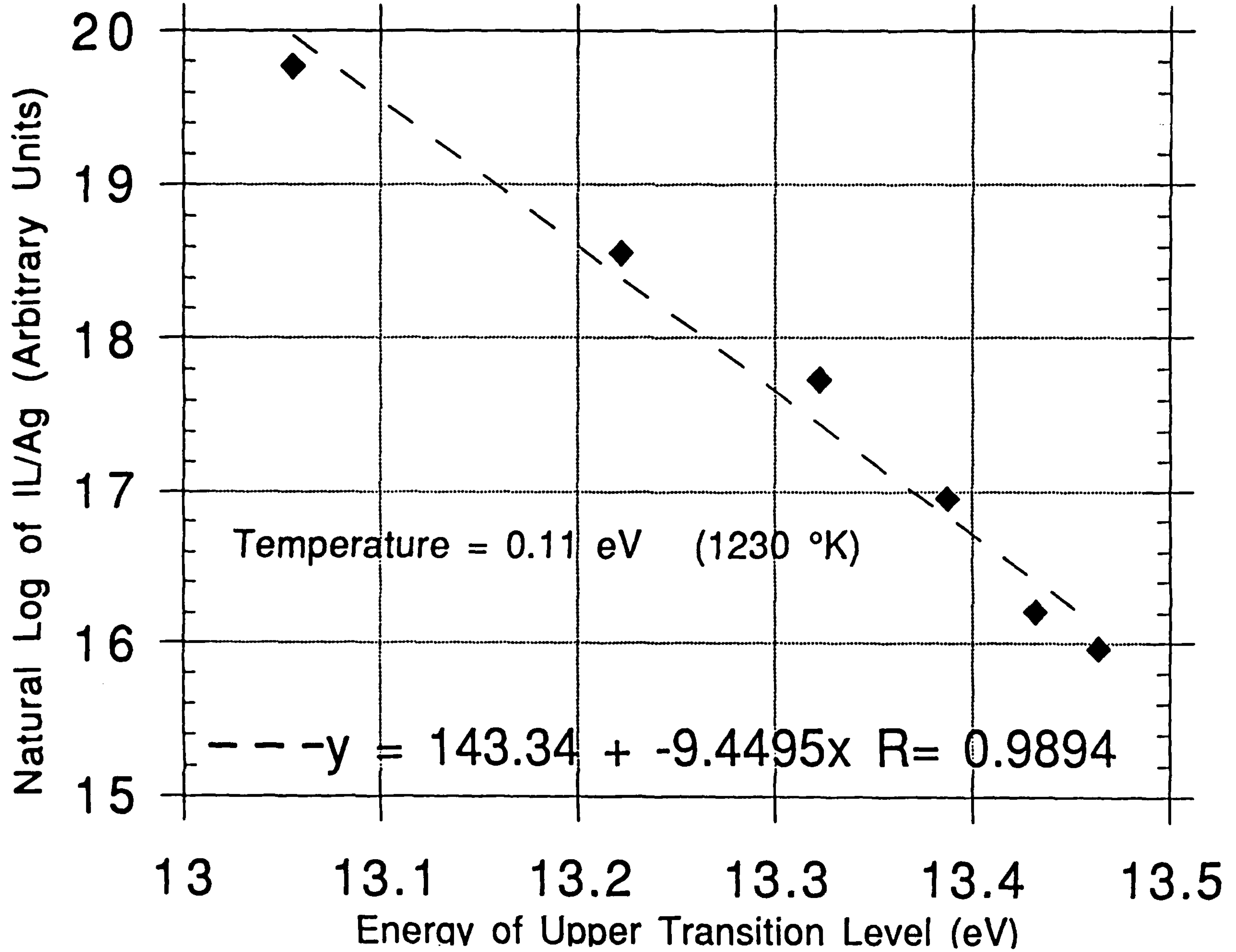

Fig. 4-1

COMPUTER-AIDED DESIGN OF TWENTY-FIRST CENTURY HEDM MATERIALS

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Final Report for:
AFOSR Summer Research Program
Phillips Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, Washington, D.C.

June-August 1993

COMPUTER-AIDED DESIGN OF
TWENTY-FIRST CENTURY HEDM MATERIALS

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Abstract

Semi-empirical quantum mechanical methods used to determine the heats of formation of High Energy Density Materials (HEDMs) were studied. The goal was then to use computation to predict the specific impulse (or I_{sp}) of these materials, thus narrowing down the experimental search for improved HEDM materials to the most promising synthetic targets. In order to achieve this goal, the MOPAC™ module within the GAMESS (General Atomic and Molecular Electronic Structure System) program was used to calculate optimized molecular geometries and heats of formation for each of forty-nine HEDM targets. Three different semi-empirical methods, Parameterization Method 3 (PM3), Austin Method 1 (AM1), and Modified Neglect of Differential Overlap (MNDO) were evaluated. Upon comparing the calculated heats of formation to experimental values, it was found that the PM3 calculations came closest to the experimental heats of formation. Inspection of the data shows the PM3 method to be able to predict the heats of formation of HEDM molecules incorporating a variety of relevant functional groups with errors of 8.6 kcal mol^{-1} (average absolute error) and +3.4 kcal mol^{-1} (average total error). A plot of experimental versus PM3 heats of formation shows a coefficient of determination of 0.91, a slope of 0.9348, and an intercept of -0.1740, very close to ideal values. The I_{sp} of select molecules from the forty-nine HEDM targets were calculated, using experimental and calculated heats of formation, to test the sensitivity of the I_{sp} determination to the heat of formation. It was found that great differences in heats of formation generally do not mean great variations in I_{sp}.

COMPUTER-AIDED DESIGN OF

TWENTY-FIRST CENTURY HEDM MATERIALS

Alexandra R. Kitty

Introduction

As we move into outer space, the use of High Energy Density Materials as monopropellants, bi-propellants, and fuel additives grows more important. A main goal of the research surrounding HEDM molecules is to find an economically sound way to launch and transport greater payloads using less propellant. Whether or not a compound could work efficiently as a HEDM molecule can, of course, be determined experimentally. It would also be highly desirable to be able to employ computational methods to predict the suitability of a potential HEDM target, before going to the time and expense of synthesizing them. Computational methods were used for this project because the experimental methods can be time-consuming and subject to inaccuracy. Ideally, computational methods will enable researchers to accurately calculate heats of formation (and thus I_{sp}) with a good degree of confidence in order to determine which molecules are promising additives or mono-propellants for directed synthesis.

I_{sp} is defined as the total impulse per pound of propellant. It is important to keep in mind that the higher the I_{sp}, the greater the payload that can be put into space for a given weight of propellant. In order to calculate the I_{sp}, it is necessary to know the heat of formation of the HEDM propellants. The MOPAC module within the GAMESS program was used to calculate heats of formation of forty-nine select HEDM target molecules. Molecules were chosen to contain cyano and nitro functional groups, N-N bonded groups, and strained rings as they represent molecules currently under experimental investigation by the HEDM group at the Phillips Lab at Edwards Air Force Base (Figure 1).

The main goal of this project is to be able to accurately predict the heats of formation (and thus the I_{sp}) of potential HEDM molecules. These calculations are important as they will help to focus experimental efforts toward the most promising HEDM targets. The ability to predict the performance of molecules as fuels will save time and resources as well as give researchers a safer way to estimate their suitability. Additionally, we will gain a fundamental understanding of how to manipulate functional groups to yield twenty-first century HEDM molecules.

Computational Method

Chem3D™ was used as a graphical user interface to generate starting molecular geometries for GAMESS. These structures were constructed and optimized in Chem3D™ using a simplified molecular mechanics approach before down-loading them to the Silicon Graphics personal IRIS workstation where GAMESS was incorporated. Determination of the optimized geometries and heats of formation at the optimized molecular geometries for HEDM targets were calculated using the MOPAC module within GAMESS. The energy hessian was calculated in order to confirm that optimized geometries were indeed minima. MOPAC contains the semi-empirical AM1, PM3, and MNDO Hamiltonians. The philosophy behind the derivation of semi-empirical parameterization schemes can be found elsewhere.[1,2,3] The calculated heats of formation, charted and plotted with KaleidaGraph™, were compared to experimental values (where available) and/or estimates obtained using Benson's group additivity rules[4] (Figure 2).

Several test cases were selected with which to investigate the sensitivity of the calculated I_{sp} to the varying heats of formation. The I_{sp} calculations were run in three regimes using HEDM as additives (LOX + HEDM + RP1), fuels (LOX + HEDM), and mono-propellants (nitro-containing HEDM)*. In the additive calculations, the liquid oxygen, HEDM, and RP1 were calculated at a fixed ratio (LOX:HEDM:RP1 = 69.697:6.061:24.242). The fuel computations were two-component (LOX + HEDM), optimizing the fuel/oxidizer ratio to give maximum I_{sp}. The experimental heat of formation was used in the optimized fuel calculations; the calculated heats of formation were then used to calculate I_{sp} at the previously determined optimum fuel/oxidizer mix. Only nitro-containing HEDM's were used to perform the mono-propellant calculations as only these molecules, among those studied, could function as both fuel and oxidizer.

Results and Discussion

The HEDM molecules chosen for analysis in this project fall into four different functional groups: strained-ring hydrocarbons, nitro-containing, cyano-containing, and N-N bonded. Representative examples are plotted in Figure 1. Note that only a few molecules display a significant deviation from experiment, i.e. ΔH_f (calc.)-ΔH_f (expt.) $\geq$ 10 kcal/mol. Differences between calculated and experimental heats of formation were further analyzed to determine which method worked best for which functional group. It was found that PM3, AM1, and MNDO all work well for cyano-containing molecules, i.e. giving heats of formation closest to experimental numbers (Fig. 2). For the best method (PM3), strained-ring hydrocarbons showed the smallest average

* LOX = liquid oxygen; RP1 = rocket propellant #1 (a refined grade of kerosene).

absolute difference (using absolute as opposed to total differences) between experimental and calculated heats of formation.

PM3 is the superior semi-empirical method in terms of calculated heats of formation; the PM3 values came closest to the experimental values found in the compilations by Benson[4] and Cox and Pilcher[5]. To confirm this empirical observation, the best fit line of calculated versus experimental heats of formation were analyzed for each method. The equations are shown in Figures 3,4, and 5. Note that the PM3 method shows the slope which is closest to unity and the intercept which is closest to zero (see Figures 3-5).

In order to test the I_{sp}'s sensitivity to the varying calculated heats of formation, eight molecules with a great range of experimental and calculated numbers were selected to compute the I_{sp}. It is important to note that these are "worst case" and the majority of molecules show good agreement between theory and experiment. The fuel calculation (the fuel-oxidizer ratio was optimized using the experimental heat of formation) using the AM1 heat of formation for cubane yielded an I_{sp} of 317.195 seconds, the highest, and tetranitromethane with 179.062 seconds (using the PM3 heat of formation) as the low. It was determined that the varying heats of formation did not greatly influence the calculation of the I_{sp} (see Figure 6). For example, a 14 kcal mol^{-1} difference in the heat of formation between the PM3 and experimental heat of formation for quadracyclane translates into an I_{sp} difference of only 2.5 seconds. For the majority of molecules which show good agreement between PM3 and experimental values, the I_{sp} differences will be much smaller.

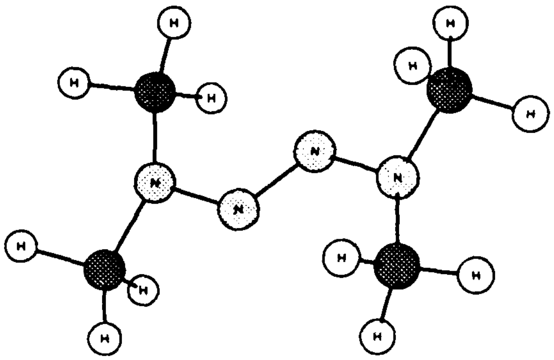
Summary and Conclusion

The purpose of this research was to determine whether or not semi-empirical quantum mechanical methods can be used to determine the heats of formation (and thus the specific impulse, I_{sp}) of High Energy Density Materials accurately and in a timely fashion. It was found that these methods can be used and PM3 accomplishes this with an error of up to 9 kcal mol^{-1}. The semi-empirical methods are best used for cyano-containing molecules as they return heats of formation closest to experimental numbers. Based on this research, the recommendation would be to use PM3 when calculating heats of formation (especially for cyano-containing molecules) to be used in determination of I_{sp}.

Acknowledgments

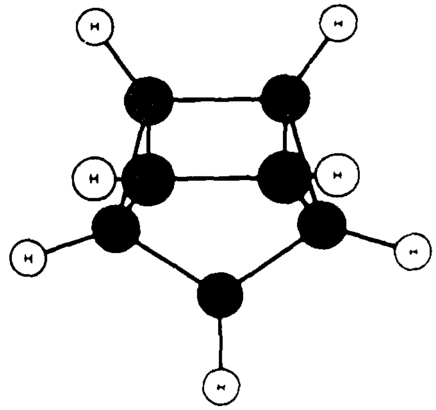
Thank you to both of my mentors, Dr. Tom Cundari and Dr. E.J. Wucherer, for a summer filled with new ideas and much to learn. Mary and John Rusek deserve great appreciation (and much more) for living with a niece for three months and, along with grandma and Cpt. Tim Thompson, for critiquing my work here. I would like to thank my newly adopted family, Mike, Ronnie, and Robert Griggs, who gave me something to look forward to and were always there for me without question. Also, thanks to Jerry Boatz for letting me invade his office . Finally, none of this would have been possible without you, mom. Thank you for everything.

FIGURE 1: SELECT MOLECULES DEPICTING FUNCTIONAL GROUPS OF INTEREST



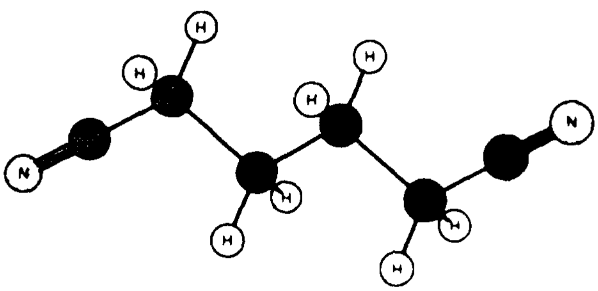
TETRAMETHYLTETRAZINE:

representative of the
N-N bonded group.



QUADRACYCLANE:

representative of the
strained-ring hydrocarbon
group.



ADIPONITRILE.
representative of the
cyano group

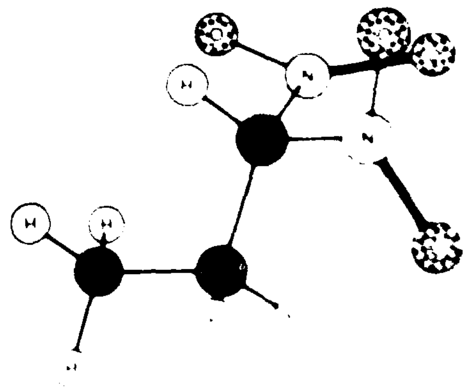


FIGURE 2

HEATS OF FORMATION

CALCULATED VS EXPERIMENTAL

(kcal/mol)

COMPOUND	ΔHf-expt.	ΔHf-PM3	ΔHf-AM1	ΔHf-MNDO
C_8H_{14}	-6.52	-6.68	-15.75	-9.80
1,1,2 triMecyclopropane	42.89	41.75	52.64	42.04
C_8H_{12}	52.70	48.54	63.45	33.94
$C_3(CN)(NO_2)_2$	85.00	100.67	131.70	142.41
$C_4N_4H_6$		104.24	104.10	66.13
nitro		222.95	284.27	149.19
$C_9H_{12}N_2$	48.50	94.23	122.55	100.03
cubane	150.00	113.77	151.22	99.06
prismane	122.40	136.02	165.03	121.88
quadrocyclane	72.20	86.32	104.35	79.09
spiropentane	44.23	43.11	50.45	33.69
bicyclo 2,1,0 butane	51.90	69.24	78.10	64.06
n-propylnitrate	-29.70	-26.77	-23.70	-8.12
1,1 dinitropropane	-25.90	-21.95	-9.20	19.43
tetracyanoethylene	168.50	169.14	152.38	148.02
fumaronitrile	81.30	85.99	76.01	164.62
isopropyldiazine	19.40	6.00	12.94	3.84
tetramethyltetrazine	65.70	62.22	88.57	47.84
pyridazine	66.50	55.99	55.32	43.61
pyrimidine	47.00	37.97	43.91	34.97
pyrazine	46.90	39.32	44.21	37.76
tetrazole	79.50	88.41	113.29	58.11
nitromethane	-17.86	-15.93	-9.93	3.32
isopropylnitrate	-33.20	-27.14	-21.64	-6.33

FIGURE 2 (con't)

COMPOUND	ΔHf- expt.	ΔHf- PM3	ΔHf- AM1	ΔHf- MNDO
trinitromethane	-0.20	-4.67	24.99	58.70
trinitrotoluene	12.30	3.94	41.40	76.67
tetranitromethane	19.20	6.44	53.07	94.98
azirane	30.24	31.61	33.13	25.09
n-propylcyanide	8.12	13.40	13.40	11.30
i-propylcyanide	6.30	13.40	8.47	11.30
methylhydrazine	22.60	17.90	16.86	14.37
cyanogen	73.84	77.47	67.93	66.59
malononitrile	21.99	64.44	54.27	55.61
cyclopropene	66.20	68.17	74.81	68.30
cyclopropane	12.73	16.27	17.78	11.22
methylenecyclopropane	47.92	44.52	47.66	37.90
methylcyclopropene	58.21	60.18	67.68	60.60
cyclobutene	37.45	37.67	45.76	64.40
dimethylcyclopropane	69.15	72.87	77.02	64.40
trimethylcyclopropane	90.70	100.88	105.58	90.73
u-dimethylhydrazine	20.04	15.10	23.96	18.14
dimethylhydrazine	21.99	15.58	21.53	15.04
methylazide	67.00	72.44	76.67	66.40
cyclohexylazide	36.90	50.85	49.75	47.91
cyclopentylazide	52.80	58.37	61.61	50.99
rdx	16.90	40.57	105.12	103.65
2,1,0 bicyclopentane	37.60	37.80	46.05	30.20
cyclopropylcyanide	43.50	52.16	48.80	44.63
adiponitrile	35.00	43.31	30.45	38.61
diaminotetrazine	69.00	82.59	99.67	57.89
dicyanoacetylene	127.50	128.10	119.80	111.40

Figure 3: Heats of Formation - Experimental vs PM3

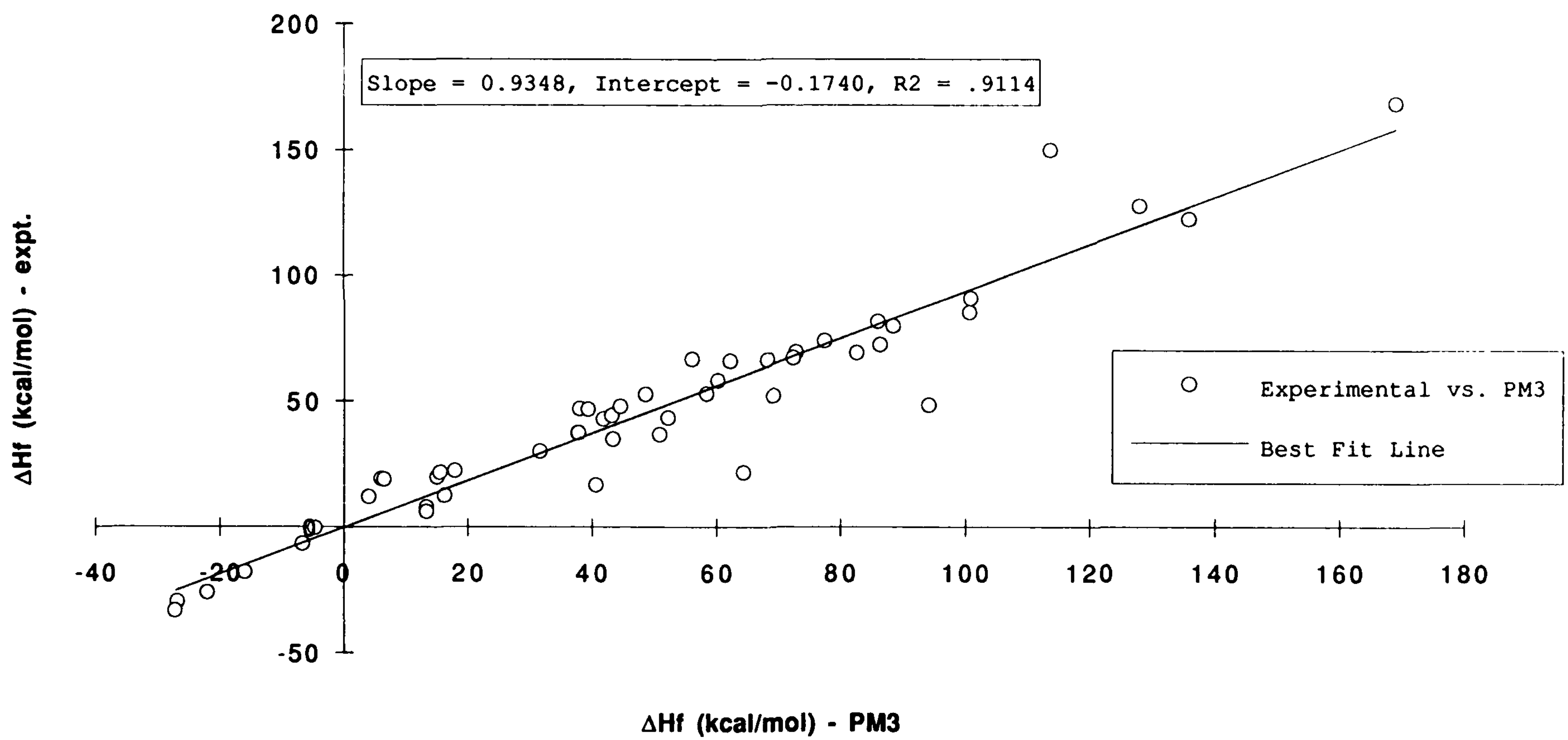


Figure 4: Heats of Formation - Experimental vs AM1

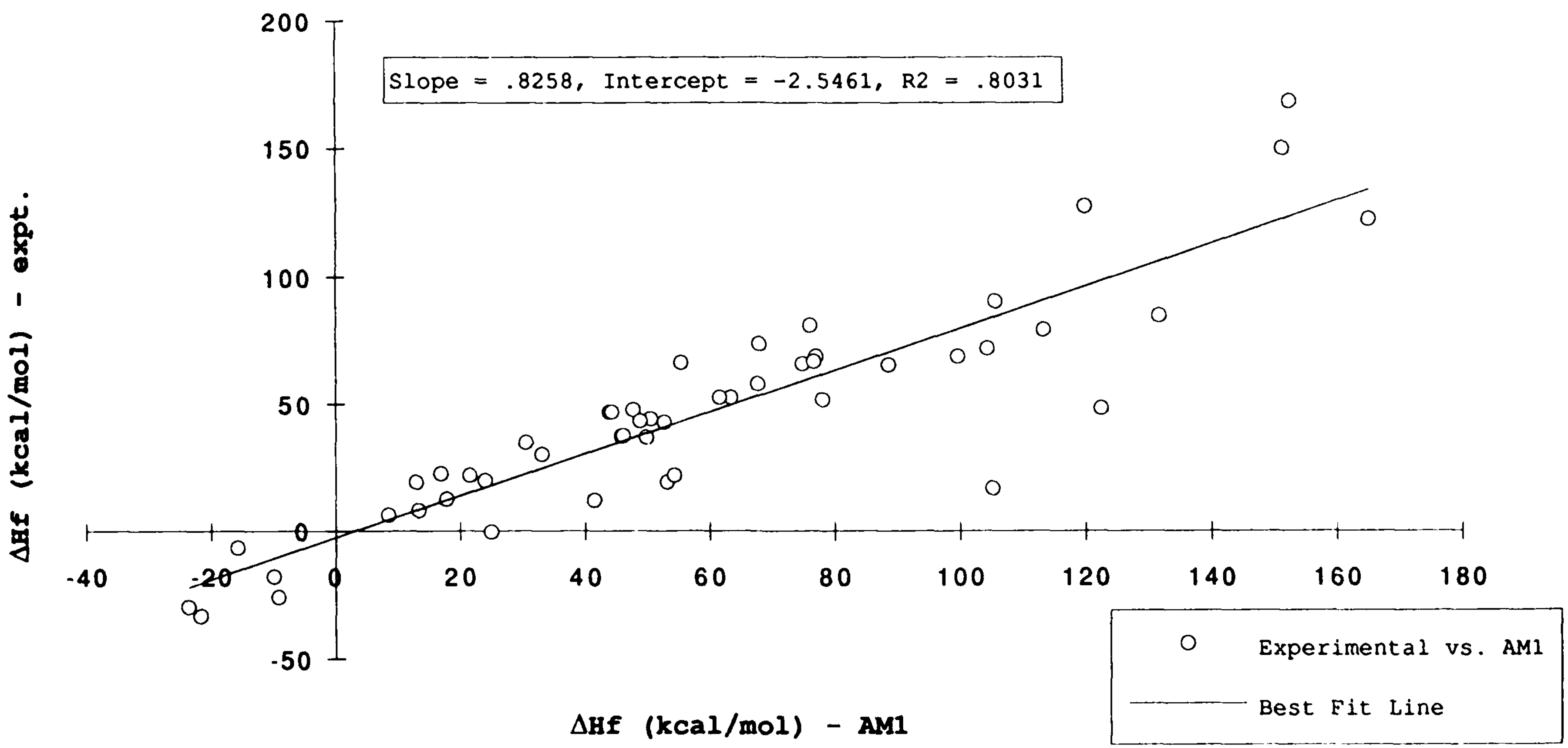


Figure 5: Heats of Formation - Experimental vs MNDO

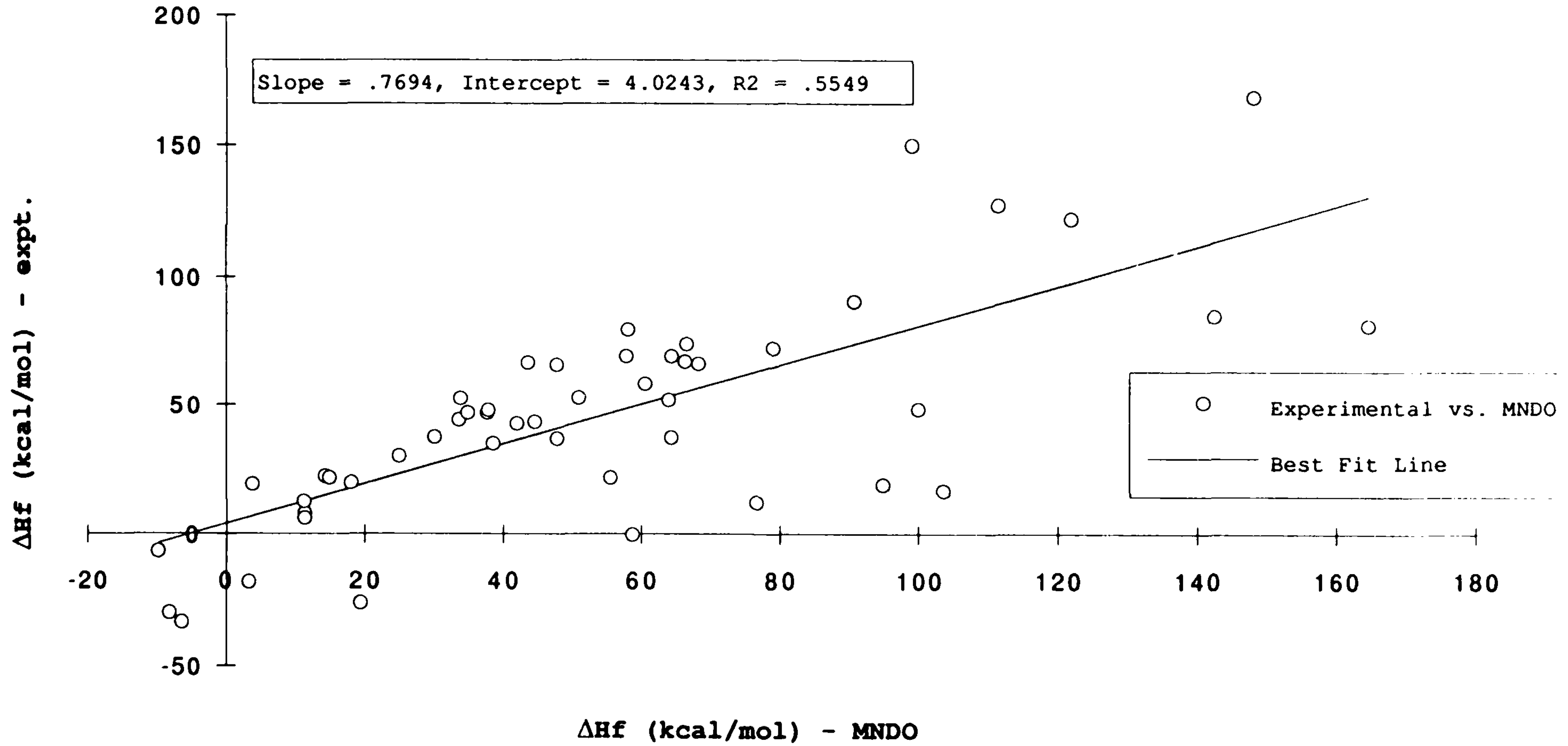


FIGURE 6 - I_{SP} CALCULATIONS

FUNC.GROUP / HEDM	FUEL (ISP/TEMPERATURE)	ADDITIVE (ISP/TEMPERATURE)	MONO-PROP. (ISP/TEMPERATURE)
<u>strained-ring</u>			
CUBANE			
PM3	309.7s / 2243K	301.5s / 2180K	
AM1	317.2s / 2396K	302.5s / 2205K	
MNDO	306.6s / 2181K	300.7s / 2169K	
EXPT	317.0s / 2391K	302.5s / 2204K	
QUADRACYCLANE			
PM3	309.7s / 2472K	301.1s / 2157K	
AM1	313.0s / 2540K	301.8s / 2171K	
MNDO	308.3s / 2443K	300.8s / 2151K	
EXPT	307.0s / 2415K	300.5s / 2146K	
<u>nitro</u>			
1,1 DINITROPROPANE			
PM3	286.8s / 2333K	298.1s / 2513K	240.1s / 988K
AM1	290.2s / 2407K	298.3s / 2518K	249.9s / 1025K
MNDO	297.5s / 2543K	298.9s / 2529K	271.0s / 1178K
EXPT	285.7s / 2309K	298.0s / 2512K	237.1s / 979K
TETRANITROMETHANE			
PM3	179.1s / 882K	295.0s / 2615K	179.1s / 882K
AM1	209.5s / 1252K	295.5s / 2623K	209.5s / 1252K
MNDO	231.9s / 1596K	296.1s / 2630K	231.9s / 1596K
EXPT	188.0s / 983K	295.1s / 2617K	188.1s / 983K
<u>cyano</u>			
ADIPONITRILE			
PM3	296.2s / 2433K	299.2s / 2223K	
AM1	293.9s / 2381K	298.7s / 2214K	
MNDO	295.4s / 2414K	299.0s / 2220K	
EXPT	294.8s / 2400K	298.9s / 2217K	
<u>N-N bonded</u>			
ISOPROPYLDIAZINE			
PM3	303.5s / 2250K	300.0s / 2137K	
AM1	304.6s / 2273K	300.2s / 2141K	
MNDO	303.1s / 2242K	299.9s / 2135K	
EXPT	305.6s / 2295K	300.4s / 2145K	
TETRAMeTETRAZINE			
PM3	308.3s / 2231K	301.2s / 2274K	
AM1	313.3s / 2336K	301.9s / 2290K	
MNDO	305.4s / 2172K	300.8s / 2265K	
EXPT	309.0s / 2245K	301.3s / 2276K	
TETRAZOLE			
PM3	299.8s / 2403K	299.1s / 2503K	
AM1	311.9s / 2642K	300.1s / 2522K	
MNDO	282.1s / 2011K	297.9s / 2479K	
EXPT	295.0s / 2293K	298.8s / 2496K	

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REDUCTION AND ANALYSIS OF EXTENDED X-RAY ABSORPTION FINE STRUCTURE (EXAFS) DATA

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High School Apprenticeship Program
Phillips Laboratory

Sponsored by:
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Bolling Air Force Base, Washington, D.C.

August 1993

REDUCTION AND ANALYSIS OF EXTENDED X-RAY ABSORPTION FINE STRUCTURE (EXAFS) DATA

Brad M. Lormand
Student
Rosamond High School

Abstract

Previously obtained synchrotron radiation absorption data was reduced to a usable form and analyzed to determine structural properties of the involved species. The compounds being tested included Rubidium perchlorate, a Bromohydroquinone-Terepthalyic acid polymer, and the Bromohydroquinone monomer by itself. The acquired data was reduced using the computer program Genplot (by Computer Graphics Service, Ltd.).

REDUCTION AND ANALYSIS OF EXTENDED X-RAY ABSORPTION FINE STRUCTURE (EXAFS) DATA

Brad M. Lormand

Introduction

As new polymers are synthesized, it is critical that their physical and chemical characteristics are obtained. Certain information can tell whether a plastic will be suitable for use in rocket propulsion and perhaps eventually for use in other industries.

One method of analyzing a polymer and its components is to submit it to synchrotron radiation and measure the absorption. This measurement can help to determine the distances between the specimen's atoms and can provide clues as to the way the different chains of the polymer interact with themselves and those surrounding them.

The original data obtained from the experiments (Figure 1) can be classified into 4 regions. Starting from the left end of the data, the pre-edge region (13200-13475eV) has little relevance and leads into the Bromine K-edge (13475eV). The K-edge occurs at the initial electron binding energy of the major element involved. Directly following the peak of the K-edge is the XANES (X-Ray Absorption Near Edge Structure) region. This [illegible] can be useful, but it will not be explored in this report. The critical area of the data is the EXAFS (Extended X-ray Absorption Fine Structure) region. This area, which is believed to start about 50 eV from the K-edge, was separated from the raw data and reduced to provide a meaningful representation of nearest neighbor distances and atomic location within the studied compounds (Figures 8-12).

Procedure

Each data file was reduced in the same general way. The reducing was performed with aid of the program Genplot. Genplot is a PC program used for scientific and engineering calculations and graphing. Use of this program made the data reduction more user interactive than in previous years of running a program off a VAX Computer with little human input.

The files from the experiments were first converted to machine code which Genplot can understand. This was easily accomplished by the use of a FORTRAN program. The data was then read into Genplot (Figure 1) and the pre-edge region was subtracted off of the data. This was done by fitting a line to the region and subtracting that line from the whole data set. The next step was to determine the inner potential (E_0) of the species and subtract it from the data. The E_0 is the point at which the K-edge occurs. It is located by finding the peak in the derivative of the data (Figure 2). The final normalization step involved finding a zero in the derivative of the data somewhere between 20 and 50eV. The data was then divided through by the yield of this zero to center the data between 0 and 1 on the y-axis (Figure 3). Notice that the bottom of the K-edge is located at (0,0). All similar data files were normalized in a consistent way to enable the final results to be compared without translation.

Once normalized, the EXAFS region is separated from the rest of the data and its background is subtracted. This is done by loosely fitting a cubic spline (FIT(x)) to the region (Figure 4) and dividing through by that spline. Background subtraction is a sensitive process because too tight of a spline fit can result in degraded peaks in the eventual Fourier Transform. The x values of the data are then multiplied by a constant to convert the data to k-space (Figure 5).

At this point in the reduction, the data was traced with a cursor to identify noise and glitches. These ugly spikes in the data could be deleted, but it is questioned whether this can be done and not alter the data. All large glitches were removed from these data files nonetheless.

For removal or reduction of high frequency noise, another cubic spline was fit tighter to the deglitched data. The spline, following the same path as the data, but considerably smoother, was substituted for the actual data (Figure 6).

In order to clear up "leakage" in the fast Fourier Transform about to be taken, a Hanning window was applied to the data (Figure 7):

$$y=y*0.5*(1-\cos((2*pi*x)/(x_{max}-x_{min})))$$

When the final chi data is achieved, a 1200 point grid was fixed to the data to improve the resolution of the fast Fourier Transform (FFT) that was then taken and the magnitude plotted (Figure 8). The abscissa was converted to angstroms by multiplication by pi. Phase correction of the FFT and singling out separate peaks in the pre-FFT data must also be done, but were not performed because of a lack of time.

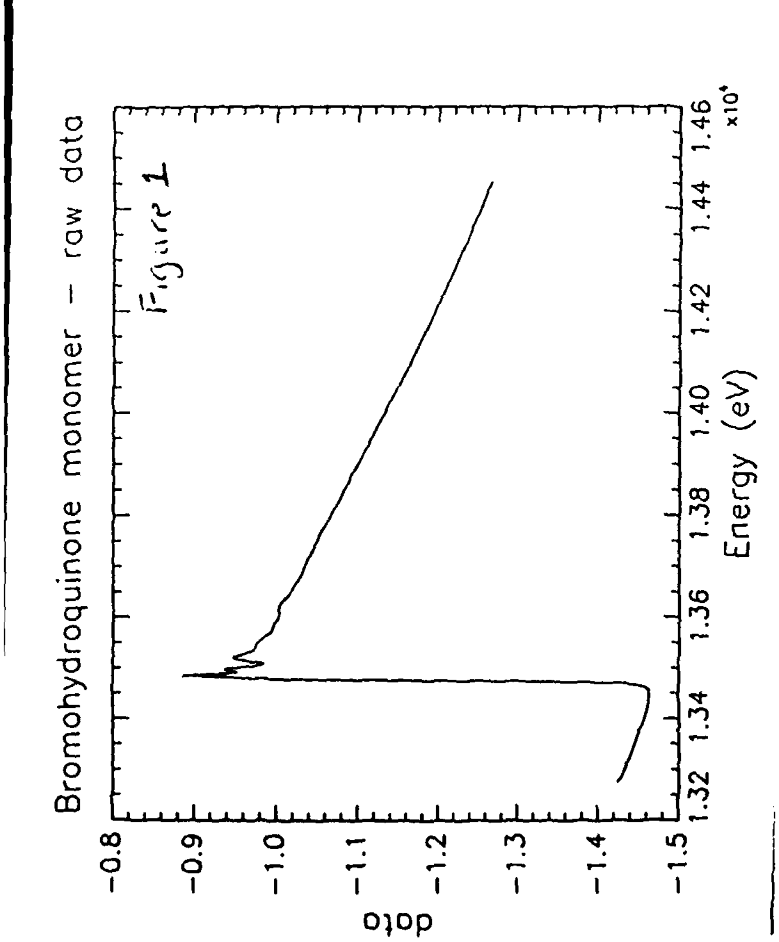
All processes previously described were expedited by the use of macros in Genplot to combine steps, shorten keystrokes, etc.

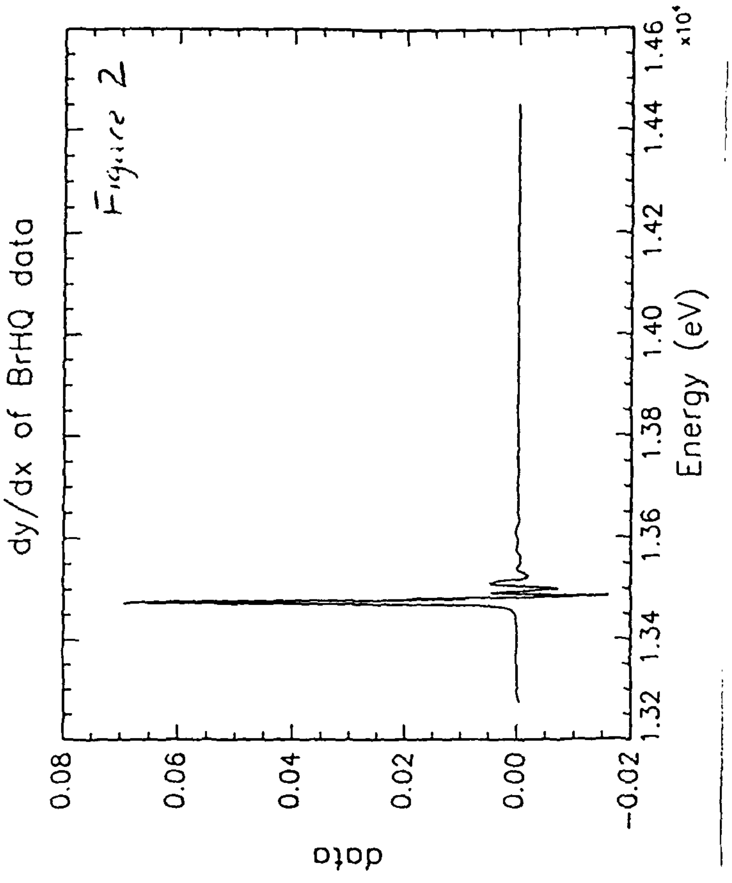
Conclusions

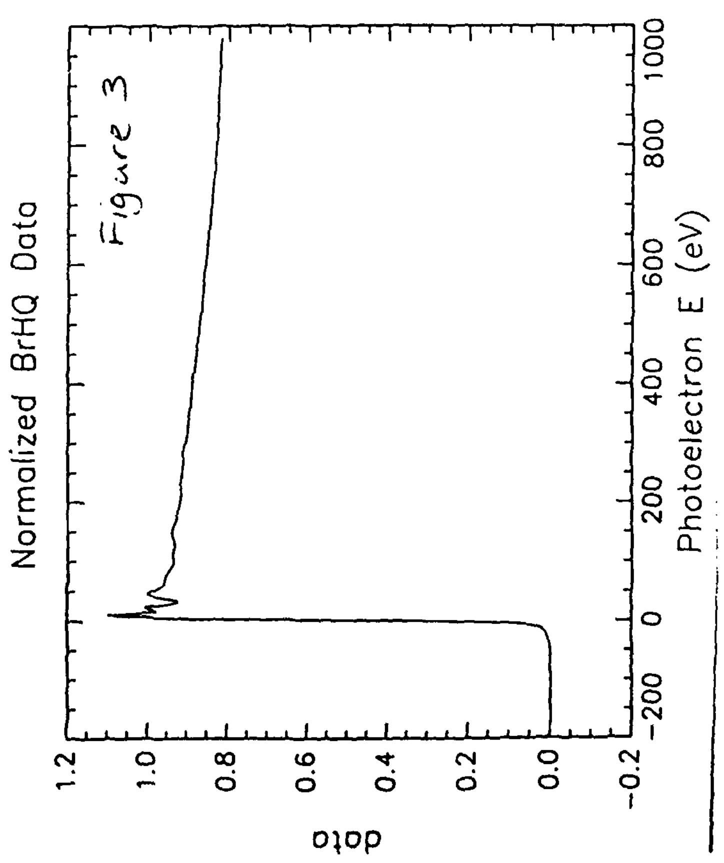
As shown in figure 12, the FFTs of the bromo-polymer being analyzed each show the large peak centered at about 1.8 angstroms. This non-phase-corrected peak is known to be the distance between the bromine and the [illegible] of the benzene ring it is attached to within the polymer. The annealed and aligned method between 2 glass plates specimen (brplano.avg) and the aligned only specimen (brplmto.avg) show subtle differences in peak shoulders and peak heights than the untouched polymer (brpolno.avg). These could actually show differences in physical make-up or just be due to inconsistency in background subtraction. The smaller peaks could be showing separate polymer chains interlocking with each other to form a physically stronger compound. Presumably, synchrotron diffraction is just a small step in discovering the many different physical characteristics of Advanced Polymer Components.

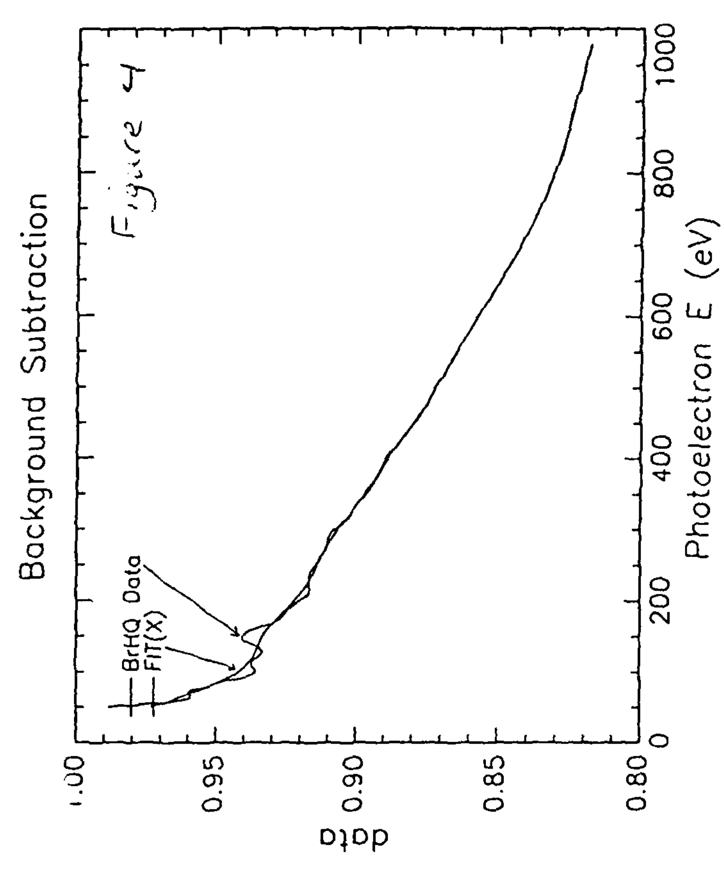
Acknowledgements

I indeed wish to thank Dr. Kevin Chaffee of the Phillips Laboratory for another summer of nonstop learning about Physics and other significant topics. And thanks to Dr. John Rusek of the Phillips Laboratory for all the first-rate career-broadening moves and musical enjoyment.

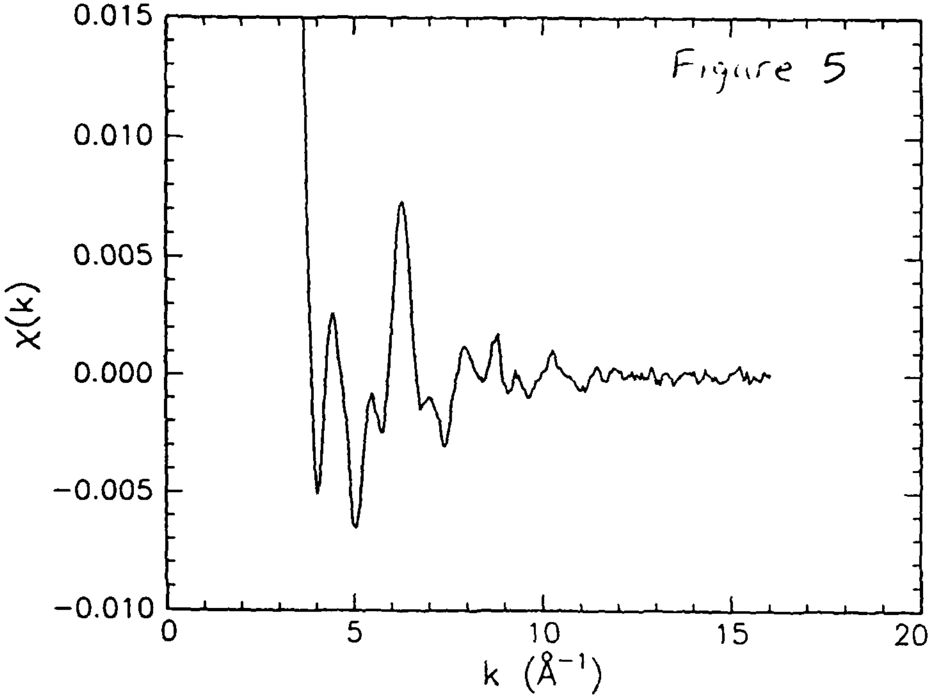

Bromohydroquinone monomer - raw data
Figure 1
data
Energy (eV)
x10⁴


dy/dx of BrHQ data
Figure 2
data
Energy (eV)
x10⁴

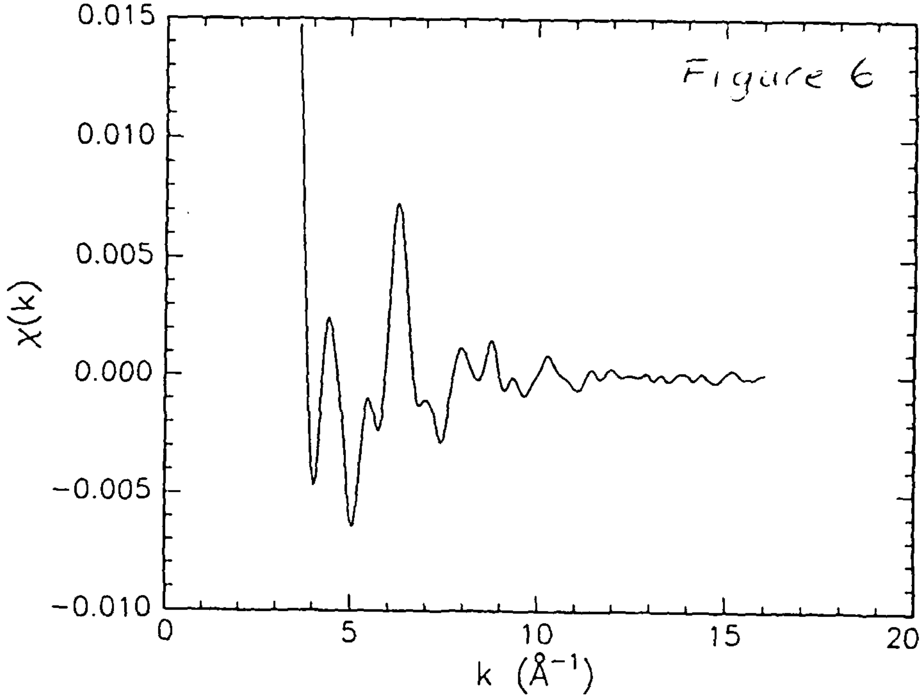

Normalized BrHQ Data
Figure 3
data
Photoelectron E (eV)


Background Subtraction
Figure 4
BrHQ Data
FIT(X)
data
Photoelectron E (eV)

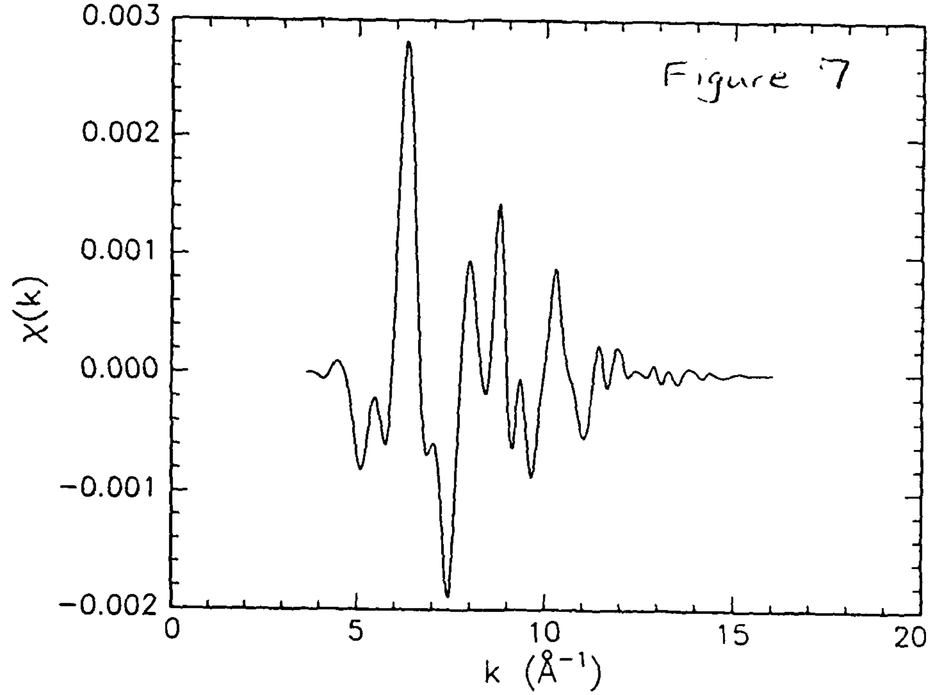
BrHQ chi data - unsmoothed



BrHQ chi data - smoothed



BrHq chi data w/hanning window



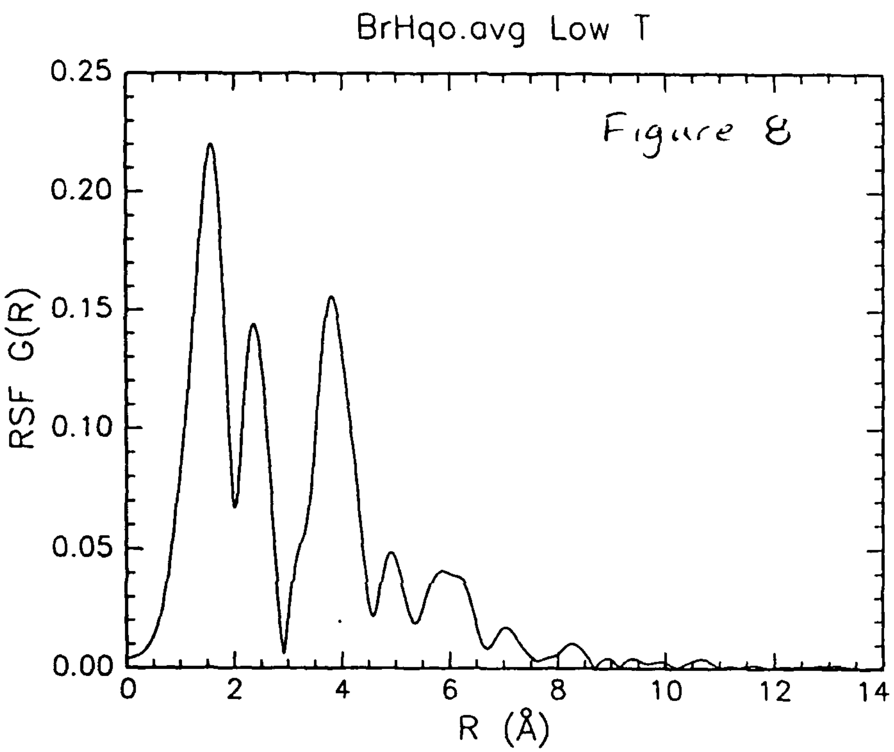


Figure 8

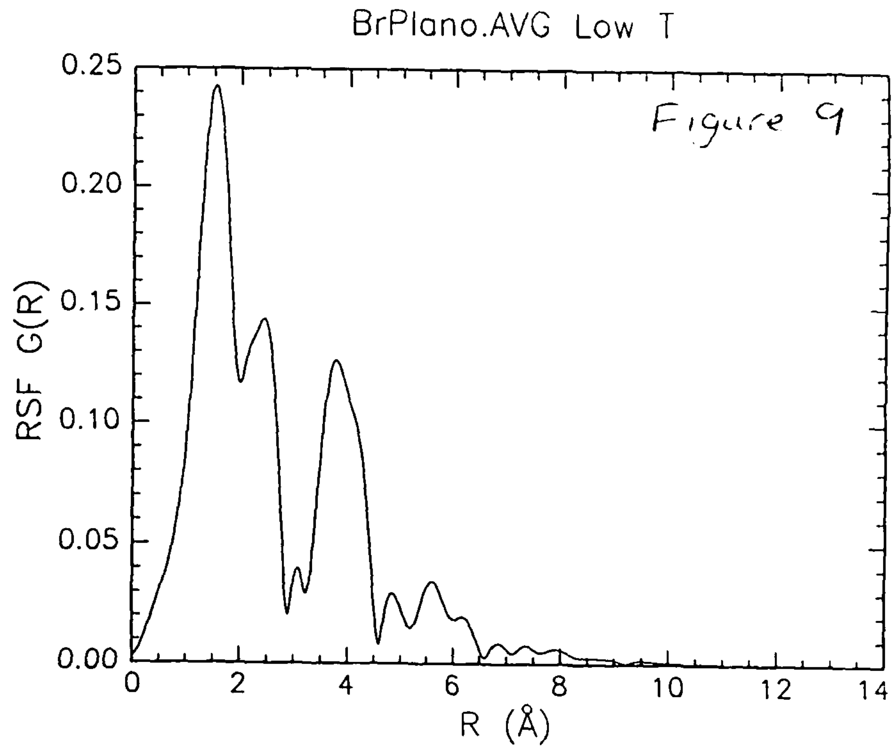


Figure 9

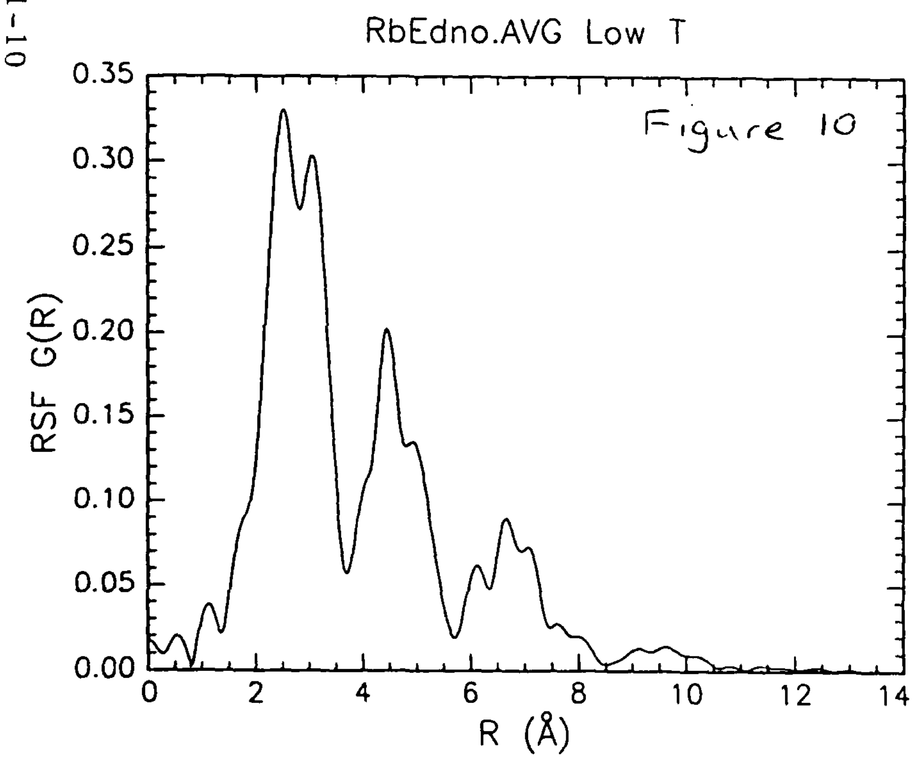


Figure 10

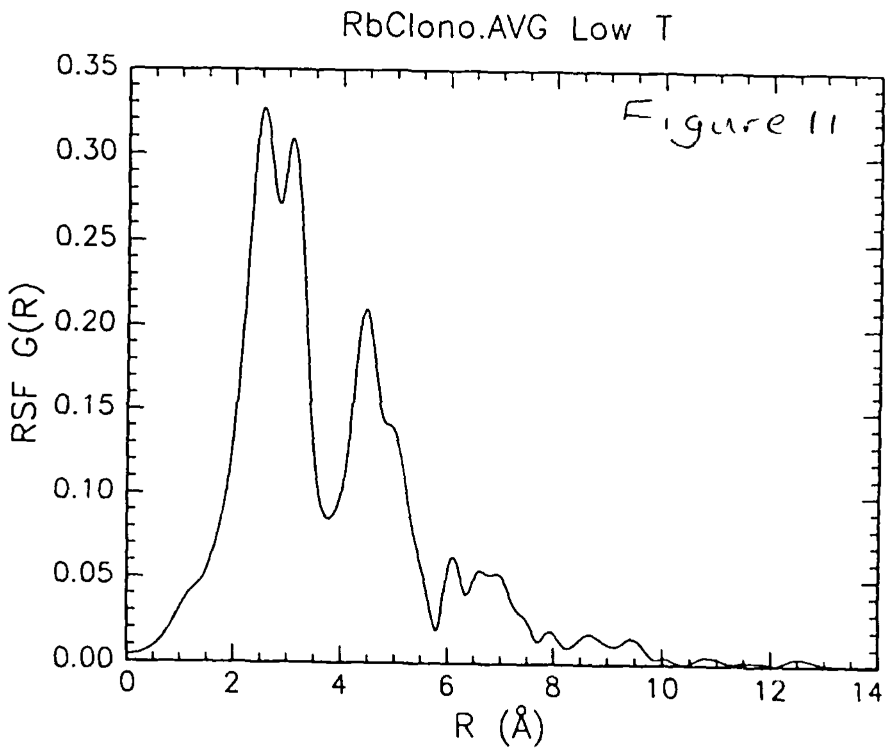
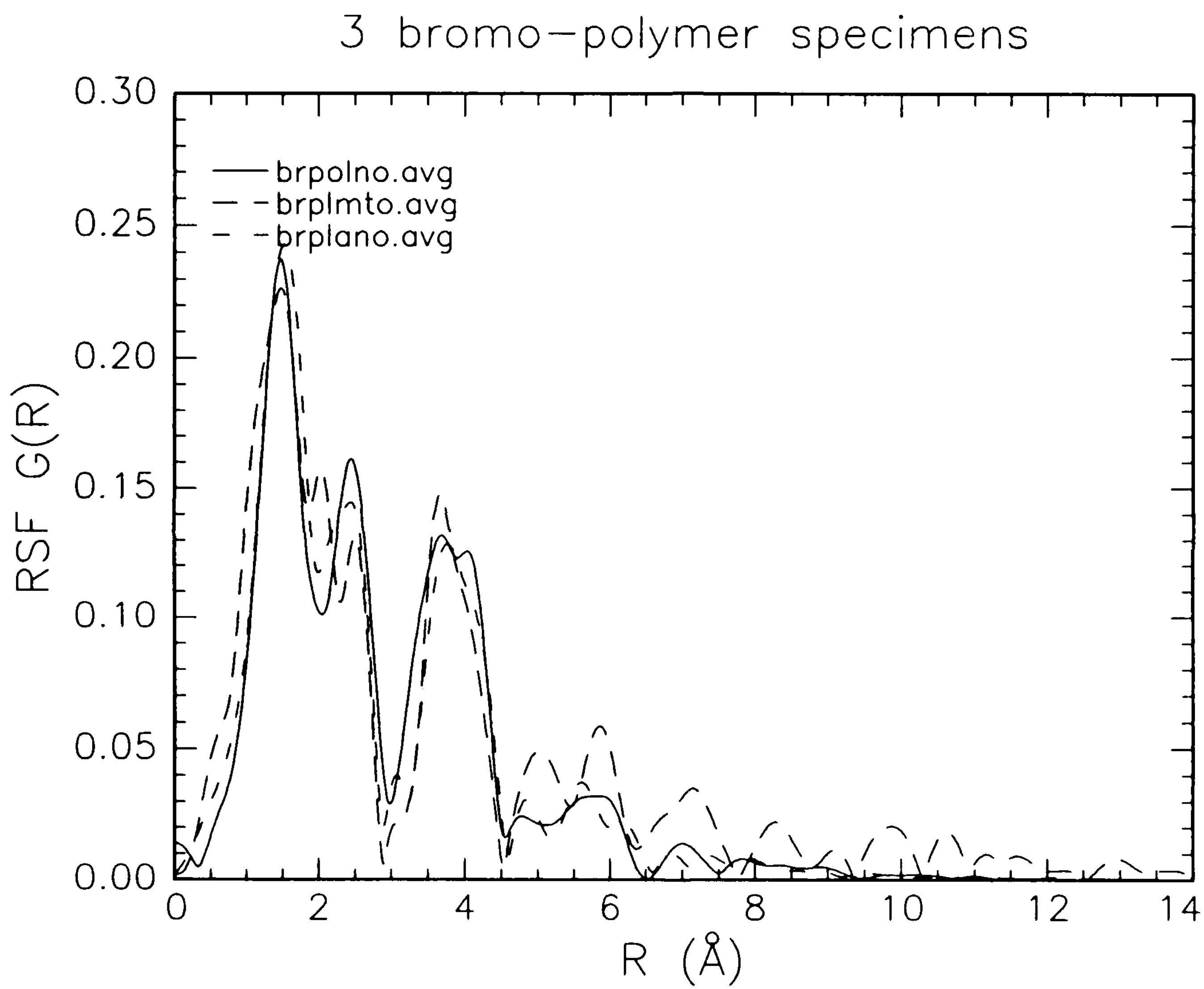


Figure 11

Figure 12



3 bromo-polymer specimens
brpolno.avg
brplmto.avg
brplano.avg
RSF G(R)
R (Å)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14

DEVELOPMENT AND TESTING OF LIQUID CRYSTAL POLYMER SOLID ROCKET MOTORS

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Final Report for:
Summer Research Program
Phillips Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, Washington, D.C.

August 1993

DEVELOPMENT AND TESTING OF LIQUID CRYSTAL POLYMER SOLID ROCKET MOTORS

Tracy R. Reed

Abstract

A working solid rocket motor with all structural components made out of liquid crystal polymers (LCP's) was built and tested. The motor cases and nozzles were injection molded. Three propellant formulations with different burn rates were tested in the motors. After development and testing, the rocket motors will be sent to the U.S. Air Force Academy for their advanced Astronautics curricula.

DEVELOPMENT AND TESTING OF LIQUID CRYSTAL POLYMER SOLID ROCKET MOTORS

Introduction

The goal of this experiment was to develop and produce a working solid rocket motor with nozzle and case made out of Liquid Crystal Polymers (LCP's). Three different propellants with three different burn rates were formulated. Due to the nature of LCP's, it was necessary that the propellants be non-aluminized to cut down on nozzle throat erosion. After development and testing, the motors were sent to the U.S. Air Force Academy for ground launch. These newly developed motors will replace the old motor the Academy used in its experiments. The rocket motor used at the Academy is often referred to as the Academy motor. The old Academy motor was labor intensive and expensive to produce. The new motor requires very little machining and is easy to assemble. The cases and nozzles are injection molded into the correct shape. This cuts down on the cost of machining the case and nozzle, as was required by the old Academy motor. The old Academy motor used only one propellant formulation. Three new propellants were developed for the new motor to provide more flexibility.

Procedure

The first step in the development of the motor was the propellant formulation. Three different types of propellant were developed with three significantly different burn rates. The propellant was based on the prior Academy motor propellant and modified to produce the new propellants. Each propellant was to have a unique plume and physical color. Different additives were added to each propellant to provide these different colors. The physical color of the propellant was easy to achieve due to the different colors of the burn rate modifiers. The unique plume colors were significantly more difficult. The propellants were referred to as high, medium, and low, according to burn rate. The high propellant is black, the medium propellant is red, and the low propellant is yellow. The plume color for the high propellant is green, medium is red, and low is blue. The theoretical I_{sp} for all of the propellants is approximately 240 sec. to give all of the motors the same total impulse.

All solid ingredients were dried in a drying oven for at least 24 hours before being used except for the copper ammonium chloride which was ground and dried until all water appeared to be driven from the hydrated crystals. This turns the blue crystals into a red-brown powder. To date, only the medium propellant has been successfully mixed and fired in an Academy motor. The low propellant began to cure in the mixing pot on attempts to mix it. This may be happening due to the copper ammonium chloride which may be acting as a cure catalyst causing the propellant to cure faster than it should. Great effort was required to get the low propellant cast before it was completely cured in the pot. This propellant was hand cast into the 2x4 motors due to its extreme viscosity. The other two propellants were vacuum cast. All of the propellants have been fired in a 2x4 motor configuration to provide burn rate and K_n data. The high propellant has not been cast into Academy motors yet, but this should occur in the near future. More effort will have to be put into the low propellant cure problem.

The propellants were cast into cardboard tubes for the Academy motor that had been lined on the inside with a mixture of R45M (a hydroxy terminated polybutadiene) containing AO2246 (an anti-oxidant) and DDI (dimeryl diisocyanate) to ensure a good bond between the propellant and the tube. This tube was then fit into an outer tube. The two tubes fit perfectly inside one another. The outer tube was then cut to 7 1/4" long. The inner tube containing the propellant was slid into the outer tube, and this whole assembly was inserted into the motor. The nozzle was then pressed into place and held with rivets. Detailed instructions on the assembly of an Academy motor may be found near the end of this paper.

The original grain design was a grain 7 1/4" long with a 3/8" bore. The propellant was then to be cut radially into three pieces. The first was to be 2 1/2" long, the second 2", and the third 2 1/2". This would allow the propellant to burn in the center as well as on the ends. This was to provide even surface area throughout the burn. The combustion chamber in the case is slighly larger than 7 1/4" long. This allowed the propellant grains to move around slightly. It was discovered during the first five test firings that there was a tremendous pressure differential over the length of the propellant grain. This caused the propellant segment nearest the nozzle of the motor to be forced down the nozzle intake, compressing the end of the propellant and pinching off the flow of exhaust. This caused an immediate over-pressurization and explosion of the case. The solution to the problem was a phenolic spacer between the nozzle and propellant that would hold the propellant firmly in place. Cardboard spacers made out of the same material as the inner tube were first tried. but it was found that they lacked sufficient compressive strength. During the subsequent firings of the Academy motors the LCP nozzle throat eroded to such an extent that the pressure loss inside the motor became unacceptable. It was decided that the burn time must be made short enough such that all of the propellant could be burned before the nozzle eroded completely through. Various grain configurations were tried in an effort to increase the burn surface area. The final solution was to inrease the bore to 49/64" with no radial cuts. This worked quite well, giving a burn time of approximately 3 seconds with a maximum thrust of approximately 50 lbs. All motor testing was done on pad 44 in area 1-30 at Phillips Laboratory, Edwards Air Force Base. Burn rate and K_n dat may be found at the end of this paper. K_n is defined as A_{grain}/A_{throat}. Burn rate is in in./sec.

Results

It was proven that an all LCP rocket motor could be manufactured and fired. Three propellants with different burn rates were formulated and tested by means of 2x4 and LCP motor firings. An all LCP case and nozzle was engineered, tested, and found capable of withstanding the required operating pressures. The nozzle still erodes significantly, just barely burning though the nozzle throat. In the future, nozzles may be coated with silicon nitride or silicon carbide in an attempt to relieve this problem. This should give a significant increase in motor performance.

ACADEMY MOTOR PROPELLANT FORMULATIONS

High

Ingredient	% by weight
R45M with AO2246	10.46
DOZ	2.15
DDI	2.39
AP (400 mc)	27.11
AP (200 mc)	27.11
AP (25 mc)	20.78
Boron	5.00

Medium

Ingredient	% by weight
R45M with AO2246	10.46
DOZ	2.15
DDI	2.39
AP (400 mc)	25.17
AP (200 mc)	25.17
AP (25 mc)	25.17
Fe_2O_3	0.20
$Sr(NO_3)_2$	9.29

Low

Ingredient	% by weight
R45M with AO2246	10.46
DOZ	2.15
DDI	2.39
AP (400 mc)	40.00
AP (200 mc)	20.00
AN	15.00
Copper ammonium chloride	2.00
Potassium perchlorate	8.00

INSTRUCTIONS FOR ASSEMBLING AN ACADEMY MOTOR

1. Bore nozzle to 54/64" using a type Q drill

2. Cut outer tube to 7 3/4" long.

3. Insert out tube into case and compress.

4. Tape 1" long phenolic spacer to the end of the propellant grain using 1 layer of masking tape

5. Slide grain into outer tube in case and press down firmly

6. Trial fit nozzle on the end of the motor making sure that there is no more than a 1/8" gap between the nozzle and the end of the case.

7. Prepare polyurethane sealant.

8. Apply polyurethane to the nozzle end of the motor case and both sealing surfaces on the nozzle

9. Wipe off excess polyurethane.

10. Insert nozzle and compress.

11. Insert 2 1/8" rivets each on opposites sides of the motor and use a vice to press them in. Rivets should go in firmly, but don't force them. Make sure the holes on the nozzle and case are aligned.

12. Insert other 2 rivets using the same procedure as step 11.

13. Prepare the igniter by cutting a piece of the ANB to 1/4x1/4x1/8"

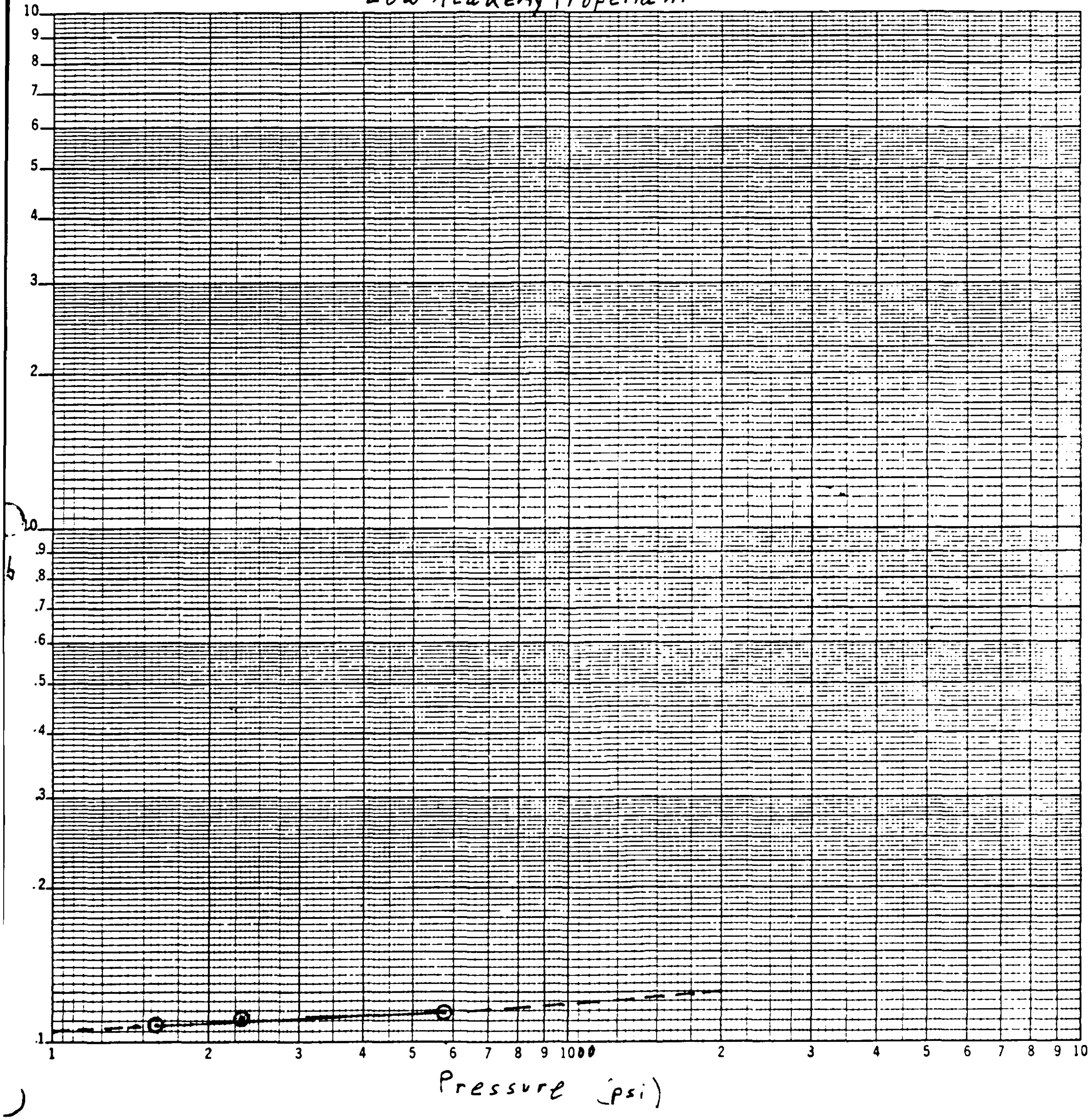
14. Push 4" of #26 nichrome wire through the center of the face of the propellant.

15. Cut 18" of #26 strain gauge wire (stranded) and twist 1 1/2" of it to the nichrome wire.

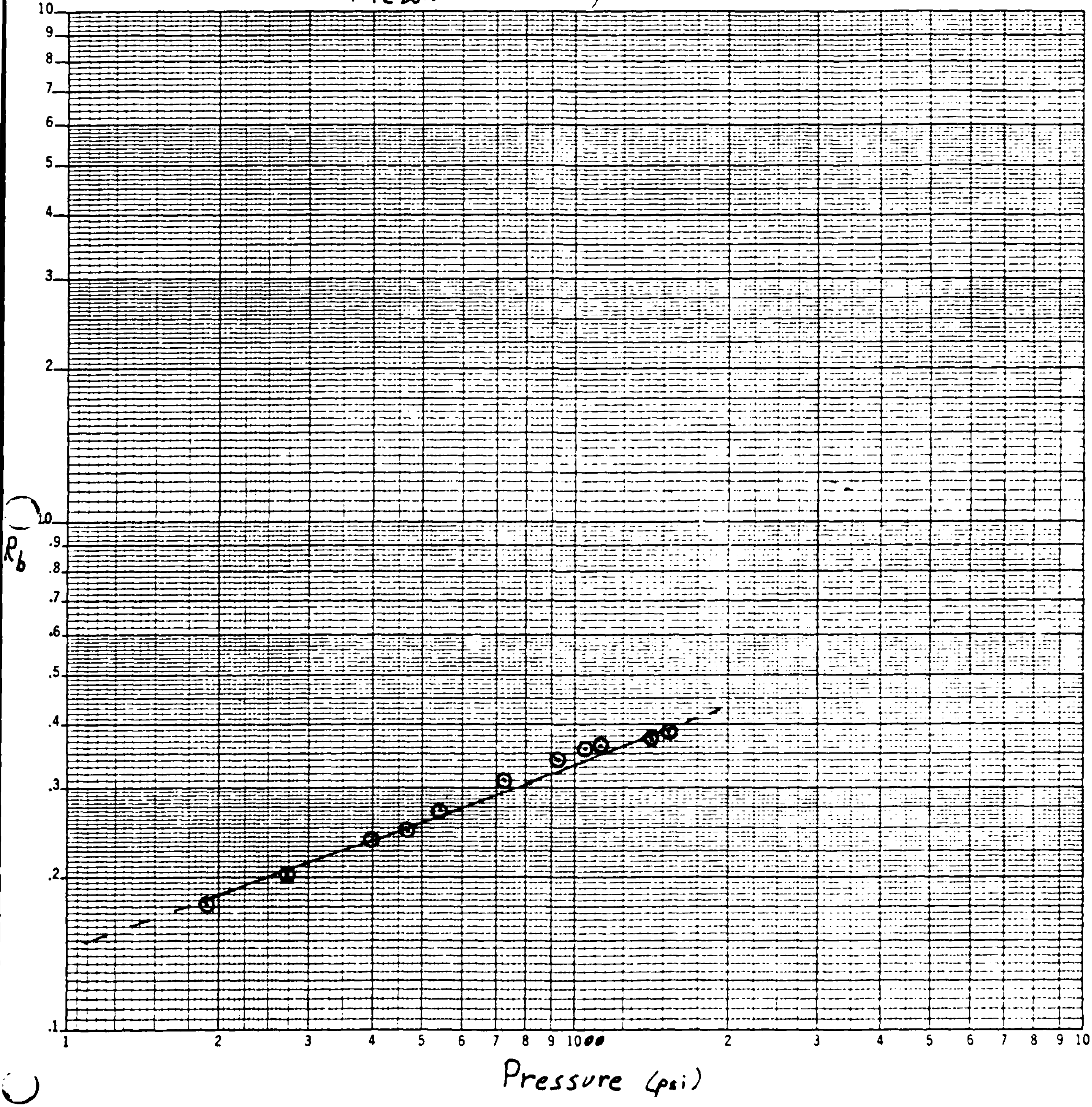
16. Insert the igniter 1/2 way down propellant grain.

17. Secure the igniter wires to bottom of motor with tape.

Low Academy Propellant

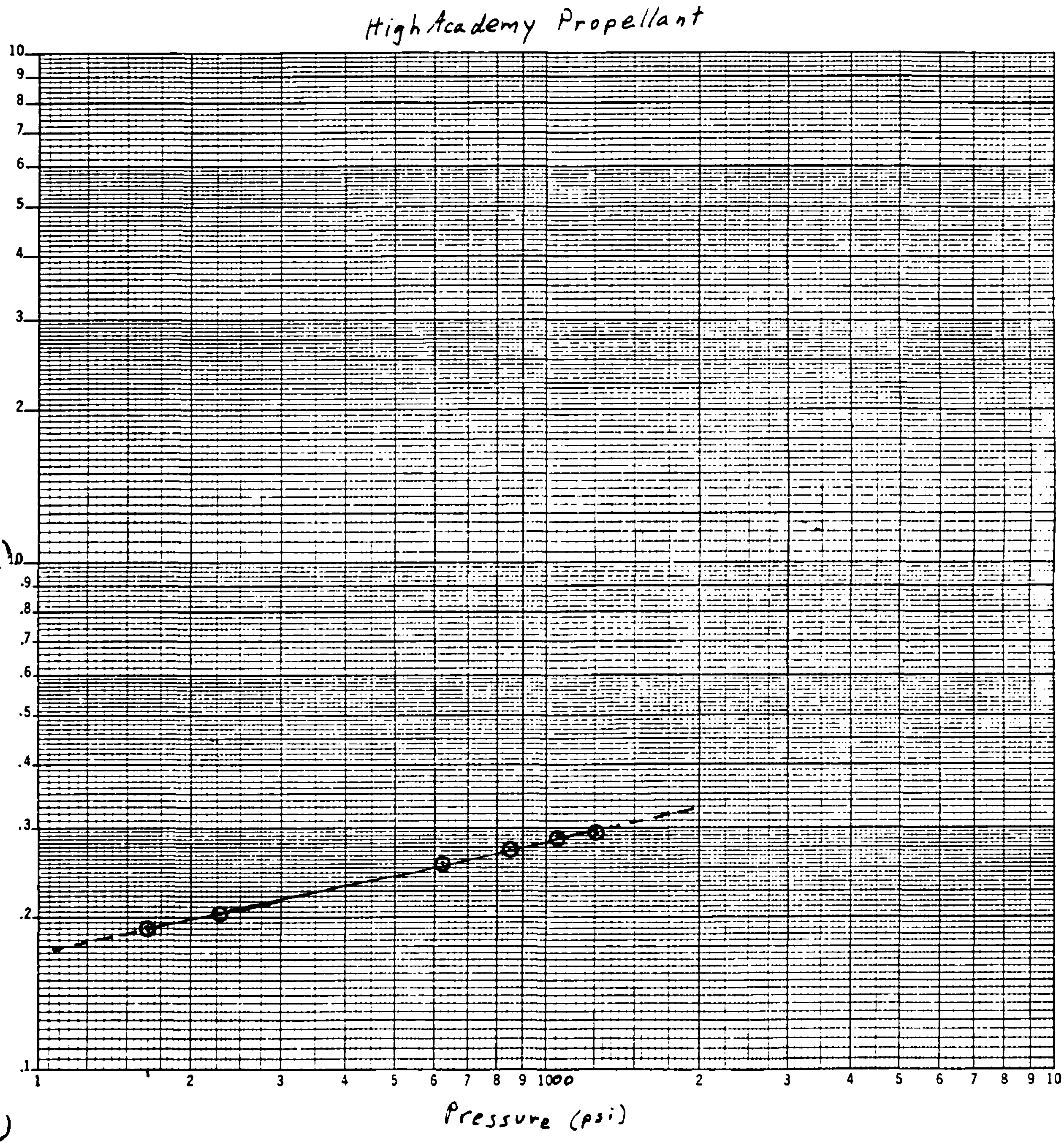


Medium Academy Propellant



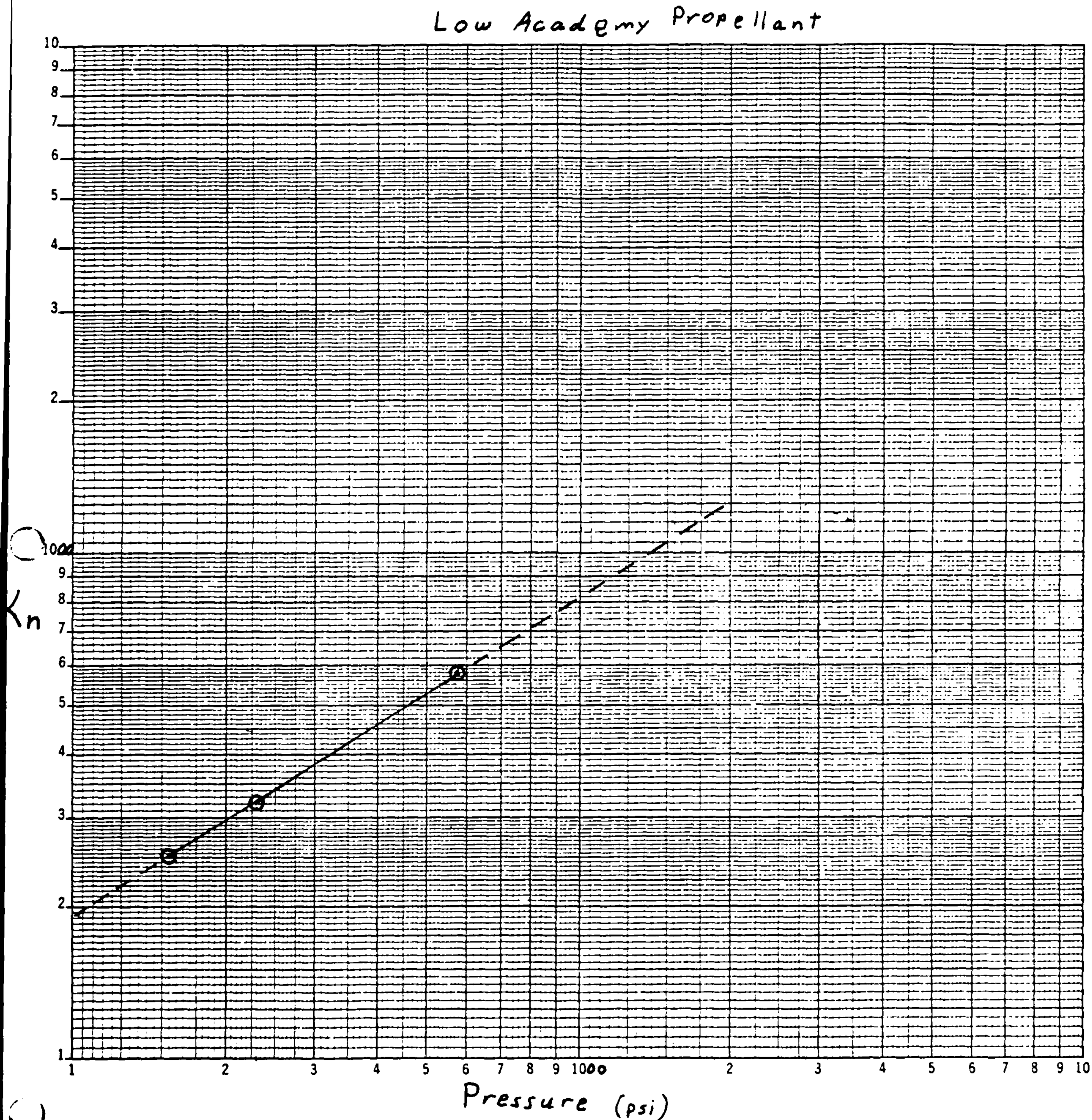
12-10

LOGARITHMIC 2 CYCLES BY 2 CYCLES
CONTROL COMPANY

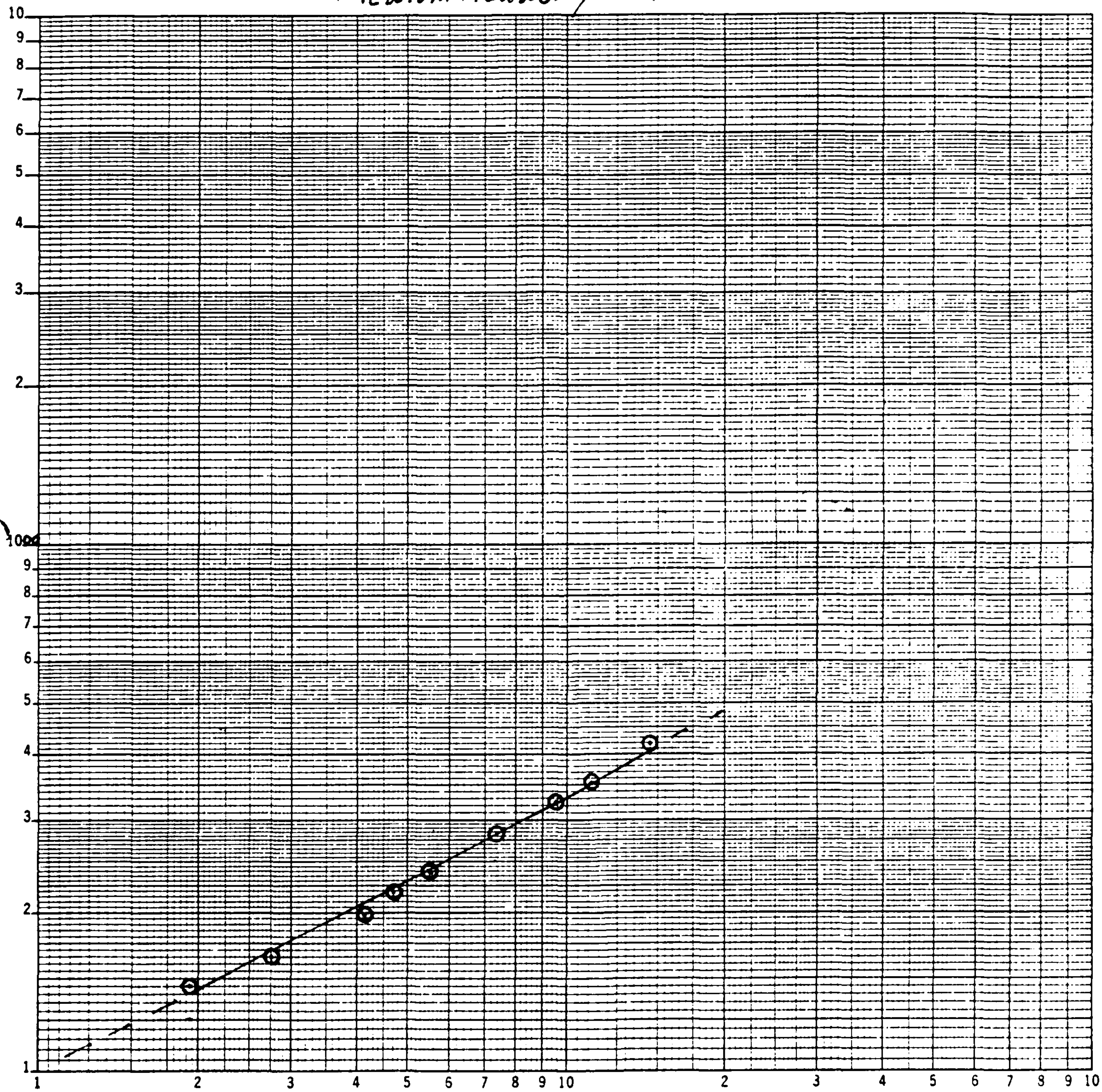


12-11

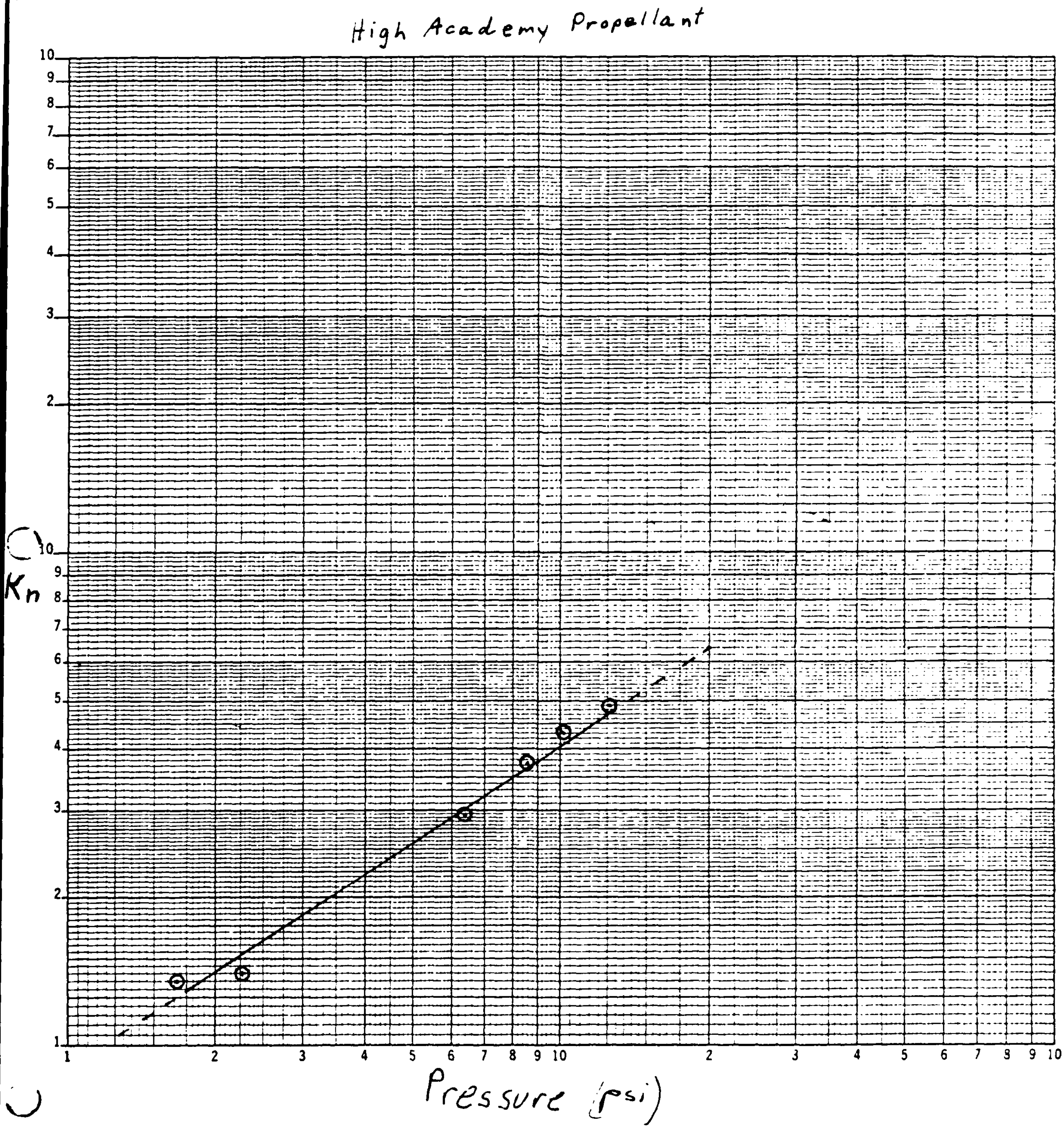
LOGARITHMIC 2 CYCLES BY 2 CYCLES
CONTROL COMPANY


Low Academy Propellant
Kn
Pressure (psi)
1000

Medium Academy Propellant



Pressure (psi)


High Academy Propellant
Kn
Pressure (psi)
10
9
8
7
6
5
4
3
2
1
2
3
4
5
6
7
8
9
10

PROPELLANT	HF	DENSITY	WEIGHT	MOLES	VOLUME
AP	-70.6900	1.9500	60.0000	.5107	30.7692
R-45	-.2500	.9300	10.4600	.1675	11.2473
DOZ	-336.8000	.5190	2.1500	.0052	4.1426
DDI	-206.3000	.9240	2.3900	.0041	2.5866
AN	-87.2000	1.7300	15.0000	.1874	8.6705
CuAMCl	-70.0000	2.0000	2.0000	.0072	1.0000
KClO4	-102.8000	1.7300	8.0000	.0577	4.6243

GRAM ATOMS / 100 GRAMS
C .9559 CL .5973 CU .0072 H 4.4129 K .0577 N .9081 O 2.9664

ENTHALPY = -61.52411   DENSITY =1.586
CSTAR (FT/SEC)= 4844.128

	CHAMBER	THR(SHIFT)	EXH(SHIFT)
PRESSURE (PSIA)	1000.00	566.036	14.6960
EPSILON	.000000	1.00000	8.49201
ISP	.000000	101.717	238.594
ISP (VACUUM)	.000000	186.942	257.384
TEMPERATURE(K)	2773.08	2534.26	1317.30
MOLECULAR WEIGHT	25.2081	25.2751	25.4036
MOLES GAS/100G	3.96698	3.95646	3.93645
CF	.000000	.675590	1.58470
PEAE/M (SECONDS)	.000000	85.2246	18.7902
GAMMA	1.21713	1.21954	1.25215
HEAT CAP (CAL)	44.1909	43.6755	38.8467
ENTROPY (CAL)	239.204	239.203	239.204
ENTHALPY (KCAL)	-61.5241	-73.4098	-126.921
DENSITY (G/CC)	.75381E-02	.46813E-02	.23501E-03
ITERATIONS	23	14	25

PROPELLANT	HF	DENSITY	WEIGHT	MOLES	VOLUME
AP	-70.7000	1.9500	74.8000	.6367	38.3590
R-45	-.2500	.9300	10.4600	.1675	11.2473
DOZ	-336.8000	.5190	2.1500	.0052	4.1426
DDI	-206.3000	.9240	2.3900	.0041	2.5866
FE2O3	-197.0000	5.1200	.2000	.0013	.0391
SR(NO3)2	-233.8000	2.9860	10.0000	.0473	3.3490

GRAM ATOMS / 100 GRAMS
C .9559 CL .6367 FE .0025 H 4.0807 N .7394 O 2.9500 SR .0473

ENTHALPY = -58.94820   DENSITY =1.674
CSTAR (FT/SEC)= 4863.014

	CHAMBER	THR(SHIFT)	EXH(SHIFT)	EXH(SHIFT)
PRESSURE (PSIA)	1213.00	691.096	14.6900	4.7586
EPSILON	.000000	1.00000	10.2562	23.999
ISP	.000000	101.174	244.861	263.31
ISP (VACUUM)	.000000	187.291	263.636	277.55
TEMPERATURE(K)	2944.47	2719.11	1460.60	1190.9
MOLECULAR WEIGHT	26.8584	26.9818	27.4697	27.476
MOLES GAS/100G	3.72323	3.70621	3.64037	3.6395
CF	.000000	.669373	1.62002	1.7421
PEAE/M (SECONDS)	.000000	86.1170	18.7740	14.231
GAMMA	1.21125	1.21252	1.23237	1.2442
HEAT CAP (CAL)	42.4241	42.0213	38.3670	36.840
ENTROPY (CAL)	228.773	228.772	228.773	228.77
ENTHALPY (KCAL)	-58.9478	-70.7069	-127.825	-138.60
DENSITY (G/CC)	.91753E-02	.56868E-02	.22910E-03	.91042E-0
ITERATIONS	9	20	48	3

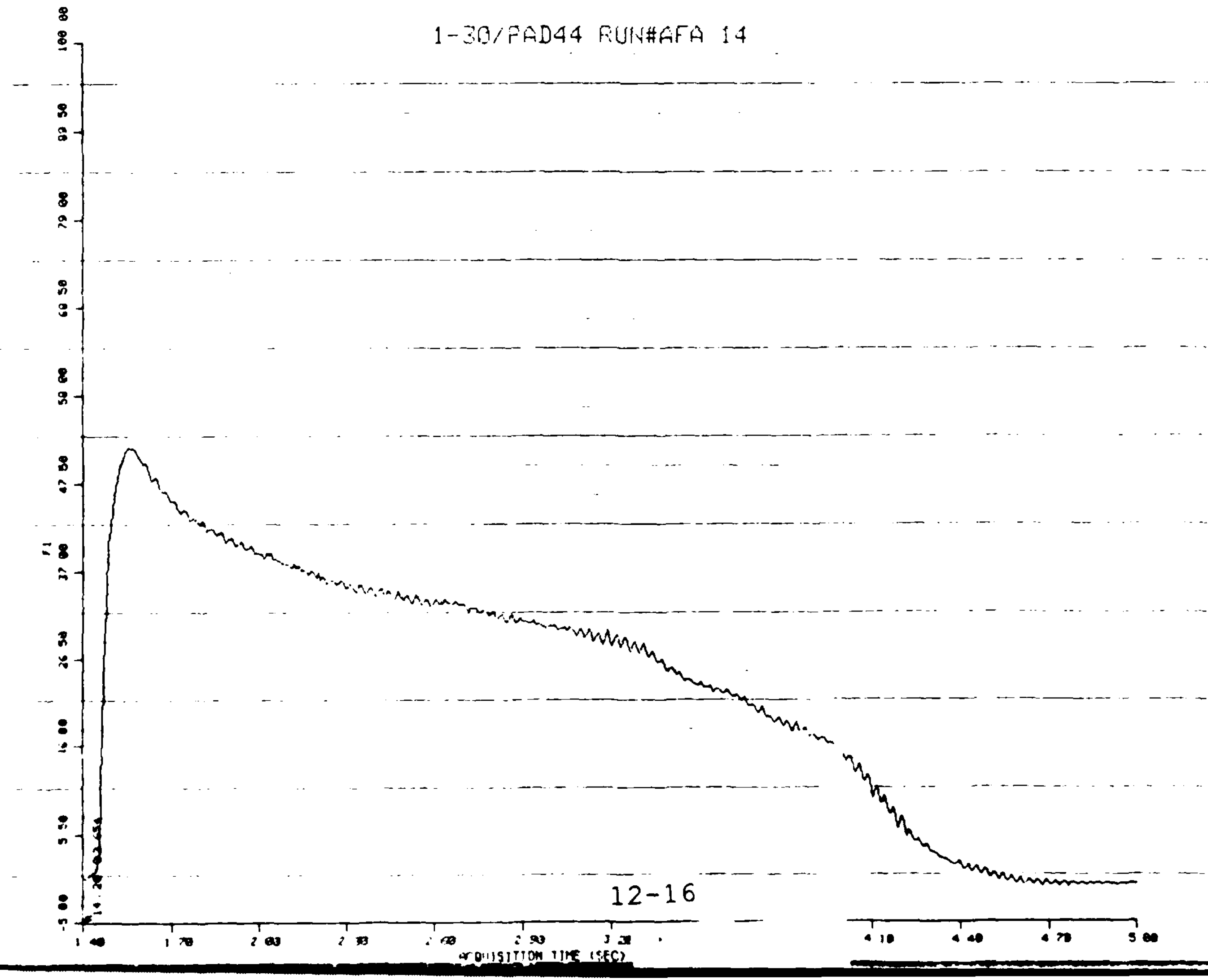
Micro Version by Beckman & Acree   Revision: 5/89   13:11:02

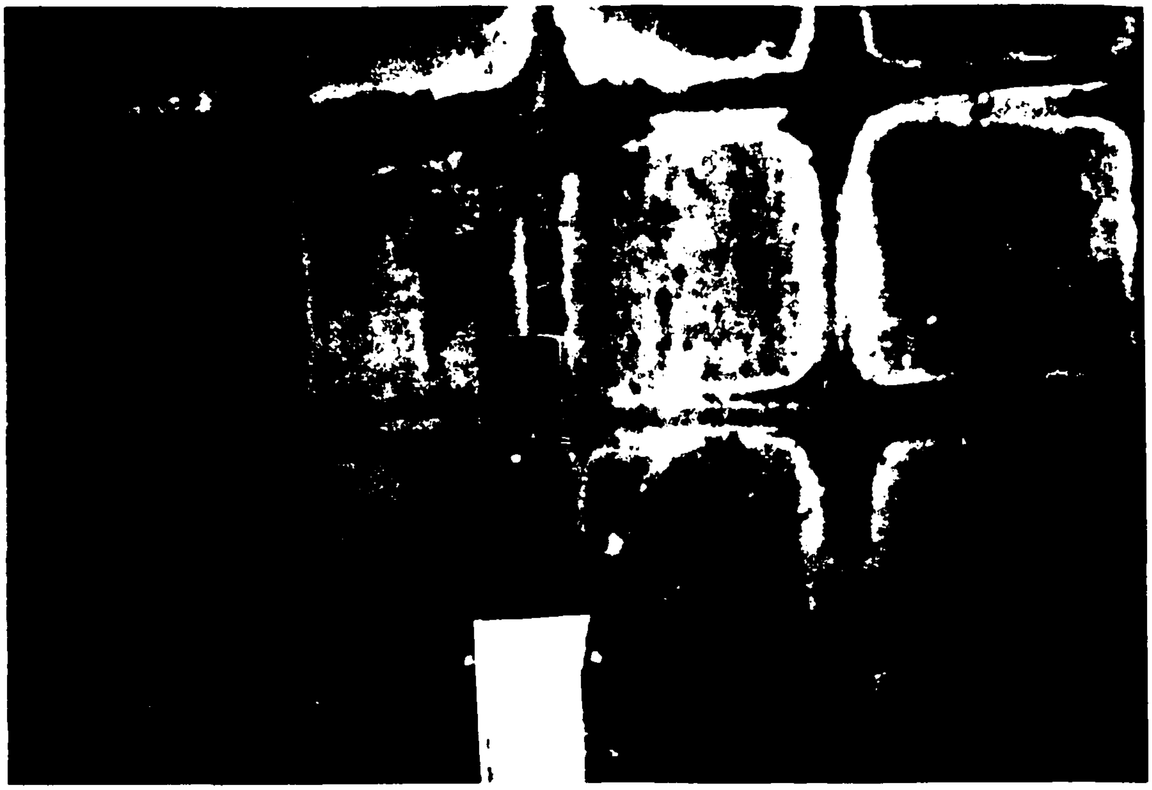
PROPELLANT	HF	DENSITY	WEIGHT	MOLES	VOLUME
AP	-70.6900	1.9500	75.0000	.6384	38.4615
R-45	-.2500	.9300	13.9500	.2233	15.0000
DOZ	-336.8000	.5190	2.8600	.0069	5.5106
DDI	-206.3000	.9240	3.1900	.0055	3.4524
BORON	.0000	2.3400	5.0000	.4625	2.1368

GRAM ATOMS / 100 GRAMS
B .4625 C 1.2745 CL .6384 H 4.5988 N .6493 O 2.7082

ENTHALPY = -48.64441   DENSITY =1.549
CSTAR (FT/SEC)= 4824.350

	CHAMBER	THR(SHIFT)	EXH(SHIFT)
PRESSURE (PSIA)	1000.00	560.671	14.6960
EPSILON	.000000	1.00000	9.44873
ISP	.000000	102.675	244.742
ISP (VACUUM)	.000000	186.748	265.564
TEMPERATURE(K)	2492.92	2246.21	1395.80
MOLECULAR WEIGHT	22.4660	22.4973	23.6810
MOLES GAS/100G	4.45117	4.44497	4.22280
CF	.000000	.684751	1.63220
PEAE/M (SECONDS)	.000000	84.0722	20.8217
GAMMA	1.24040	1.24406	1.23906
HEAT CAP (CAL)	45.6406	45.0262	43.4950
ENTROPY (CAL)	251.367	251.367	251.367
ENTHALPY (KCAL)	-48.6444	-60.7551	-117.455
DENSITY (G/CC)	.74731E-02	.46567E-02	.20676E-03
ITERATIONS	25	7	21





Academy motor on pad 44 after firing.

Acknowledgments

I wish to thank Mr. Hieu Nguyen who was a great help throughout the course of this project. I also wish to thank Dr. John Rusek and Dr. Kevin Chaffee for all of their advice and help. Finally, I wish to thank the crew of Area 1-30 for their constant cooperation and understanding.

Aaron Cabral's report not available at time of publication

MY SUMMER APPRENTICESHIP AT KIRTLAND AIR FORCE BASE, PHILLIPS LABORATORY

Andrea Garcia
High School Student
West Mesa High School

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Albuquerque, NM 87105

Final Report For:
AFOSR Summer Research Program
Phillips Laboratory

Sponsored By:
Air Force Office of Scientific Research
Kirtland Air Force Base, Albuquerque, NM

August 1993

My Summer Apprenticeship At Kirtland Air Force Base, Phillips Laboratory

Andrea Garcia

As I walked through the SX (Space Experiments) building for the first time, at Kirtland Air Force Base, I had no idea what to expect. My heart was racing as I looked for the office, where I would spend the next eight weeks. As I reached my destination I became more relaxed, but I still did not know what to expect. I did not know what I was going to be doing, who I was going to meet, or what I was going to learn. My adventure was just beginning as I turned and walked into the office.

As I entered I met Mr. Jeff West, my mentor. Soon Rudy showed up, my co-worker, I was going to be working with him for the next couple of weeks. As soon as I was arrived we started to meet new people. We were able to go to the computer laboratory at Phillips Lab. There we were able to see some of the biggest and fastest working computers in the world. After going to the computer lab we went to get checked in. We received our clearance badges, and we now were official members of the Phillips Laboratory staff. As we went to finish getting cleared we toured the many buildings of Phillips Lab. On this day we learned of what one of our tasks was going to be. We were going to be working on the High Altitude Balloon Experiments Project (HABE). We were not only going to be working on this project, but we would actually get to see it happen.

The lift off was going to happen on June 16, 1993 in Clovis, NM, at approximately 6:00am. To be there on time we left at midnight. The first part of the lift off was to fill the tow balloon (figure 14-1) with helium. We waited with anticipation for this balloon to fill up. Then we had to wait for the winds to be precise for lift off. After the conditions were adequate it was time for the launch to take place. As soon as the HABE Check0 Flight Structure (figure 14-1) was up in the air the main balloon and parachute (figure 14-1) were supposed to release and the main balloon, fill up with the helium from the tow balloon. At 7:15am the structure lifted under a partial moon and an overcast sky. The rapid ascent quickly brought the system to an altitude at which reel down was to occur and the initiating RF command were sent with no visual response from the flight structure. The commands were tried again, but failed. If the balloon would continue to ascend it would result in a failure of the main balloon due to the expanding volume af helium within the closed envelope. A command was given to open the helium vent valve and bring the structure down. The descent would be helped by the balloon it would not be controlled. There could have been an immense accident, but with expertise of the ground crew the structure was brought down as fast as possible without causing much damage. Unfortunately it was back to the drawing board for the HABE project. Now what were our duties going to be back home?

Fortunately there was data from this flight that we were going to be able to use. We were going to be graphing the data from HABE using the Microsoft Excel program. We graphed several different points: Altitude vs. Relative Humidity (figure 14-2), Altitude vs. Wind Direction (figure 14-3), Altitude vs. Wind Speed(figure 14-4), Altitude vs. Pressure (figure 14-5), Altitude vs. Temperature (figure 14-6), and Altitude vs. Time (figure 14-7). By creating these graphs we were able to see what the structure was doing and where it was going at different altitudes during the flight. However, these were not the only graphs we made. We wanted to find a way to graph a point without having to manually do it. We did this by setting up a regression chart for several of the graphs listed above. By doing this we were able to contrive a formula which fit our data. One which we did was for the wind direction (figure 14-8). We separated the first graph into three parts and came up with three different equations. We did this with the help of Major Rudd.

We were also able to work in the meteorology department with Lieutenant Colonel Roadcap in the WE (weather experiments) building. There we developed graphs using a different program in which we could see wind currents during the different months. In this department we worked with the Sarek, UG1, and FTP programs. Also with this department we were able to set up a weather station with Lieutenant Sardonia. This was a fun project, which we enjoyed working on.

During my stay at Kirtland Air Force Base we took upon many challenges and we did our best to conquer them. I will treasure this experience for ever. I never thought I would accomplish or learn as much as I was able to, or meet as many people as I did. This experience has prepared me for my future in the "real" world.

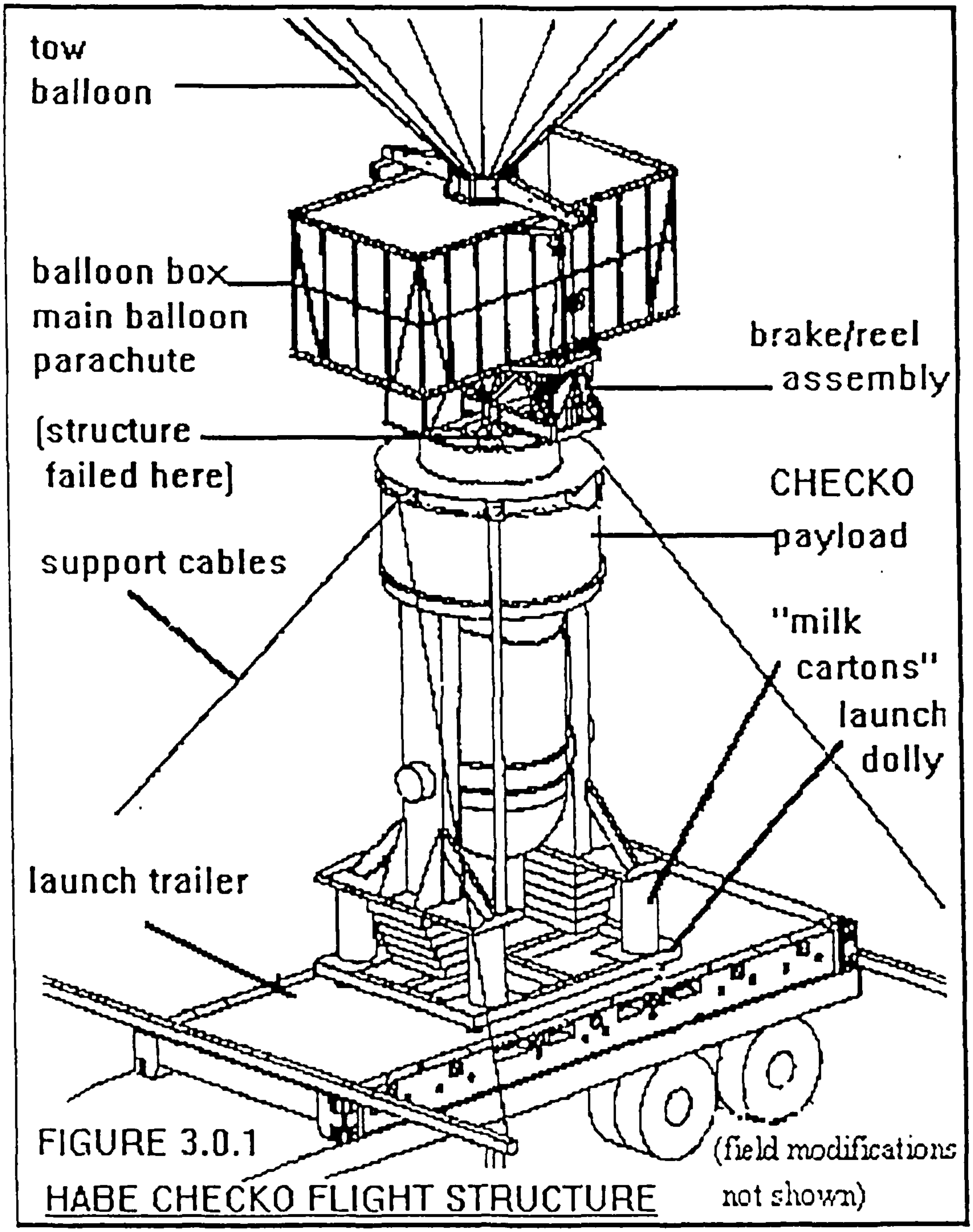

tow
balloon
balloon box
main balloon
parachute
brake/reel
assembly
[structure
failed here]
CHECKO
payload
support cables
"milk
cartons"
launch
dolly
launch trailer
FIGURE 3.0.1
HABE CHECKO FLIGHT STRUCTURE
(field modifications
not shown)

Figure 14-1

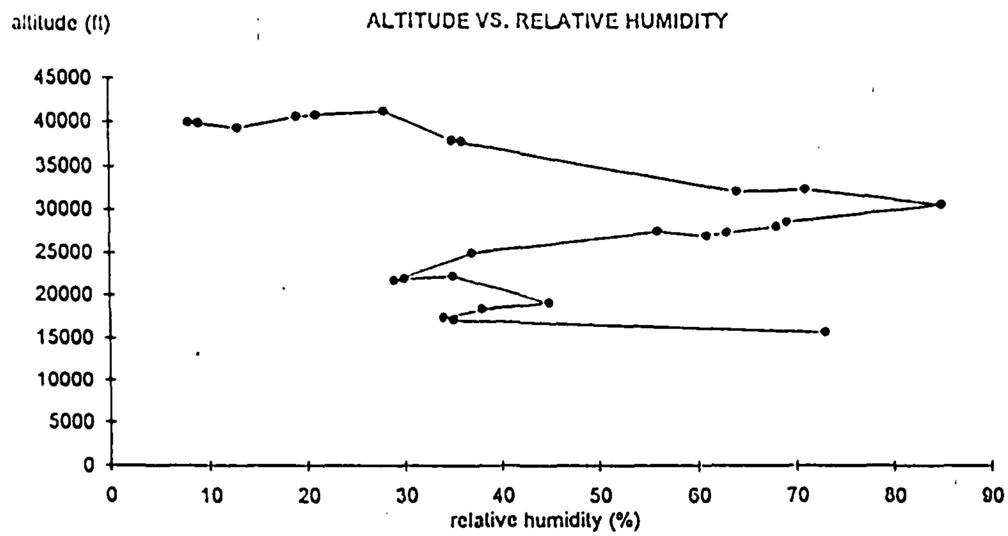


Figure 14-2

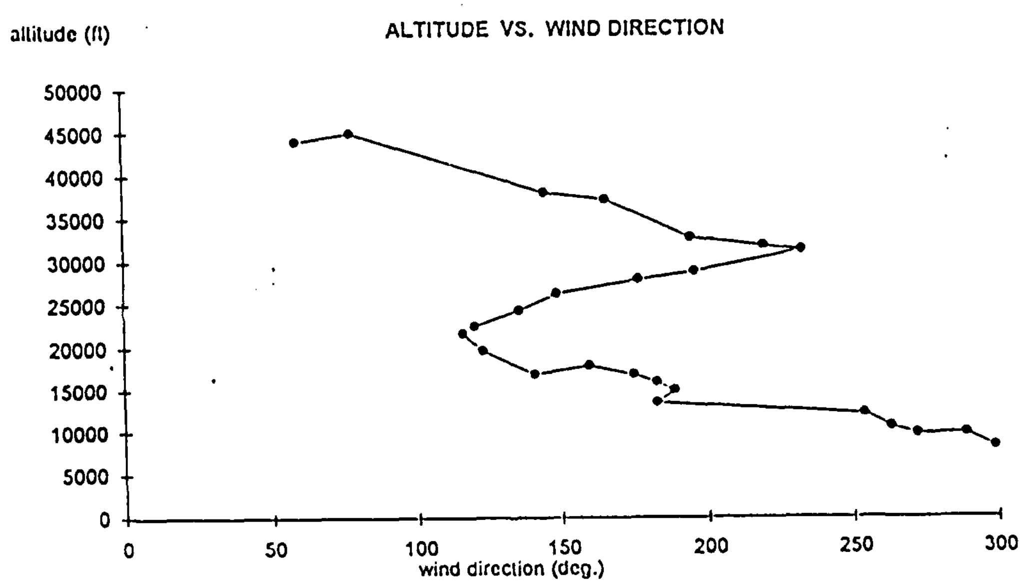
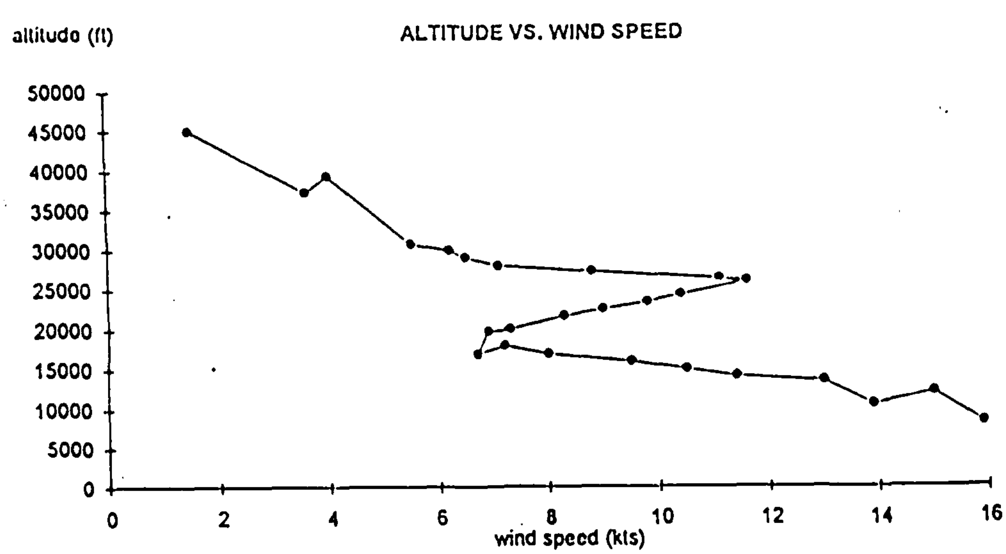


Figure 14-3



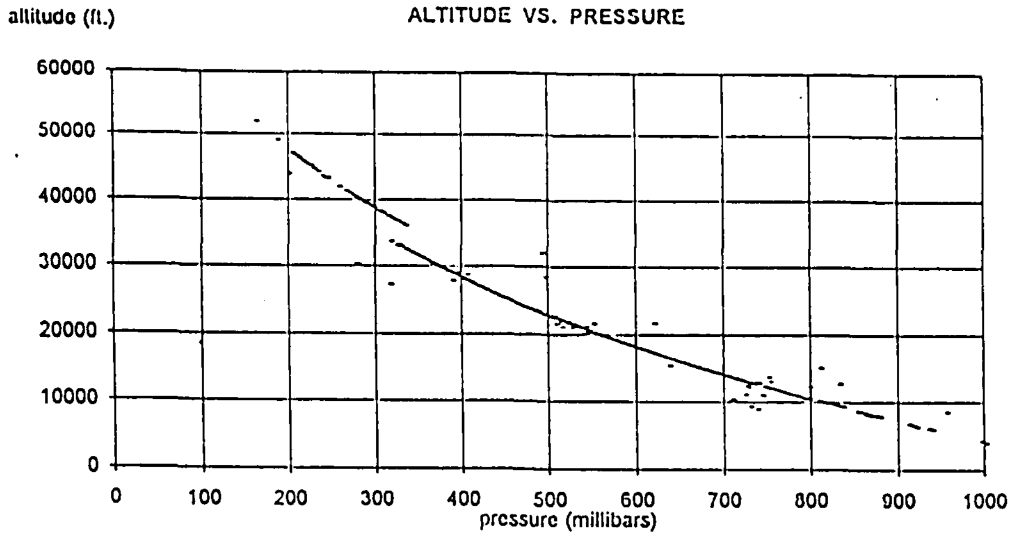


Figure 14-5

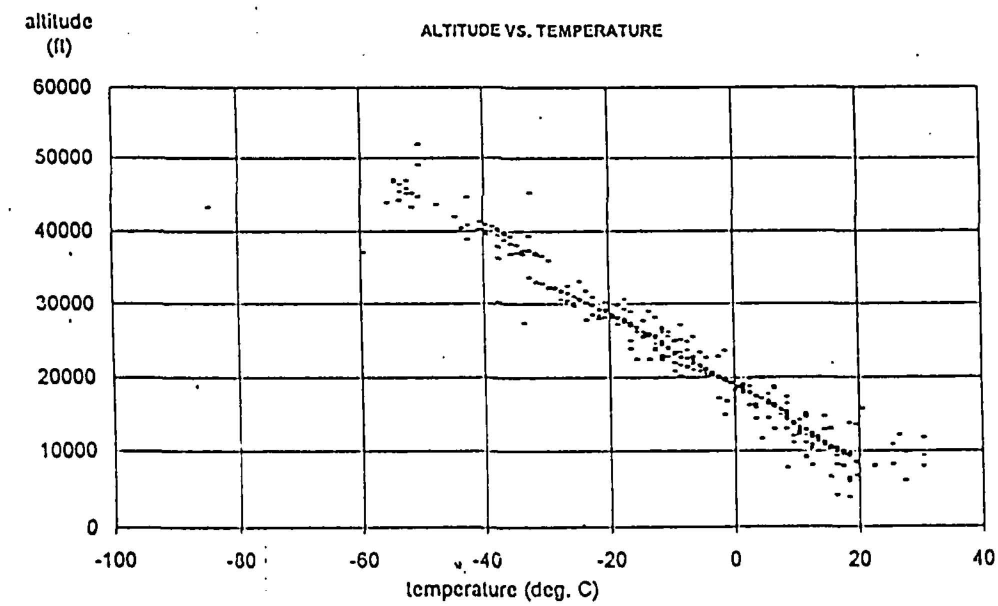


Figure 14-6

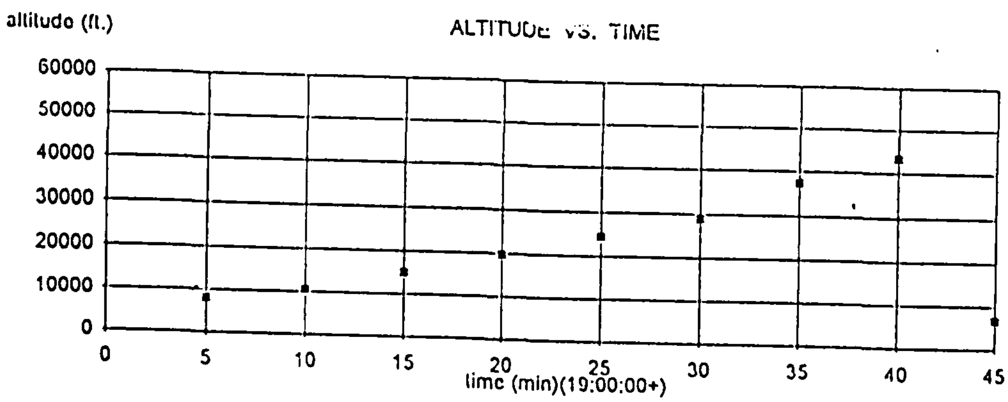
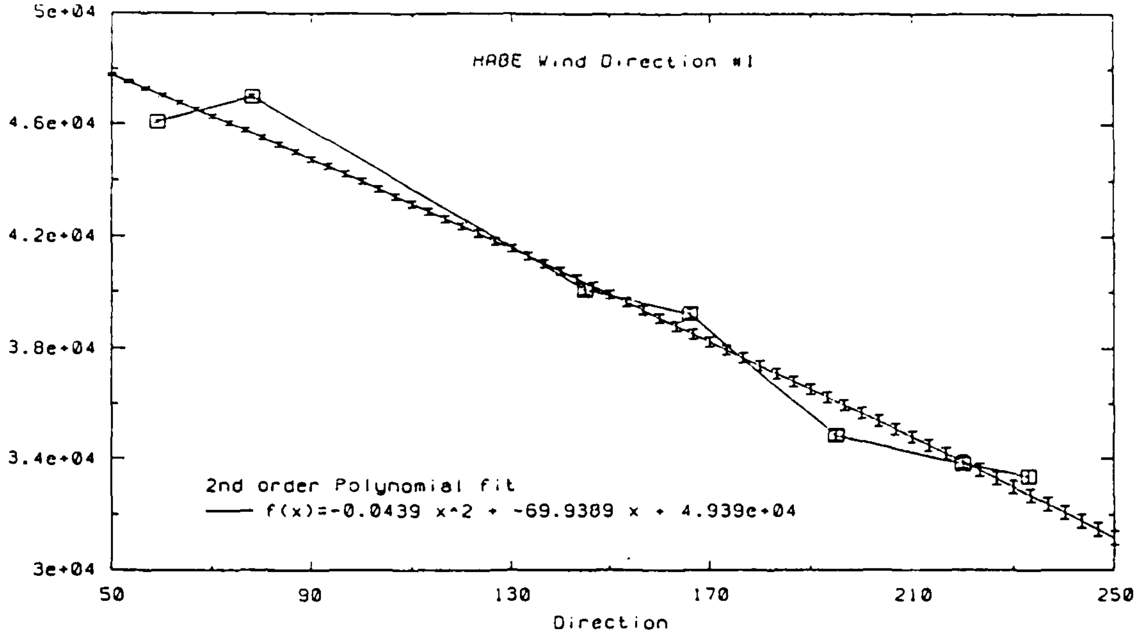
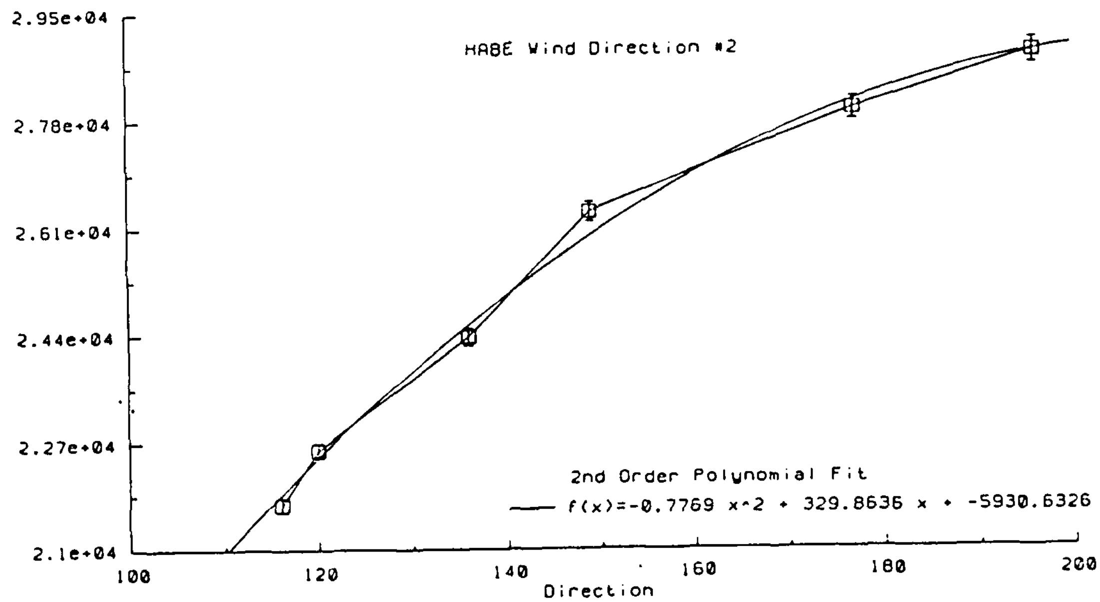
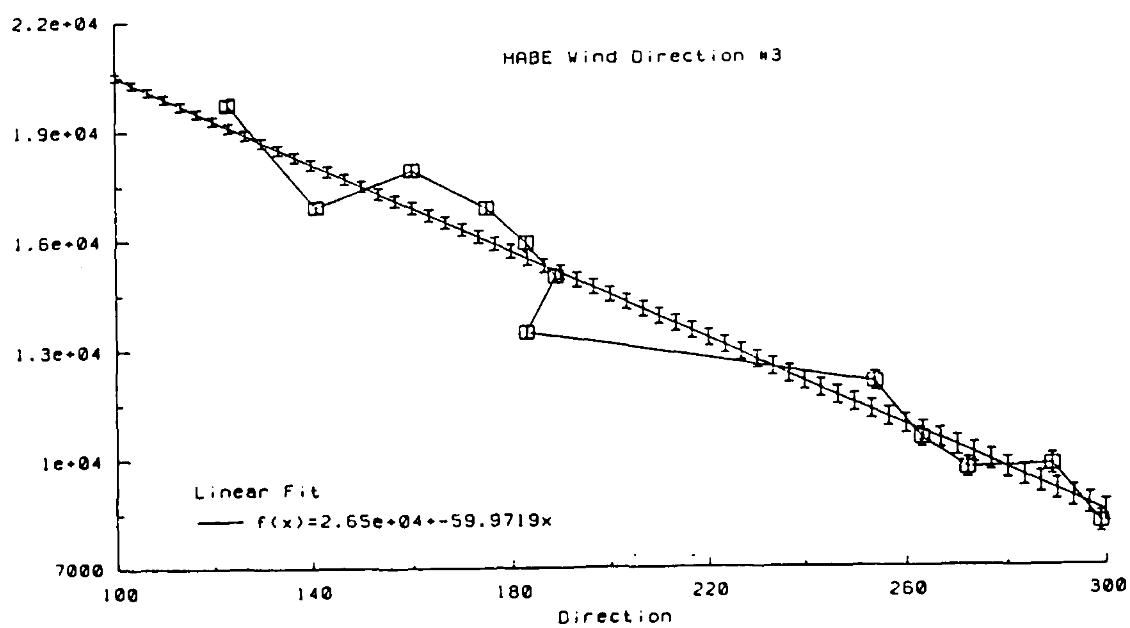


Figure 14-7

Figure 14-8


HABE Wind Direction #1
2nd order Polynomial fit
f(x)=-0.0439 x^2 + -69.9389 x + 4.939e+04
5e+04
4.6e+04
4.2e+04
3.8e+04
3.4e+04
3e+04
50
90
130
170
210
250
Direction


HABE Wind Direction #2
2nd Order Polynomial Fit
f(x)=-0.7769 x^2 + 329.8636 x + -5930.6326
2.95e+04
2.78e+04
2.61e+04
2.44e+04
2.27e+04
2.1e+04
100
120
140
160
180
200
Direction


HABE Wind Direction #3
Linear Fit
f(x)=2.65e+04+-59.9719x
2.2e+04
1.9e+04
1.6e+04
1.3e+04
1e+04
7000
100
140
180
220
260
300
Direction

THE SUN

SUZANNE MATTHEWS

Final Report for:

AFOSR Summer Research Program,
Phillips Laboratory, Space Experiments Division

August 1993

ABSTRACT

The project's objective was to set up a Sun Microsystems computer workstation to receive, decrypt, and analyze data from an unspecified satellite. Five Sun SPARC-station 10 systems were used. They are linked together by two Ethernets, one set on the default, and an extra to handle classified data.

THE SUN

Suzanne Matthews

INTRODUCTION

The objective for this summer was to set up a Sun Microsystems computer workstation to receive, decrypt, and analyze data from an unspecifed satellite. The project has not yet been completed due to outside circumstances, such as table tops not being delivered and the absence of power to three computer stations.

BACKGROUND

Sun stands for Stanford University Network. It is a printed circuit board designed to run Unix. Sun Microsystems was instumental in bringing Unix to the desktop.

The Sun Operating System, or SunOS, is a Unix based system (to be explained later). It consists of five basic parts; the kernel, a file system, the shell, graphical user interfaces, and utility programs.

The kernel is the heart of the system. It is located in the memory. The kernel is responsible for managing the hardware, scheduling and terminating running programs, and keeping track of the file system and other important functions.

The file system is integrated with the kernel and provides the organizing structure for data storage. It uses a hierarchial file system. It uses directories set up like a family tree.

The shell of the system interprets the commands. It manages the interaction of the user with the kernel. There are three types of shells; the C Shell, BourneShell, and KORNShell. The C Shell is the standard one used.

Sun Microsystems uses the OpenLook Graphical User Interface, or GUI. This is otherwise known as OpenWindows. It is a collection of graphical based applications, using icons, menus, and windows.

The Utility Programs are lists of instructions and data interpreted by the computer. Basically, they just make using the system much easier.

The Unix system that Sun Microsystems uses is the AT&T Unix System V Release 4. It is a blend of Berkley Unix and AT&T System V. Unix has a multiprocess architecture. It is a multi-user, multi-tasking system based on time sharing. It has the ability to initiate asyncronous processes. It has a hierarchial file system that features dismountable volumes. It has compatible file, device, and inter-process input output. Unix possesses a system user language selectable on a per-user basis. Although, the user command interface is not intergrated with the operating system.

Ethernet was created in 1980 by Xerox. It is a simple medium to transfer data and share all resources completly and effortlessly. It is limited to one building or one section of a building. For workstations, it is reccommended that a thin wire cable be used. The Intellink Cluster Module uses a twisted pair cable. This enables any Ethernet compatible device to be connected and communicate with other connected Ethernet devices. the Intellink Cluster Module performs the same functions as the Standard Ethernet tranceiver. It buffers received and transmitted data, detects attempts by two or more stations to obtain access to the line simultaneously, signals the presence of a collision to the transmitting stations, and transmits the jam signal.

THE WORKSTATION

Sun SPARCstation 10 systems were used. There are five systems linked together by two Ethernets. The first Ethernet was set on the default (le0) and set up with Star topology using a twisted pair cable. The second Ethernet (le1) has a Bus topology using a thick net cable. It has not yet been determined whether a twisted pair cable is usable. (See figure 1). The reason for the second Ethernet is for classifed data. This requires an extra S-bus card to be inserted into the CPU. This is for the Loral, which handles the satellite data.

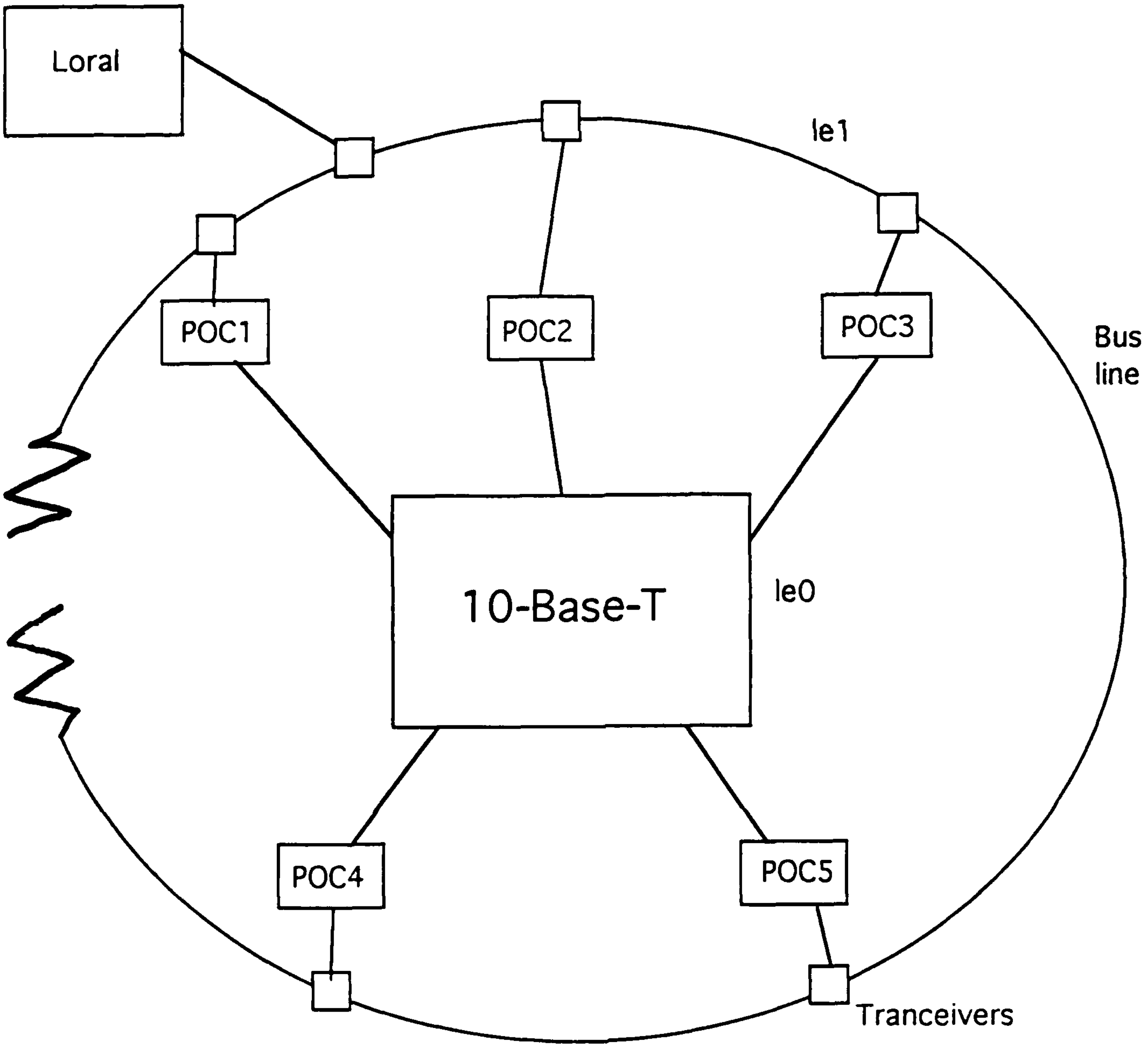

Loral
le1
POC1
POC2
POC3
Bus
line
10-Base-T
le0
POC4
POC5
Tranceivers

Figure 1

CONCLUSION

Only two of the five computer stations were able to be completely set up and running. Meanwhile, I had the chance to learn about the Sun, Unix and how to use them.

My Summer Working with Phillips Laboratory

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Final Report For:
AFOSR Summer Research Program
Phillips Laboratory

Sponsored By:
Air Force Office of Scientific Research
Kirtland Air Force Base, Albuquerque, NM

August 1993

My Summer Working with Phillips Laboratory

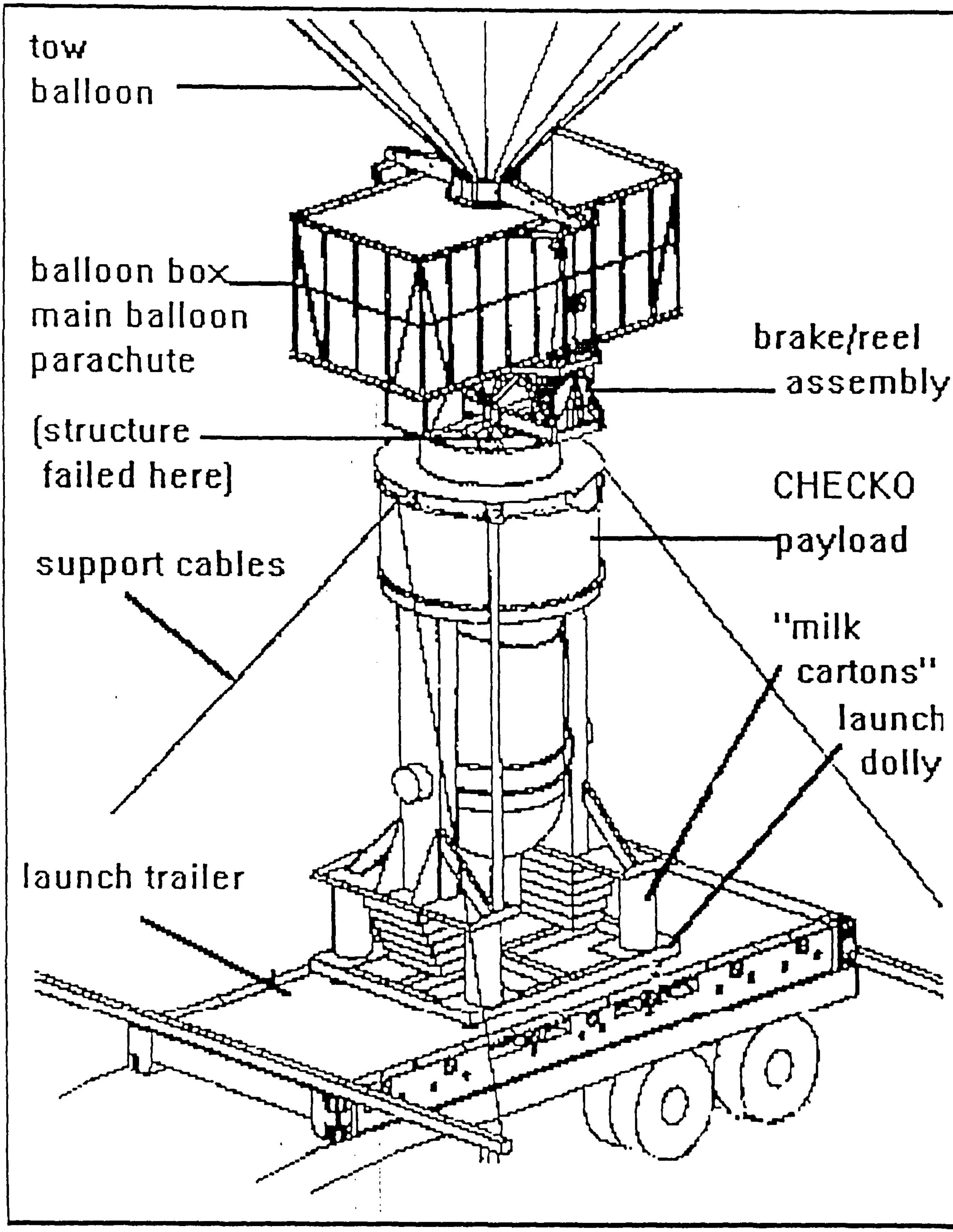
By Rudy Wright

This summer working with Phillips Laboratory has been an experience. I had the privilege of working in two buildings. These buildings were the Space Experiment Building (SX) and the Meteorology Building (WE). Working in these buildings brought new challenges ahead for me and my co-worker Andrea Garcia. This eight week program has been a learning experience. I have learned many new things this summer like working with computer packages, weather files, and many people.

My first week here I had the opportunity to see the lift off of a project that had been in the making for quite some time. This project was called HABE. HABE stands for High Altitude Balloon Experiment. It was to be launched at 0600 on June 15 in Clovis, New Mexico. Once we arrived at the launch site we took a first look at HABE. The launch actually took place at 0715. The takeoff was a success but after that everything went on the down side. Attached (figure 16-1) is a picture of the structure of HABE and it shows where it went bad. What went wrong was a mystery for a while. It turned out that some wires had been miswired. This shows how something as little as a wire can foul up an entire experiment. Once we returned from our destination it was time to start working on the data received from this mishap. We worked on this for quite sometime. While doing this we learned how to work with programs such as Microsoft Excel, Mathcad, and Drawperfect(See figures 16-2/16-9). Figures 16-2 through 16-6 show altitude versus pressure, temperature, time, relative humidity, and wind direction of the HABE project. Figures 16-7 through 16-9 are linear regressions of wind direction of the HABE project. This project took up most of our time and enabled us to learn how Phillips Laboratory worked.

After working with Jeff West (our mentor) and many other staff of the SX building we transferred to the WE building. Working in the WE building brought many challenges. We learned how a network of computers works, how to work with different computers, and how to build a weather station. At this building we worked with computer networks such as SAREK, UG1, and FTP. Using SAREK we typed in and edited weather data, using UG1 and FTP we plotted this data and printed it out. During this time we learned many important things about computers that can be valuable in our future. Once completing some of the files we went with Captain Jim Sardonia to build a weather station. This weather station wasn't that big, but it took hard work to complete. The staff at WE was very easy to work with. We worked with people such as Lt. Col. Roadcap, Captain Morgenstern, and Captain Sardonia.

All in all these eight weeks have been a grand opportunity to broaden my outlooks on how Kirtland Air Force Base, and Phillips Laboratory work. I have acquired a lot more knowledge than most of my friends during this summer and I owe it all to the Air Force Office of Scientific Research (AFSOR).



HABE FLIGHT STRUCTURE

FIGURE 16-1

FIGURE 16-2

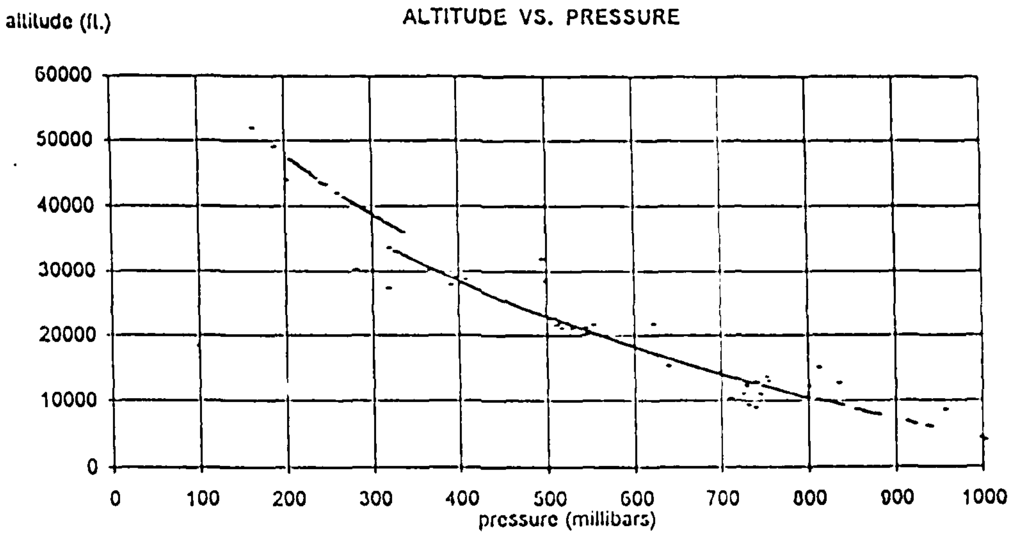


FIGURE 16-3

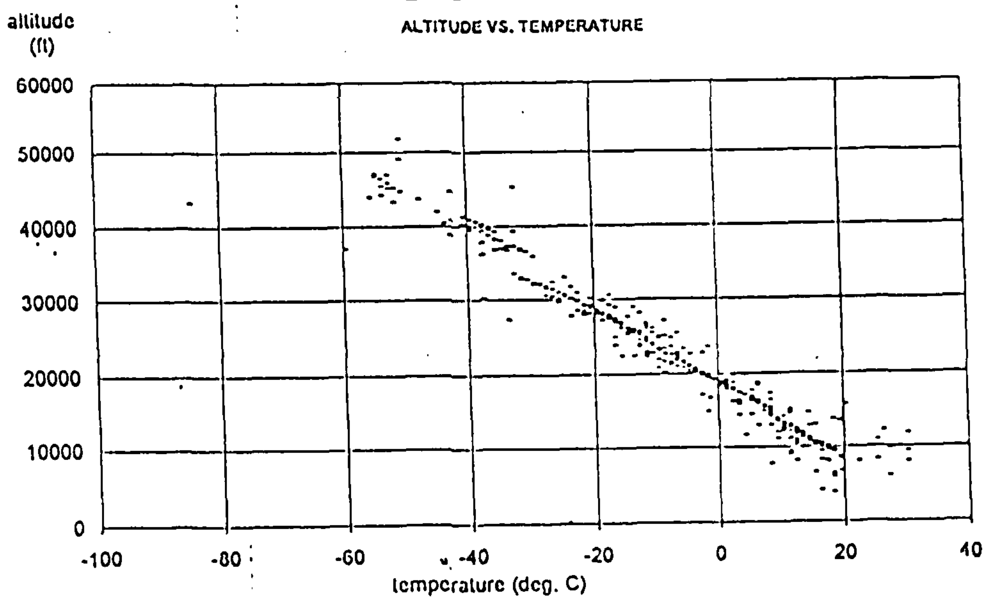


FIGURE 16-4

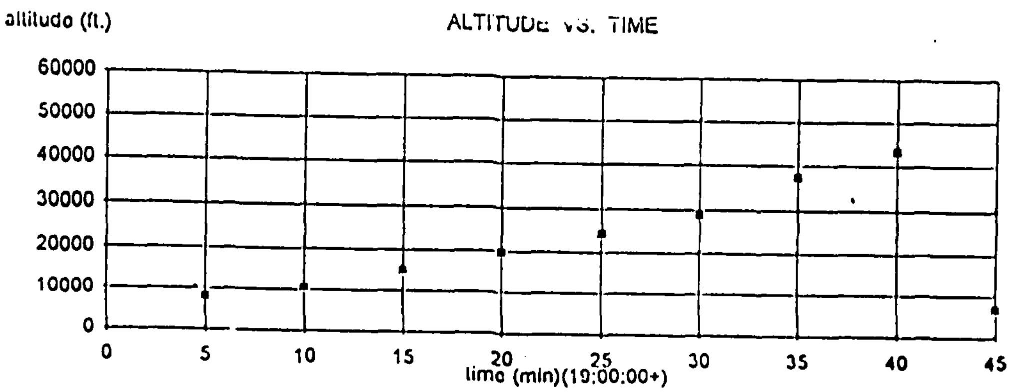


FIGURE 16-5

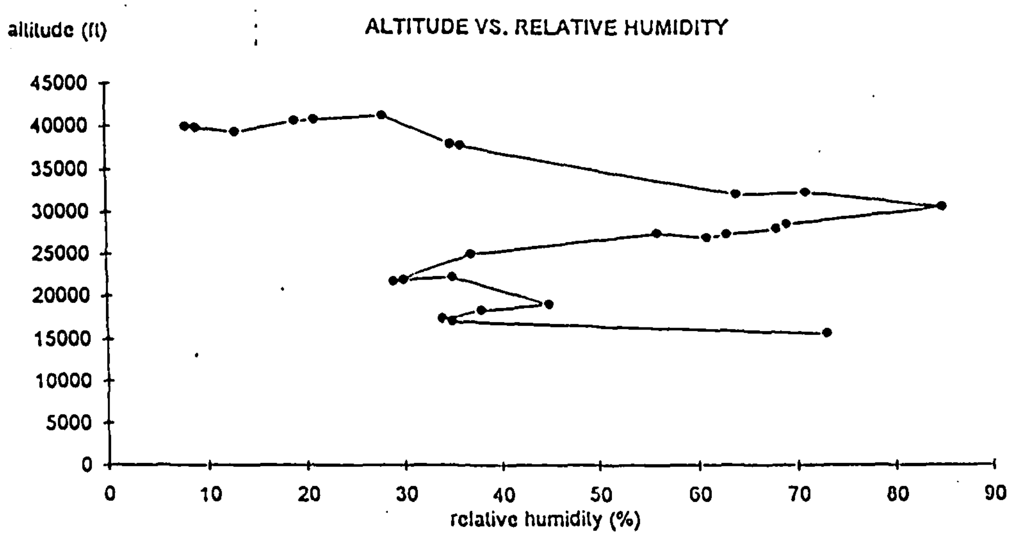


FIGURE 16-6

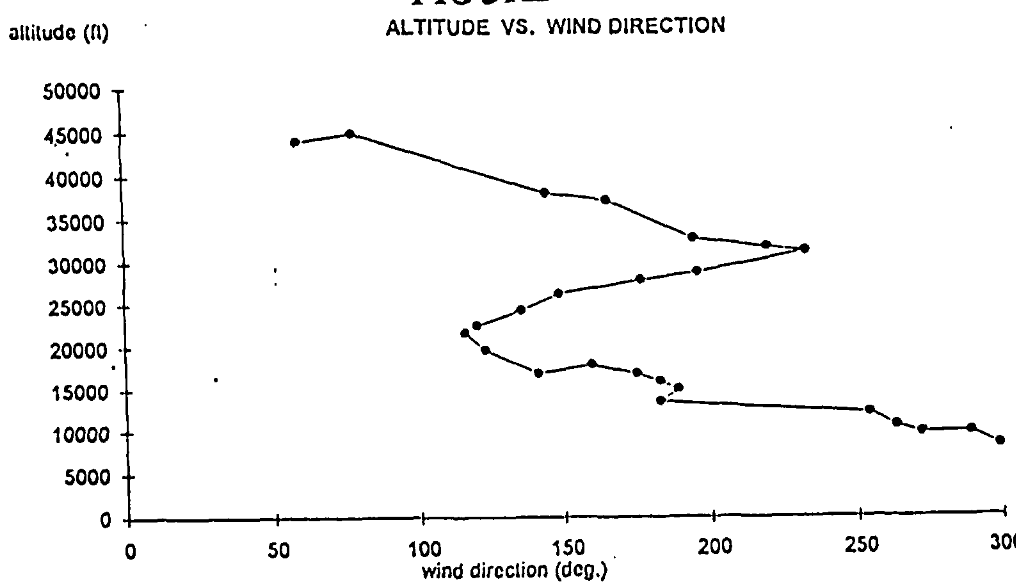


FIGURE 16-7

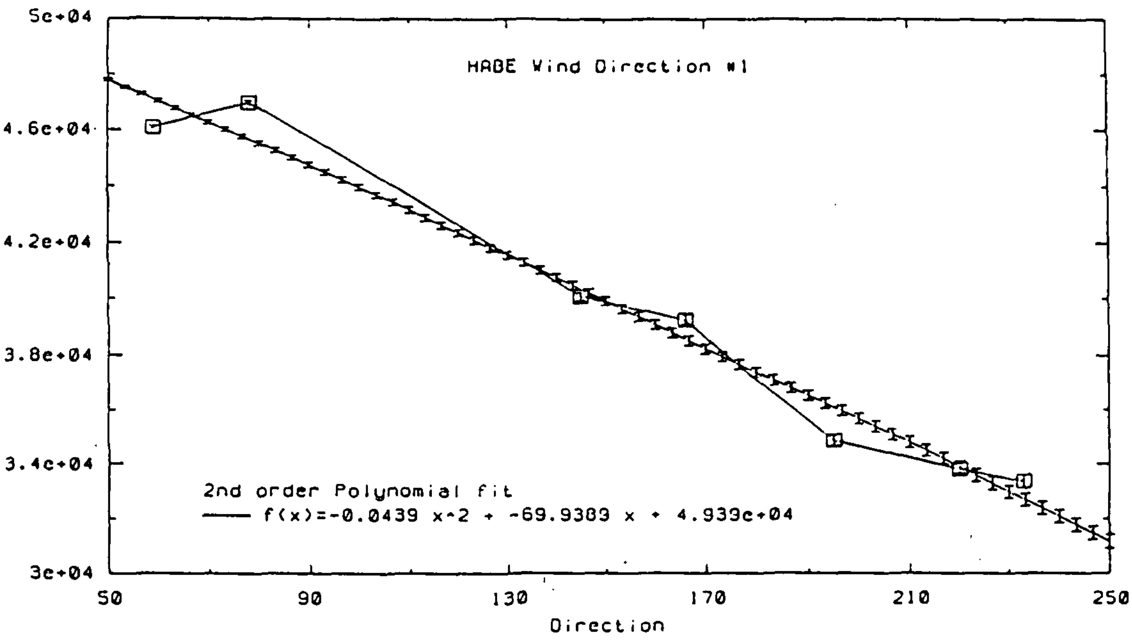


FIGURE 16-8

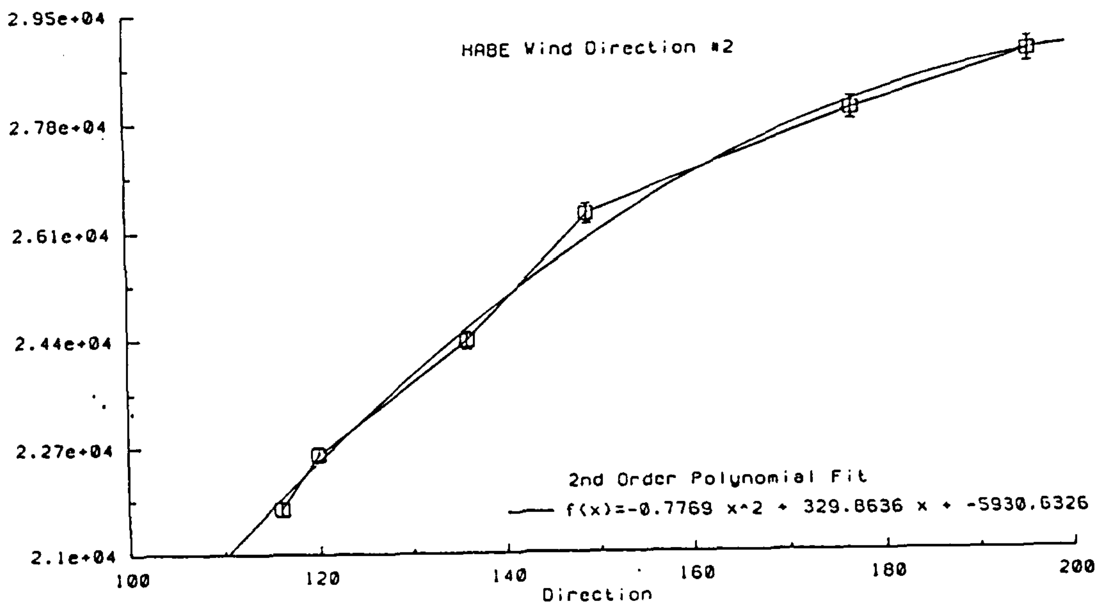
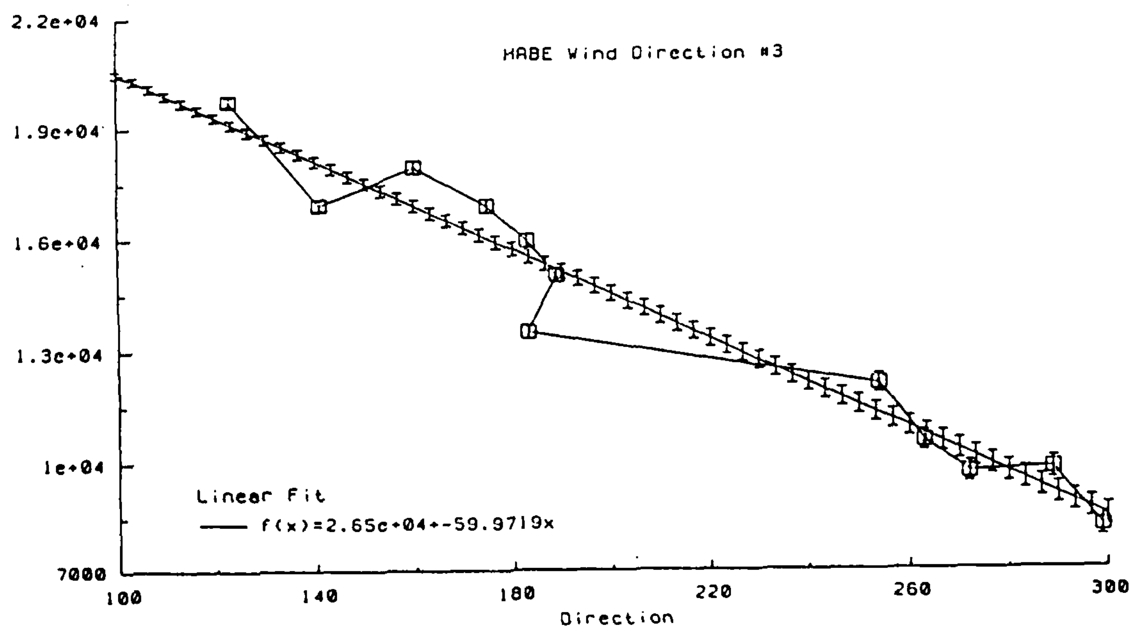


FIGURE 16-9



Eric McEuen's report not available at time of publication.

Optical Scatter Measurements in an Ultrahigh Vacuum Chamber

Tony Tecumseh
Summer Intern
University of Puget Sound

Final Report for:
AFOSR Summer Research Program
Phillips Laboratory

Sponsored by:
Air Force Office of Scientific Research
Kirtland Air Force Base, Albuquerque, N.M.

July 1993

Optical Scatter Measurements in an Ultrahigh Vacuum Chamber

Tony K. Tecumseh
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University of Puget Sound

Abstract

The optical scatter of light off a sample was studied. A dye laser pumped by a Nd:YAG laser was used as the light source. A dye laser was also used in order to pulse the beam. The actual scattering measurements occurred inside an ultrahigh vacuum (UHV) surface analysis chamber. A researcher, targeting a sample, was able to obtain a bidirectional reflectance distribution function (BRDF) measurement. Various samples were analyzed. Most of the samples had a coating of contaminant. A sandblasted stainless steel disc was used as a secondary reference standard. A second laser was used to align the sample. The system is capable of measuring optical scatter levels around 10^{-7} sr^{-1}.

Optical Scatter Measurements
in an Ultrahigh Vacuum Chamber

INTRODUCTION

The Advanced Materials and Measurements Physics Laboratory (AMMPL) at Kirtland AFB measures the optical scatter of metallic substrates in a vacuum chamber. Optical scatter is the change in direction of light particles after contact with a substance. As light hits an object, individual particles of light stray from the object. This change in velocity can be caused by topographical features, natural or synthesized. Optical scatter is very important for satellite operation. Optical scatter can cause performance degradation since unwanted light can mislead sensitive instruments onboard the satellite. At AMMPL, scatter is measured using BRDF (Bi-directional Reflectance Distribution Function). The BRDF of a surface is a mathematical entity which describes the concentration of reflectance of a surface per unit solid angle, under specified restrictions such as uniformity, isotropy, and infinitesimal measurement parameters.[1]

APPARATUS AND USAGE

The ultrahigh vacuum chamber used for experimentation/manipulation consists of three main components: a surface preparation/analysis chamber, an optical scattering chamber, and the ultrahigh vacuum (UHV) pumping manifold.

The surface analysis chamber is equipped with a dual anode x-ray source, an electron gun, an ion gun, and a quadrupole mass spectrometer. The x-ray source, ion

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[1] A new design for an ultrahigh vacuum surface analysis chamber with optical scatter measurement capability. by Altamirano, M.M., Champtetier, R.J., Cohen, M.R. Simonson, R.J., Snyder, J., and Stapp, R.S.; Rev. Sci. Instrum. 64(5), May 1993.

gun, and electron gun were used to monitor or change the surface of the sample. Once, the electron gun was aimed at one small area for about twenty hours. The area that was exposed to the electron bombardment (radiation) was visibly different. There was a small diamond shaped area that was darker than the rest. It looked like tea or coffee had been spilled onto the sample. By exposing the sample to different electron radiation intensities, the optical scatter may be altered.

The optical scattering chamber scatters a laser beam off the sample to a device that measures the scatter. The laser beam is generated by a dye laser that is pumped by a Nd:YAG laser. The primary reason for the dye laser is to shorten the incident pulse for time resolution of scatter signals. A Streak Tube located outside the chamber measures the light that bounces off of the sample. The secondary standard is also located in the scatter chamber. It is a sandblasted stainless steel disk. The scattering chamber and the surface preparation/analysis chamber are connected. The scattering chamber is located below the manipulation chamber. A sample manipulator transports the sample between the two chambers. Using the sample manipulator, the sample can be moved directly to the scatter chamber without exposing the sample to any foreign elements.

The ultrahigh vacuum pump manifold mainly consists of Varian vacuum pumps. A rough pump and a turbo pump are connected so the pressure inside the chamber is comparable to near-space. The turbo pump's fan runs very fast, about the speed of a jet airplane's fan. The rough pumps remove most of the air before the turbos can begin to operate. Turbo pumps can not work without rough pumps backing them up. There are three rough pumps and three turbo pumps directly attached to the chambers.

The streak tube and the laser power meter were linked with a computer which would display the readings. Usually one hundred scatter measurements were displayed. Then the computer would calculate the BRDF measurement.

RESULTS

The photomultiplier signals for the stainless-steel standard and for the sample are normalized by their power reference and optical filter densities. The BRDF of the sample was calculated by using the equation:

Where: 0.116 sr^{-1} is the BRDF value of the *in situ* stainless-steel standard; I_S=detector photomultiplier current, sample; R_S=beam power reference voltage, standard; OD_S=optical density of the incident beam optical filter(s), sample; OD_R=optical density of the incident beam optical filter(s).

Even for a low scatter sample, BRDF about 10^{-7} sr^{-1}, the photomultiplier signal is about 6x larger than the measured detector dark current.

CONCLUSIONS

Although, acquiring data was as simple as pressing a few buttons, a great amount of planning was necessary to make the experiment function properly. Maintenance was often a lengthy task. In order to take accurate measurements, the equipment had to be cleaned on a regular basis. The sample manipulator was removed in order to change the sample. After the manipulator was put back in place, the chamber and all the equipment had to be outgassed. This process expels all excess gas particles that could alter the experiment. The outgassing process took a few days. Often, the sample was out of place. Either the sample or the streak tube had to be moved. A slight bump against the streak tube, a mirror, or the table could cause the sample to misallign. Once the sample or streak tube were moved, realignment of the detection system had to be confirmed before taking measurements. I had never realized how much effort was needed to take a few simple measurements

In order to keep informed in their field, scientists must read articles and journals. They also have to keep accurate notes in a lab notebook. Scientists often have little time to actually take data. Being a scientist takes lots of patience. On some experiments, data accumulation takes months or even years. I only learned a small amount of information on the topic of optical scatter. In order to fully comprehend optical scatter, many years of study would be necessary. Being a scientist doesn't necessarily mean knowing only science. In conclusion, science isn't just a subject it's a combination of skills and abilities.

Figures:

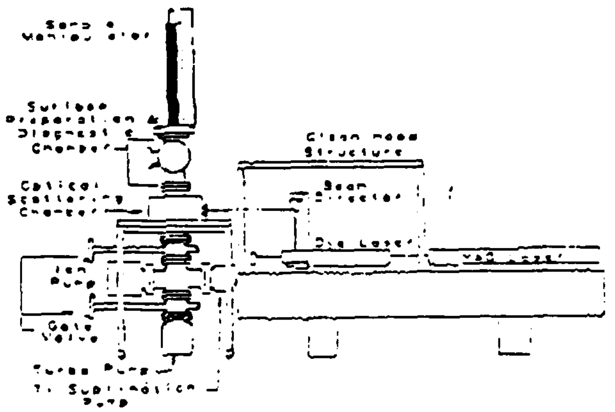


FIG. 1. Schematic side view of the ultrahigh vacuum chamber and pulsed optical source. The particle filter hood structure protects optical components in the input beam path from contamination by airborne particulates.

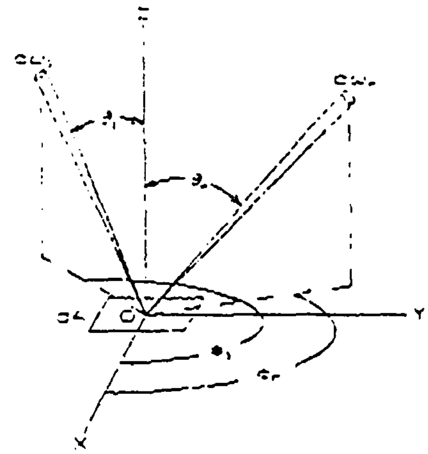


FIG. 3. Geometry of incident and reflected elementary beams in BRDF measurements, showing definition of angular quantities used in Eq. (1). Definitions and notations are those of Ref. 4.

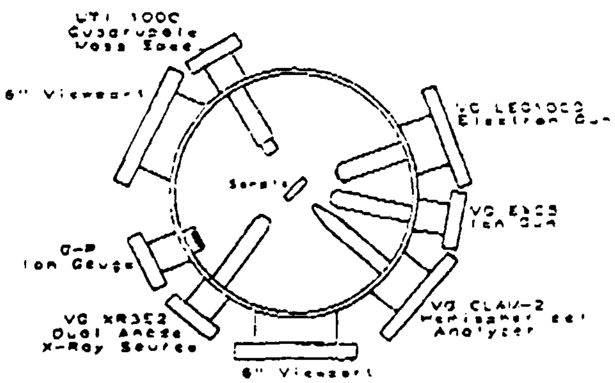


FIG. 2. Schematic top view, shown in cross section, of the surface preparation and diagnostic chamber. The sample manipulator is omitted from this figure for clarity.

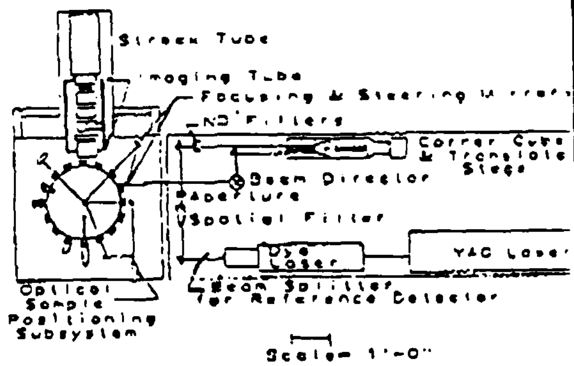


FIG. 4. Schematic top view of the optical path used for BRDF m- ments of samples in the UHV system optical scattering chamber.

[1] A new design for an ultrahigh vacuum surface analysis chamber with optical scatter measurement capability, by Altamirano, M.M. Champetier, R.J., Cohen, M.R., Simonson, R.J., Snyder, J., and Stapp, R.S.; Rev. Sci. Instrum. 64 (5), May 1993.

DATA ORGANIZATION AND ANALYSIS USING MICROSOFT EXCEL AND WORD, ELECTRO-OPTICAL RESEARCH

C. David Brown

Final Report for:
AFOSR Summer Research Program
Phillips Laboratory

AFOSR Sponsorship

August 1993

DATA ORGANIZATION AND ANALYSIS USING MICROSOFT EXCEL AND WORD. ELECTRO-OPTICAL RESEARCH

C. David Brown

Abstract

This summer I was given the opportunity to work in both a lab and an office during my tour of Phillips Laboratory. In the office I used a Macintosh IIci computer with Microsoft Excel and Word to organize and analyze the results of a laboratory survey, and I designed a spreadsheet to keep track of employees salaries and awards in my directorate. In the lab I assisted in state-of-the-art electro-optical research. The goal of this research was to eliminate the current problems associated with using an antenna for hardness *testing on* military systems by replacing the antenna with an electro-optical transducer crystal. I have divided the paper into two sections; the first dealing with my work in the office, the second with my laboratory work.

DATA ORGANIZATION AND ANALYSIS USING MICROSOFT EXCEL AND WORD, ELECTRO-OPTICAL RESEARCH

C. David Brown

Section 1: Office Work

Introduction/Discussion of problem

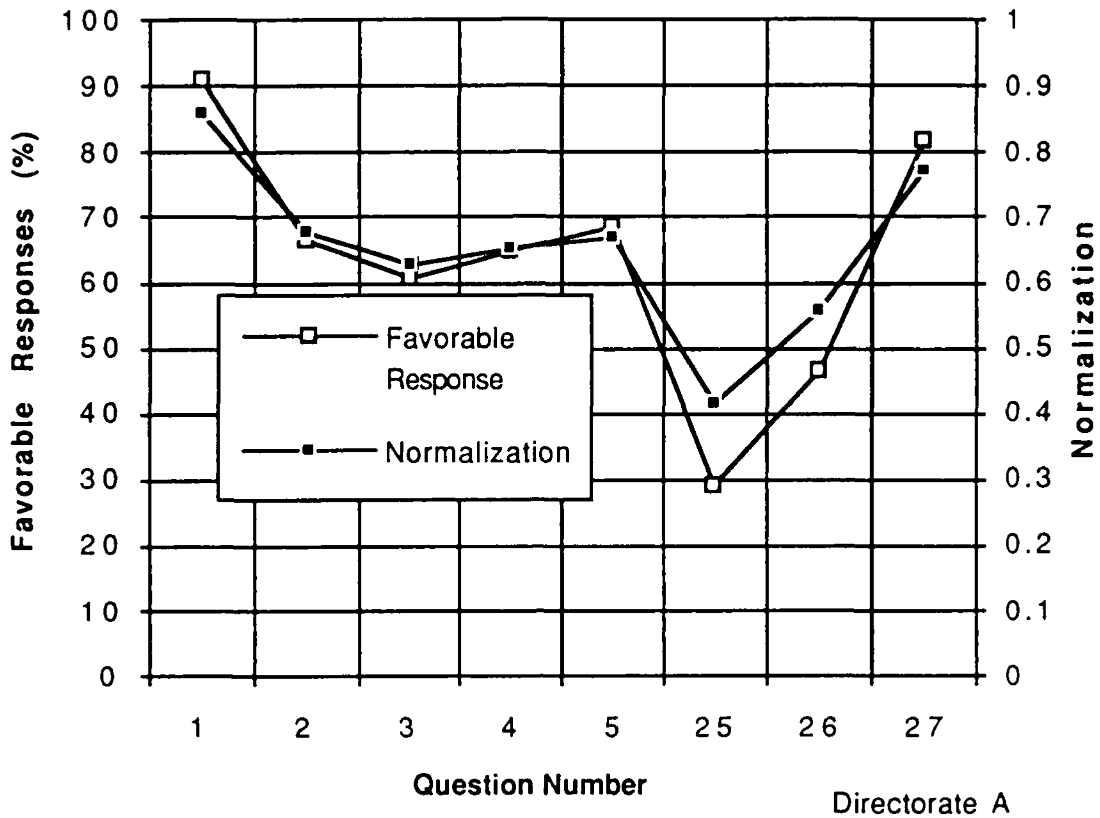
Before my arrival at Phillips Laboratory a survey was sent out to all employees. The purpose of this survey was to assist in, "Creating and maintaining an environment free of fear and anxiety that fosters teamwork, empowerment, and open communication." The questions on the survey were designed to provide PL with information about the quality of their work environment and the satisfaction of their employees. In order for the results of the survey to be useful, they first had to be entered into the computer and then organized into like categories. Finally the results had to be analyzed and graphed so that important information could be seen and understood at a glance.

Methodology

There were two parts to the survey. The first part was a multiple choice section; the second was a written comments section. In the first part of the survey there were eight questions that had five possible responses ranging from strongly disagree to strongly agree. The first step in analyzing these questions was to create a favorability index. It was used to objectively determine the level of satisfaction or dissatisfaction with the state of the survey's main topics. The two steps used to calculate the favorability index were: 1.) Total the number of responses for each possible survey question response. 2.) Calculate the percentage of favorable responses for each survey question by dividing the total number of favorable responses by the total number of responses and multiplying the result by 100. The resulting favorability index is equal to the percentage of favorable responses. The second step in analyzing these questions was to normalize the results to 1. This helps to take out any bias and tells the extent of standard deviation. The formula for calculating the normalization is: $x1=\Sigma(.25(n-1))/R$ where R is equal to the number of responses and n equals 1-5 since there are five possible responses for each question. I did the normalization calculations and graphed the results along with the favorability index results for comparison (see fig. 1-1).

When the normalization curve is below the favorable response curve then the favorable responses are on the low end of the favorable response scale (i.e. most of the favorable responses are agree). When the normalization curve is above the favorable response curve then the favorable responses are on the high end of the scale (i.e. most of the favorable responses are strongly agree).

Fig. 1-1: Normalization Chart



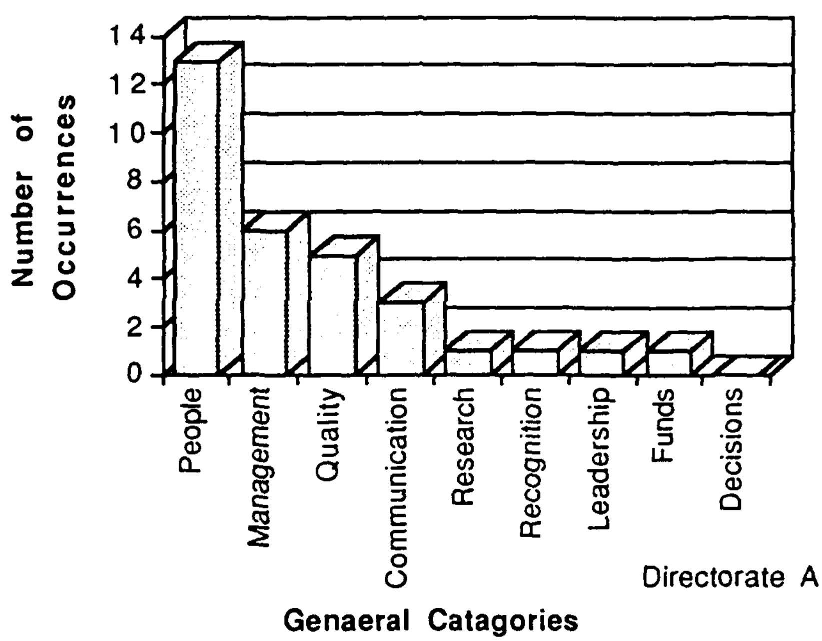
The written comments section consisted of four questions. I used two different methods to analyze the results. The first method I used was a key word search. In this method I counted (with the computer) the number of times a key word appeared in all the written responses to one question for one directorate and then totaled the key word counts to come up with a category count that I then graphed (ex. 1-1, fig. 1-2). This method is known as a thematic analysis. In example 1-1 "People" is the general category and the key words are counted under this category.

Ex. 1-1
People 6
- personnel 4
- customer 0
- team building 0
- teamwork 0
- training 3
- team 0

$\Sigma = 13$

Fig. 1-2: Written Comments-Themat Analysis

1. My Directorate is especially effective in...



After using this method to analyze the written comments' results for two directorates, I realized that it was inaccurate because I had assumed that the responses for certain questions would be positive and for others would be negative. However after reading over the responses to the questions I discovered that people had written negative responses to questions that I had assumed would have positive responses. One example that I came across was, "My directorate is especially effective in... 'wasting time.'" Because the results of this method were inaccurate I had to develop a new method for analyzing the written comments.

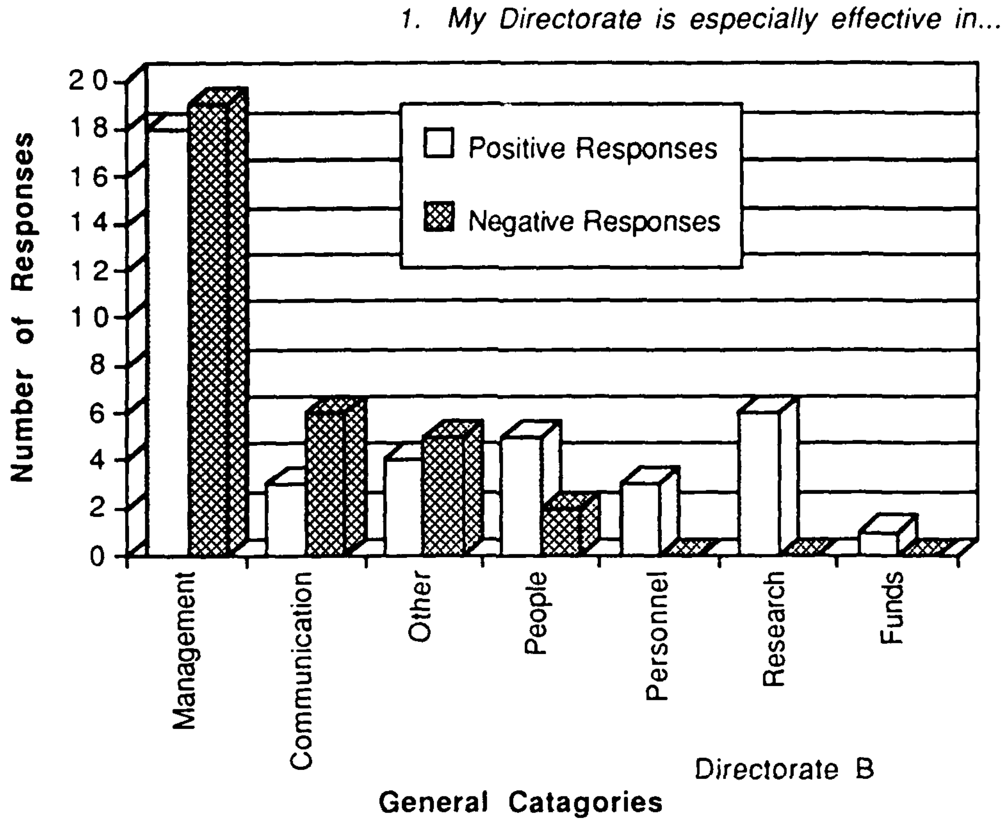
The new method of analysis I chose was to read all the responses to each question, decide if the response was positive or negative, and group them into seven main categories(management, people, personnel, communication, research, funds, other). Next I totaled the number of positive and negative responses for each category and graphed the results for each question(see fig. 1-3). This method was accurate, but it took up much time.

Results/Conclusions

While working in the office I acquired many new skills. I learned how to efficiently use Microsoft Excel and Word; in fact, I became somewhat of an expert with both. I also learned how to do a statistical analysis of survey results and how to interpret the data. I discovered the results of a survey are often unexpected and thus unpredictable.

I felt the work environment in the office was excellent. Every one treated me as a member of the team instead of looking down on me because I was younger or not as educated. Whenever I had a problem with a project someone was always willing to help me. I'm sure the office experience I gained this summer will prove useful in the future.

Fig. 1-3: Written Comments Analysis



Section 2: Laboratory Work

Introduction/Discussion of Problem

Survivability is defined as a systems ability to withstand an attack by an outside force. Hardness is the survivability of an electric system; that is, the system's ability to function properly while being acted on by an outside electromagnetic force. The hardness of military systems, such as the F-16, is an important concern of the WS directorate. Much time and effort is spent testing the hardness of different systems and developing better ways to shield the system against electromagnetic radiation. The current method for testing hardness is to place an antenna inside the system to measure the amount of electromagnetic radiation that is getting through to the electronics. This method works well if you are testing the hardness of the surface of a system against EMP's(ElectroMagnetic Pulses, 0--100MHz). However, this method doesn't work if you are testing HPM's(High Power Microwaves, 1--40GHz) on the surface or if you are testing EMP's or HPM's inside the system because the antenna distorts the electromagnetic field that is being measured. One possible solution to this problem is to replace the antenna system with an electro-optical system.

Methodology

The method for using an electro-optical system is simple from a theoretical physics point of view. A laser beam is shot into and reflected by a crystal as an electromagnetic pulse acts on the crystal and changes the polarization of the beam(see fig. 2-1). We used a 1320nm laser that we shot through a Wollaston Prism to correctly polarize the light. If the light were not circularly polarized, it would go through the crystal rather than being reflected, and the system would not work. Before entering the crystal the beam is focused by a lens and then hits the center of the crystal where the active medium is. An electromagnetic source is then applied to the crystal by a split ring accelerator connected to a network analyzer. This changes the polarization of the light from the laser. Upon leaving the crystal, the beam is again focused by the lens. Next the beam is reflected into a polarizer where the light is changed from circular polarization to linear polarization so that the beam can be seen by the photo detector. From there the signal enters the network analyzer where we can measure the change in amplitude of the original electromagnetic wave we sent out compared to the one we received. From this change in amplitude we can calculate the strength of the original electromagnetic pulse.

However, theoretical physics and engineering are two entirely different matters. I was involved with the engineering aspect of this experiment. After four weeks of work, we have still not gotten it to work correctly. The first and most complicated of our numerous problems was setting up the beam path. Since we were working with an infrared(1320 nm) laser we had to use infrared(1300 nm) viewing cards and an infrared scope to see the beam. In the original setup (fig. 2-1) we tried to hit a 1 micron fiber optic patch cord after the beam had hit the crystal. This proved to be impossible with the tools we were using, and after much frustration we decided to give up hitting the fiber optic cord and to hit the photo detector directly with the beam. Also, we researched the use of the half wave plate and discovered that it was not needed. We still aren't sure whether we need the quarter wave plate or not. After many modifications to the experiment setup we found the most efficient one; in other words the setup that allowed us to get the strongest signal on the photo detector and allowed us to aim the laser with the least amount of effort (fig. 2-2).

Fig. 2-1: Original Elctro-Optical Transducer
Experiment Setup and Beam Path

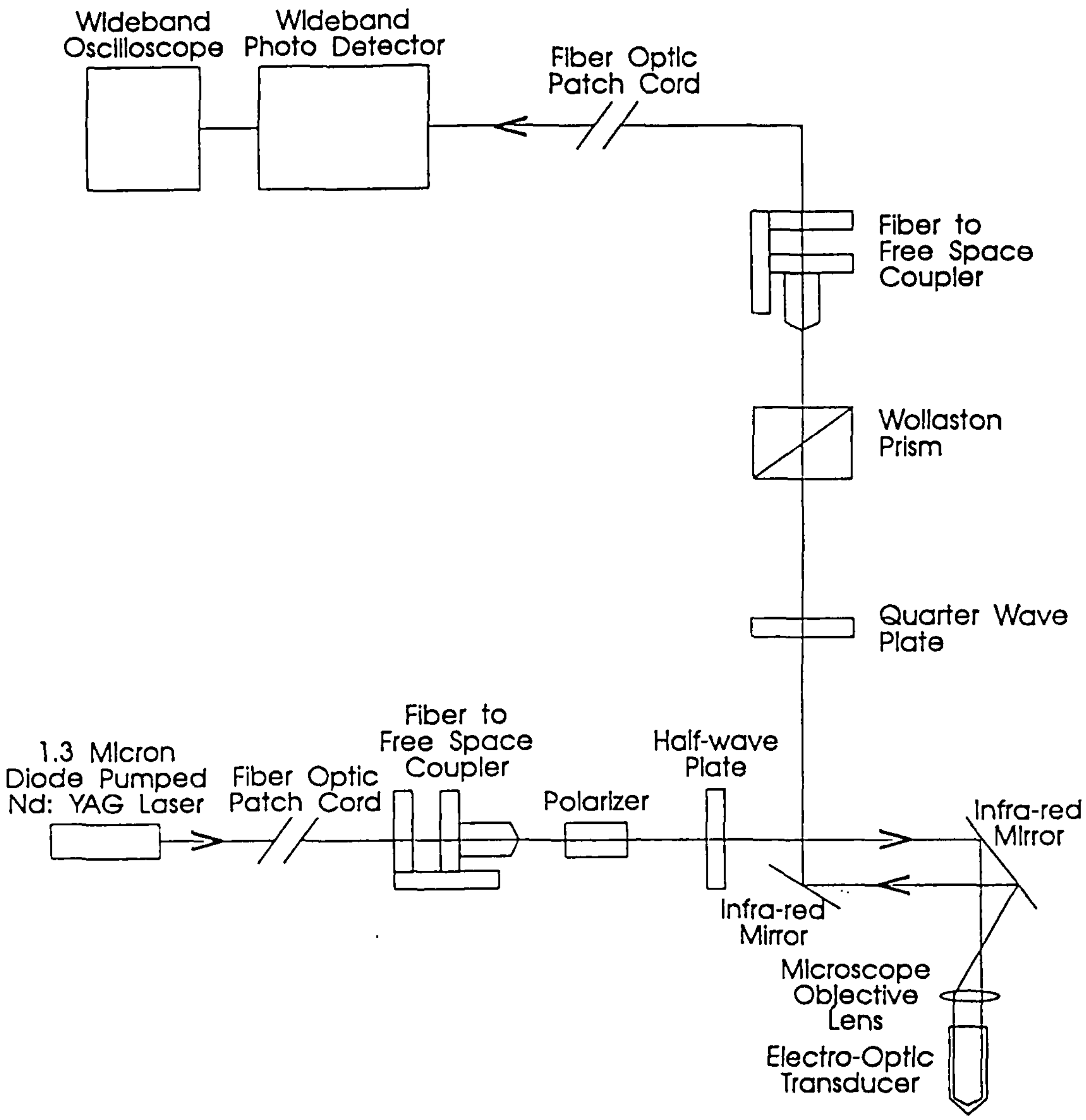
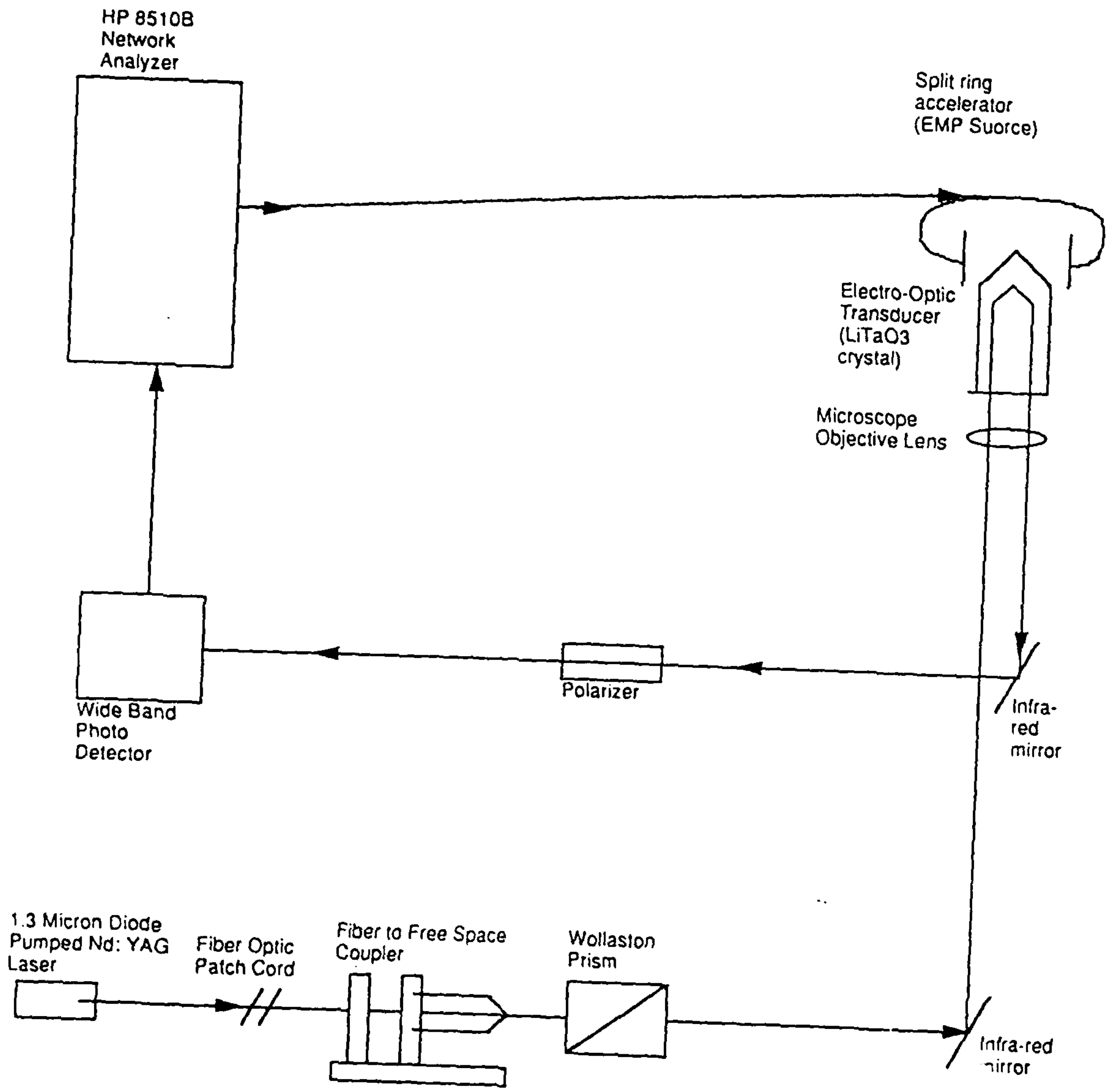


Fig. 2-2: Current Electro-Optical Transducer Experiment Setup and Beam Path



Drawing not to scale

Results/Conclusions

When it appeared we had finally solved all of our setup problems we applied the electromagnetic pulse to the crystal. Nothing happened. One of the engineers wrote a computer program that would tell us what was wrong. He plugged the physical constants of our crystal into an equation and found that the active zone on our crystal, 200 μm, was too small. The experiment, however, still appears promising. We will just have to special order a crystal built to our specifications and it should work fine.

SPREADSHEETS, CADS AND C

Thomas Rader

Final Report For:
AFOSR Summer Research Program, Phillips Laboratory

AOFSR Sponsorship

August 1993

SPREADSHEETS, CADS AND C

Thomas Rader

Abstract

Phillips Laboratories had many tasks to accomplish this summer and the jobs were divided between the various divisions. The divisions that I was a part of was concerned with with gathering and displaying many types of data. I was mainly involved with the display of data.

SPREADSHEETS, CADS, AND C

Thomas Rader

Introduction

Over the course of the summer, I was involved in several different projects. I learned to use many different programs on the computer to do these tasks. The programs included Microsoft Excel, Auto Cad, and Turbo C ++. This software greatly helped me do these projects.

Methodology

The first project that I was involved in was a spread sheet problem. A program was needed in which data could be inputted, tracked over time, graphed, then finally updated. Microsoft Excel seemed to be able to do this best. A set of 40 anonymous commissioned officers along with the points they had accumulated toward rank advancement was used. The total points were broken down into several categories and the points for each were listed. After the data was inputted, the next decision was which graph to use to best show the information. Several different styles of graphs were used. The examples that were clearest were the bar graph and the 3-D bar graph. After this project was completed, samples were sent out to various divisions for evaluation.

The second project that I was asked to do involved Auto Cad, a program used for computer aided drafting. Joe Sadler, an electrical engineer, asked me to take the rough sketches he provided and redraw them using a computer. I experimented with several different art programs before Auto Cad and found that none of them were powerful enough to get the job done. Auto Cad seemed to just have more options available than any other PC program available. The drawings were of an experiment that was taking place in Sadler's lab. The experiment dealt with electromagnetic pulses and what they would do to electronic hardware. Microwaves, used in the simulation, were projected toward scale models of devices. A thermal camera was used to measure where the "hot spots" on the model existed. The devices drawn on the Auto Cad program were of the hardware setup in the experiment. These drawings included placement of the microprocessor, the coaxial cable, and the table on which they were mounted.

The next job that I began involved trying to write a program that would randomly generate a series of numbers and assign each number to a specific sentence. After all the numbers were assigned, the program would then print the sentences to the screen and, if prompted, would then print on a printer. My previous knowledge of programming was strictly in basic. I began trying to write the program in basic. This turned out to be a bad idea. Basic was much too slow, the programs were harder to understand, and the programs could only be run from basic itself. A program was needed that could be run from DOS. After talking with various knowledgeable people on the subject and after reading many books, I decided to start over in the programming language of C. I acquired Turbo C++ for Windows and began. At first I thought that it wouldn't be possible to learn C in the time that I had left, but it slowly began to come along. As my example, I used Central Casting, a series of 77 tables of data that all needed randomly generated numbers. It took four of five tries to get the random number generator right, but it finally worked. Minor hang-ups in the logic of the program also set me back. Finally after much trial and error, the program began to run. From then on, it was all a matter of inputting the sentences to be outputted to the screen or printer.

Conclusion

This summer, I learned many very valuable programs. Programs such as Microsoft Excel, Auto Cad, and Turbo C++ will be useful in many circumstances. These programs helped me to do a better and more efficient job a Phillips Laboratories.

2 Atch.

Excel

Auto Cad Drawings

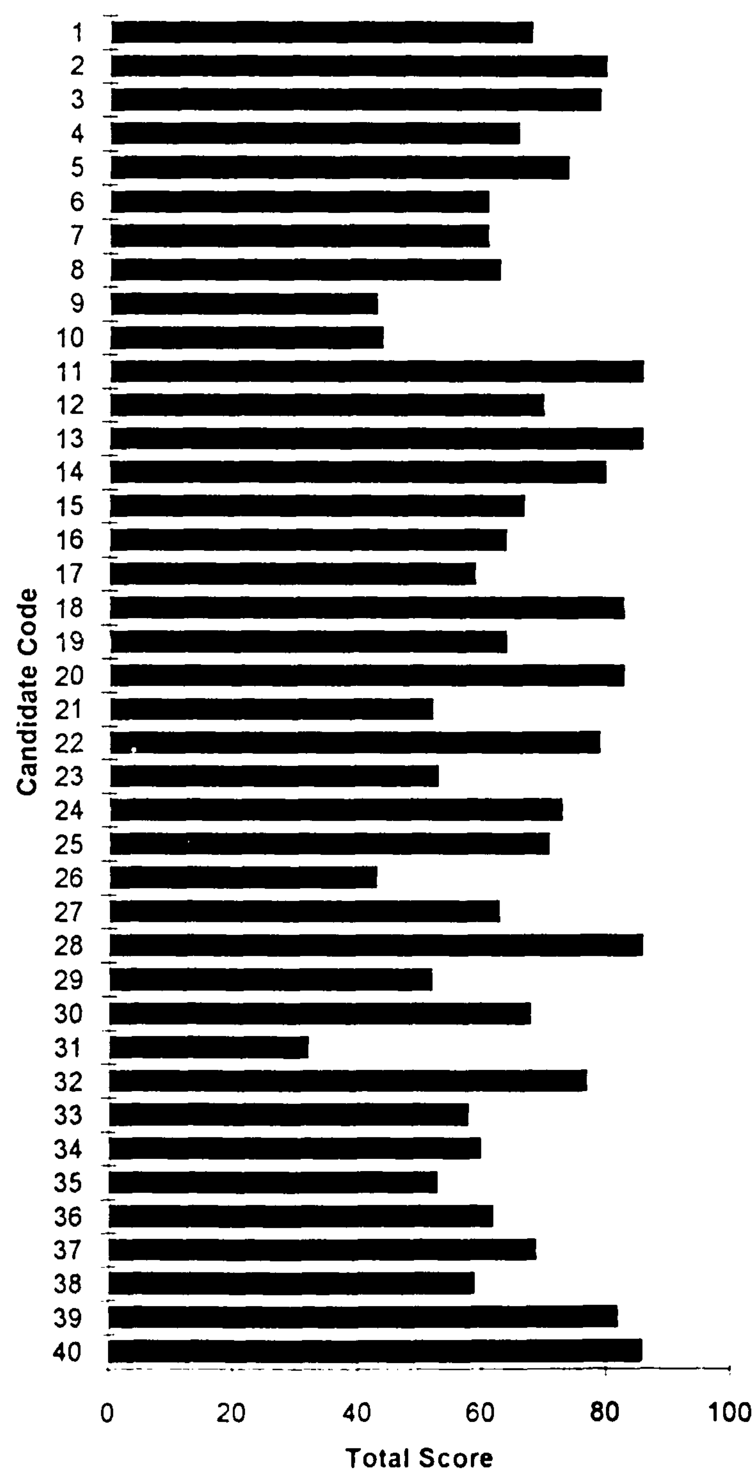
The first page includes the information database which contains the complete set of scores for all candidates along with an adjacent graph of each candidates total score. The graph is in a bar format which allows each candidate to read both his scores and his bar from left to right along a row. When information is changed in the database the bar graph will be updated automatically

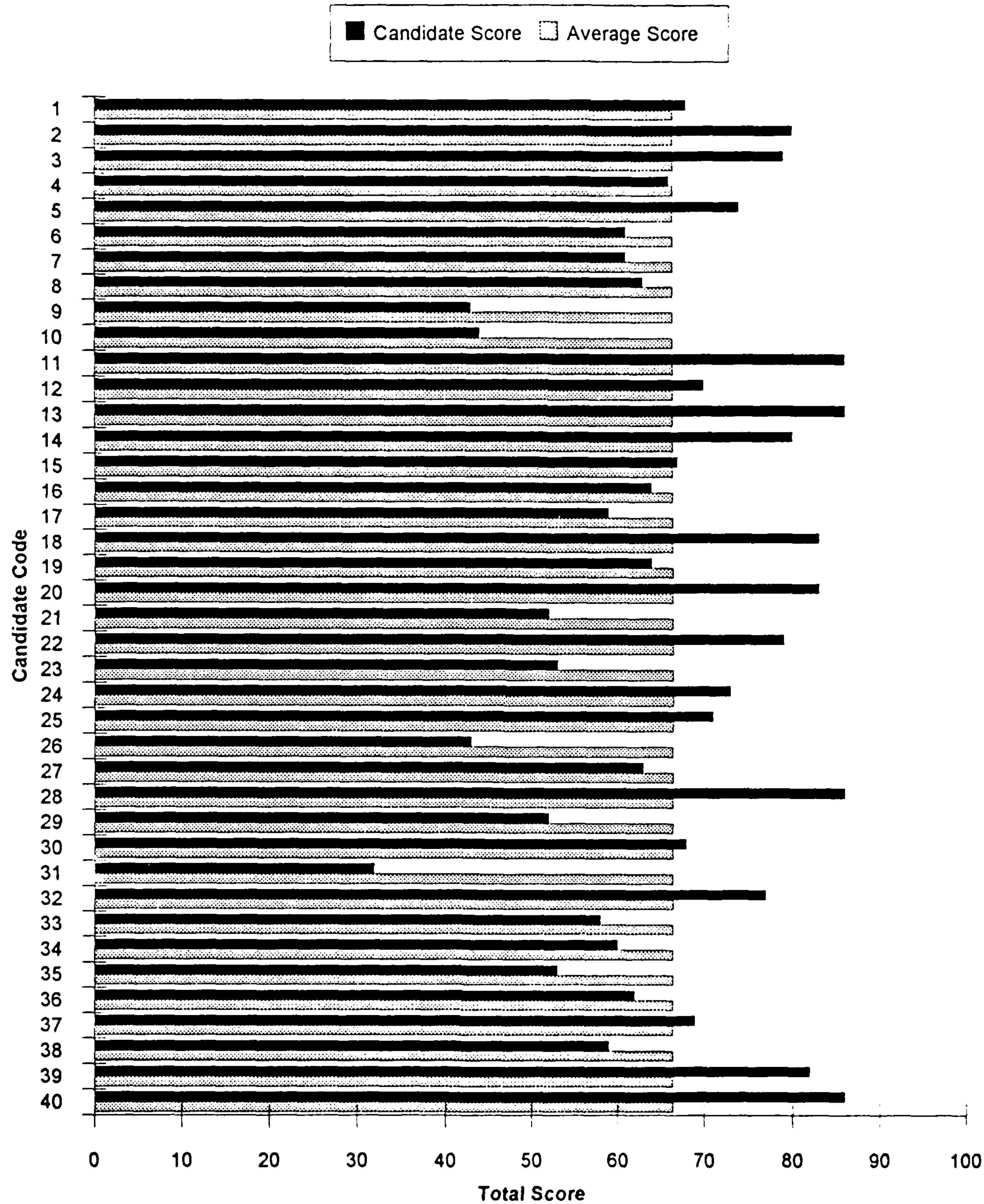
The second and third pages contain two separate graphs which display identical information. These graphs are extensions of the first page graph. Like the first graph they use bars to display the candidate scores and are linked to the database, but they also show the average score. The page two graph uses bars placed next to each candidate bar for the average, while the page three graph uses a line to depict the average. Please advise me as to which you prefer.

Page four contains the same information and graph as page one, except it is arranged in descending order according to the candidate total scores. The vertical axis of the graph also differs in that the numbers represent a candidate's rank rather than being an identifier of the candidate. It is still read as a row however. For example, if candidate 6 wishes to know his rank he finds the bar which aligns horizontally to his row of scores. He would find that he is ranked 27th. Likewise, candidate 20 is ranked 5th.

On the fifth page one can find a new database which charts each candidates scores over several time periods. The two accompanying graphs, both the one on the same page and the one on the following page, depict the information in this database. When changes are made in the database, the graphs automatically adjust.

Candidate	Total Score	Completed ACSC	Advanced Degrees	APDP Certification	Medals/Significant Awards	Current Official Photograph	Number of Bases Assigned to	Level of Responsibility	Face Time Last Six Months	Variety of Assignments	Other Significant Responsibilities
1	68	20	15	0	5	5	2	5	6	7	3
2	80	20	15	3	6	0	12	5	2	12	5
3	79	20	15	8	7	5	6	10	2	6	0
4	66	0	15	10	8	5	6	10	5	2	5
5	74	20	15	0	1	5	6	15	5	2	5
6	61	20	0	10	5	0	2	2	10	12	0
7	61	20	0	10	3	5	2	5	10	6	0
8	63	0	15	8	7	0	12	5	5	6	5
9	43	0	10	8	5	0	6	2	5	2	5
10	44	0	10	8	10	0	6	2	2	6	0
11	86	20	0	3	12	23	6	10	5	2	5
12	70	20	0	0	12	5	2	15	10	6	0
13	86	20	10	3	4	5	2	15	10	12	5
14	80	20	15	8	6	5	2	2	10	12	0
15	67	20	15	10	7	0	6	5	2	2	0
16	64	20	10	10	3	0	2	10	2	2	5
17	59	0	10	8	10	5	12	10	2	2	0
18	83	20	10	8	11	0	12	15	5	2	0
19	64	20	0	8	7	0	2	15	5	2	5
20	83	20	0	8	7	5	6	10	10	12	5
21	52	0	0	3	12	5	6	10	10	6	0
22	79	20	10	10	7	5	6	5	5	6	5
23	53	20	10	0	8	0	6	5	2	2	0
24	73	20	0	0	9	0	12	5	10	12	5
25	71	20	15	0	5	0	12	2	10	2	5
26	43	0	15	3	5	5	2	2	5	6	0
27	63	0	10	8	6	5	2	10	5	12	5
28	86	20	10	8	10	5	6	10	5	12	0
29	52	20	0	3	10	5	2	5	5	2	0
30	68	20	0	10	11	0	6	5	10	6	0
31	32	0	0	0	10	5	2	2	2	6	5
32	77	20	10	10	5	5	12	2	2	6	5
33	58	0	10	10	3	0	12	10	2	6	5
34	60	20	10	3	0	0	6	5	10	6	0
35	53	0	10	8	0	5	6	10	2	12	0
36	62	0	10	8	0	5	12	15	5	2	5
37	69	0	10	8	12	5	2	15	5	12	0
38	59	0	0	10	12	5	6	15	5	6	0
39	82	20	15	0	5	5	6	10	10	6	5
40	86	20	15	10	5	5	6	6	8	6	5




Candidate Score
Average Score
Candidate Code
1
2
3
4
5
6
7
8
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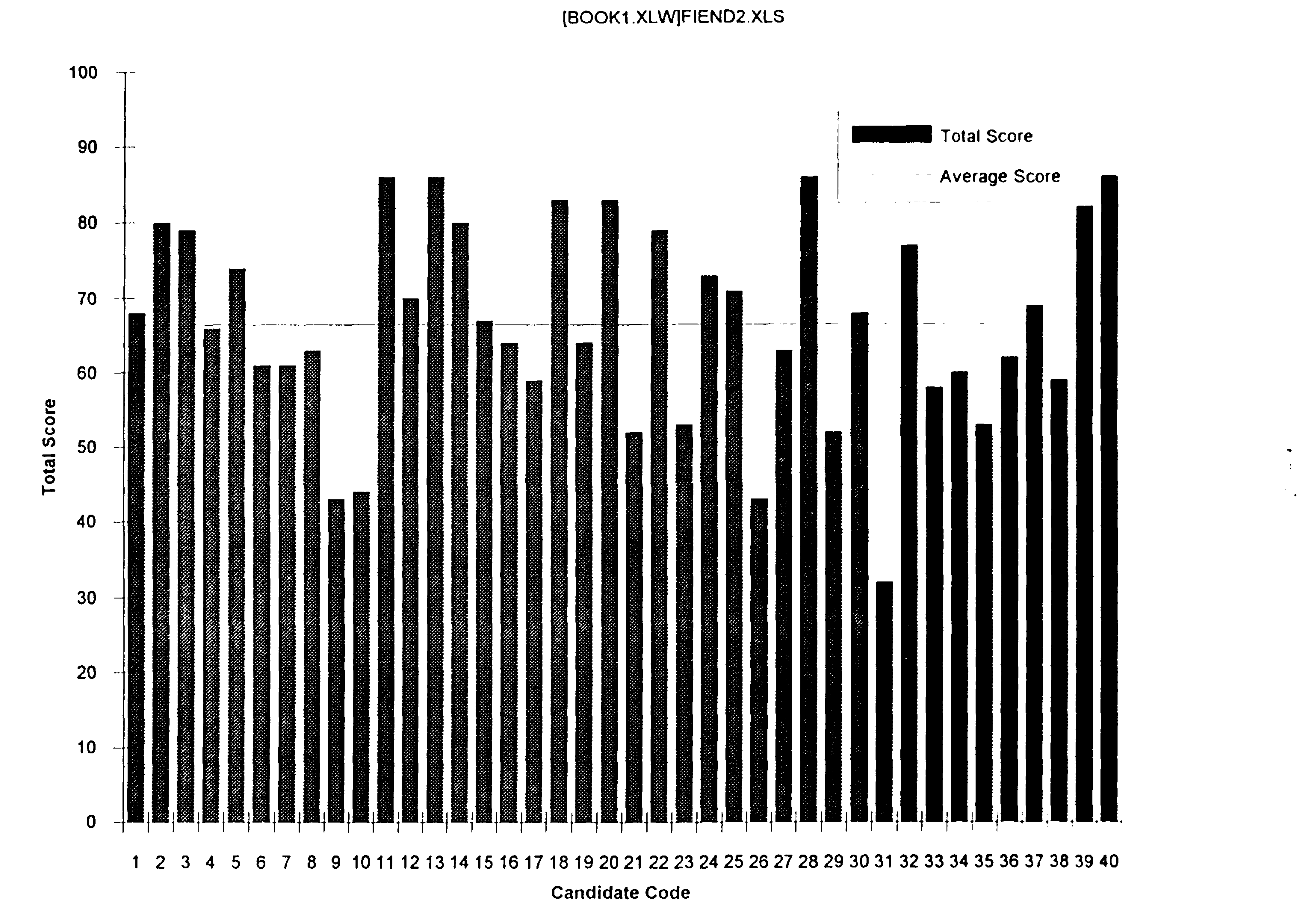
40
50
60
70
80
90
100
Total Score


[BOOK1.XLW]FIEND2.XLS
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Average Score
100
90
80
70
60
50
40
30
20
10
0
Total Score
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Candidate Code

Candidate	Total Score	Completed ACSC	Advanced Degrees	APDP Certification	Medals/Significant Awards	Current Official Photograph	Number of Bases Assigned to	Level of Responsibility	Face Time Last Six Months	Variety of Assignments	Other Significant Responsibilities
11	86	20	0	3	12	23	6	10	5	2	5
13	86	20	10	3	4	5	2	15	10	12	5
28	86	20	10	8	10	5	6	10	5	12	0
18	83	20	10	8	11	0	12	15	5	2	0
20	83	20	0	8	7	5	6	10	10	12	5
39	82	20	15	0	5	5	6	10	10	6	5
2	80	20	15	3	6	0	12	5	2	12	5
14	80	20	15	8	6	5	2	2	10	12	0
3	79	20	15	8	7	5	6	10	2	6	0
22	79	20	10	10	7	5	6	5	5	6	5
32	77	20	10	10	5	5	12	2	2	6	5
5	74	20	15	0	1	5	6	15	5	2	5
24	73	20	0	0	9	0	12	5	10	12	5
1	71	20	15	3	6	0	6	2	2	12	5
25	71	20	15	0	5	0	12	2	10	2	5
12	70	20	0	0	12	5	2	15	10	6	0
37	69	0	10	8	12	5	2	15	5	12	0
30	68	20	0	10	11	0	6	5	10	6	0
15	67	20	15	10	7	0	6	5	2	2	0
4	66	0	15	10	8	5	6	10	5	2	5
40	65	20	15	3	6	5	6	2	2	6	0
16	64	20	10	10	3	0	2	10	2	2	5
19	64	20	0	8	7	0	2	15	5	2	5
8	63	0	15	8	7	0	12	5	5	6	5
27	63	0	10	8	6	5	2	10	5	12	5
36	62	0	10	8	0	5	12	15	5	2	5
6	61	20	0	10	5	0	2	2	10	12	0
7	61	20	0	10	3	5	2	5	10	6	0
34	60	20	10	3	0	0	6	5	10	6	0
17	59	0	10	8	10	5	12	10	2	2	0
38	59	0	0	10	12	5	6	15	5	6	0
33	58	0	10	10	3	0	12	10	2	6	5
23	53	20	10	0	8	0	6	5	2	2	0
35	53	0	10	8	0	5	6	10	2	12	0
21	52	0	0	3	12	5	6	10	10	6	0
29	52	20	0	3	10	5	2	5	5	2	0
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9	43	0	10	8	5	0	6	2	5	2	5
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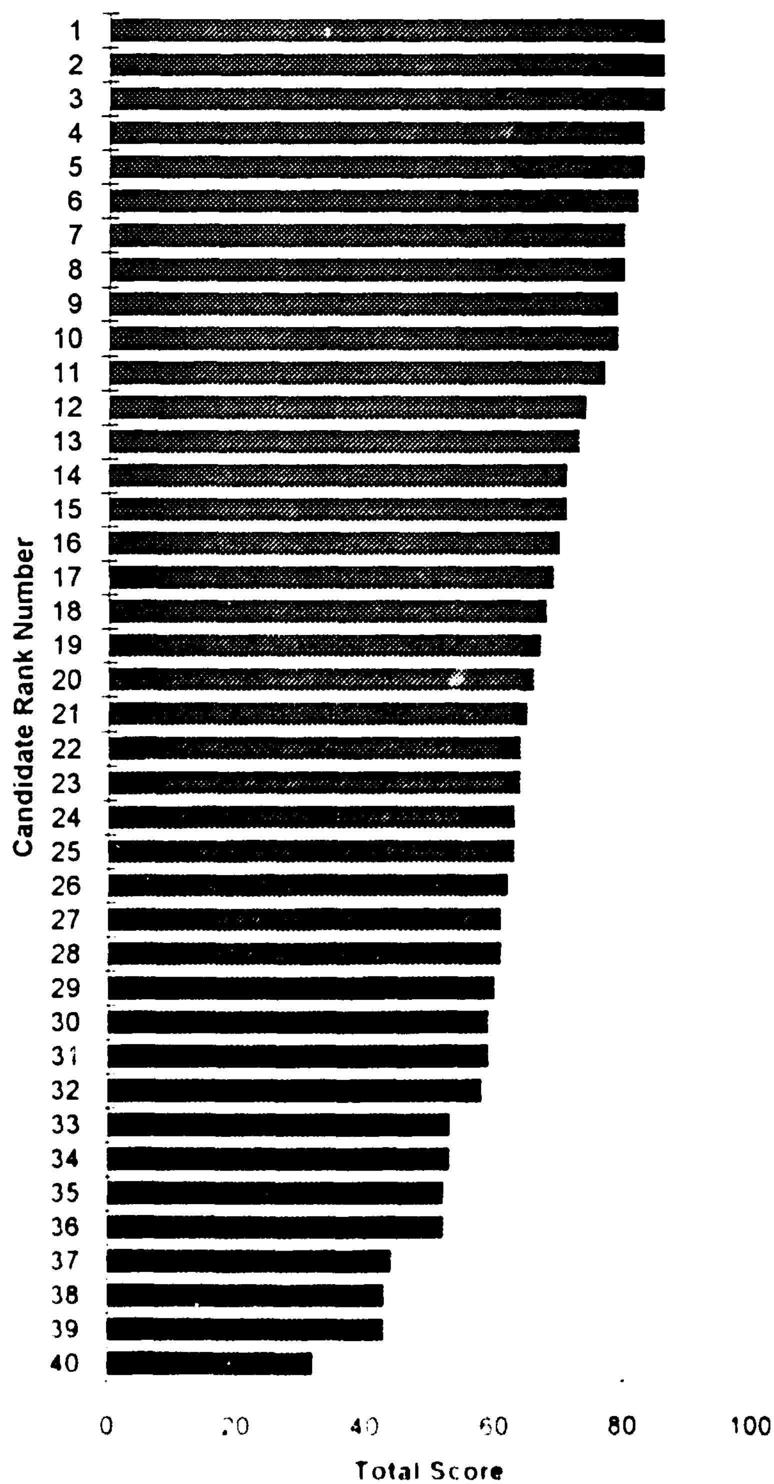
31	32	0	0	0	10	5	2	2	2	6	5



	FY93 Quarter			
	1	2	3	4
1	71	77	77	80
2	80	80	80	87
3	79	82	82	82
4	66	66	70	70
5	74	74	74	74
6	61	61	80	80
7	61	65	65	70
8	63	66	70	78
9	43	53	53	60
10	44	64	64	64
11	86	86	86	87
12	70	75	82	85
13	86	89	89	90
14	80	80	85	85
15	67	67	67	70
16	64	64	64	70
17	59	65	65	68
18	83	83	83	87
19	64	64	64	74
20	83	90	90	94
21	52	60	68	68
22	79	83	85	85
23	53	53	63	63
24	73	73	78	84
25	71	71	76	80
26	43	50	50	50
27	63	63	70	70
28	86	92	92	92
29	52	52	52	56
30	68	70	70	76
31	32	32	40	50
32	77	90	90	90
33	58	60	67	71
34	60	60	63	63
35	53	57	57	57
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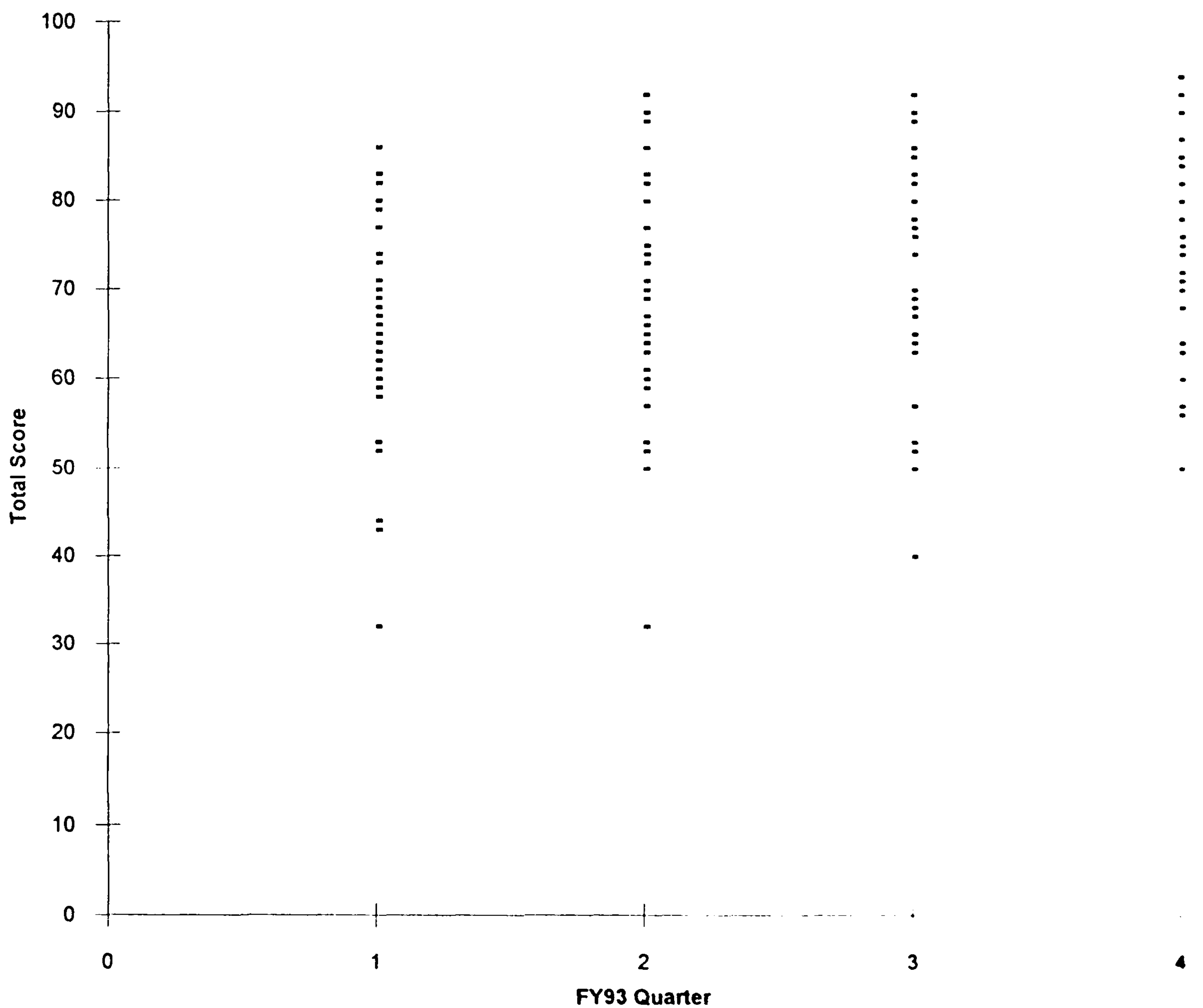
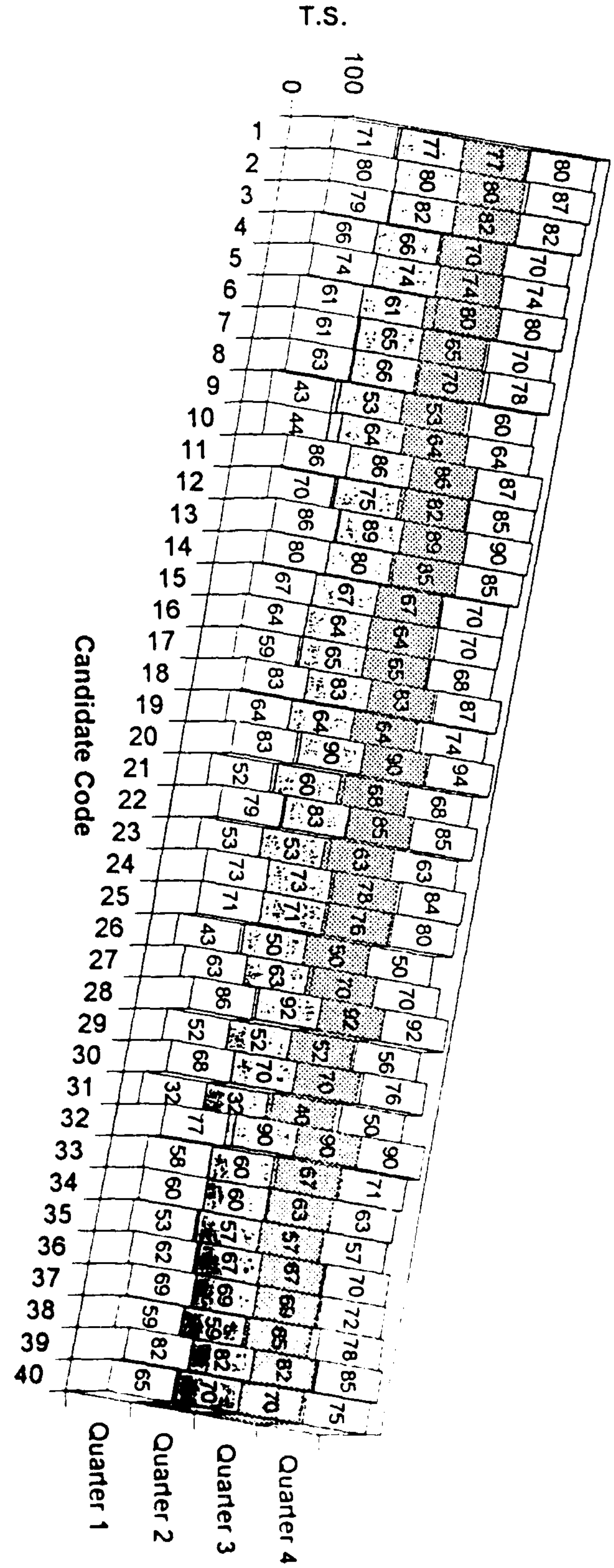
39	82	82	82	85
40	65	70	70	75




T.S.
0
100
Candidate Code
Quarter 1
Quarter 2
Quarter 3
Quarter 4

"Axial" Incidence

Vertical $\vec{E}$: $\vec{E}$ |
Horizontal $\vec{H}$: $\vec{H}$—
Propagation Vector $\vec{k}$: into plane of paper

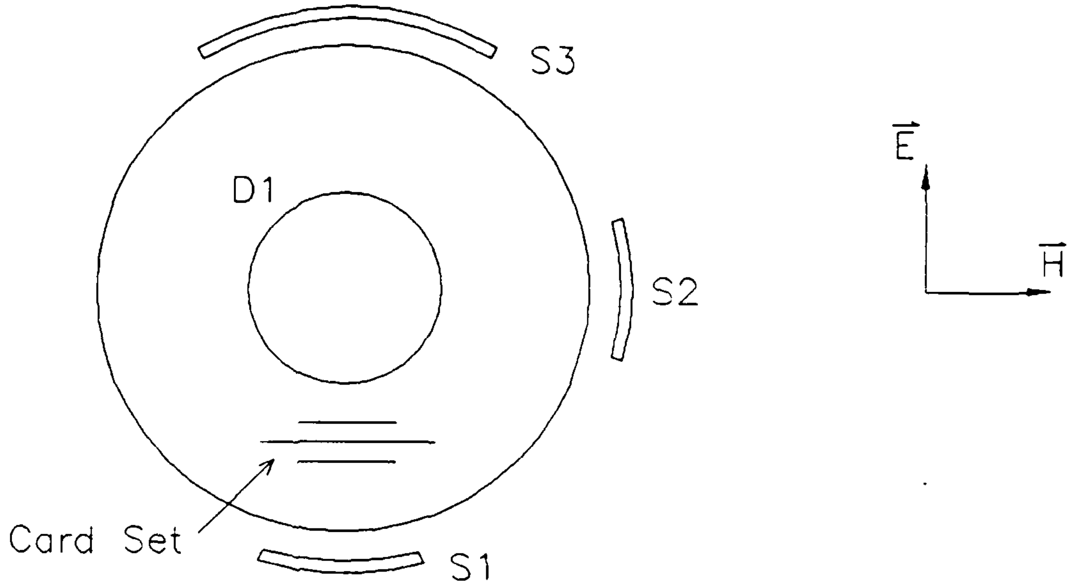
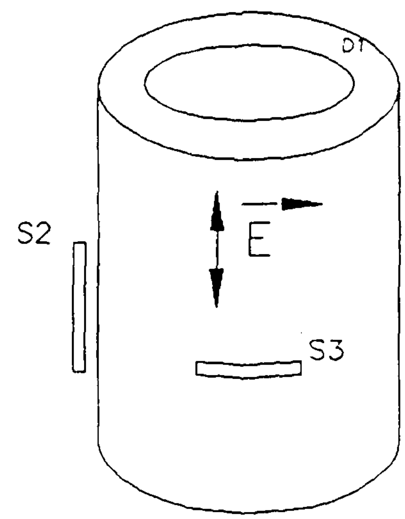


Figure 1

"Transverse" Incidence



Vertical $\vec{E}$ along cylinder axis

Horizontal $\vec{H}$

Propagation vector $\vec{K}$ into S3

Figure 2

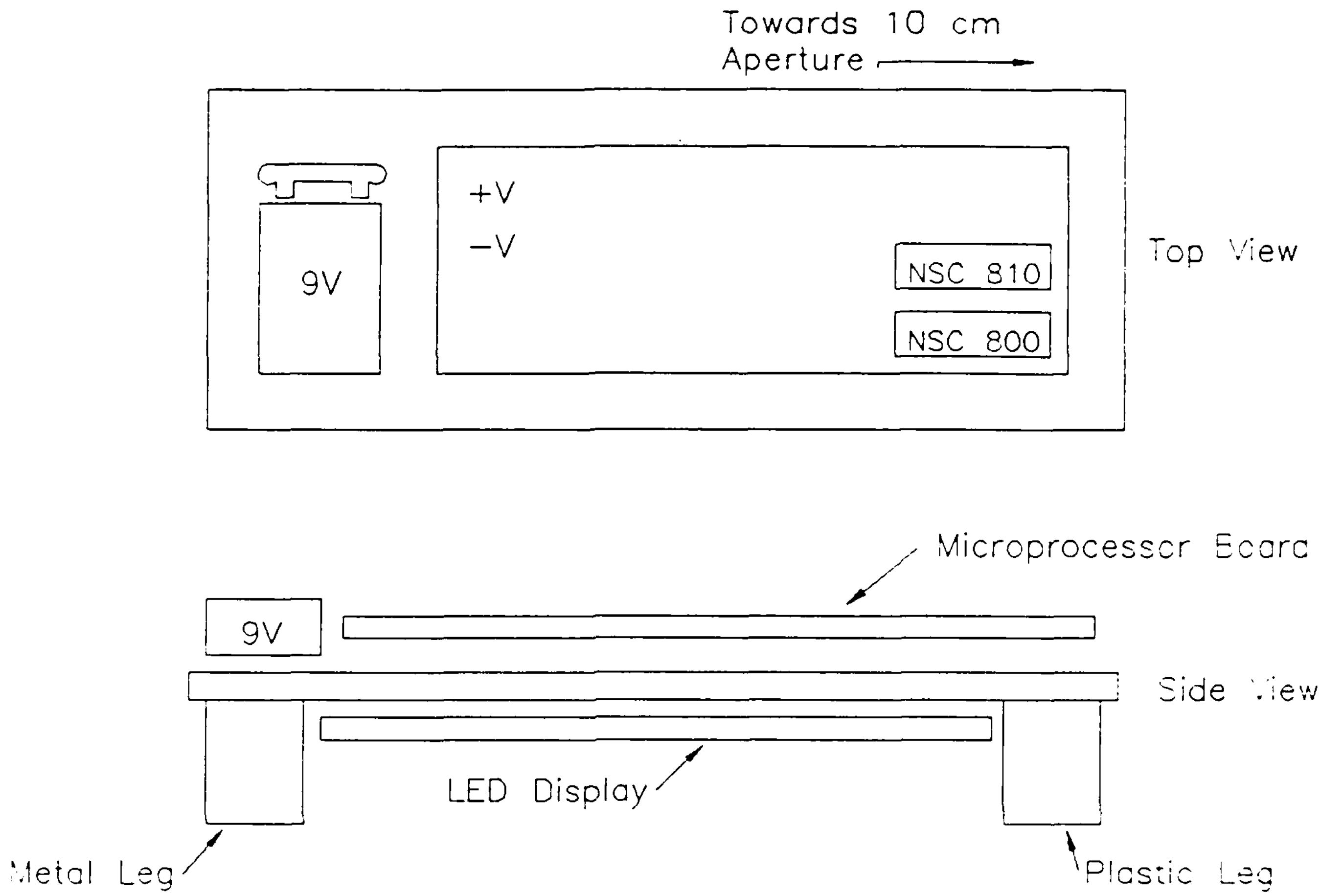
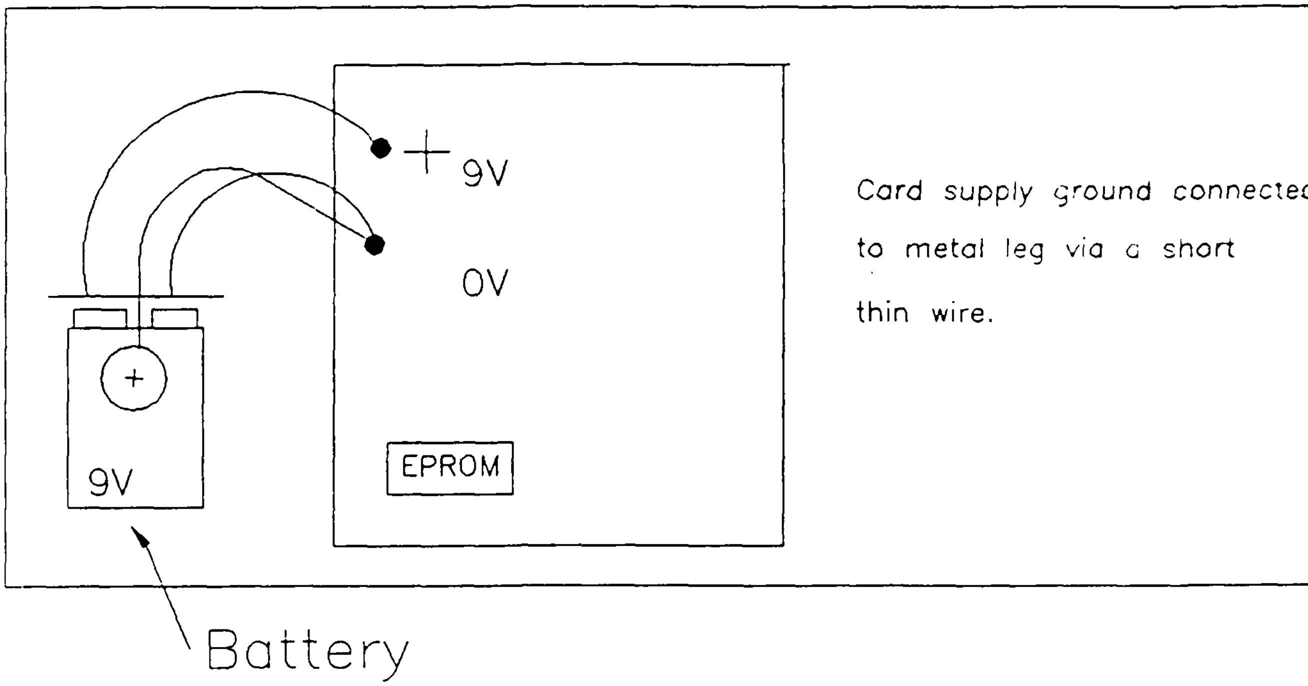

Towards 10 cm
Aperture
9V
+V
−V
NSC 810
NSC 800
Top View
Microprocessor Board
9V
Side View
LED Display
Metal Leg
Plastic Leg

Figure 3



Note: The location of the screw for the metal leg as depicted in this sketch, may not be accurate

Figure 4

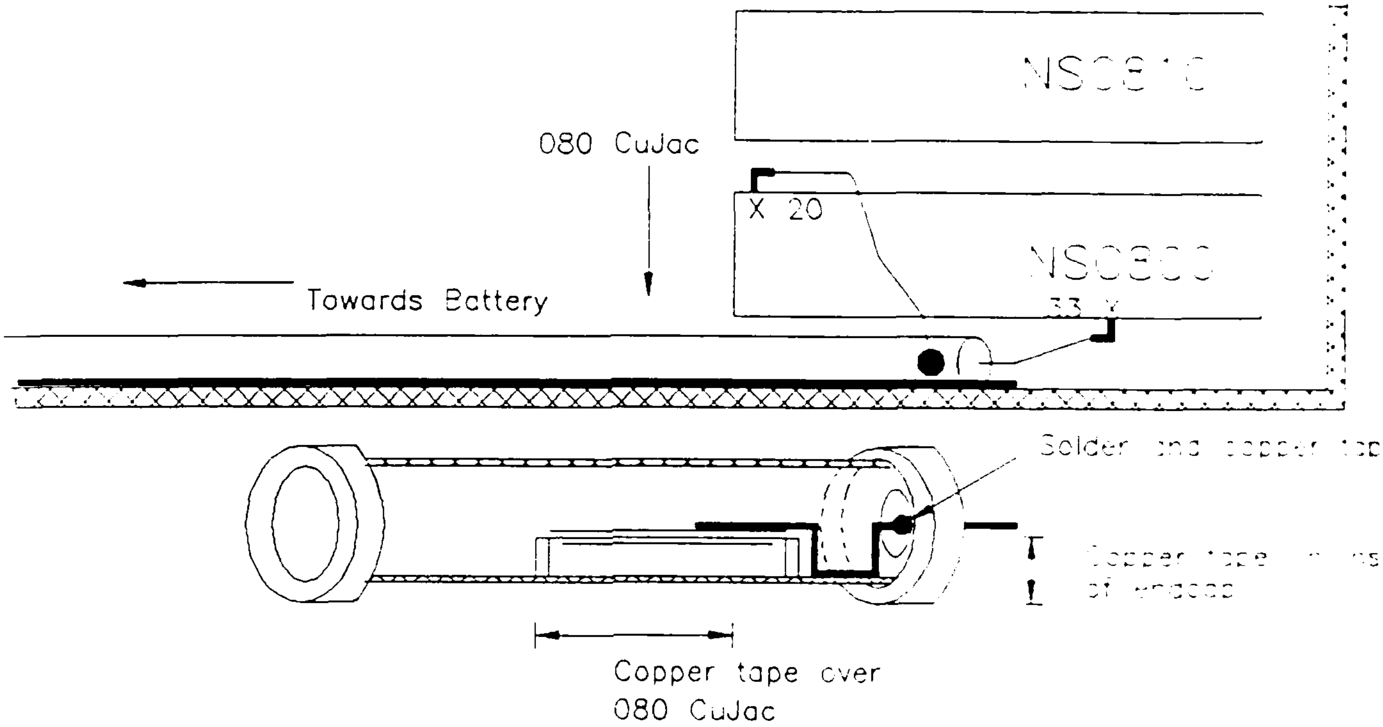
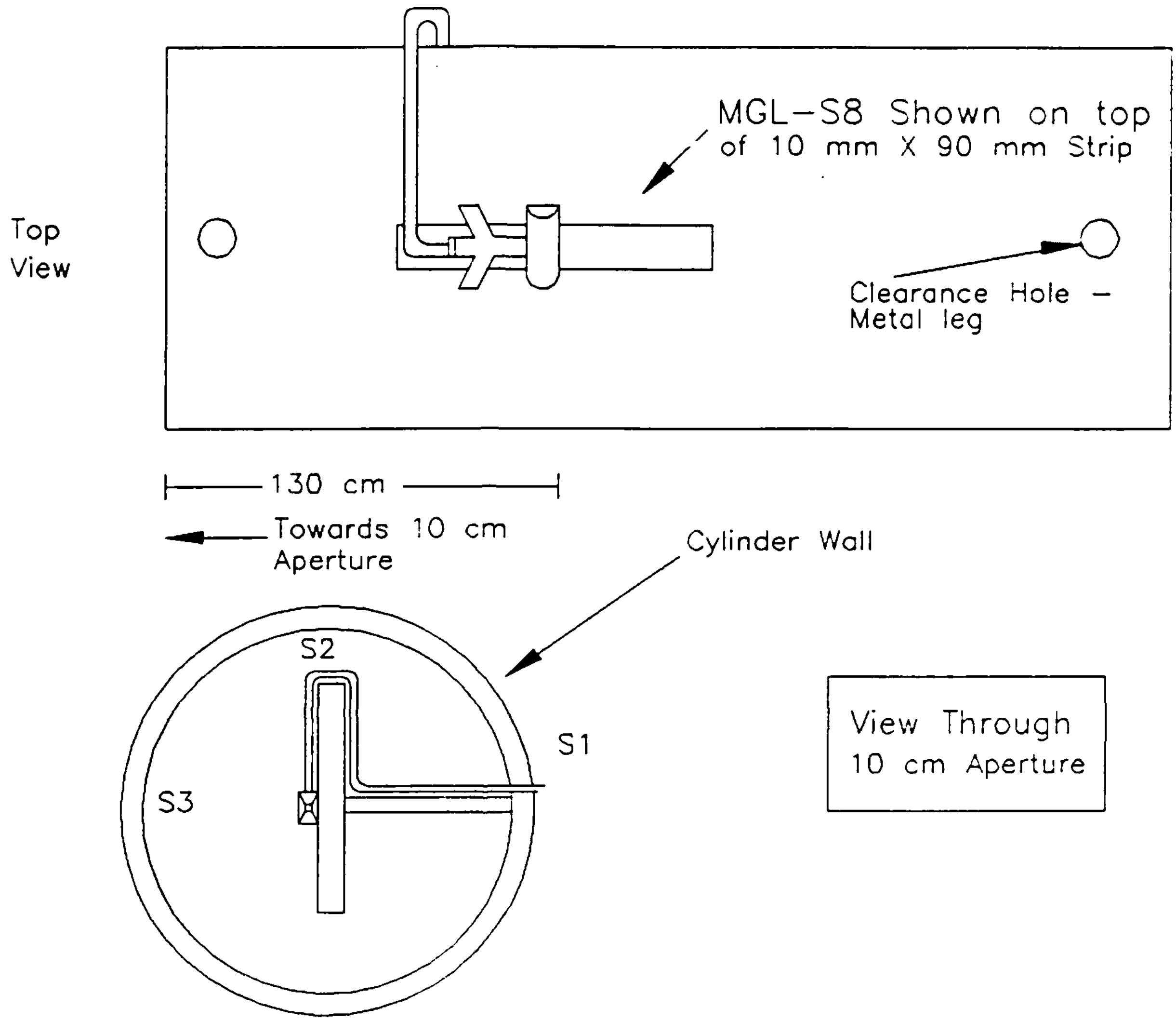
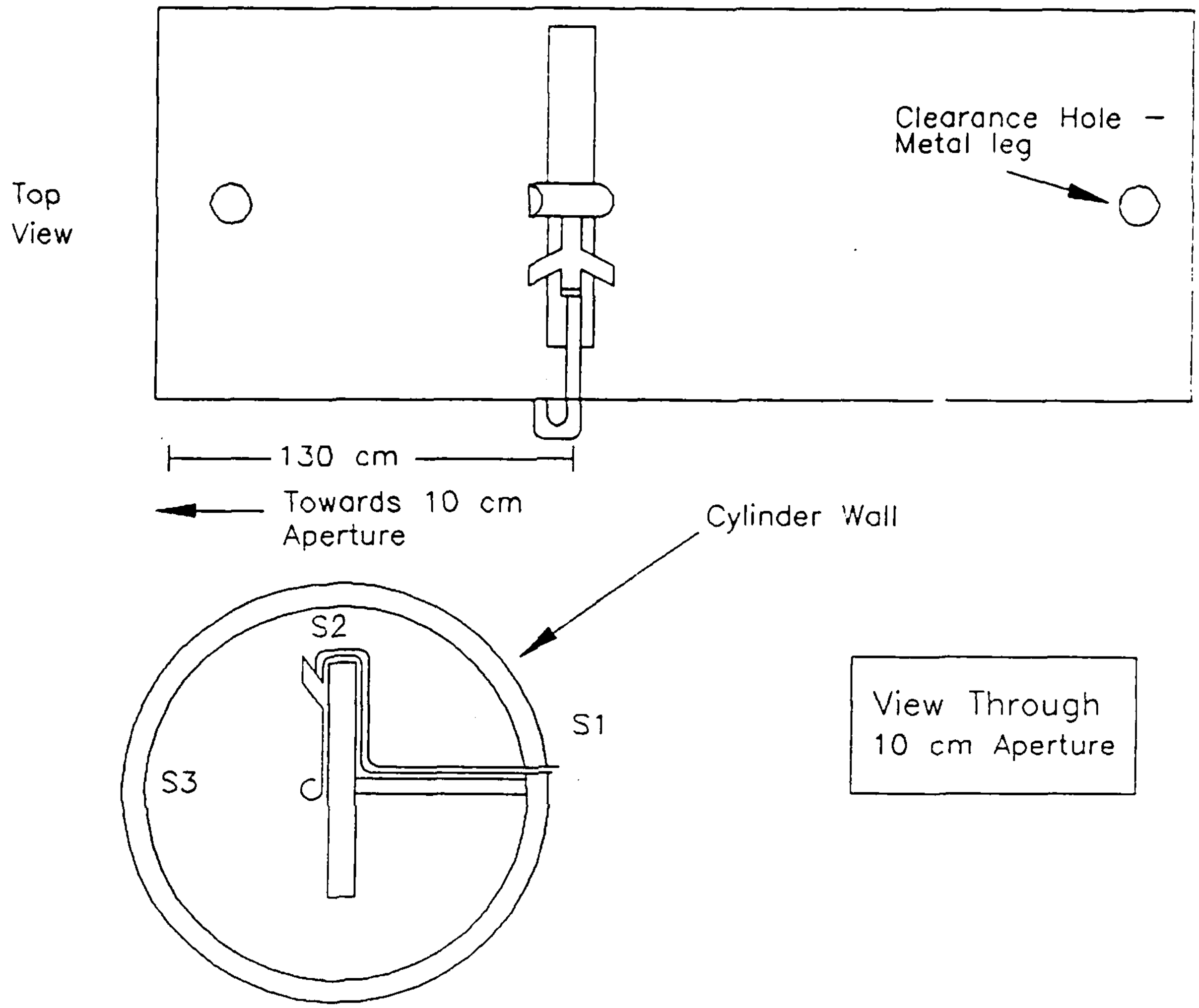

080 CuJac
X 20
Towards Battery
Solder
Copper tape over
080 CuJac

Figure 5



Example showing card A

Figure 6



Example showing card B

Figure 7

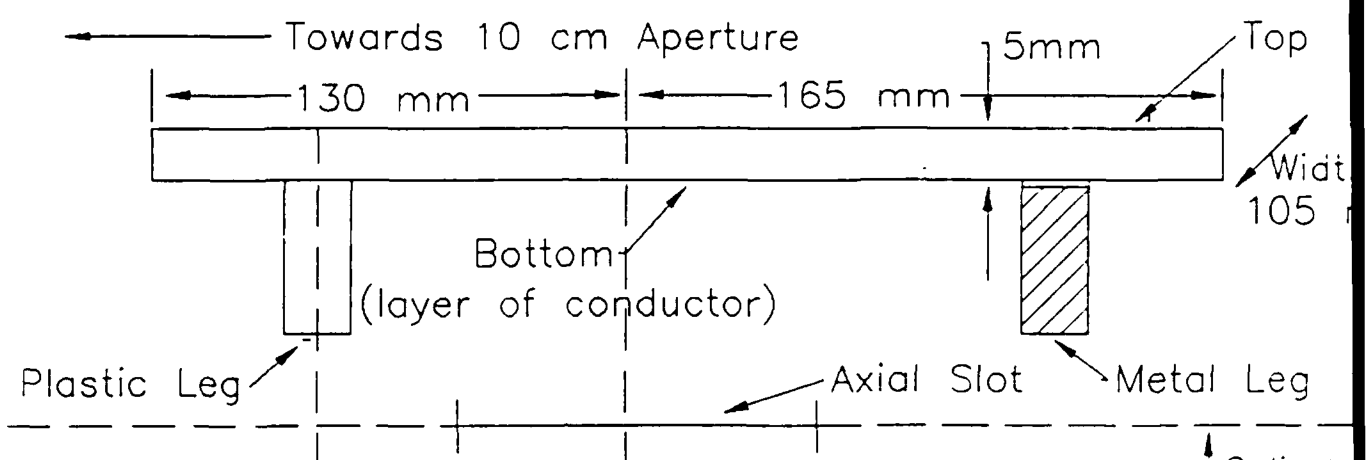


Figure EM-01
(not to scale)

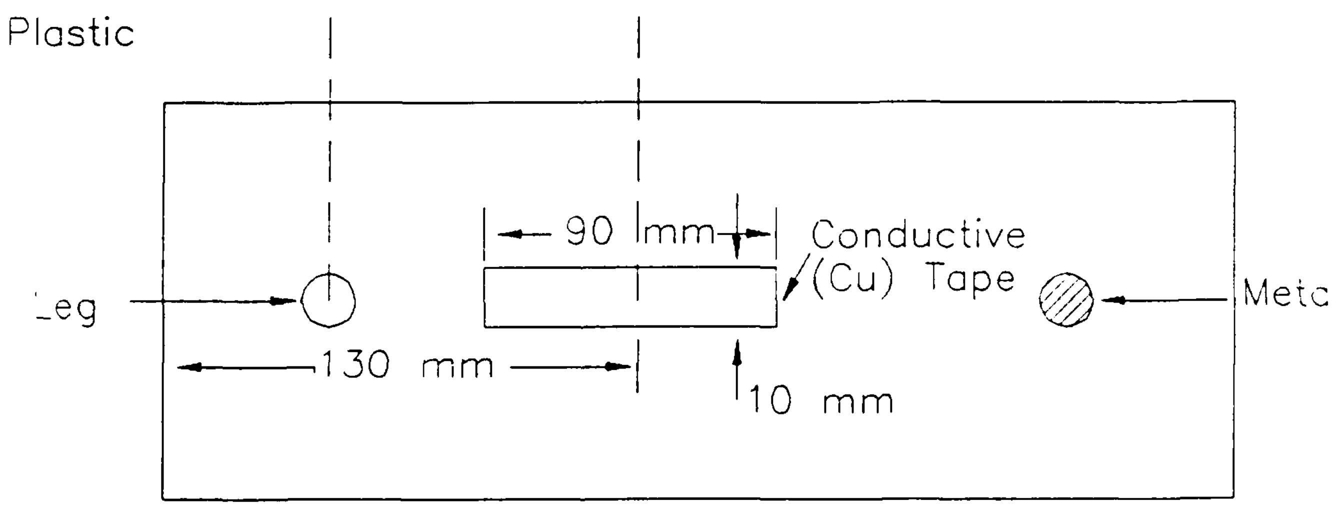


Figure EM-02 : Card A
(not to scale)

DATABASE PROCESSING AND SECONDARY ELECTRONS

Matthew J. Wick

Final Report For:
AFOSR Summer Research Program, Phillips Laboratory

AFOSR Sponsorship

August 1993

DATABASE PROCESSING AND
SECONDARY ELECTRONS

Matthew J. Wick

Abstract

This summer I worked in both an office and a laboratory at Phillips Laboratory. This division of time offered extensive variation in my daily activities. To enhance this variation, I was assigned several short tasks to complete rather than one or two lengthy ones. These tasks ranged from managing personnel data in a spreadsheet database to designing and building a dial counter to measure the degree rotation of an electron gun located inside a vacuum chamber.

DATABASE PROCESSING AND SECONDARY ELECTRONS

Matthew J. Wick

Introduction of problems and Methodology

My first assignment was to create a database which could be used to measure the promotional potential of captains and majors. Given only specified scoring categories and a rough estimate of the number of people to be entered into the database, I began designing a database spreadsheet which would automatically tally totals and update linked graphs. The process began with familiarizing myself with Microsoft Excel, a program which interfaces spreadsheets, databases, and graphs. Once I felt comfortable with Excel, I engaged in thorough experimentation, searching for a spreadsheet design which required the least amount of maintenance. I proceeded by linking the data in the spreadsheet to graphs so that any changes in the data would automatically be reflected in the graphs. Finally, I designed two time-tracking graphs which would display each candidate's current quarter score and his previous scores for the last few quarters. These graphs allowed candidates to compare their scores and progress with that of other candidates.

After the spreadsheet program was adjusted to my satisfaction, I made printouts of each spreadsheet page, including all graphs and distributed them to the appropriate individuals. I also included instructions on both the database in general and more specific instructions concerning how to accurately update the information without damaging the spreadsheet in this packet. After the distribution, we awaited feedback and suggestions from those individuals who we distributed packets to initially. We finished by incorporating these suggestions into the database and making a few minor improvements. For further understanding of the database itself please refer to the attached packet.

My next project was far simpler than my previous one due to my newfound understanding of Microsoft Excel. I was instructed to set up an organizational database to track publications and awards within the WS Directorate at Phillips Laboratory. The information already existed within an excel spreadsheet, but was disjointed and did not function as a database, therefore it lacked the ability to extract specific information and to easily add additional information. I completed the bulk of this project within two days and made minor modifications to accommodate requests from users of the database. With the completion of this project, my use of Excel and office work also terminated.

Upon the completion of the Excel databases, I began assisting in a laboratory experiment by producing technical drawings with AutoCad, an automated computer aided drafting program. The purpose of the experiment was to test the ceptibility of various aerospace crafts to high power microwave radiation using an infrared thermal camera. I have included some select drawings that I, along with a coworker, produced during these experiments.

Following this project I worked as an assistant in a laboratory in the Spacecraft Environment Branch of the WS Directorate. The laboratory was conducting an experiment to measure secondary electron release from several materials within a vacuum. An electron gun fired electrons towards materials inside the vacuum chamber, and a detector set at variant locations measured the total electron release. This information was then processed through a series of steps using a current to voltage converter, an amplifier, a battery, an analog to digital converter, and a multi-channel analyzer.

Before the actual experiment could begin, a calibration of the entire data processing system being utilized in the experiment was necessary. Once this calibration data was collected, I was asked to make plots using GNUPLOT which could measure the accuracy of our data processing system. I began by familiarizing myself with the UNIX System and a plotting program called GNUPLOT. This took a few days as I had never used a UNIX before and it differed from MS-DOS. After I was comfortable maneuvering within the UNIX System and GNUPLOT I began plotting data. I produced numerous graphs for each set of data by altering the axis ranges. From these graphs I measured the full-width half maximums of the several apparent peaks which occurred on the graph to estimate error. After analyzing the data we concluded that the calibration had been successful.

My next task in the labora was to build a connector cable using two coaxial cables and seven high voltage cables. I initially soldered male connectors to the ends of each cable. I stripped the rubber coating off of the two coaxial cables, peeled their shield back about a half inch, and soldered them to adjoining high voltage cables. When this was complete, I placed all the male connectors into their appropriate locations in a nine prong connection. I then bound the cables together with nylon binding assuring that the coax cables were covered to avoid sparks from the high voltage. When I reached the other end I proceed in the same manner as with the first end, using female connectors instead. The cable was complete and was ready to be placed in the vacuum chamber.

My final project required designing and building a dial counter to measure degree rotation of the electron gun located within the vacuum chamber. Apparently, during a trial run, the electron gun had rotated a few degrees due to the pressure applied to the gun from connected cables. At that time there was no way of measuring rotation so the alteration went undetected. To correct this problem, I worked with AutoCad and drafted a polar graph which had degree labels which were adjusted to comply with the three to one rotation ratio between the electron gun and the dial (i.e. to rotate the electron gun once it was necessary to turn the knob three times so a three degree rotation only rotated the electron gun one degree). After printing out the AutoCad drawing, I built a mount which enabled me to place the drawing over the knob on a flat surface. I then attached a gear with a pointer onto the shaft which the knob was atop so that the pointer hovered above the polar graph about one eighth of an inch. This concluded the project and my work in the lab.

Conclusion

Through my work at Phillips Laboratory I have gained practical computer experience and laboratory exposure. I have also enjoyed a mutually beneficial relationship with my mentor and associates. I have simultaneously assisted others and furthered my own knowledge and experience.

2 Atch.
Excel
AutoCad Drawings

DEPARTMENT OF THE AIR FORCE
PHILLIPS LABORATORY (AFMC)
3550 ABERDEEN AVE SE
KIRTLAND AFB, NM 87117-5776

From the Desk of: *Directorate Chief Scientist*
Advanced Weapons & Survivability Directorate

06/28/93

Memorandum for: Dr. Godfrey
Mr. Contreras
Dr. Baker
Mr. Serna
Capt Amon
All WS Division Chiefs

1. You may recall that we have implemented a metric to track officer promotion potential for Captains and Majors as a TQL initiative. The initial data is due into the Directorate in mid-July.

2. I have asked Matt Wick, an AFOSR high school apprentice, to create a database and associated graphs which can be easily used and updated. We have chosen Microsoft Excel to implement this task.

3. Attached you will find a brief description and sample graphs of what has been created thus far. The data is, of course, purely fictional. Please review this package and offer whatever suggestions seem appropriate to you.

4. You can reach Matt through my office. If you let us know your ideas by 9 July, Matt can make the required adjustments before the actual data starts arriving in the WS front office. Thanks for your help.

John G.

JOHN A. GAUDET, Lt Col, USAF

Description of General Database and Attached Printouts

Page one of the attached printouts includes the information database which contains the complete set of scores for all candidates along with an adjacent graph of each candidates total score. The graph is in a bar format which allows each candidate to read both his scores and his bar from left to right along a row. When information is changed in the database the bar graph will be updated automatically

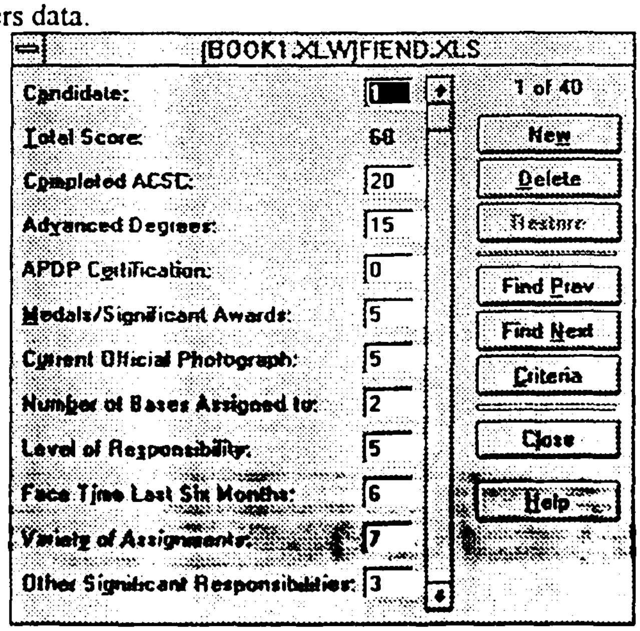
The second and third pages contain two separate graphs which display identical information. These graphs are extensions of the first page graph. Like the first graph they use bars to display the candidate scores and are linked to the database, but they also show the average score. The page two graph uses bars placed next to each candidate bar for the average, while the page three graph uses a line to depict the average.

Page four contains the same information as page one, but the information is arranged in descending order according to the candidate total scores. The vertical axis of the graph also differs in that the numbers represent a candidate's rank rather than being an identifier of the candidate. However, the information and graph are still read as a row. For example, if candidate 6 wishes to know his rank he finds the bar which aligns horizontally to his row of scores. He would find that he is ranked 27th. Likewise, candidate 20 is ranked 5th. Both the data and graph on page four are linked to the data from page one, so that any changes in the page one data will be automatically incorporated in page four.

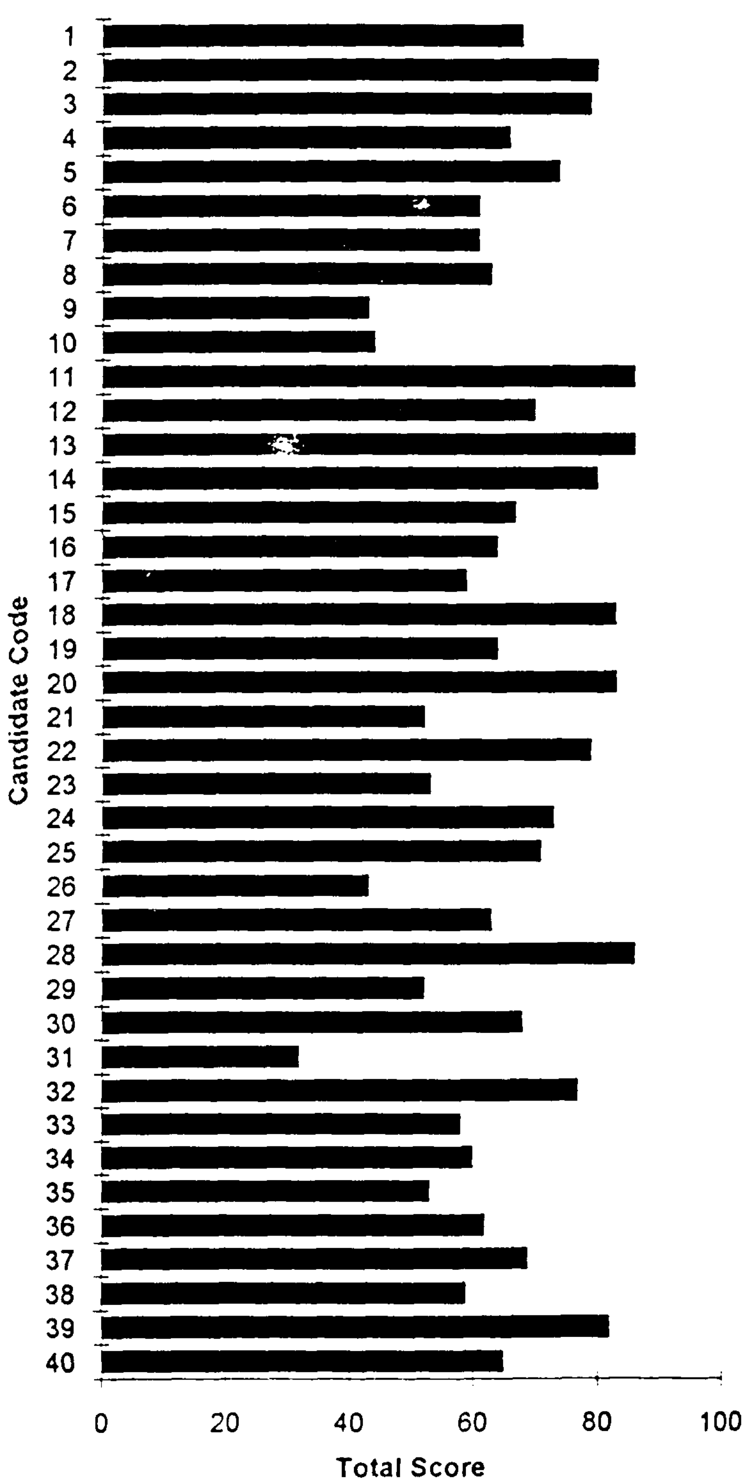
On the fifth page one can find a new database which charts each candidates scores over time. The two accompanying linked graphs, on pages five and six, display the information in this database. When changes are made in the database, the graphs automatically adjust.

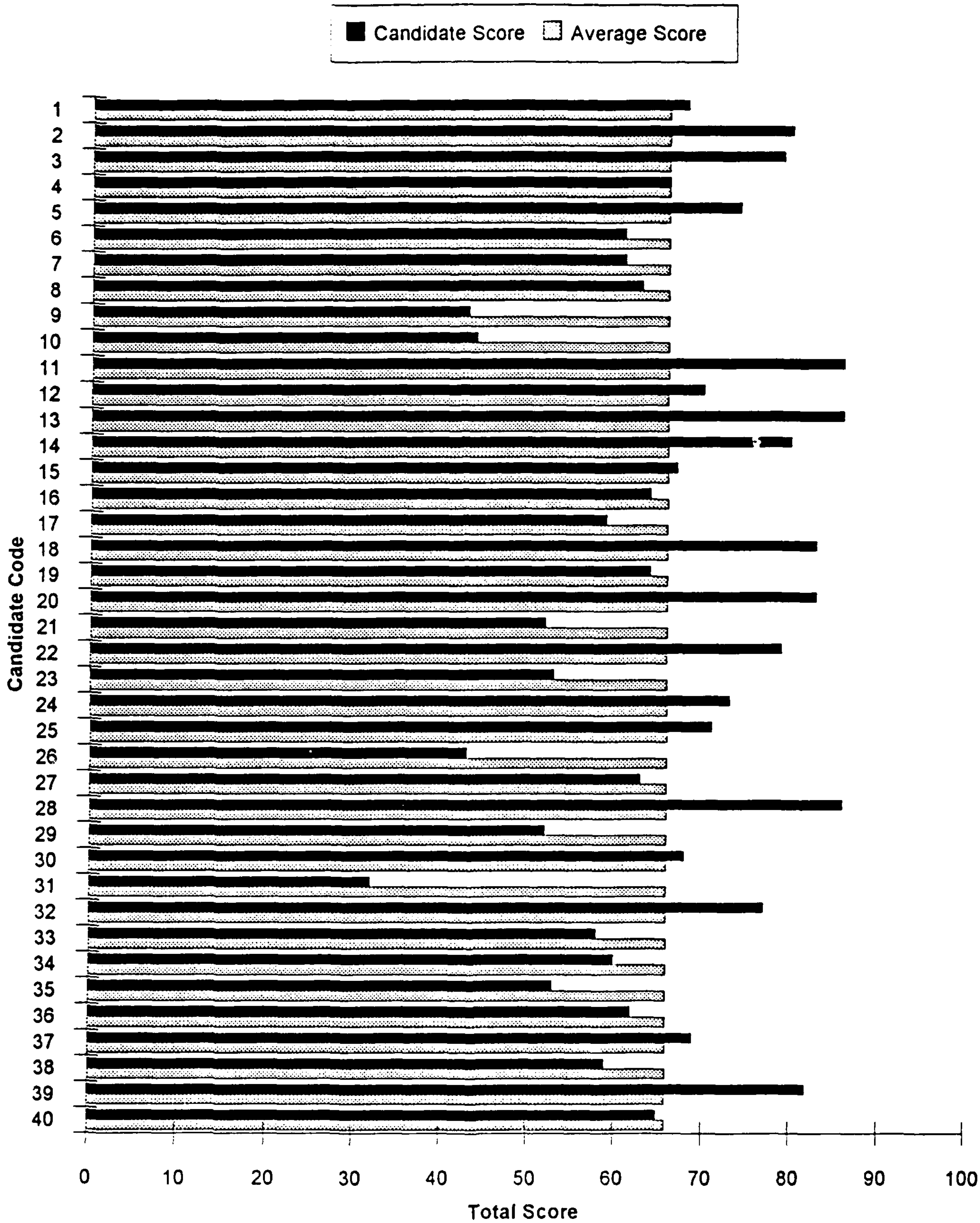
Updating the Excel Database

1) Open file 1 in the workbook.
2) Click on the Data Menu at the top of the screen.
3) Choose Data Form from the Data Menu. (See Diagram Below)
4) The pop-up Data Form should appear on your screen.
5) The first white box contains the candidate code, or candidate number.
6) The following boxes contain the data for specified categories.
7) To the immediate right of these boxes is a scroll bar which allows the user to scroll through all the candidates (each candidate has their own sheet).
8) To update the information of any score simply scroll to the desired candidate sheet, click on the box which contains the outdated score, and type in the updated score. Proceed with all other changes in this manner until all changes have been made. To incorporate these alterations into the database click on the close button on the right of the Data Form.
9) Although the changes are automatically included in the database, the rank order for the second database does not necessarily adjust. In order to assure accuracy, press "control" + "s". This will resort the information accordingly.
10) All information and graphics in pages one through four will be updated at this point.
11) To continue, click on the File Menu at the top of the screen and select Print Preview. Check to make sure that your pages appear in the correct format. If they do not, adjust the margins or graph sizes until the desired outcome is reached. When everything is in order, click on the print button at the top of the screen.
12) Click on the File Menu and select Save As. Save the file under a new name so that each quarters data will be saved under a separate filename rather than over-writing the previous quarters data.
13) Click on the File Menu and select Open.
14) Open File 2
15) Enter the total scores in the appropriate column of the database in this file.
16) The two time-tracking graphs (located on pages five and six) will automatically update itself using the newly included data.
17) As before, click on the File menu and choose Print Preview. Check the format, then print. Again, click on the File Menu and select Save As, then save the file under a new name so that it will not over-write the previous quarters data.

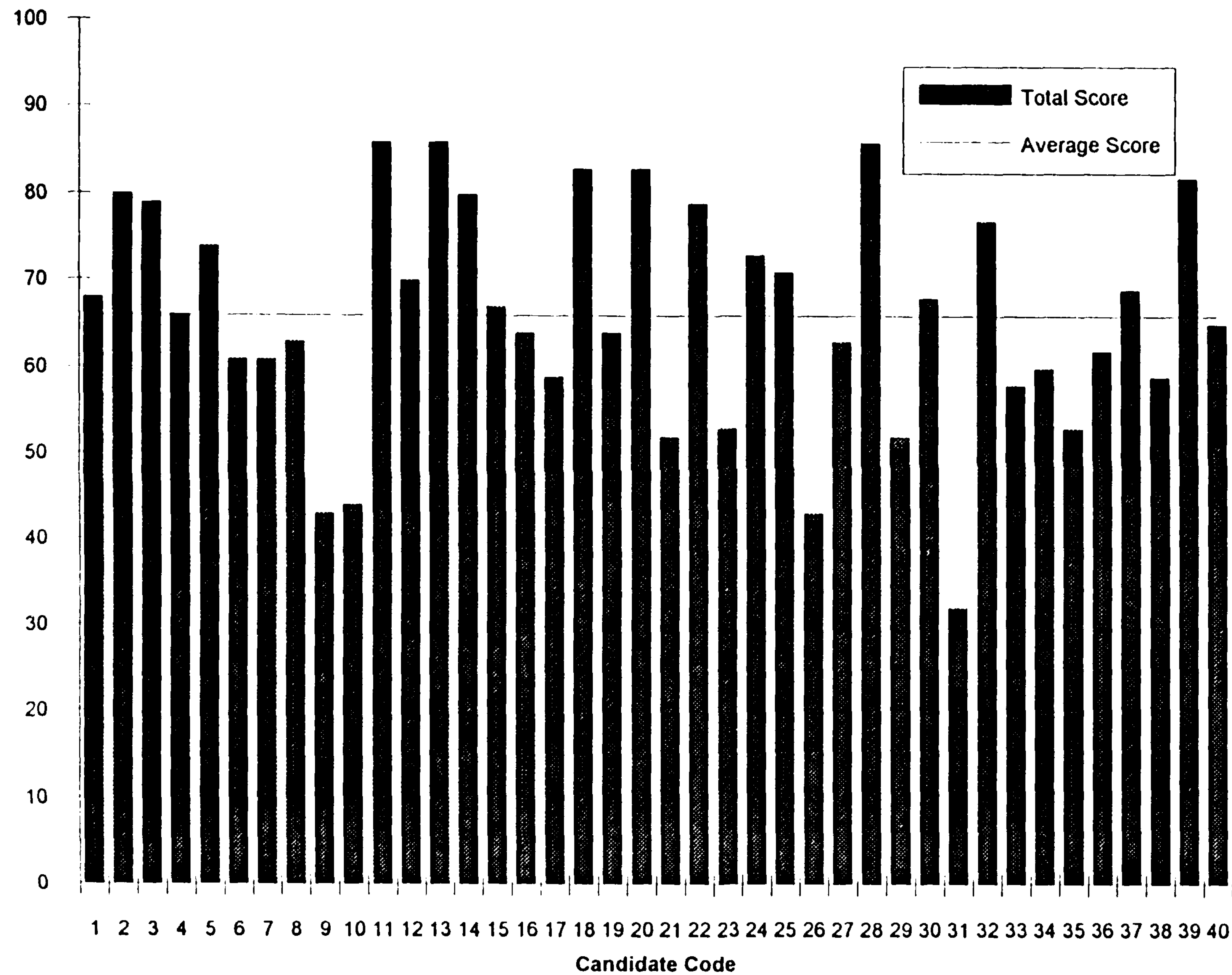


Candidate	Total Score	Completed ACSC	Advanced Degrees	APDP Certification	Medals/Significant Awards	Current Official Photograph	Number of Bases Assigned to	Level of Responsibility	Face Time Last Six Months	Variety of Assignments	Other Significant Responsibilities
1	68	20	15	0	5	5	2	5	6	7	3
2	80	20	15	3	6	0	12	5	2	12	5
3	79	20	15	8	7	5	6	10	2	6	0
4	66	0	15	10	8	5	6	10	5	2	5
5	74	20	15	0	1	5	6	15	5	2	5
6	61	20	0	10	5	0	2	2	10	12	0
7	61	20	0	10	3	5	2	5	10	6	0
8	63	0	15	8	7	0	12	5	5	6	5
9	43	0	10	8	5	0	6	2	5	2	5
10	44	0	10	8	10	0	6	2	2	6	0
11	86	20	0	3	12	23	6	10	5	2	5
12	70	20	0	0	12	5	2	15	10	6	0
13	86	20	10	3	4	5	2	15	10	12	5
14	80	20	15	8	6	5	2	2	10	12	0
15	67	20	15	10	7	0	6	5	2	2	0
16	64	20	10	10	3	0	2	10	2	2	5
17	59	0	10	8	10	5	12	10	2	2	0
18	83	20	10	8	11	0	12	15	5	2	0
19	64	20	0	8	7	0	2	15	5	2	5
20	83	20	0	8	7	5	6	10	10	12	5
21	52	0	0	3	12	5	6	10	10	6	0
22	79	20	10	10	7	5	6	5	5	6	5
23	53	20	10	0	8	0	6	5	2	2	0
24	73	20	0	0	9	0	12	5	10	12	5
25	71	20	15	0	5	0	12	2	10	2	5
26	43	0	15	3	5	5	2	2	5	6	0
27	63	0	10	8	6	5	2	10	5	12	5
28	86	20	10	8	10	5	6	10	5	12	0
29	52	20	0	3	10	5	2	5	5	2	0
30	68	20	0	10	11	0	6	5	10	6	0
31	32	0	0	0	10	5	2	2	2	6	5
32	77	20	10	10	5	5	12	2	2	6	5
33	58	0	10	10	3	0	12	10	2	6	5
34	60	20	10	3	0	0	6	5	10	6	0
35	53	0	10	8	0	5	6	10	2	12	0
36	62	0	10	8	0	5	12	15	5	2	5
37	69	0	10	8	12	5	2	15	5	12	0
38	59	0	0	10	12	5	6	15	5	6	0
39	82	20	15	0	5	5	6	10	10	6	5
40	65	20	15	3	6	5	6	2	2	6	0



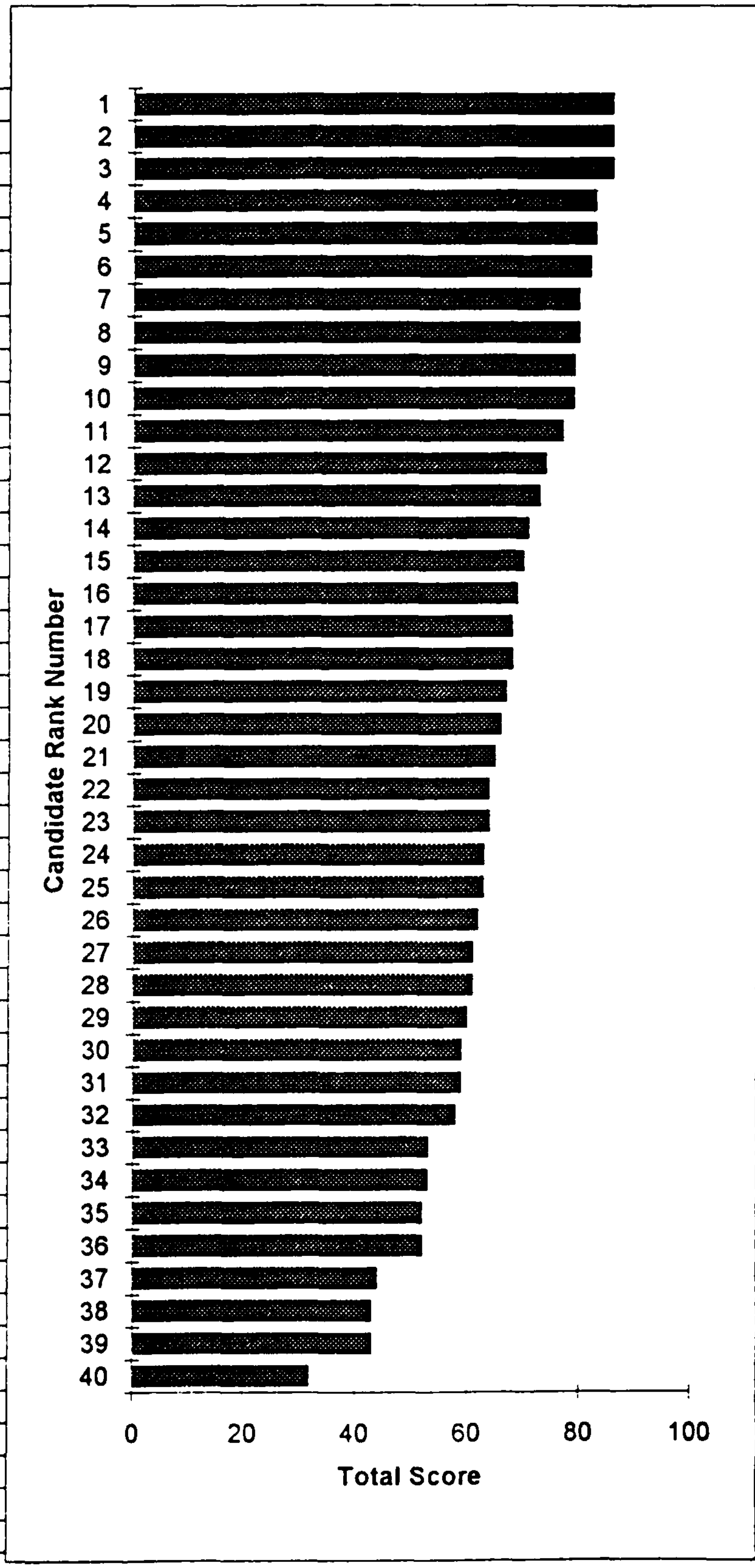


Candidate Score
Average Score
Candidate Code
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
0
10
20
30
40
50
60
70
80
90
100
Total Score

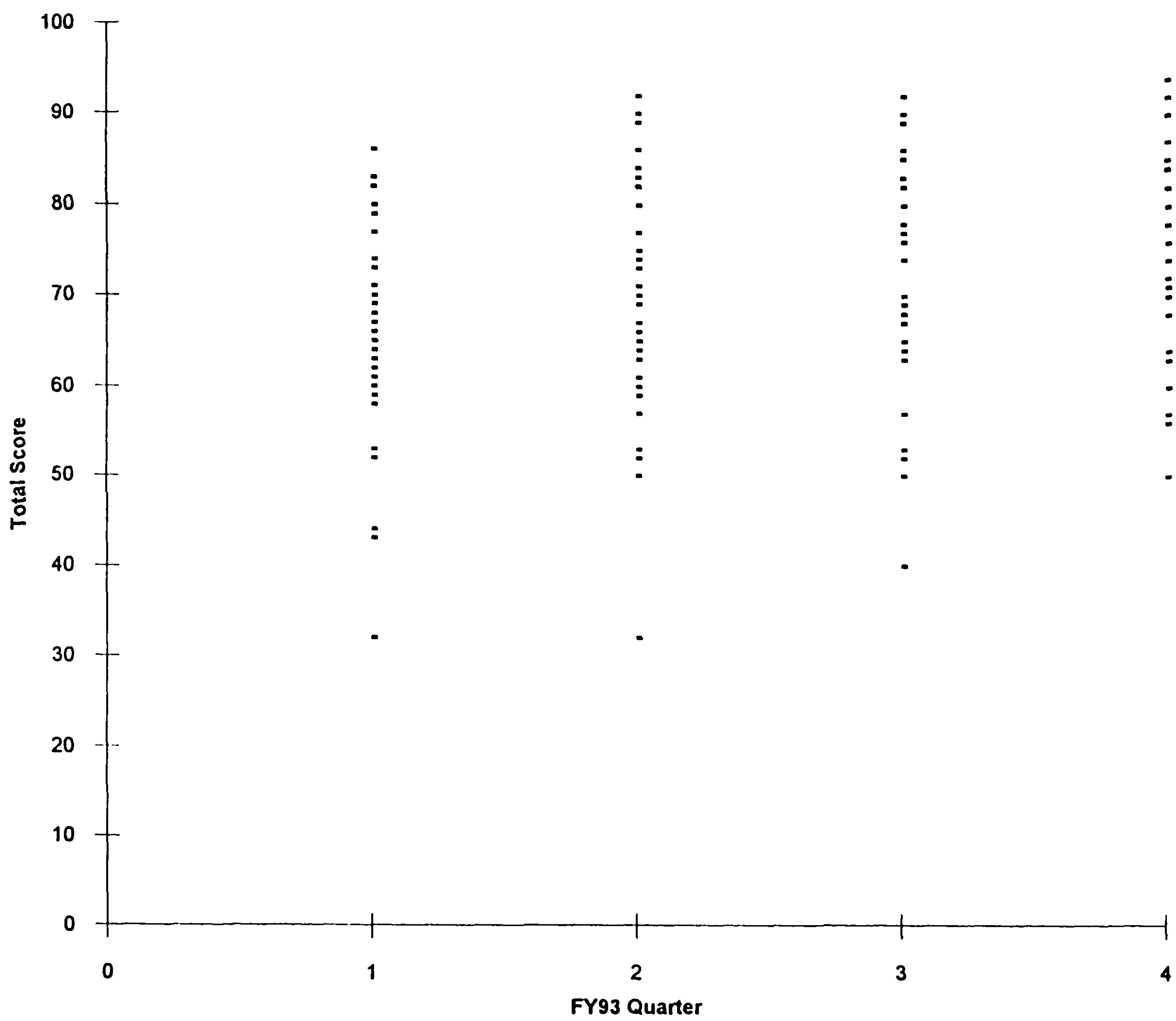


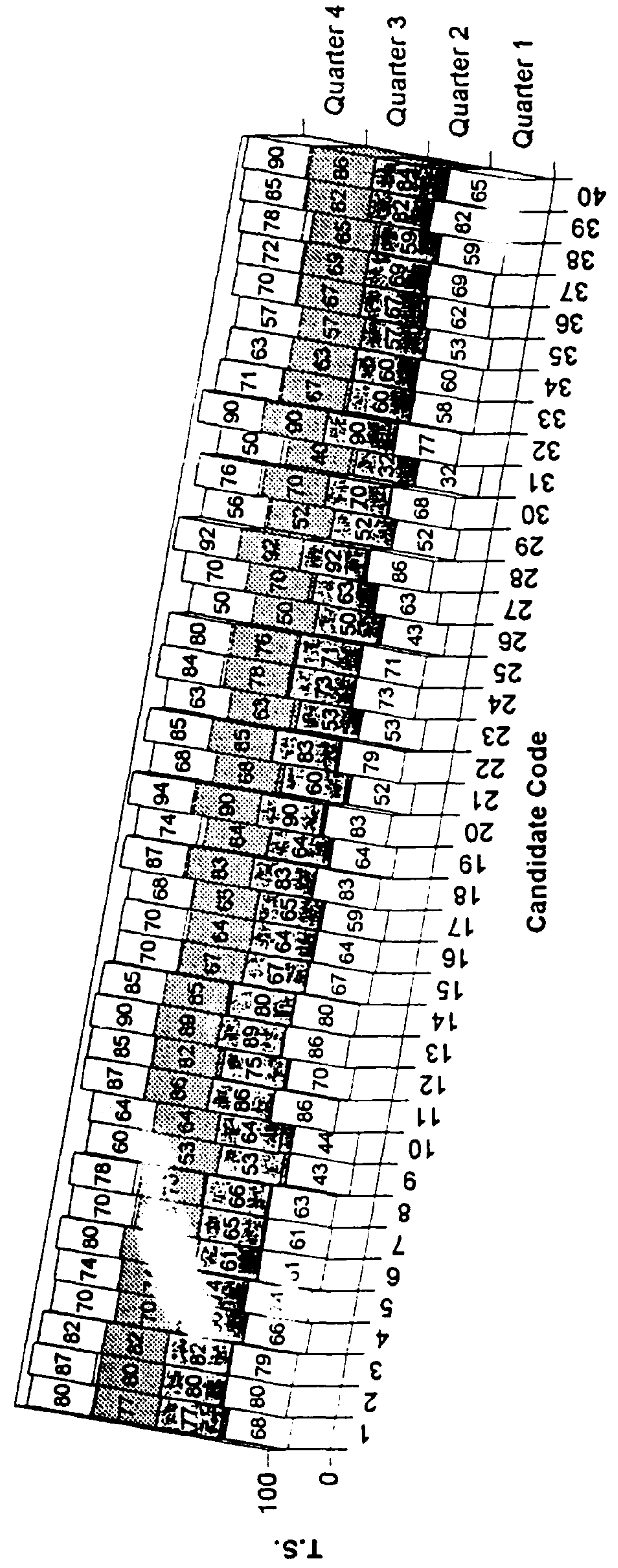
Total Score
Average Score
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Candidate Code
Total Score

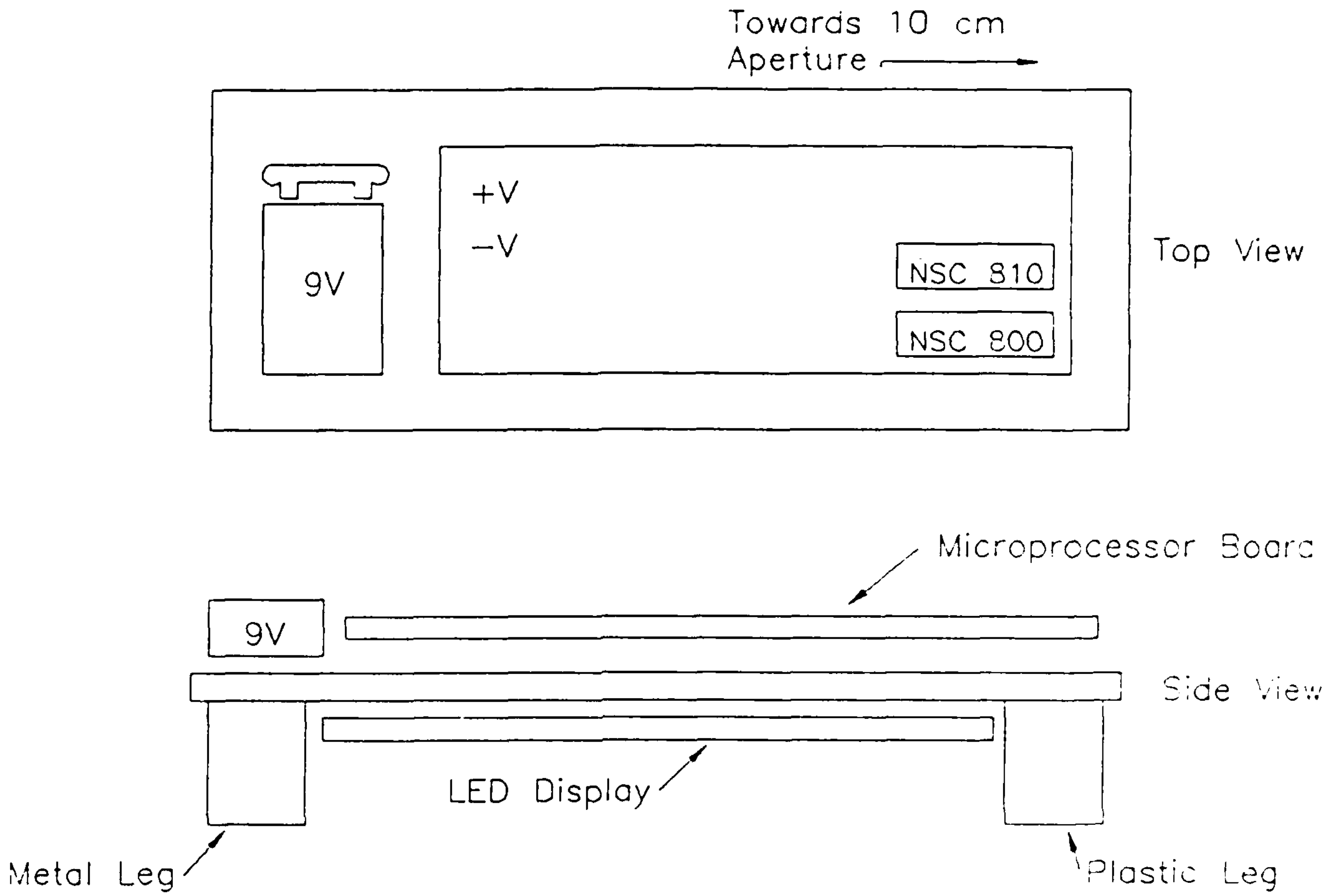
Candidate	Total Score	Completed ACSC	Advanced Degrees	APDP Certification	Medals/Significant Awards	Current Official Photograph	Number of Bases Assigned to	Level of Responsibility	Face Time Last Six Months	Variety of Assignments	Other Significant Responsibilities
11	86	20	0	3	12	23	6	10	5	2	5
13	86	20	10	3	4	5	2	15	10	12	5
28	86	20	10	8	10	5	6	10	5	12	0
18	83	20	10	8	11	0	12	15	5	2	0
20	83	20	0	8	7	5	6	10	10	12	5
39	82	20	15	0	5	5	6	10	10	6	5
2	80	20	15	3	6	0	12	5	2	12	5
14	80	20	15	8	6	5	2	2	10	12	0
3	79	20	15	8	7	5	6	10	2	6	0
22	79	20	10	10	7	5	6	5	5	6	5
32	77	20	10	10	5	5	12	2	2	6	5
5	74	20	15	0	1	5	6	15	5	2	5
24	73	20	0	0	9	0	12	5	10	12	5
25	71	20	15	0	5	0	12	2	10	2	5
12	70	20	0	0	12	5	2	15	10	6	0
37	69	0	10	8	12	5	2	15	5	12	0
30	68	20	0	10	11	0	6	5	10	6	0
1	68	20	15	0	5	5	2	5	6	7	3
15	67	20	15	10	7	0	6	5	2	2	0
4	66	0	15	10	8	5	6	10	5	2	5
40	65	20	15	3	6	5	6	2	2	6	0
16	64	20	10	10	3	0	2	10	2	2	5
19	64	20	0	8	7	0	2	15	5	2	5
8	63	0	15	8	7	0	12	5	5	6	5
27	63	0	10	8	6	5	2	10	5	12	5
36	62	0	10	8	0	5	12	15	5	2	5
6	61	20	0	10	5	0	2	2	10	12	0
7	61	20	0	10	3	5	2	5	10	6	0
34	60	20	10	3	0	0	6	5	10	6	0
17	59	0	10	8	10	5	12	10	2	2	0
38	59	0	0	10	12	5	6	15	5	6	0
33	58	0	10	10	3	0	12	10	2	6	5
23	53	20	10	0	8	0	6	5	2	2	0
35	53	0	10	8	0	5	6	10	2	12	0
21	52	0	0	3	12	5	6	10	10	6	0
29	52	20	0	3	10	5	2	5	5	2	0
10	44	0	10	8	10	0	6	2	2	6	0
9	43	0	10	8	5	0	6	2	5	2	5
26	43	0	15	3	5	5	2	2	5	6	0
31	32	0	0	0	10	5	2	2	2	6	5



	FY93 Quarter			
	1	2	3	4
1	68	77	77	80
2	80	80	80	87
3	79	82	82	82
4	66	66	70	70
5	74	74	74	74
6	61	61	80	80
7	61	65	65	70
8	63	66	70	78
9	43	53	53	60
10	44	64	64	64
11	86	86	86	87
12	70	75	82	85
13	86	89	89	90
14	80	80	85	85
15	67	67	67	70
16	64	64	64	70
17	59	65	65	68
18	83	83	83	87
19	64	64	64	74
20	83	90	90	94
21	52	60	68	68
22	79	83	85	85
23	53	53	63	63
24	73	73	78	84
25	71	71	76	80
26	43	50	50	50
27	63	63	70	70
28	86	92	92	92
29	52	52	52	56
30	68	70	70	76
31	32	32	40	50
32	77	90	90	90
33	58	60	67	71
34	60	60	63	63
35	53	57	57	57
36	62	67	67	70
37	69	69	69	72
38	59	59	65	78
39	82	82	82	85
40	65	84	86	90




Quarter 4
Quarter 3
Quarter 2
Quarter 1
Candidate Code
T.S.
100
0



Towards 10 cm
Aperture
9V
+V
−V
NSC 810
NSC 800
Top View
Microprocessor Board
9V
Side View
LED Display
Metal Leg
Plastic Leg

Figure 3

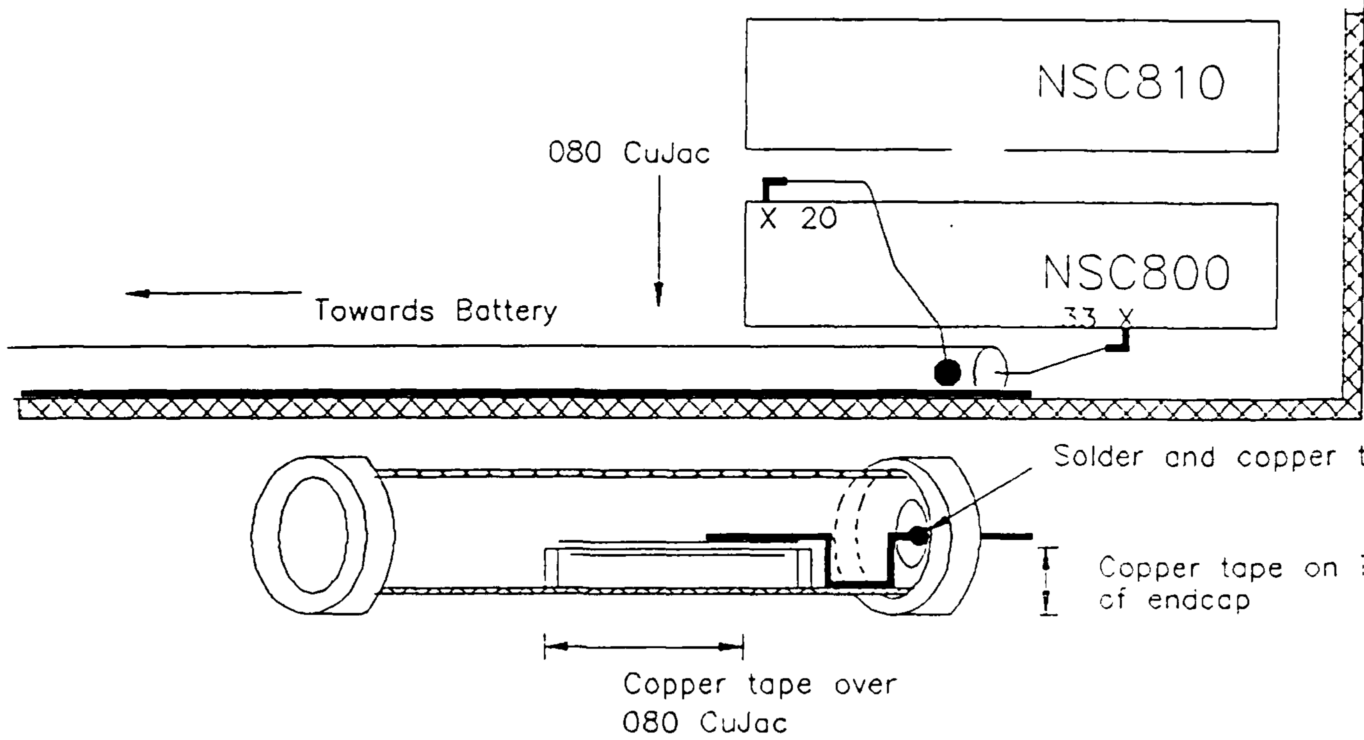
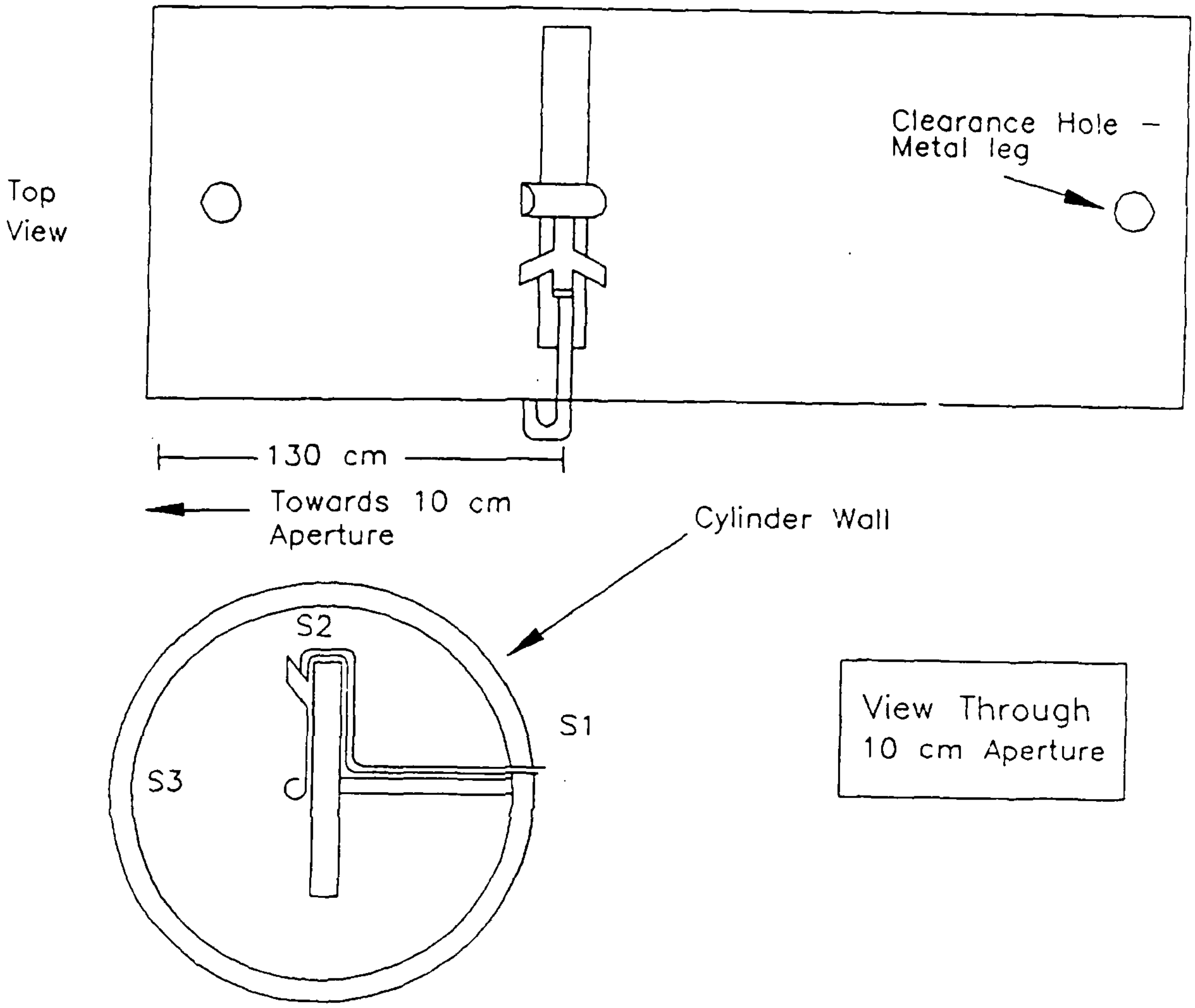

NSC810
080 CuJac
X 20
NSC800
Towards Battery
33 X
Solder and copper t
Copper tape on
of endcap
Copper tape over
080 CuJac

Figure 5



Example showing card B

Figure 7

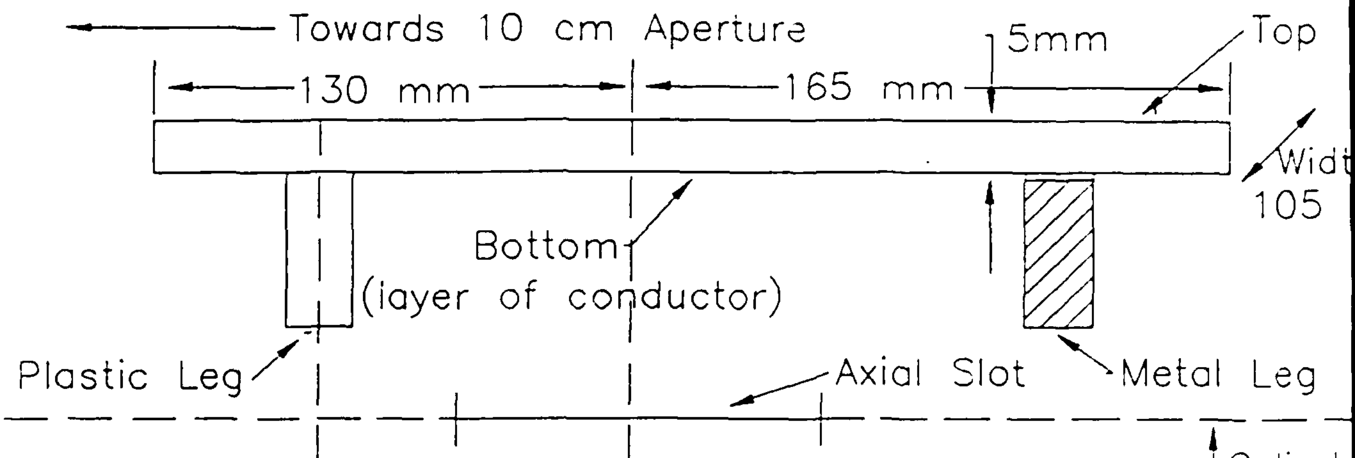


Figure EM-01
(not to scale)

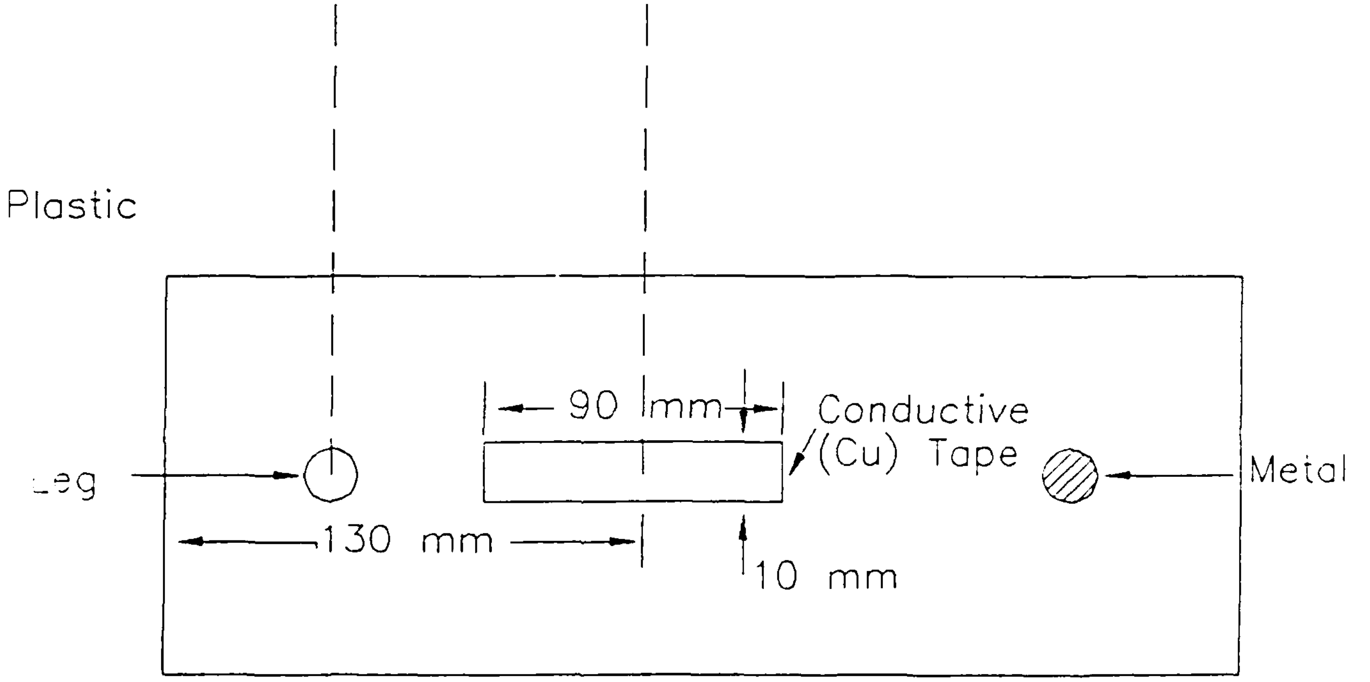


Figure EM-02 : Card A
(not to scale)

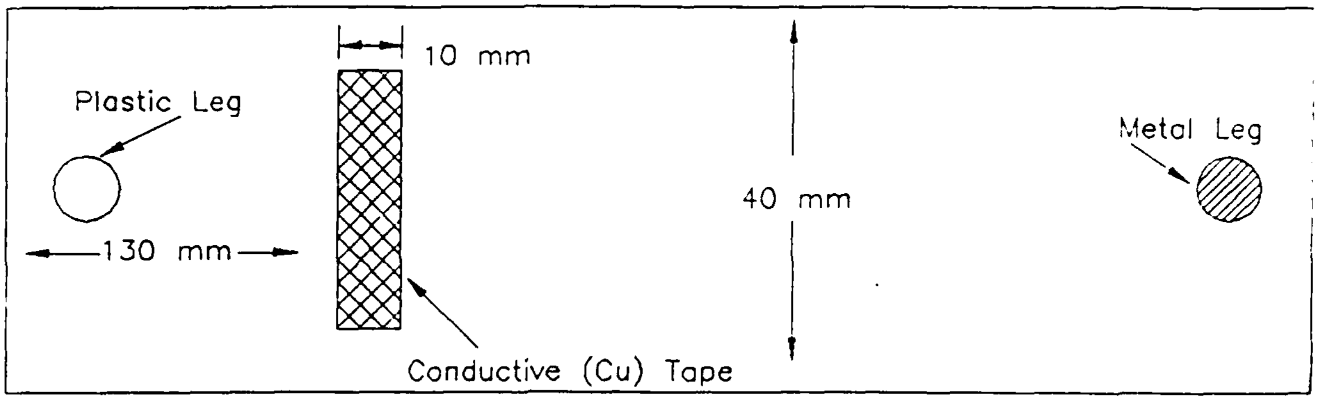
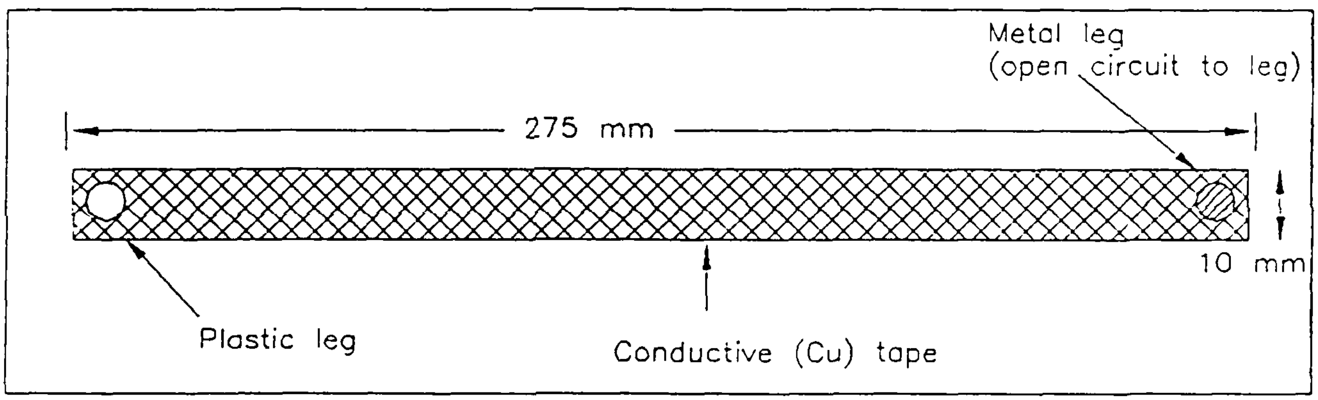


Figure EM–03: Card b
(not to scale)



Fiaure EM–04: Card c (not to scale)

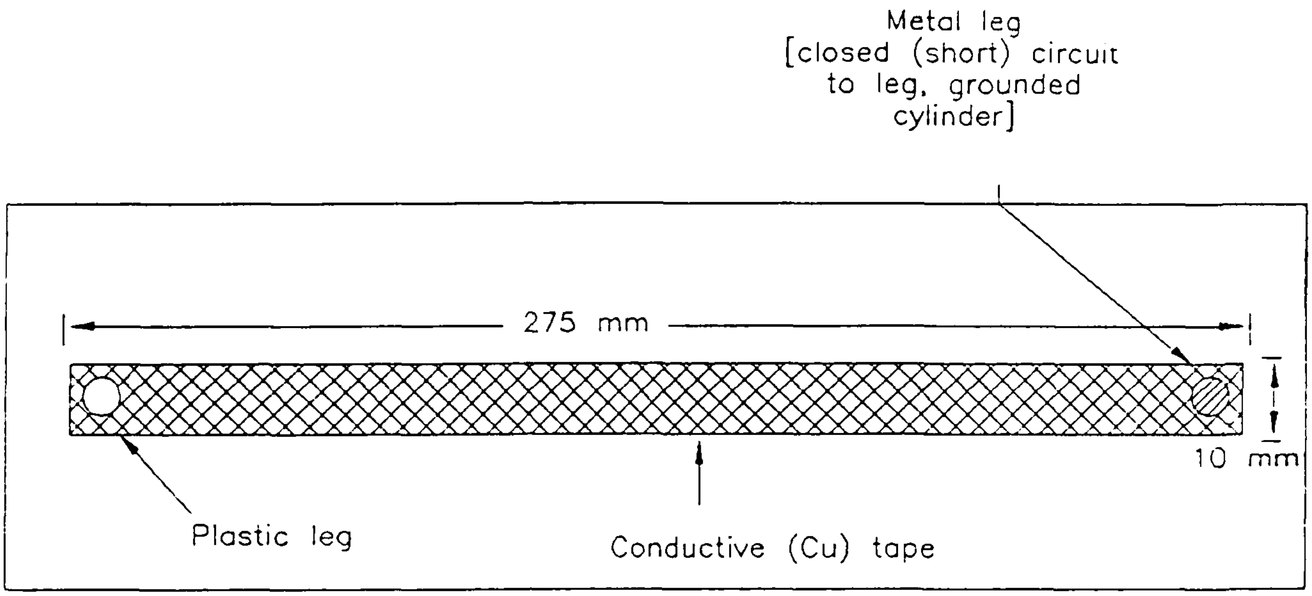


Figure EM-05: Card d (not to scale)