MOLECULAR ION PHOTOFRAGMENT SPECTROSCOPY

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ABSTRACT

A new molecular ion photofragment spectrometer is described which features a supersonic molecular beam ion source and a radio frequency octapole ion trap interaction region. This unique combination allows several techniques to be applied to the problem of detecting a photon absorption event of a molecular ion. In particular, it may be possible to obtain low resolution survey spectra of exotic molecular ions by using a direct vibrational predissociation process, or by using other more indirect detection methods. The use of the spectrometer is demonstrated by measuring the lifetime of the $0_2^+(^4\pi_u)$ metastable state which is found to consist of two main components: the $^4\pi_{5/2}$ and $^4\pi_{1/2}$ spin components having a long lifetime (~129 msec.) and the $^4\pi_{3/2}$ and $^4\pi_{1/2}$ spin components having a short lifetime (~6 msec.).

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I. INTRODUCTION: CONSEQUENCE SPECTROSCOPY

Spectroscopy in the traditional sense is the measurement of those wavelengths of the electromagnetic spectrum at which molecular or atomic species will absorb or emit radiation. From detailed measurements one can infer energy levels and from these one can obtain a distinct picture of the potential energy surfaces influencing the motions of the atoms within a molecular species and how these atoms are arranged geometrically in space. For nonreactive neutral species, spectroscopy can be just a matter of getting a sample of the species in question, shining light through the sample and making one or both of two basic measurements: one can measure the amount of light getting through the sample as a function of wavelength (the absorption spectrum) or one can measure the fluorescence from the sample. These measurements can be conducted with ease. By the astute application of lasers, with their well known properties, one may produce extremely high resolution spectra (the discussion here being limited to the gas phase spectroscopy of molecular and atomic species). But when speaking of the spectroscopy of molecular ions in this context, one finds that even at the most basic level, spectral information is quite limited. As for neutrals, knowing the spectroscopy of molecular ions would lead to the characterization of the potential energy surfaces of the ion and to its geometry. Knowing these facts about the ion can also lead to a better understanding of the neutral species the ion is derived from, as was the case in atomic spectroscopy.

The presence of gas phase ions in flames, plasmas, electrical discharges, planetary atmospheres and interstellar clouds as well as their more common existence in liquids and solids has made their spectroscopy a valued resource to many scientists. With the spectra of an ion known, its presence in outer space can be evaluated and its influence in the chemistry of interstellar space and the atmospheres of planets (like Earth) can be modelled more accurately. In the laboratory, knowledge of the potential energy surfaces of ions in experiments measuring ion-molecule reactions in a state-to-state determination is, of course, vital.

The molecular ion CH^+ was detected spectroscopically in space some forty years ago⁽¹⁾ and for years stood as the only known absorption spectrum of a molecular ion. In the last ten years, however, there has been a virtual revolution in the field of ion spectroscopy. New sensitive techniques⁽²⁾ along with laser light sources have been applied with gratifying success. About sixty ions have been studied with techniques which yielded at least rotational resolution.^(2f) But this fact can be placed somewhat in perspective when one learns that to this date the structure of the common ion CH_5^+ has not been spectroscopically determined and that the high resolution spectra of H_3O^+ was reported only very recently by Saykally et al.⁽³⁾ With these facts in mind, we set out to build a spectrometer which would help fill in the void found in gas phase molecular ion spectroscopy by using a technique which would be more generally applicable than the methods used by existing instruments.

The difficulty.

Why is the gas phase spectroscopy of molecular ions so difficult? Well, to put the relative difficulties somewhat in perspective, let us consider taking the infrared spectrum of HCl gas at room temperature. Suppose one fills some sample cell with 1 torr of HCl gas. With very little trouble, then, one has a sample density of $\sim 3 \times 10^{-16}$ particles/cm³ of essentially one species, with a well defined thermal population distribution to accomplish one's measurements with. One may generate an absorption spectrum with ease.

Now that one has the infrared spectrum of HCl neutral, it would be nice to have the spectrum of HCl^+ say, to be able to make all the comparisons one would like. Putting aside all the details of how the following condition is actually arrived at, we now have a container with electrons whizzing about creating HCl^+ from the neutral HCl gas originally in the container. But in addition to the two species above, one also has other neutral and ionic species—a veritable zoo of charged and uncharged species. So here at the start our spectroscopy is complicated by the fact that we have a mixture in our container, rather than just a single species as in the neutral case. This condition is exacerbated by the fact that ion-molecule reactions are among the fastest of chemical reactions. Thus, the HCl^+ created tend to be short lived because they recombine with electrons found in their environment, react with other species present, or find their way to a container surface and thereby annihilating themselves. This all leads to ion densities in typical experimental arrangements of 10^4 to 10^8

ions/cm³. Note that the best case here is down by a factor of 10^8 from our 1 torr sample of HCl neutral. Of the HCl^+ that is created in this hodgepodge one has to put up with an additional obstacle: because their environment is generally hot, and because of the mechanism by which they are created, their population is partitioned among a large number of translational, rotational, and vibrational states, and perhaps even long lived electronic states. In short one does not have a 1 Torr sample of HCl^+ gas to work with. What one does have is a sample so dilute and dirty that spectroscopy becomes a very difficult, if not impossible, task.

The problems in trying to do spectroscopy on molecular ions in the gas phase have been mentioned above. What course should be taken if one wants to succeed in overcoming these problems? Many approaches have been taken, several very similar to ours. The following discussion will develop our approach to the problem of gas phase molecular ion spectroscopy, with particular interest in the infrared region, and concurrently will outline some detection techniques which have been tried by us and others or that could possibly be used with some success.

A pure sample.

The first problem to be taken care of is the "hodgepodge" which exists in most ion sources. That is, we want only one molecular ion species in our "sample bottle," i.e. our interaction region. Thus, no matter what our source of ions is, the source must be followed by some

sort of mass filter which allows only the ion of interest through into the interaction region. We then have a nice pure sample of a known species to work with. How this situation is maintained will be addressed later.

Once the ions are in the interaction region they encounter a flux of photons from a light source and if the energy of these photons is equal to the spacing of some allowed transition in the ion, photon absorption by the ions will take place. Here comes the part where "technique" is written in large letters: How does one tell whether or not the molecular ions have absorbed any of the incident photons? Well, one searches for possible consequences of the adsorption process and then chooses the one best suited as a detection technique under the prevailing circumstances. At this point I wish to emphasize that the following is not intended to be, by any means, a comprehensive review of the techniques used in gas phase molecular ion spectroscopy. Rather, it is just a bare bones sampling of the techniques, to somewhat acquaint the reader with the field. Details may be gathered from the references found at the end of this chapter.

Absorption and emission.

At the beginning of this chapter, two standard spectroscopic techniques were mentioned: absorption and emission. Direct absorption measurements are generally not practical in molecular ion spectroscopy. For example, suppose one has 10,000 ions of species A^+ in an interaction region through which is passed an infrared light pulse

containing 10^{16} photons (~ 1 mJ/pulse at 3.5μ). And suppose one ion in 100 absorbs a photon, i.e. 100 photons were absorbed by the sample. One can easily see that there is no way that this absorption loss will be measured in a photon pulse containing 10^{16} photons originally. However, although uncommon, there are experimental arrangements which make the above technique possible. For example, in 1974, a direct microwave measurement of CO^+ through the plasma of a DC glow discharge was accomplished by Dixon and Woods⁽⁴⁾ yielding very high resolution spectra. While the source provided a greater-than-average ion density ($\sim 10^{10}$ ion/cm³), the spectra of the ions were quite weak. Therefore use of sensitive modulation methods and computer signal averaging are required to make the measurements possible. More recently the technique of velocity-modulation absorption spectroscopy developed by Saykally et al.⁽⁵⁾ has been successful in observing the spectra of several ions with high resolution in the infrared.

Emission and fluorescence studies of molecular ions in the visible and near ultraviolet parts of the spectrum is feasible, but difficult because of low ion number density. Unfortunately, in the infrared region of the spectrum, lack of detectors with extremely high sensitivity, coupled with the long lifetimes of vibrationally excited states, make this method impractical.

Laser magnetic resonance^(2f) has also been successfully applied to the study of molecular ions. However, since this technique, applies only to paramagnetic species, it is not as general as one would like.

Also the spectroscopy is complicated by the required presence of a magnetic field and by the fact the plasma source used in such experiments usually produces a mixture of ions which is vibrationally very hot. The technique does, however, yield nice high resolution data.

Ions are charged.

Most of the methods described above do not make any use of the fact that ions, by their defining characteristic, are charged species. The charged quality is of course the root of the difficulty in attempting their spectroscopy, but one may in turn use this apparently baneful characteristic to great advantage and thus overcome some of the shortcomings involved. One attribute of ions is that they can be detected with efficiencies close to unity. Thus if the "consequence" to be measured pertained to ion counting, rather than photon counting as above, one could possibly achieve the very high sensitivity necessary to combat the problem of low ion density.

Consider again the 10,000 ions in an interaction region in their ground state and call them species A^+ . Suppose that in the ground state species A^+ will not react with the neutral background species B, which is also in the interaction region, but if A^+ absorbs an IR photon, it will then react with B to give products C^+ and D, according to the following reaction:

Furthermore, suppose that in some way all the ions can be guided to a mass filter which transmits only species C^+ to an ion detector having near unit counting efficiency. Now before the light pulse passes through the interaction region, all the A^+ are in their ground state. This implies there will be no reaction, and thus no C^+ production. If the ions were to be sent on towards the detector, no counts would result. After the light pulse passes through, 100 A^+ ions are no longer in their ground state (using the same figures as before) and may now react with species B to form C^+ and D. Now sending the ions forward through the mass filter would result in approximately 100 counts being registered (100 C^+ product). These 100 counts are attributed to the absorption events. Here we have a case where by using ion counting, one can detect virtually every absorption event which took place in this very small sample of ions.

The types of reactions which may be used in schemes such as the one above are:

- (1) charge exchange

- (2) collision induced dissociation

- (3) proton transfer

and (4) other reactions where mass $A \neq$ mass C

The situation described above is of course the ideal case with no C^+ being produced when the light is off and all C^+ produced when the light is on being caused by the absorption events. There are numerous examples which approach this ideal. But more generally one may expect that the lower state will have a reactive cross section comparable to the upper state and of course the species A^+ in the interaction region may well be spread over several states initially. Thus, when the A^+ absorbs photons, only a change in the amount of C^+ produced will be seen; but this percentage change is still very much larger than the percentage of photons lost to the sample. Thus, in most cases the detection process is more difficult than the ideal flip-in experiment, but is still very doable.

Charge exchange was the detection scheme used by Wing et al.⁽⁶⁾ who were the first to observe the infrared spectrum of a molecular ion, specifically HD^+ . After the HD^+ had interacted with a laser beam, it was passed through a target gas (Ar, N_2 , or H_2) and the surviving HD^+ exiting the target region was measured by a Faraday cup. Since the charge exchange process occurring in the target gas region is a function of the vibrational state of the HD^+ , small changes in the beam current (~ 3 ppm) were observed when on resonance. Carrington et al.⁽⁷⁾ also used the charge exchange technique to detect electronic absorptions in the molecular ion CO^+ and used the reactive cross section method in observing a single rotational line of H_2O^+ .^(2f)

Photodetachment.

Photodetachment is a technique applicable to negative ions.^(2e)

The technique hinges on the fact that absorption of a photon with energy above some limit will cause the ejection of an electron from the ion, thus creating a neutral species:

Here one monitors the decrease of the A^- parent ion as a function of wavelength. This results in data with more noise than a flop-in experiment since one is often times observing small changes in the parent ion count rate caused by the photodetachment process. This would be like detecting the decrease in the parent ion A^+ rather than detecting the appearance of C^+ product in the ideal chemical reaction technique considered earlier.

Photofragmentation.

Dunbar says in his review^(2b) "photodissociation spectroscopy relies on the truism that before an ion can dissociate, it must absorb a photon." Photofragmentation is another one of the possible consequences of an ion absorbing a photon, but it is a very important one in the field of molecular ion spectroscopy. Photofragmentation offers extremely high detection sensitivity because one detects the daughter ion fragment formed in the process

just as one would detect the C^+ product ion in the chemical reaction scheme discussed before. But in photofragmentation all one needs in the interaction region is the species being studied. There is no need for a neutral reaction partner. So one always has an "ideal" case as long as the vacuum in the interaction region is good enough to prevent ion-molecule reactions, now unwanted, from occurring. The success or failure of the photofragmentation detection method rest mainly in the properties of the ion under study. Are the potential energy surfaces of the ion placed so that upon absorption of a photon of a particular energy, fragmentation will occur?

Electronic transitions leading to direct dissociation or predissociation have now been used extensively to obtain the photofragment spectra of gas phase molecular ions both large and small. When conditions are right, as for the O_2^+ ($4\Sigma_g^- \leftarrow 4\Pi_u$) bands, photofragment spectroscopy with fast ion beam techniques yield very high resolution spectra which are unsurpassed by other techniques. The photofragment spectrometer at SRI International is one of the most sophisticated fast ion beam instruments,⁽⁸⁾ and it can be operated in several modes (e.g., optical-optical double resonance has been performed on O_2^+)⁽⁹⁾ yielding a remarkable quantity of detailed information on the O_2^+ quartet potentials.

Vibrational Predissociation.

Vibrational predissociation has not been used as a detection scheme in molecular ion studies. This is simply because, unlike optical transitions which pump a considerable amount of energy into a molecule, vibrational transitions in infrared ($400\text{--}4000\text{ cm}^{-1}$) typically do not have enough energy to initiate fragmentation. But there are exceptions. Some ions produced by electron impact ionization are highly vibrationally excited. To the extent that some levels populated are near a dissociative channel of the ion, absorption of an IR photon can induce fragmentation of the ion.

Clusters, or van der Waals molecules, are chemical species which are held together by weak bonds; usually about one tenth the energy of an IR photon. In the case of neutral van der Waals complexes, vibrational predissociation has been observed and has been used as a spectroscopic tool to generate the spectra of molecular clusters:⁽¹⁰⁾

Lasers.

Just as one may take advantage of the great sensitivity afforded by ion detection schemes to help overcome the low number densities typically found in gas phase ion spectroscopy, so has the advent of the laser as a common spectroscopic light source been invaluable in the study of molecular ions. The laser, with its well known beam

qualities, makes it possible to achieve high photon fluxes through the ion interaction region, thus helping to compensate for the low ion number densities one has to work with.

One should not take a cavalier attitude when it comes to the design or selection of the laser light source. There are numerous factors which must be kept in mind in this regard. One simple feature which should not be overlooked in evaluating the effectiveness of the light source is its linewidth relative to that of the molecular transition one is expecting to excite. Serious deviations in the expected signal-to-noise can result if this is not considered. For example, say the laser produces lots of IR photons ($\sim 10^{16}$ per pulse), but that the spectral width of the pulse is $\sim 1 \text{ cm}^{-1}$ while the transition of the molecular ion has a total width of $\sim 0.01 \text{ cm}^{-1}$. In this case, because of the spectral width mismatch, only ~ 1 percent of the laser energy will be resonant with the transition. It becomes obvious that one should tailor the laser's characteristics so as to optimize the desired resolution and signal of the particular measurement being made.

Design goals.

One desired condition in the spectroscopy of molecular ions is to have a pure sample. Hence, it is desirable to use a mass filter following the ion source. In addition several detection schemes have been outlined. Before making any further statements about how the

spectroscopy is to be accomplished, one should state what the desired goals are for the spectrometer. These design goals should be within the limits set by experimental practicability.

What is it that we want to accomplish in this field where practically any piece of information is a new piece of information? Our primary objective was to have a generally applicable technique able to generate survey infrared spectra of gas phase molecular ions. High resolution spectroscopy was relegated to subsequent investigations. That is, once one has a low resolution spectra of an ion, then one can go back and use techniques that yield higher resolution, but that would have been impractical to use as a survey method.

Thus, our primary aim is to do survey (low resolution) infrared spectroscopy of ions in a general fashion. Clearly, it would be nice to have a sample of cold ions—ions in their ground electronic and vibrational state. This would make the spectrum generated easier to interpret and would give information concerning the lower levels of the ground electronic state, information generally difficult to obtain for ions. If one had enough resolution to resolve rotational structure, then moments of inertia could be calculated, yielding structural information. Of the techniques mentioned previously, which would give the ability to observe the infrared absorption process directly with the required high sensitivity so necessary for success. Well, vibrational predissociation is a likely candidate, but what about having cold ions and the desired generality of the scheme

The molecular beam mentality.

Our research group is heavily into molecular beams. As a consequence, solutions to many problems are viewed with a certain molecular beam mentality, which many times is quite fruitful. In this case, the knowledge that with molecular beams one can easily make very cold clusters of various compositions, made the idea of vibrational predissociation of neutral and ionic van der Waals complexes a natural.

The idea goes like this. Suppose one wants to get the infrared spectrum of the molecular ion M^+ . What one does is form the van der Waals species $M^+ \cdots X$, where $X = \text{He}$ or Ar . The binding energy of this complex is bound to be quite low, undoubtedly much lower than the energy of an infrared photon ($400\text{--}4,000\text{ cm}^{-1}$).⁽¹²⁾ Once we have formed this species, things are a snap. The selected complex is deposited into the interaction region, which is a region of ultra high vacuum thus minimizing collisional dissociation of the weakly bonded complex by neutrals. While in the interaction region, the ions are bathed with a healthy pulse of IR photons. If the wavelength is correct, the $M^+ \cdots X$ complex will absorb a photon. The energy absorbed will rattle around the complex until enough is transferred to the weak bond to cause its rupture,

So here we have a method which promises to be general (so long as the complex can be made) and which uses vibrational predissociation to directly view the absorption process. Very high sensitivity would be

achieved by mass selective ion counting. A spectrum would be generated by counting the M^+ product as a function of the infrared wavelength, which is scanned.

Drawbacks.

The scheme looks good. Much could be learned about the $M^+ \cdots X$ complex itself and about the M^+ ion, if all worked out well. But, as hinted at above, barriers exist which might prevent our goal from being achieved. For one thing no proven source for generating lots of the $M^+ \cdots X$ complex exist. The end result may be that we will have very few complexes to work with—much less than typically found in ion spectroscopy. But it should be easier to generate ion clusters of the type $(M)_n^+$ or the protonated $(M)_nH^+$ species with which one could perform vibrational predissociation experiments if the cluster size is large enough:

The number of ion clusters may be so low that the number of ions illuminated by a light beam with 1 cm^2 cross section, crossing at right angles to the ion beam, would be quite a bit less than one. To help mitigate the problem of having extremely few ions, a coaxial light source, slow-ion-beam arrangement was decided upon. Thus, in an ultra high vacuum environment, slowly moving ions travel through a long interaction region through which a light pulse propagates. This

configuration provides good spatial overlap of the ions with the light source and increases the number of ions in the interaction region per -light pulse.

In addition to the need for a good ion beam-light beam overlap, one also needs all ions (targets and fragments) to be guided to the detector. A radio frequency (RF) ion guide can accomplish this task quite efficiently. And as an added bonus, by placing ion mirrors at either end of the ion guide, one can trap the ions within the guide.

Having an RF ion trap for an interaction region proves beneficial in other respects. With the trap one need not worry about the time it takes for the vibrational predissociation event to take place. One just keeps the excited complex trapped until the bond rupture takes place, then feeds the products to the detector. Experience gained from the vibrational predissociation of neutrals indicates that these times are short, and thus are of no practical concern.

If one is working with ions which are vibrationally or electronically hot, one may use the trap as a cooling tank. Not only could one possibly use this method to get the spectrum of the relaxed ion, but one could also measure the radiative lifetimes of various excited states. One excellent use of the ion trap is to guide reactant ions and their products through a background gas and finally to the detector in schemes which fall under the "chemical reaction" category discussed earlier. A machine in our group uses this "guided ion

technique" to measure total cross sections in ion-molecule reactions.⁽¹¹⁾ Having an RF ion trap for the interaction region is very convenient.

Let us get back to the draw backs of using $M^{+...X}$ complexes in our spectroscopy scheme. The spectrum we are after is that of the M^{+} ion, but what we are generating is the spectrum of the complex. Now this in itself is of interest, since it gives us structural information of the complex and possibly the time scale for the predissociation. However, the intent is to study the of M^{+} ion. The situation here is not too bad. Although the rotational structure of the transitions would be expected to be characteristic of the complex as a whole, the vibrational structure should be essentially that of M^{+} alone. Furthermore, as stated before, once one has found the wavelength regions where the M^{+} ion absorbs by using the survey method, perhaps one can return to the problem with a high resolution technique, and acquire the rotational structure of the uncomplexed ion.

Roundup.

Here the essential qualities of a spectrometer capable of acquiring the low resolution infrared spectrum of a molecular ion M^{+} by directly observing the vibrational predissociation products of the related van der Waals ion $M^{+...X}$ ($X = \text{He, Ar}$), are stated. The basic requirements are:

- 1) An ion source region with high pumping speed and high throughput capability able to support the gas loads created by the

supersonic molecular beam source used to form the cold $M^{+...X}$ type van der Waals molecular ions.

2) A mass filter following the ion source so that one may select the species placed into the interaction region. The filter should provide good ion-beam quality and luminosity.

3) An ultra high vacuum interaction region should provide a clear through shot for the light source and should support slowly moving ions over a long straight path so that good spatial overlap between the ion beam and light beam can be achieved. The ion optics here must be able to guide all ions, parents and fragments, to the final sections of the spectrometer.

4) After the interaction region comes a second mass filter which allows one to select which mass the ion detector views. This gives the high sensitivity, low background detection necessary for success.

5) One needs an ion detector with low inherent dark count and reasonably fast response time.

6) And finally, a necessary component which is physically separate from the above, but is an integral part of the spectrometer system, is the light source. Without the advantages rendered by a good infrared laser light source, the project would be doomed. Lots of photons are needed to help overcome the lack of ion density.

A functional block diagram of the spectrometer is shown in Fig. 1. The success of the instrument as an infrared molecular ion spectrometer of general utility depends on the successful operation of the following three components:

- 1) the ion source producing $M^+ \cdots X$ complexes.
- 2) the ion trap used to achieve adequate ion-laser spatial overlap and to guide all ions to the detection stage.
- 3) the infrared laser light source.

If any of the three fails, then the spectrometer becomes just a run-of-the-mill tandem mass spectrometer capable of low resolution photofragment spectroscopy.

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FIGURE CAPTION

Fig. 1. A functional block diagram of the molecular ion photofragment spectrometer using a tandem mass filter configuration and an ion guide interaction region.

Figure 1

II. THE SPECTROMETER

In Chapter I the general description of the spectrometer we wished to construct was laid out. It was to be a low resolution infrared photofragment spectrometer of general applicability. This chapter will take a look at what was actually built in the attempt to reach our design goals.

A. The Ion Source

On first seeing our spectrometer, one is apt to ask "why in the heck is the darn thing so big?" The answer is two-fold. First, some parts are large because they are just remakes of existing beam designs found in our group or are surplus items, such as the large sector magnet used as the first mass filter. Second, and more importantly, the source region is large because it has to accommodate not only conventional ion sources, such as electron impact ionizers, duoplasmatrons, etc., but also the high pressure expansion beam source. The molecular beam source operates at about one atmosphere through a 100 μm diameter orifice creating a large demand on the system's pumping speed and throughput capabilities. The spectrometer must have sufficient differential pumping to maintain the interaction region at about 10^{-12} atmospheres when the nozzle is operating at 1 atmosphere.

The ion source is mounted in Region I of the spectrometer (see Fig. 1). This region is pumped by a high speed 10 inch diffusion pump (Varian VHS-10) charged with Convalox-10 pump oil, as are the other

two diffusion pumps used on the spectrometer. This pump is trapped by a liquid nitrogen cooled chevron baffle in order to minimize the backstreaming of oil into the ion source region. Metal surfaces must be kept free of oil, so that surface charge build up will not be a problem. If the throughput from this region is large, the diffusion pump is backed by a 150 lsec^{-1} Roots blower. This combination can maintain the high pumping speeds and throughputs which are necessary when the supersonic beam source is employed.

Region II of the source (see Fig. 1) contains the lens system (Fig. 2) used to accelerate and focus the ions issuing from the ion source. Deflection plates steer the ion beam either to a quadrupole mass spectrometer for source optimization or to the sector magnet which selects the ion mass sent on into the interaction region. Region II is pumped by a liquid nitrogen trapped, six inch diffusion pump (Varian M-6). This region should have pressures below 10^{-5} torr when the supersonic source is being used.

The supersonic ion beam source to be described is basically an atmospheric pressure ionizer⁽¹⁾ used in mass spectrometry, except that here the intent is to form clusters, or van der Waals complexes of some particular species M^+ . The working idea is to form a weak plasma at pressures of about one atmosphere by using the α -rays of some radioactive element, usually ^{63}Ni or ^3H . Because high temperature bakeouts are often needed to clean out the nozzle system, ^{63}Ni is perhaps the better choice, but we bought ^3H foils opting for the higher activity available from tritiated foils. As Fig. 3

shows, the radioactive foil, curled to form a cylinder, is placed in a small tube so that it is near the nozzle orifice. The gas mixture to be ionized is fed in through the inlet tube until it fills the nozzle cavities. If the vent line of the nozzle is closed, the only flow of gas is through the orifice placed near the foil's active region. If the vent line is opened, one may have a controlled flow of gas above that which flows out the orifice, so that one may dictate the amount of time the volume of gas remains in the region of the radioactive foil. This extra flow can mitigate the effects of unwanted side reactions.

The light plasma, formed within the nozzle by the β -particles acting on the gaseous species, gives rise to a complicated array of ion chemistry. One wants the β -particles to interact with some carrier gas directly, to form ions and excited states, and then subsequently to have these ions and/or metastable species interact more softly with the species one really wants ionized, but not torn to bits. For example, suppose one wants to ionize species M by using the above scheme. One would whip up a mixture of say 99 percent argon and 1 percent species M, and then send it down the tube to meet its foil. Within the foil's volume, the β -particles would, by chance, interact with the argon atoms directly, forming Ar^+ and Ar^* (metastable state). These two species would then interact with M via collisions within the light plasma:

Process (3) is simply a charge exchange reaction and process (4) is termed Penning ionization. Ideally these would be the only processes occurring within the plasma. The light plasma consisting of charged species M^+ , e , and Ar^+ would expand into the vacuum along with the neutrals Ar and M to form the supersonic molecular beam. One would then adjust parameters such as temperature and stagnation pressure to optimize the formation of the desired van der Waals ion, which might be $\text{M}^+ \cdots \text{Ar}$ in this case. If enough of the complex is made, then the fun part begins. What color light makes it fall apart again

But things are somewhat more complicated than outlined above. The complication arises because ion-molecule reactions, as stated earlier, are very fast, and so the charge can be passed from one species to another. The positively charged species found in the plasma, referred to as the terminal ions, are those which are the most stable. Water seems to be present in any vacuum system, so given sufficient time, one usually ends up with the terminal ions being $\text{H}_3\text{O} \cdot (\text{H}_2\text{O})_n^+$ ions, where n range from zero to surprisingly large numbers. This distribution of water cluster ions depends on the temperature, the water concentration, other species present, and the time given to react.^(1a) Thus, it becomes more clear why it is desirable to be able to bake out the system, control the temperature, and by using the extra flow via the vent tube, to control the residence time of the

plasma in the foil region. The ion spectrum one gets in a particular case is difficult to predict because of the wide variety of ionization routes available. These can be characterized as follows:

(5)	$A^* + B \longrightarrow (AB)^+ + e$	associative ionization
(6)	$A^* + B \longrightarrow B^+ + A + e$	Penning ionization
(7)	$A^+ + B \longrightarrow A + B^+$	charge transfer
(8)	$A + B + e \longrightarrow A^- + B$	electron attachment
(8a)	$AB + e \longrightarrow A^- + B$	
(9)	$AH^+ + B \longrightarrow A + BH^+$	proton transfer
(10)	$A^- + BH \longrightarrow AH + B^-$	deprotonation
(11)	$A^+ + BC \longrightarrow A + B^+ + C$	dissociative charge transfer
(12)	$A + B^+ + C \longrightarrow AB^+ + C$	clustering
(13)	$MC1 + O_2^- \longrightarrow MO^- + OC1$	substitution

Let's consider again the action of this type of source on a gas mixture composed of argon and the species M we wish to ionize. In particular say the mixture is 95 percent Ar and 5 percent O_2 (used because it was on hand). Then a realistic scheme representing the primary positive ion chemistry in the foil region of the nozzle would be the following:

(14)	$B + Ar \longrightarrow Ar^+ + 2e$
(15)	$B + Ar \longrightarrow Ar^* + e$
(16)	$Ar^+ + 2Ar \longrightarrow Ar_2^+ + Ar$

Reactions similar to (23) would lead to clusters of the type $\text{H}_3\text{O} \cdot (\text{H}_2\text{O})_n^+$ with the distribution of n being highly dependent—as noted before—on the temperature, the water concentration, other impurity species present, and the time given to react. Of course clustering of the various species with each other will be taking place also, not to mention the added complication of other impurity species found in the nozzle.

The prototype nozzle shown in Fig. 3 was designed to discover the influence of gas flow, nozzle aperture size, nozzle-skimmer acceleration gradients, nozzle-skimmer distance, and gas mixture on the ion spectrum produced by the nozzle. In addition we hoped to learn whether the pumping capabilities met the demands of the source. The tests which were carried out using this nozzle were very preliminary in nature—just to get an inkling of whether the idea would work and how one might set up to study the nozzle more systematically. Unfortunately, in the following years, the time was never found to return to characterize the nozzle well. In short, the ion mass

spectra presented here, which display the effects of varying some of the various parameters mentioned above, are not of good quality. Nevertheless the spectra are presented to show that one does have some control over the cluster types and the cluster distribution produced by this ion source, giving hope that one may be able to optimize the production of a particular ion cluster.

The first ion mass spectra to be presented show how an extra flow of gas (that is in addition to the flow of gas through the nozzle orifice) can change the product ion distributions. Figure 4 shows how an additional flow can eliminate the production of ions derived from an impurity. In this case the impurity is ethanol which was used as a cleaning solvent. The flow is enough to remove the ethanol clusters from the spectrum, but it changes the water cluster distribution minimally. In Fig. 5 a more drastic flow is used and in addition to suppressing the ethanol clusters, the water cluster distribution is radically altered. Sometimes extra flow through the foil region does not bring a benefit. For example, if one were trying to produce the van der Waals ion $\text{Ar} \cdot \text{H}_3\text{O}^+$, then having less residence time in the foil region would seem to be a definite disadvantage. Figure 6 shows that extra flow results in the disappearance of the $\text{Ar} \cdot \text{H}_3\text{O}(\text{H}_2\text{O})_n^+$ type clusters from the mass spectrum.

One would like the ions which leave the nozzle to go through the skimmer orifice and into Region II of the source, but of course only a fraction of the total ion flux makes it through. To increase the number of ions which pass through this orifice, an electric field is

established between the nozzle and the skimmer to accelerate the ions towards the skimmer. But there are consequences to this procedure. Figure 7 shows that there is a decrease in average cluster size with increasing accelerating electric field. This shift in cluster size may be understood by recognizing that the acceleration takes place in a region of high pressure. Thus, the clusters may be fragmented by colliding with neutrals which are present in the beam. Another possibility is that ions are pulled away from the expansion zone where, via three body collisions, the clusters are becoming larger. But one must also add focusing effects to the above. It may be that there is a shift in ion mass transmission through the skimmer orifice as the electric field gradient is changed.

Although the ion mass spectra seen so far were taken as a mixture of Ar/O_2 was fed into the source, one does not see any O_2^+ in Figs. 4, 5, 6 or 7. Figure 8 is included to show that with the addition of heat (nozzle tip 100°C) and extra flow one can produce the O_2^+ ion. Thus, one may conclude that with a source of this type, one does have a handle on what is produced by it. Hopefully, there is enough control to generate the prerequisite quantity of the species needed for spectroscopy.

A good case.

Suppose that the species that one is trying to create is $\text{Ar}\cdot\text{H}_3\text{O}^+$. Figure 9 shows the ion spectrum generated from the Ar/O_2 gas mixture discussed before, but with various parameters

adjusted to optimize the generation of the $\text{Ar}\cdot\text{H}_3\text{O}^+$ ion. If the spectrum shows all the masses being produced under the conditions, then the $\text{Ar}\cdot\text{H}_3\text{O}^+$ peak comprises about 25 percent of the total ion flux. That is about as good as one might expect to achieve for the production of a van der Waals ion. If the total ion flux from the nozzle is $5 \times 10^8 \text{ ion sec}^{-1}$ (~50 mCi tritiated foil) then one would have $\sim 1.2 \times 10^8 \text{ ion sec}^{-1}$ of $\text{Ar}\cdot\text{H}_3\text{O}^+$. Assuming an efficiency of 10^{-5} (that is one ion in 10^5 survives the skimmer, Region II collisions with neutrals, and all the ion optics), one gets $\sim 1.2 \times 10^3 \text{ ion sec}^{-1}$ arriving at the interaction region. It takes about 1 msec for the ions to traverse the interaction region, so at any given time one has about one $\text{Ar}\cdot\text{H}_3\text{O}^+$ to work with. This is less than originally expected and is unacceptable.

Ten to one hundred times this many ions are needed in the interaction region to have a workable experiment. What went wrong. The original error was in over estimating the number of β -particles that could be delivered per second into the ionization volume by the tritiated foil. Tritiated foils were chosen because they are available with higher activities than are the ^{63}Ni foils. The error made was that the quoted activities of the various foils were converted directly to β -particles sec^{-1} without considering the correction necessary for saturation due to self-absorption. This cost about a factor of 20 in the ion flux estimates and may spell doom for the experiment as presently configured. Some improvement may be realized by using ^{63}Ni foils which are bakeable and yield β particles which are more energetic than those produced by ^3H .

B. The Sector Magnet: momentum analysis

The ions which are extracted from the source are accelerated to a given potential, focused, and sent on to Region III by the action of the ion optics in Region II. Region III, shown schematically in Fig. 10, is maintained at 2×10^{-8} torr by a liquid nitrogen baffled, 4 inch diffusion pump (Varian VHS 4). Ions of differing masses travel together until encountering the magnetic field of the sector magnet. The magnetic field is arranged to be perpendicular to the ion trajectories. Each ion type, all having the same average kinetic energy, is forced to travel in a circular path by the influence of the magnetic field. The radius of the circular path followed by a particular ion is proportional to the momentum of the ion and thus to the square root of the ion's mass. Therefore, if only a limited range of curvatures are allowed to be transmitted (by using physical beam stops), one has a mass separator. In this case, since the energy and transmitted radius is fixed, one selects which ion mass gets passage by setting the value of the magnetic field.

The magnet used is a 60° sector. It is situated so that the ions enter the sector region with trajectories perpendicular to the pole piece and exit with trajectories perpendicular to the exit pole boundary if their radius of curvature is 8 in. while in the magnetic field. Ions traveling through the magnetic sector in this fashion are focused in the radial direction but experience no focusing in the direction parallel to the magnetic field. This poses a serious problem, because if the ion beam approaches the mass filter with an

expanding circular cross section, lack of z direction focusing in the sector would result in a substantial loss of ions—something which cannot be endured in the van der Waals ion experiment.

The sector magnet was chosen as a mass separator in part for its excellent beam quality, but to work well it must also exhibit adequate resolution and high transmission. Usually, the resolution is obtained by proper use of slits and lenses (other factors being constant). However, this would only add to the losses mentioned above unless the lens corrects for the lack of z focusing. One wants a method which will satisfy the resolution requirements and at the same time, increase, rather than decrease, ion transmission efficiencies.

C. The Quadrupole Lens Pair

The focusing properties of an electrostatic quadrupole lens pair (QLP) has these desired qualities. The QLP consists of a double set of four rods each creating an electrostatic quadrupole field. The orientation of one quadrupole field is rotated 90° from that of the other. The QLP will transform a rectangular ion beam entering it into one which is parallel in one plane and is converging in the other, thus focusing the ions onto a line (see Fig. 11). This result is excellent because focusing to a line will enhance the mass separator's resolution, and having a wedge-shaped beam means that no z direction focusing is required; thus, losses in the sector magnet can be reduced. The QLP's characteristics have been detailed by several authors.⁽²⁾ It is enough to say here that the characteristics of the

lens are ideally suited for use with magnetic mass separators.⁽³⁾ Our mass spectrometer uses no mechanical slits within Region III. (The only apertures are those used to establish the differential pumping regions.) Instead, one QLP is used at the entrance to transform the beam into a wedge and another used at the exit is to transform it back to a collimated beam. One added feature of the QLP is that it can be operated with pole voltages offset symmetrically to act as beam deflectors without loss of focusing. This is quite convenient.

Figure 12 shows the improvement afforded by the QLP's action. The resolution goes from $M/\Delta M = 85$ with the QLP's off to $M/\Delta M = 150$ with them on. The ion count rate is improved by 16 fold with the use of the QLPs. These mass spectra were taken using an ion energy of only 350 eV. The resolution at this energy is rather poor, but is typically good enough for our purposes for $M/e < 100$. The resolution can be greatly improved by increasing the ion energy should the need arise. The present condition is tolerated because (1) it is quite adequate for experiments being done and (2) raising the ion energy would require a slight modification of the quadrupole mass filter used downstream of the interaction region.

When leaving Region III the ions pass through a small tube which serves to limit conductance between Region III, which is held at $\sim 2 \times 10^{-8}$ torr, and Region IV, which is usually $\sim 2 \times 10^{-9}$ torr or less under operating conditions. Region IV (see Fig. 13) is pumped by a 220 lsec^{-1} ion pump. It contains the ion-laser interaction region

and the ion photofragment detection system. Both Regions III and IV are designed to be bakeable.

The discussion in Chapter I pointed out that one of the design objectives of the spectrometer was to have a "clear through" shot for the light beam. This would make alignment less of a problem, especially when using infrared light. Because of our configuration, reaching this objective necessitated bending the ion beam. Electrostatic deflection was selected to accomplish this job since one voltage setting would track all masses transmitted by the sector magnet. There are several types of electrostatic deflectors in common use, but most of them will not allow the ion beam to be merged with a light beam without having holes in one or more of the electrodes. The presence of these holes disturbs the electric field within the deflector and thus its operating characteristics. If a wire mesh is used over the hole to preserve the electric field, then the light beam may produce unwanted side effects when it strikes the mesh.

D. The Quadrupole Field Deflector

There is, however, a marvelous electrostatic deflector which is simple to build, has excellent deflection properties and provides an unobstructed merging path for the light and ion beams. The device is a two dimensional electrostatic quadrupole field deflector (QFD) which is detailed by Zeman.⁽⁴⁾ If designed properly the QFD gives excellent beam quality. In the present case its full abilities in this regard were not needed and so a simplified design was used (see

Figs. 13 and 14). Figure 15 shows the equipotentials calculated for the simple QFD used here. The grounded elements are used to terminate the fringing field extending from the electrodes. The hyperbolic electrodes are approximated by circular ones.

The figures which are presented (Figs. 16-21) show ion trajectories through a QFD and serve to display some of its characteristics. The trajectories are those for an ideal quadrupole field with a sharp cut off fringe field. Figure 16 shows the lowest energy solution for which ions execute a 90° deflection. This solution is also the one with the least aberrations. The energy of the ions in this case is assigned the relative energy 1.00. Figure 17 shows the action of the QFD on a narrow beam of ions which is not monoenergetic and Fig. 18 shows a monoenergetic wide beam entering the deflector. Figure 19 has a converging monoenergetic beam entering the QFD. Figures 20 and 21 show the trajectories of two higher order solutions (with relative energy 1.925 and 1.858, respectively), which have aberrations making them unsuitable for this application; besides, the ions would strike the pole piece unless it were modified to provide the necessary clearance.

Slow them down.

Following the QFD the ions enter a constant gradient decelerator⁽⁵⁾ which has an einzel lens as a last stage. The ions are slowed down to about 5 eV and then focused into the octapole RF trap with the einzel lens.

E. The RF Octapole Trap

The octapole region is one of central importance to the spectrometer. It must contain all ions, parents and offspring, and deliver them to the final mass filter. In selecting an ion guide for this purpose, one must be aware of its functional limitations. For example, the most common ion guide used is the RF quadrupole. But this ion guide has strict initial conditions which must be met by the ions for them to be contained by the guide.⁽⁶⁾ In our spectrometer an RF ion guide developed by Teloy and Gerlich⁽¹⁰⁾ is used because it is felt that their octapole imposes initial condition requirements which are less severe than those of the quadrupole guide. Thus, more ions are confined in the octapole guide. The octapole used consists of eight parallel, 20 inch long, 1/8 inch diameter, molybdenum rods, equally spaced about a circle of 1/2 inch diameter (see Fig. 22). Alternate poles are connected to opposite ends of a coil so as to form a resonant circuit; the parallel rods forming the "capacitor" of the circuit. This parallel LC circuit is excited inductively by a single loop of wire powered by an RF generator tuned to the resonant frequency of the tank. Molybdenum is the material used for the rods and the entrance and exit lenses of the octapole because of its ability to maintain uniform surface potentials.⁽⁷⁾ This is a must in applications using low energy charged particles. But if one must have an extensive lens system, the cost of using molybdenum can be sobering. Pollard⁽⁸⁾ describes the fabrication of a less expensive, but completely satisfactory, lens system made of aluminum coated with

molybdenum. For large systems this may be the preferred route to take. A detailed drawing showing how the eight rods are held in place at the ends of the guide is shown in Fig. 23. Only the topmost and bottommost rods are shown for clarity. The ends of the rods are rounded to minimize the tendency for arcing under the influence of the RF field. The machinable ceramic annulus, used for electrical isolation, is kept well away from the ion beam by use of stainless steel spacers. The entrance (exit) lens element controls the flow of ions into (out of) the octapole ion guide.

Trapped trajectories.

Based on Kapitza's analysis of classical mechanics in a fast oscillating field,⁽⁹⁾ the average motion of a slow moving charged particle in an RF n-pole field is described by:

$$(24) \quad m \frac{d^2 \vec{r}}{dt^2} = - \vec{\nabla} V_{\text{eff}}(r)$$

where

$$(25) \quad V_{\text{eff}}(r) = \frac{q^2 E^2(r)}{4m\omega^2} + q\phi_s(r)$$

and q is the charge of the particle, E is the amplitude of the RF, ω is the angular frequency of the RF, r is the smoothed distance from the axis of the trap to the ion, and ϕ_s is the electrostatic potential (see Fig. 22). The potential for an ideal octapole oscillatory field is given by

$$(26) \quad \phi(t) = \frac{V_0}{r_0} (x^4 + y^4 - 6x^2y^2) \cos(\omega t + \theta)$$

where any static component is neglected. This potential yields amplitudes for the E field components and $E^2(r)$ as follows:

$$(27) \quad E_x = -\frac{\partial \phi}{\partial x} = -\frac{4V_0}{r_0} (x^3 - 3xy^2)$$

$$(28) \quad E_y = -\frac{\partial \phi}{\partial y} = -\frac{4V_0}{r_0} (y^3 - 3yx^2)$$

$$(29) \quad E^2 = E_x^2 + E_y^2 = \frac{16V_0^2}{r_0^8} (x^2 + y^2)^3 = \frac{16V_0^2}{r_0^2} \left(\frac{r}{r_0}\right)^6$$

Thus, for an octapole field one has

$$V_{\text{eff}}(r) = 4K\left(\frac{r}{r_0}\right)^6, \quad ,$$

where

$$K = \frac{q^2 V_0^2}{m\omega^2 r_0^2} \quad .$$

In a similar fashion the effective potential for a quadrupole field is given by

$$(31) \quad V_{\text{eff}}(r) = K\left(\frac{r}{r_0}\right)^2$$

The effective potentials for an octapole and a quadrupole with the same K value are shown in Fig. 24. It is immediately evident that the octapole field provides an effective potential which has higher walls

than does the quadrupole field. As stated before, we believe that the octapole is better suited for "trapping" ions. Figure 25 shows the trajectory (x-y coordinates) for a singly charged ion in an octapole ion guide with $r_0 = 0.64$ cm, $\omega/2\pi = 7.5$ MHz, and $m = 32$ amu. The trajectory is generated by integrating out the equations of motion and not by using any effective potential approximations. The trajectory shown follows the course of the ion over a 112 μ sec. period given an initial radial energy (ϵ_0) of ~ 1 eV. If this ion had a z-axis (the axis of the trap) energy of 0.65 eV, then it would take ~ 250 μ sec. to traverse the length of the octapole ($m/e = 32$), and would "bounce" off the effective potential wall about 40 times during this time.

Figure 26 shows the trajectories for singly charged ions with masses of 32 amu and 16 amu traveling with initial radial energies of 0.6 eV and 0.3 eV, respectively. The octapole field parameters are $V_0 = 200$ V, $\omega/2\pi = 15$ MHz, and $r_0 = 0.48$ cm. The trajectory is carried out for 20 μ sec. for both ions. Figure 27 displays the probability of finding the ion of mass 32 at a reduced distance r/r_0 from the center of the ion guide, while Fig. 28 gives the radial energy probability distribution of the ion (with $\epsilon_0 = 100$). Note that while the most probable energy is the initial energy, the ion has radial energies substantially below and above its initial value for very significant amounts of time.

When using the octapole to confine ions one must always bear in mind that the equation describing its effective potential (Eq. 30) is valid only if the approximating conditions used in its derivation are

met.⁽¹⁰⁾ Also note that the effective potential is a function not only of the angular frequency, but also of the mass of the ion: ions of different mass coexisting in the ion guide will be governed by different effective potentials. This means that an octapole guide operating so as to guide a reactant ion, say H_2^+ , may fail to effectively confine the product mass created within the guide if the product is more massive than the reactant. For example, in the following reaction

the product has greater mass than the reactant. One must ensure that the ion guide is operating with its parameters set so it will confine both species, or measurements made on the system will be misleading.

The octapole ion guide can also operate as an ion trap if ion "mirrors" cap the ends of the guide. Such an arrangement is used in our system. A neat way to observe the trapping effect is to lower the potential of the entrance mirror for a short length of time and then raise it again. This allows a bunch of ions into the trap. This bunch of ions can now be made to "bounce" back and forth in the ion guide by having the mirrors totally reflecting. But if no ions escape to the detector, one observes nothing. Now if the exit mirror is made partially transmitting, then every time the bunch of ions strikes it, some ions will pass through to be detected and the rest will be reflected back down the axis of the guide. The results of such a measurement (ion counts vs time) are shown in Fig. 29. Note that at the end of each round trip the transmitted peak becomes broader until

a peak no longer exists and all one gets is a constant leakage of ions from the trap. At this point there is no longer any bunching in the trap: it is homogeneously filled with ions which have a broad kinetic energy distribution. This loss of bunching occurs because the "mirrors" are scattering the ions back into the guide in a diffuse manner. This transfers kinetic energy originally in the z coordinate to the x and y coordinates until the energy is equally shared. This means that ions which have been stored in the trap for more than one millisecond become translationally very hot. This is a bad consequence in terms of the photofragment spectroscopy because of the large Doppler widths which result from it.

Another problem associated with our octapole mirrors is that they leak ions out of the trap when they are not supposed to. The leaking ions are not escaping down the axis of the spectrometer since none reach the detector. They must be popping out to the sides or slamming into metal surfaces. It seems though, that only ions above some critical kinetic energy leak out; for once these escape, the remaining ions are trapped efficiently. Figure 30 shows O_2^+ trapped out to 100 msec. Note that almost all the ions which will escape have done so by 50 msec. of trapping time. Figure 31 shows the trapping efficiency out to 5 minutes. This figure clearly demonstrates that after the initial loss of ions, the remaining ions are trapped very well indeed. Overall, the RF octapole ion guide works quite satisfactorily. The use of the guide as an ion trap may be made more efficient by carefully designing the mirrors at the ends of the

octapole. These mirrors must be able to reflect the ions well while not disturbing the effective potential created by the RF field.

Aside from the obvious assets of large ion-laser overlap, containment of all product ions, and the use of the trap to allow the relaxation of excited states, one may also use the trapping feature for temporal discrimination. That is, if the firing of the light source creates electronic noise or photon induced background in the detector, one may confine the meaningful light correlated products in the ion trap until the noise settles down--then allow the products to pass on to the detector. This capability is very advantageous to have since its application can increase the signal-to-noise ratio significantly.

F. The QMF and Detector

After the octapole ion guide has done its thing with the ions, they are extracted from the guide and focused into a commercially produced quadrupole mass filter (Extranuclear Laboratories, Inc.). The mass filter is set to transmit the laser correlated products to the final stage of the spectrometer in a typical flop-in type experiment. The ions which exit the quadrupole are directed towards a Daly⁽¹¹⁾ detector or a Ceratron⁽¹²⁾ electron multiplier. The Ceratron, although having less gain than the Daly scheme, is convenient because both positive and negative ions can be detected by just changing the polarity of the power supplies. Both detectors were configured for pulse counting.

G. The Light Source

The light source used with the spectrometer is based on a pulsed Nd:YAG (Quanta-Ray DCR) laser pump which produces up to 700 mJ (10 nsec. pulse duration) of 1.06 μ radiation. This fundamental can be doubled, tripled, or quadrupled with harmonic generating crystals. These harmonics are used either directly in the spectrometer or are used to pump a dye laser (Quanta-Ray PDL) to yield tunable visible radiation. In addition, the 1.06 μ light can be sent into an optical parametric oscillator⁽¹³⁾ (OPO) thus producing tunable infrared (~1.5 to 4.3 μ) light.

H. Data Acquisition and Control

Many of the spectrometer functions are automated making long data taking runs requiring many changes in instrumental parameters possible without much personal attention. A microcomputer (DEC LSI-11) performs the task of controlling these parameters and of collecting the data being generated. Communication between the computer and the spectrometer is accomplished via A2D and D2A converters in the computer backplane, in addition to having a CAMAC crate interfaced to the computer. A programmable clock controls the trapping time of the octapole ion trap (see Fig. 32). Other accessories include a video terminal, a plotter, a DMA driven display scope, a printer and a floppy disk. The program used to operate the system is written in assembly language (see Appendix). It allows one to operate the sector magnet, the octapole ion trap, the quadrupole mass filter, and the laser via computer command.

I. Performance: Photofragmentation in the Visible

The performance of the spectrometer was evaluated by observing the photofragmentation of some ions using visible light. This choice was made because with visible light one does not need a very weak bond to be present in the ion for photofragmentation to occur and so ions created by an electron impact ionizer could be used. Using the Nd:YAG pumped dye laser as the light source, CH_3I^+ , C_6H_6^+ and O_2^+ were photofragmented.

First consider the CH_3I^+ ion. This ion can dissociate yielding the CH_3^+ ion⁽¹⁴⁾ if it absorbs a photon with sufficient energy. Figure 33 shows the laser correlated $M/e = 15$ product as a function of wavelength from 5000 to 5400Å sampled in 0.96Å steps. The structure seen is due to transitions to a bound upper state which subsequently leads to fragmentation.^(14a) As another trial, the photofragmentation of C_6H_6^+ was observed. In this case the dye laser was not frequency scanned; instead, the laser correlated mass spectrum was generated at a single frequency. Figure 34 shows the result. It is seen that at the laser intensity used, two daughter fragments are produced, C_3H_3^+ and C_4H_4^+ , as a result of a multiphoton absorption process.⁽¹⁵⁾ Finally, Fig. 35 shows the laser correlated product mass spectrum of O_2^+ being irradiated by 5100Å light. In each of these cases, the photofragmentation events were trivial to observe. But of these trials, only the photofragmentation of O_2^+ was studied in more detail; the results of the work on O_2^+ is the subject of Chapter III.

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FIGURE CAPTIONS

- Fig. 1. General schematic of source regions.
- Fig. 2. The ion lens system following the ion source: (1) nozzle assembly, (2) skimmer, (3) accelerating and focusing elements (4) and (5) ion beam deflectors.
- Fig. 3. Detail of the supersonic nozzle ion source.
- Fig. 4. Mass scans of ions produced by the nozzle source. The top scan is with a light extra flow of gas through the nozzle: the ethanol impurity peaks disappear with this extra flow.
- Fig. 5. Two mass scans of ions produced by the nozzle source. The bottom scan is with no extra flow; the top is with a heavy flow. Impurities peaks disappear and water cluster distribution shifts downward with extra flow.
- Fig. 6. Extra flow through the nozzle can produce unwanted results. The top mass scan taken with extra flow has no $\text{Ar} \cdot (\text{H}_2\text{O})_n \text{H}^+$ clusters.
- Fig. 7. The cluster size distribution from the nozzle source shifts to smaller average size as the electric field between the nozzle and the skimmer is increased.
- Fig. 8. Illustration of the use of nozzle temperature and flow to enhance the quantity of O_2^+ produced.
- Fig. 9. Mass scans of nozzle source with parameters set to optimize the creation of $\text{Ar} \cdot \text{H}_3\text{O}^+$.
- Fig. 10. Schematic of Region III: the magnetic sector.

Fig. 11. The quadrupole lens pairs (QLP) transforms a rectangular beam into a wedge-shaped beam.

Fig. 12. A comparison of mass spectra taken with the QLP on (top) and QLP off (bottom).

Fig. 13. Schematic of Region IV, the interaction region: (1) to Region III, (2) to window, (3) to ion detector, (4) quadrupole field deflector, (5) decelerator, (6) einzel lens (7) octapole trap, (8) quadrupole mass filter.

Fig. 14. A closer view of the quadrupole field deflector.

Fig. 15. Calculated equipotentials for the quadrupole field deflector.

Fig. 16. Solution through the quadrupole field deflector with the least aberration: relative ion energy of 1.00.

Fig. 17. A narrow beam of ions which is not monoenergetic deflected by the QFD.

Fig. 18. A wide monoenergetic ion beam deflected by the QFD.

Fig. 19. A converging monoenergetic beam deflected by the QFD.

Fig. 20. A solution with a higher aberrations with a relative ion energy of 1.925.

Fig. 21. A solution with higher aberrations with a relative ion energy of 1.858.

Fig. 22. A cross section of the octapole trap: r_0 is the radius of the circle inscribed within the rods and r is the distance of the ion from the origin. Also shown schematically is the tank coil and the exciter loop.

Fig. 23. A close up view of one end of the octapole assembly.

- Fig. 24. Effective potentials for an octapole and a quadrupole with the same dimensions, applied voltages, and the same ion mass.
- Fig. 25. The trajectory of an ion in an octapole (transverse coordinates). The dotted circle has radius r_0 .
- Fig. 26. A comparison of the trajectories of a 16 amu ion and a 32 amu ion with initial radial energies of 0.3 eV and 0.6 eV, respectively in an octapole; other parameters are the same in each case.
- Fig. 27. The relative probability of finding the 32 amu ion in Fig. 26 at position r/r_0 .
- Fig. 28. The relative probability of finding the 32 amu ion in Fig. 26 with energy ϵ/ϵ_0 .
- Fig. 29. The density of ions at the exit mirror of the octapole vs time when a short pulse of ions is initially let into the trap.
- Fig. 30. The number of O_2^+ ions in the octapole trap as a function of time in 10 msec steps out to 100 msec.
- Fig. 31. The number of O_2^+ ions in the octapole trap as a function of time in 500 msec. steps out to 5 minutes.
- Fig. 32. Block diagram of the computer and its accessories.
- Fig. 33. Photofragmentation of CH_3I^+ with detection of CH_3^+ as a function of wavelength. Signal is sampled every 0.96Å.
- Fig. 34. Laser correlated mass spectrum of $C_6H_6^+$ photofragmented by 5100Å light.
- Fig. 35. Laser correlated mass spectrum of O_2^+ photofragmented by 5100Å light.

Figure 1

LBL 8310-12201

XBL 795-9759

Figure 2.

XBL 795-9758

Figure 3

JBL 8310-12202

Figure 4

XBL 8311-4419

Figure 5

Figure 6

XBL 8310-12206

Figure 7

Figure 8

Figure 9

XBL 8310-12208

Figure 10

SIDE VIEW

END VIEW

63

QUADRUPOLE LENS PAIR

Figure 11

Figure 13

QUADRUPOLE FIELD DEFLECTOR

XBL 8310-12196

Figure 14

U-CONTOURS
 1 -70.000
 2 -60.000
 3 -50.000
 4 -40.000
 5 -30.000
 6 -20.000
 7 -10.000
 8 0.
 9 10.000
 10 20.000
 11 30.000
 12 40.000
 13 50.000
 14 60.000
 15 70.000

QFD EQUIPOTENTIAL PLOT

-- XBL 8310-12197 --

Figure 15

XBL 8310-12184

Figure 16

XBL 8310-12191

Figure 17

XBL 8310-12192

Figure 18

XBL 8310-12193

Figure 19

XBL 8310-12194

Figure 20

XBL 8310-12195

Figure 21

RF
EXCITER

OCTAGONAL ARRAY
OF RODS

Figure 22

XBL 8310-12183

Figure 23

NBL 8310-12182

Figure 24

XBL 8310-12181

Figure 25

Figure 26

RELATIVE PROBABILITY

$$\frac{f}{f_c} \times 100$$

Figure 27

XBL 8310-12187

RELATIVE PROBABILITY

$\frac{e}{e} \times 100$

Figure 28

XBL 8310-12186

Figure 29

XBL 8310-12188

XBL 8310-12190

Figure 30

XBL 8310-12189

Figure 31

NBL 83-10-1200*

Figure 32

III. PHOTOFRAGMENTATION OF O_2^+ : THE LIFETIME OF THE $a^4\pi_u$ METASTABLE STATE

A. Introduction

Molecular oxygen, an abundant and reactive species, is involved in many chemically important environments. Of interest is the fact that many of these environments are harsh enough to create the O_2^+ ion. In the gas phase one finds O_2^+ in flames (combustion), plasmas, electrical discharges, and by solar ionization, in the upper atmosphere. The ambition to better understand and predict the chemical evolution of these systems leads to the desire to know as much as possible about this important species.

Because O_2^+ has been the subject of much experimental and theoretical work, it is one of the most understood molecules. Its spectroscopy, in particular the $b^4\Sigma_g^- \rightarrow a^4\pi_u$ First Negative band, has been studied for many years by emission techniques. The high resolution emission work of this band by Nevin⁽¹⁾ in 1938 provided high quality information on the $b^4\Sigma_g^-$ and $a^4\pi_u$ states. Figure 1 shows the pertinent potential curves for this discussion.

More recently Vestal et al.⁽²⁾ using 6000Å radiation observed photodissociation of $O_2^+ a^4\pi_u$ created by electron impact ionization of O_2 . This led to much work on the ion using laser photofragment spectroscopy by observing the predissociation of $O_2^+ b^4\Sigma_g^-$ state resulting from transitions shown in Fig. 1 as type I.⁽³⁾ In this manner the $b^4\Sigma_g^- \leftarrow a^4\pi_u$ band was studied at very high resolution. In addition, the $f^4\pi_g \leftarrow a^4\pi_u$ system was studied

using photofragment spectroscopy—this resulted in the only reported case of a $4\pi \leftarrow 4\pi$ system. (2g,2j)

Numerous chemical studies have been done on O_2^+ . Here great advantage may be taken of the wealth of information available on the potential energy surfaces for this ion. The reaction of O_2^+ to yield O_3^+ first gave evidence that O_2^+ was formed in a metastable state by electron impact ionization. (4) The metastable state responsible for the reaction and the photodissociation by visible light was identified as the $a^4\pi_u$ state: Much of the reactivity of the O_2^+ ion is due to the $a^4\pi_u$ metastable state. (5) Thus it is clear that the lifetime of this state is an important parameter in modelling studies. For example, A. Dalgarno et al. (6) state that the composition of the ionosphere in the E- and F-regions may depend significantly on the $O_2^+ a^4\pi_u$ state. In order to evaluate how strongly the $a^4\pi_u$ state will influence its chemical environment, its lifetime must be known. However, in many studies, both chemical and spectroscopic, assumptions have had to be made concerning the lifetime of the $O_2^+ a^4\pi_u$ metastable state, since a direct measurement was lacking. The lifetime has been generally assumed to be $\tau \geq 1$ msec (7) since its radiative relaxation to the $X^2\Sigma_g$ state is spin forbidden.

Our spectrometer is a low resolution instrument, being Doppler limited. The study of the $b^4\Sigma_g^- \leftarrow a^4\pi_u$ predissociation spectrum was not of interest to us for the sake of the spectroscopy alone since it is already well known. However, because our

spectrometer could generate the photofragment spectrum as a function of time, where the time could be varied from ~1 millisecond to 100's of milliseconds, we could readily measure the lifetime of the $a^4\pi_u$ state—a measurement worth making. We recorded the photofragment spectrum of O_2^+ , generated by electron impact ionization of O_2 , at low resolution ($\sim 1 \text{ cm}^{-1}$) as a function of time. This led us to discover that the decay of the $a^4\pi_u$ state is strongly dependent on its spin component identity.

B. Experimental

The O_2^+ was produced by electron impact ionization of O_2 at 5×10^{-5} torr. The electron energy was ~80 eV. This ionization produces, after a few microseconds, O_2^+ in essentially two electronic states: ~30% in the $a^4\pi_u$ metastable state and ~70% in the $x^2\pi_g$ ground state.^(4c,8) The ions thus produced were passed through a sector magnet mass filter which allowed only O_2^+ to be placed into the RF octapole interaction region. This region was maintained at about 7×10^{-10} torr during the photofragmentation measurements.

The experiment was run in a pulsed mode. Ions were pulsed into the RF octapole trap. After a selected length of time the laser was fired, and then the product ions were sent through the final quadrupole mass filter to be counted by the ion detection system. The counts from this laser sequence were placed into a signal-plus-background (S + B) buffer. This laser sequence was followed by an identical pulse

sequence, except that the laser was not fired. The counts obtained from this no-laser sequence were placed into a "background" (B) buffer. The laser correlated signal was then taken to be $(S + B) - B$. Figure 2 shows the details of the pulse sequence used in this data collection cycle. The RF dumping pulse was used to pulse the RF supplied to the octapole rods off for a short period of time, thus ensuring that the ion trap was free of ions at the start of a new pulse sequence. The data were collected in two modes. In the first mode delay-x (D_x), the amount of time the ions remained in the trap before the laser was fired, was held constant while the laser frequency was varied: thus signal versus laser frequency was measured for a given ion storage time. In the second mode, the laser frequency was held constant while delay-x was varied: photofragment yield as a function of time for a given laser frequency was thus measured. In each mode the O^+ photofragment was detected. Figure 3 shows typical results for a wavelength dependence scan and Figure 4 shows the O^+ yield as a function of time for the indicated wavelengths.

The linewidth of the pulsed dye laser was about 0.4 cm^{-1} and its pulse width was $\sim 8 \text{ nsec}$. The lifetime measurements were carried out using ~ 0.003 watts of time averaged laser power. The repetition rate was 4.2 Hz and the beam diameter 0.4 cm . The laser beam was carefully aligned so that it passed through the spectrometer without striking any metal surfaces: no laser correlated signal was observed when no O_2^+ molecules were in the interaction region. Figure 5 shows the O^+ photofragment signal as a function of laser pulse energy. The lifetime measurements were carried out using pulse energies of $\sim 0.7 \text{ mJ}$.

The best resolution observed in the wavelength scans was $\sim 1 \text{ cm}^{-1}$. The average energy of the trapped ions was $\sim 0.65 \text{ eV}$ with a spread of about 0.3 eV . As discussed in the previous chapter, the initial axial energy of the ions is distributed to the other coordinates producing wide kinetic energy distributions in each coordinate. For O_2^+ at $\sim 0.65 \text{ eV}$ median energy, one might expect a Doppler width of $\sim 0.3 \text{ cm}^{-1}$ at $5000\text{\AA}$. Our laser had a line width of $\sim 0.4 \text{ cm}^{-1}$. Thus, the observed resolution of $\sim 1 \text{ cm}^{-1}$ is in keeping with expectation.

Before continuing, some elaboration is necessary concerning experimental difficulties encountered during the course of the measurements. The first problem, evident in Fig. 4, was the escape of parent ion O_2^+ from the ion trap (see Chap. II). This problem was not very serious since one could easily account for the loss of parent ions when treating the data. Also, as mentioned before, the losses were minimal after about 50 msec of trapping time.

There was however, a more bothersome consequence of the escaping O_2^+ parent ions. Some of these ions were being accelerated into metal surfaces during their "escape", and the resulting ion-surface collision fragmented some of the O_2^+ creating O^+ . A portion of these collisionally produced O^+ ions recoiled back into the ion trap region and were contained by the trap. This interaction was taking place at the ends of the ion guide with the ion mirrors. This was demonstrated by measuring the O_2^+ loss and O^+ appearance as a function of time while a pulse of ions was bouncing back and forth in

the ion guide. Figure 6 shows the abundance of O_2^+ and O^+ in the ion guide as a function of time. The times at which the traveling pulse of ions encounters a mirror are indicated by the arrows. (The vertical scale for each ion is different.) Note that the encounter causes a loss of O_2^+ and at the same time results in the increase of O^+ ions within the ion guide. This increase of O^+ was unexpected and produced signal-to-noise ratios which were much worse than anticipated, especially for long trapping times. Figure 7 shows how this O^+ background increased with time.

C. Results and Discussion

Figure 8 shows the results of scanning the laser wavelength from 4902 to 5025Å in 0.48Å steps with ion trapping times held at 0.1 msec and 100 msec. This wavelength region covers the left hand peak in Fig. 3. Figure 9 shows spectral simulations of the same wavelength region with the time equal to 0.1 msec and 100 msec. The spectra were calculated assuming that the F_2'' and the F_3'' spin components of the $a^4\pi_u$ state decay with a time constant of 6 msec, while the F_1'' and F_4'' components have a 129 msec time constant.

At this point I will briefly describe the two states involved in these photofragment spectra. The upper $b^4\Sigma_g^-$ state, being a state, is a Hund's case (b) state. Each rotational level is split into four components. These four components are labeled as follows:

$$\begin{aligned}
 F_1' &, J' = N' + 3/2 \\
 F_2' &, J' = N' + 1/2 \\
 F_3' &, J' = N' - 1/2 \\
 F_4' &, J' = N' - 3/2
 \end{aligned}$$

where J' is the total angular momentum quantum number and N' is the quantum number for the nuclear angular momentum apart from spin.

The lower $a^4\pi_u$ state is split into four sublevels by the spin-orbit interaction: the four levels are designated as above (e.g., F_1'' , $J'' = N'' + 3/2$). The spin-orbit interaction constant for this state is negative,⁽⁹⁾ thus one has an inverted energy ordering of the F'' components. Using the $^4\pi_\Omega$ designation⁽¹⁰⁾ for pure Hund's case (a) coupling, where $\Omega = \Lambda + \Sigma$ and Λ and Σ are the projections of the orbital and spin angular momenta respectively, one associates F_1'' with $^4\pi_{5/2}$, F_2'' with $^4\pi_{3/2}$, F_3'' with $^4\pi_{1/2}$, and F_4'' with the $^4\pi_{-1/2}$ component. The order written is increasing in energy.

The $O_2^+ a^4\pi_u$ state is characterized as Hund's case(a) for low J'' values. But as the nuclear rotational velocity increases with increasing J'' , the electron spin uncouples from the molecular axis until the state approaches a Hund's case (b) description at high J'' values. For most J'' values an intermediate description must be used to correctly characterize the levels. Figure 10 shows the quartet splitting in the $a^4\pi_u$ state for sets of J'' values. The first set has $J'' = 3-1/2, 4-1/2, 5-1/2, 6-1/2, \text{ and } 7-1/2$. The figure is drawn

with the lowest level of the set equal to zero and the largest value equal to 100. The second set of values plotted has each J'' value of the first set increased by 10, and so forth. Four such sets of J'' values are plotted. Note that for the low J'' value set, the grouping is according to Ω value (Hund's case (a) grouping), while the set with the highest J'' values is tending toward K value grouping (Hund's case (b)), where K is the resultant angular momentum quantum number formed from Λ'' and N'' . Note that this figure indicates that an intermediate Hund's case description is certainly necessary from $J'' = 16-1/2$ to $J'' = 26-1/2$.

The spin component dependence of the lifetime for the $a^4\pi_u$ state of O_2^+ is similar to that found in the Cameron system of CO ,⁽¹¹⁾ where the dependence arises from different spin-orbit mixing of the $A''\pi$ and $a^3\pi$ states. The $A^2\pi_u$ state of O_2^+ is just above the $a^4\pi_u$ state. If this $A^2\pi_u$ state mixes with the $a^4\pi_u$ metastable state via the spin-orbit interaction, then the $a^4\pi_u \rightarrow X^2\pi_g$ transition will have some allowed character.

Kovacs⁽¹²⁾ has shown how the spin-orbit mixing of a $a^4\pi_u$ state and a $A^2\pi_u$ state depends on the Hund's coupling case used to describe the states. The $A^2\pi_u$ state of O_2^+ is found to be a Hund's case (b) state.⁽¹³⁾ As discussed above, the $a^4\pi_u$ state is characterized as Hund's case (a) for low J'' , but transforms into a Hund's case (b) for high J'' values.

According to Kovacs, if the $a^4\pi_u$ state is Hund's case (a) and the $A^2\pi_u$ state is case (b), then only the $\Omega'' = 3/2$ and $1/2$ spin components of the $a^4\pi_u$ state, that is F_2'' and F_3'' , will

mix well with the $A^2\Pi_u$ state. Thus for low J'' values, the F_2'' and F_3'' components have $^2\Pi_u$ character and are able to relax faster to the $X^2\Pi_g$ state. For rotational levels with J'' great enough, the $a^4\Pi_u$ state is Hund's case (b). In this case all the Σ'' components of the $a^4\Pi_u$ state couple with the $A^2\Pi_u$ state, although the $\Sigma'' = 1/2$ and $-1/2$ couple more strongly. Therefore in the high J'' limit all the spin components gain intensity through spin-orbit mixing with the $A^2\Pi_u$ state. Kovacs' treatment suffices in giving a qualitative understanding of the origins of the spin component dependence of the lifetimes.

The $\Delta v = 3$ band of the $b^4\Sigma_g^- \leftarrow a^4\Pi_u$ system is fortuitously placed so that the F_1'' and F_4'' components are fairly easily distinguished from the F_2'' and F_3'' components. This is seen in Fig. 3 where a hole is seen in the middle of the $\Delta v = 3$ peak at $t = 100$ msec because of the absence of the F_2'' and F_3'' spin states. By using the spectra of the $\Delta v = 3$ band taken at delayed times, two wavelengths were chosen at which to perform the lifetime measurements: 4947.0Å, which contains mostly F_1'' intensity and 4967.2Å which has mostly F_2'' and F_3'' intensity. The O^+ photofragment signal, which is proportional to the amount of $a^4\Pi_u$ accessed at the particular wavelength, versus time (corrected for parent ion loss) is shown in Fig. 11. The decay at each wavelength is characteristic of several decay times. The data is complicated by the fact that at each wavelength one produces O^+ signal via direct photodissociation to the repulsive wall of the $f^4\Pi_g$ state (type II transitions in Fig. 1). This signal also has a time dependence.

To get approximate values for the lifetimes of the $F'' = 2$ and 3 and $F'' = 1$ and 4 spin components, I used a very simple model. I assumed that there were only two decay rates: one fast ($F'' = 2$ and 3) and one slow ($F'' = 1$ and 4). Added to this is the wavelength independent (but time dependent) signal from the direct dissociation. To get rid of this unwanted direct dissociation signal, the difference of the two sets of data is taken. The direct dissociation signal, being wavelength independent, vanishes from the picture. A plot of this difference will rise quickly due to the fast decay term and then fall gradually because of the slow decay. Figure 12 is a plot of the difference of the data shown on Fig. 11. The solid line is the curve generated using

$$p(t) = A_1 e^{-t/\tau_1} - A_2 e^{-t/\tau_2}$$

with $\tau_1 = 130$ msec and $\tau_2 = 7$ msec. A_1 and A_2 are population factors.

With the data we have, and using this simple approach, the following lifetimes were obtained: $\tau_1 = 130 \pm 50$ msec at $4967.2 \text{ \AA}$ (the F_2'' and F_3'' spin components) and $\tau_2 = 7 \pm 2$ msec at $4947.0 \text{ \AA}$ (the F_1'' and F_4'' spin components). Keep in mind that these are average values. As illustrated by James for the Cameron band of CO, the lifetime within a given multiplet can vary by an order of magnitude from low J to high J.

D. Conclusion

The laser photofragment spectrum of the $O_2^+ b^4\Sigma_g^- \leftarrow a^4\pi_u$ system from 4902 to 5025Å measured as a function of time indicates that the $^4\pi_{5/2}$ and $^4\pi_{-1/2}$ spin components of the $a^4\pi_u$, metastable state radiatively decay to the $X^2\Sigma_u$ ground state with a time constant of 130 ± 50 msec at 4967.2Å; and similarly the $^4\pi_{3/2}$ and $^4\pi_{1/2}$ spin components decay with a time constant of 7 ± 2 msec at 4947.0Å. This observation is qualitatively in keeping with the interpretation that these lifetimes depend on the amount of spin-orbit mixing of the $a^4\pi_u$ state with the $A^2\pi_u$ state.

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FIGURE CAPTIONS

- Fig. 1. Relevant potential energy curves of O_2^+ .
- Fig. 2. Data collection timing sequence.
- Fig. 3. The photodissociation spectrum of O_2^+ taken at trapping times of 0.1 msec and 100 msec. The data shown has had a constant subtracted from it to remove signal from the direct dissociation process.
- Fig. 4. The O^+ photofragment yield as a function of time.
- Fig. 5. Power dependence of O_2^+ photofragmentation at 5320Å.
- Fig. 6. The number of O_2^+ ions decrease while the number of O^+ ions increase when an ion bunch collides with the octapole trap mirror.
- Fig. 7. The O^+ background in the ion trap as a function of time.
- Fig. 8. The photodissociation spectrum of O_2^+ (the $\Delta v = 3$ peak) taken at trapping times of 0.1 msec and 100 msec. Again the data has a constant subtracted from it.
- Fig. 9. Computer simulation of the data in Fig. 8 calculated using a lifetime of 120 msec for the $4\pi_{5/2}$ and $4\pi_{-1/2}$ spin components and 6 msec for the $4\pi_{3/2}$ and $4\pi_{1/2}$ components.
- Fig. 10. Correlation diagram for the $4\pi_u$ state of O_2^+ showing the transition from a Hund's case (a) to nearly a Hund's case (b) description.
- Fig. 11. The O^+ photofragment yield as a function of time at 4947.0Å and 4967.2Å corrected for parent ion leakage from the trap.

Fig. 12. This figure shows the difference of the data shown in Fig. 11.

The solid curve represents a fit to the data with a long decay constant (τ_1) of 130 msec for the F_1'' and F_2'' spin components and a short decay constant (τ_2) of 7 msec for the F_2'' and F_3'' spin components. The upper and lower dotted curves use $\tau_1 = 180$ msec, $\tau_2 = 5$ msec and $\tau_1 = 80$ msec, $\tau_2 = 9$ msec, respectively.

XBL 7812-13896

Figure 1

XEL 8311-4420

Figure 2

Figure 3

XBL 8311-4415

Figure 4

XBL 8311-4414

Figure 5

Figure 6

XBL 8311-4413

Figure 7

XBL 8311-4412

Figure 8

Figure 9

XBL 8311-4470

Figure 10

XBL 8311-1

XBL 8311-4408

Figure 11

XBL 8311-4469

Figure 12

IV. APPENDIX: DATA ACQUISITION PROGRAM

The program to be listed here is a first version data acquisition/data management program written for the molecular ion spectrometer. It is to be considered in the developmental stage. The program contains oddities, inconsistencies, and some bugs (harmless bugs in the display routine and some timing constraints in the data collection cycles). But I think the program is basically sound and is presented here for reference.

ABBREVIATED MIPDS COMMAND LIST

AB	ACTIVE CHANNEL BRIGHTNESS
AC	ACCUMULATE DATA
AS	ABSOLUTE SCALING
CL	CLEAR DATA BUFFER
CU	CLOCK UNITS
CS	CHANNEL SCALE
DC	DYE LASER CALIBRATION
DI	DISPLAY
BA	BACKGROUND
DA	DATA
EX	EXPAND
PA	PARAMETERS
PN	POWER NORMALIZE

PO	POWER BUFFER
RE	REVERSE
SB	SIGNAL + BACKGROUND BUFFER
SI	SIGNAL (SB-BA)
ER	ENTER RUN NUMBER
EX	EXIT PROGRAM
GA	GAIN OF A2D CONVERTER
LO	LOW
ME	MEDIUM
HI	HIGH
HA	HALT DATA ACCUMULATION
HE	HEADER
IW	INTEGRATE WINDOW
KM	KEY MODE INTERRUPT
LA	LASER
LOCK	LOCK PROGRAM CONDITIONS
MA	MAGNET
MC	MCS UNIT
BA	PLACE DATA IN BACKGROUND BUFFER
HA	HALT DATA COLLECTION
IN	INITIALIZE
OF	OFF
SB	PLACE DATA IN SIGNAL+BACK BUFFER
ST	START DATA COLLECTION
ZZ	RELOAD COUNTERS

NC	NUMBER OF DATA CYCLES
ND	NEW DATE
NO	NUMBER OF CHANNELS
NS	NUMBER OF SCANS (SWEEPS)
PR	PRINTER COMMANDS
DA	DATA
HE	HEADER
FU	FULL INFO.
ST	STATUS
PB	PLOT BOX
PC	PLOT CHANNEL NUMBERS
PH	PLOT HORIZONTAL LINE
PL	PLOT FULL FIGURE
PM	PLOT MOVE
PP	PLOT POINTS
PV	PLOT VERTICAL LINE
QU	QUADRUPOLE
QP	QUADRUPOLE PEAKS OPTION
RE	RESET DEVICE
RD	READ DISK
RR	RECALL RUN NUMBER
RT	RE-TAKE MODE/ACCUME MODE
SA	SCALE ADVANCE
SC	SCAN DEVICE
LA	LASER

	MA	MAGNET
	MC	MCS UNIT
-	NO	"NOTHING"
	QU	QUADRUPOLE
	TR	TRAP
SD		SCALE DOWN
SE		SET DEVICE
	LA	LASER
	MA	MAGNET
	QU	QUADRUPOLE
	TR	TRAP
SF		SCROLL FASTER
SL		SCROLL LEFT
SM		SMOOTH DISPLAYED DATA
SP		SCANNING PROCEDURE
	BI	BIDIRECTIONAL
	UN	UNIDIRECTIONAL
SR		SCROLL RIGHT
SS		SCROLL SLOWER
ST		START (PERFORMS HA, RE, CL, AC SEQUENCE)
SZ		SET ZERO FOR DISPLAY
TR		TRAP
TY		TYPE TO CONSOLE DEVICE
	DA	DATA
	HE	HEADER

ST	STATUS
UP	UPDATE DISPLAY
US	UPDATE SET (CHANNELS BETWEEN UPDATES)
WA	WINDOW APERTURE
WB	WINDOW BRIGHTNESS
WD	WRITE TO DISK
WI	WINDOW INITIAL CHANNEL
WL	WINDOW LEFT
WR	WINDOW RIGHT
WB	WINDOW SCALE

```

      .TITLE MACHINE PROGRAM
;
;THE TANDEM MASS SPECTROMETER
;
;
;      SYSTEM MACROS
;      .NCALL .TTYOUT,.TTYIN,.TTINR,.PRINT,.DATE,.INTEN
;
;      GLDLIB LIBRARY GLOBALS
;
;      .GLOBL READ,ASCBIN,BINASC,DPBASC,DECOU,DCOUT2
;      .GLOBL LPOUT,LPRINT,LPCRLF,LPCO2,LPDECO
;      .GLOBL REGSAV,REGRES,DYECAL,DYELAS,DYASET
;      .GLOBL MOTOR1,MOTOR2,CRLF,QUAD,WRDISK,REDISK
;      .GLOBL LOWORD,HIWORD,A2DAMP,A2DGNS,MAGNET,PLUTTR
;
;      SYSTEM GLOBALS
;
;      .GLOBL JMUL,JDIV,JCMP,R50ASC
;
;      GLOBAL LABELS DEFINED IN THIS MODULE
;
;      .GLOBL LIST,ARG1,ARG2,RESULT,I0BUF,DAT0BUF,DAT0LD
;      .GLOBL SCCODE,LONWAV,SHOWAV,SETWAV,WAVINC,CALWAV
;      .GLOBL NSTEP,NCHAN,MDAC,MDAC1,MRES,MDAC2,MASBUF
;      .GLOBL SCFUNC,QP,CLEAR,BUFINIT
;      .GLOBL MADAC,MADAC1,MADAC2,MARES,DICHNS,DISTR
;      .GLOBL STCHAN,PLCTRL,PLMOV,PLLINE,PLCHAR,MCHSUB
;      .GLOBL RUN,YMAX,UPDATE
;
KWCSR=170420      ;CONTROL STATUS REGISTER FOR KWV11
KWBPR=170422      ;CLOCK BUFFER/PRES/ REGISTER(KWV11)
KWVEC=350         ;CLOCK INTERRUPT VECTOR
MDAC=170440       ;AAV11 FOUR CHANNEL A/D CONVERTER
MADAC=170442
XDAC=170444
YDAC=170446
ADCSR=170450      ;A/D CONTRIL-STATUS REGISTER(D12771)
XYBUF=170452      ;X/Y BUFFER
DMAPCR=170454     ;DMA POINT COUNT REGISTER
DMACAR=170456     ;DMA CURRENT ADDRESS REGISTER
DMAVEC=310        ;DMA INTERRUPT VECTOR
DATA0=166000      ;CMACAC CONTROLLER ADDRESSES
DATA1=166002
LAMLO=166004
LAMHI=166006
STATU1=166010
STATU2=166012
SCALO=167040      ;SCALER 0 (BIN 17)
SCAL1=167042      ;SCALER 1
SCAL2=167044      ;SCALER 2
SCAL3=167046      ;SCALER 3
A2DCON=167100     ;A/D CONVERTER (BIN 18)
A2DVEC=510        ;A/D CONVERTER INTERRUPT VECTOR

```

```

DMPRI=0
MCSA0=167200
MCSA1=167202
MCSA2=167204
MCSA3=167206
MCSA4=167210
MCSA5=167212
MCSA6=167214
MCSNVC=520
JSW=44
;
;
;
;
MCHSUB: MOV      #DATAIN,A2DVEC      ;SET VECTORS
MOV      #200,A2DVEC+2
MOV      #CLKINT,KWVEC             ;CLOCK VECTOR
MOV      #200,KWVEC+2
MOV      #DMAINT,DMAVEC           ;POINT PLOTTER VECTOR
MOV      #200,DMAVEC+2
MOV      #MCSINT,MCSNVC          ;MCS VECTOR
MOV      #200,MCSNVC+2
MOV      #1,NSCAN+2              ;DEFAULT VALUE
MOV      #50,UPDATE+2            ;UPDATE PERIOD
MOV      #1,MARES                ;DEFAULT STEP SIZE FOR MAGNET
MOV      #1,MARES+2              ;COPY
MOV      #340,MDAC1              ;DEFAULT LOW CURRENT FOR MAGNET
MOV      #10,MDAC1+2             ;COPY
MOV      #340,MDAC               ;SET MAGNET LOW CURRENT
MOV      #20,MDAC2               ;DEFAULT HIGH CURRENT VALUE
MOV      #1,MRES                 ;DEFAULT STEP SIZE FOR QUAD
MOV      #1,MRES+2               ;COPY
MOV      #40,MDAC1              ;DEFAULT LOW MASS FOR QUAD
MOV      #2,MDAC1+2              ;COPY
MOV      #40,MDAC               ;SET QUAD LOW MASS
MOV      #4,MDAC2                ;DEFAULT HIGH MASS FOR QUAD
MOV      #1,NSTEP                ;DEFAULT STEP SIZE FOR LASER
MOV      #1,DACYCL              ;ONE DATA CYCLE PER CHANNEL
MOV      #1,DACYCL+2            ;SAVE A COPY
MOV      #1,DELINC              ;1MSEC DELAY INCREMENT
MOV      #1,DELOFF              ;1MSEC DELAY OFFSET
MOV      #-1,KWBPR               ;LOAD CLOCK BUFFER/RESET REG.
MOV      #200,NCHAN              ;200 CHANNELS BY DEFAULT
MOV      #*UN,SCTYPE             ;UNIDIRECTIONAL SCANNING
MOV      #*NO,SCFUNC            ;*NOTHING*FUNCTION BEING SCANNED
MOV      #*NO,SCCODE            ;*NOTHING* CODE WORD
MOV      #*SI,DIFUNC            ;SIGNAL BEING DISPLAYED
MOV      #*SI,DIFUNC+2          ;SAVE CODE
MOV      #*SI,DICODE            ;LOAD DISPLAY CODE
MOV      #*SI,DICODE+2          ;SAVE DICODE
MOV      #*LO,A2DGNS            ;A2D CONVERTER GAIN LOW(X1)
MOV      #0,DISFLG              ;AUTO-SCALE
MOV      #0,FLGDIS              ;NORMAL--NOT POWER NORM.
MOV      #0,ZERFLO              ;ZERO SHIFT

```



```

100:   CMP      #'MC,SCCODE           ;IS MCS ACTIVE?
      BNE     TTIN
      BIT     #1,OVF
      BGT     CNTOVF
      BIT     #2,OVF
      BGT     RAMOVF
      BIT     #4,OVF
      BGT     ENDRUN
      BR      TTIN
CNTOVF: .PRINT  #M82                 ;COUNTER OVER FLOW
      BIC     #1,OVF
      BR      DISPLA
RAMOVF: .PRINT  #M83                 ;RAM OVER FLOW
      BIC     #2,OVF
      BR      DISPLA
ENDRUN: BIC     #4,OVF               ;RUN COMPLETED
      BIC     #1,RUNFLG             ;GENERATE MESSAGE
      INC     RUN                   ;RUNS FOR THE DAY
      MOV     RUN,RUN+2             ;SAVE COPY
      BR      DISPLA
TTIN:   MOV     #IOBUF,R1           ;STARTING ADDRESS OF I/O BUFFER IN R
1
200:   .TTINR
      BCS     DISPLA               ;IS THERE A CHARACTER?
      MOVB    R0,(R1)+             ;BRANCH TO DISPLA IF NONE
      CMPB    #12,R0              ;PLACE CHARACTER IN I/O BUFFER
      BNE     201                 ;WAS IT A LINE FEED?
      CMP     DICHNS,#11.          ;IF NO,GET MORE
      BPL     OPTION              ;HALT DMA IF TOO FEW CHANNELS
      CALL    DISHLT
;
;
;THIS OPTION SEARCHES FOR THE DESIRED OPTION BY COMPARING THE
;COMMAND ENTERED WITH THE OPTION LIST
;
OPTION: CMP     #'AC,IOBUF          ;ACCUMULATE DATA
      BNE     10
      MOV     #1,ACCFLG
      BIS     #2,RUNFLG            ;RUN IN PROGRESS
      JMP     OPTOUT              ;LEAVE
100:   CMP     #'DC,IOBUF          ;DYE CALIBRATION
      BNE     20
      CMP     LOCKKEY,LOCKKEY+2    ;ARE PROGRAM VARIABLES LOCKED?
      BEQ     1001$              ;BRANCH IF UNLOCKED
      JMP     OPTLOC              ;LOCKED! LEAVE WITH MESSAGE
1001$: CALL    DYECCAL
      JMP     OPTOUT              ;LEAVE
200:   CMP     #'DI,IOBUF          ;DISPLAY OPTION
      BNE     30
      CALL    DISOPT
      JMP     OPTOUT              ;LEAVE
300:   CMP     #'LA,IOBUF          ;DYE LASER
      BNE     40
      CMP     LOCKKEY,LOCKKEY+2    ;ARE PROGRAM VARIABLES LOCKED?
      BEQ     1003$              ;BRANCH IF UNLOCKED

```

```

1003: JMP OPTLOC ;LOCKED! LEAVE WITH MESSAGE
CALL DISHLT ;HALT DISPLA
CALL DYELAS
CMP #'LA,SCCODE ;IS IT BEING SCANNED?
BNE 1004
CALL BUFINIT
CALL CLEAR ;CLEAR DATA BUFFER
CLR UPDATE
1004: JMP OPTOUT ;LEAVE
4: CMP #'EX,IOBUF ;EXIT MACRO PROGRAM
BNE 5
.PRINT #'M71 ;EXIT PROGRAM!!
.PRINT #'M48 ;ARE YOU SURE?
CALL READ ;YES OR NO
CMPB #'Y,IOBUF
BEQ 1006
JMP OPTOUT
1006: JMP EXIT ;RETURN TO FORTRAN CALLER
5: MOV #'SA,YFUNC ;SCALE UP
CMP #'SA,IOBUF
BEQ 1005
CMP #'SU,IOBUF
BEQ 1005
MOV #'SD,YFUNC ;SCALE DOWN
CMP #'SD,IOBUF
BEQ 1005
MOV #'AS,YFUNC ;AUTO-SCALE
CMP #'AS,IOBUF
BEQ 1005
MOV #'CS,YFUNC ;CHANNEL SCALE
CMP #'CS,IOBUF
BEQ 1005
MOV #'WS,YFUNC ;WINDOW SCALE
CMP #'WS,IOBUF
BEQ 1005
BR 6
1005: CALL YAXIS ;Y-AXIS SCALING
JMP OPTOUT ;LEAVE
6: CMP #'HA,IOBUF ;HALT DATA TAKING
BNE 7
CLR ACCFLG
JMP OPTOUT ;LEAVE
7: CMP #'NA,IOBUF ;SCAN THE SECTOR MAGNET
BNE 8
CALL DISHLT ;HALT DISPLA
CALL MAGNET
JMP OPTOUT ;LEAVE
8: CMP #'NS,IOBUF ;NUMBER OF SCANS DESIRED
BNE 9
CALL NOSCHS ;SET NUMBER OF SCANS TO BE MADE
JMP OPTOUT ;LEAVE
9: CMP #'IW,IOBUF ;INTEGRATE WINDOW?
BNE 10
CALL IW
JMP OPTOUT

```

10%:	CMP	#*QU,IOBUF	IQUADRUPOLE
	BNE	11%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1010%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1010%:	CALL	DISHLT	#HALT DISPLA
	CALL	QUAD	
	JMP	OPTOUT	#LEAVE
11%:	CMP	#*RD,IOBUF	#READ THE DISK
	BNE	12%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1011%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1011%:	CALL	RDISK	#READ A DATA FILE
	JMP	OPTOUT	#LEAVE
12%:	CMP	#*RE,IOBUF	#RESET THE DEVICE BEING SCANNED
	BNE	13%	
	CALL	RESQUE	
	JMP	OPTOUT	#LEAVE
13%:	CMP	#*SC,IOBUF	#SCAN DEVICE
	BNE	14%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1013%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1013%:	CALL	SC	
	JMP	OPTOUT	#LEAVE
14%:	CMP	#*GA,IOBUF	#SET GAIN OF A2D CONVERTER?
	BNE	15%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1014%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1014%:	CALL	A2DAMP	
	JMP	OPTOUT	#LEAVE
15%:	CMP	#*TR,IOBUF	#SC TRAP
	BNE	16%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1015%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1015%:	CALL	TRAP	
	JMP	OPTOUT	#LEAVE
16%:	CMP	#*WD,IOBUF	#WRITE TO DISK
	BNE	17%	
	CALL	WDISK	
	JMP	OPTOUT	#LEAVE
17%:	CMP	#*CL,IOBUF	#CLEAR...INIT
	BNE	18%	
	CALL	CLRQUE	
	CLR	UPDATE	
	JMP	OPTOUT	#LEAVE
18%:	CMP	#*SF,IOBUF	#CHANGE METHOD OF SCANNING?
	BNE	19%	
	CMP	LOCKEY,LOCKEY+2	#ARE PROGRAM VARIABLES LOCKED?
	BEQ	1018%	#BRANCH IF UNLOCKED
	JMP	OPTLOC	#LOCKED! LEAVE WITH MESSAGE
1018%:	CALL	SCNPRO	

```

190:    JMP      OPTOUT      ;LEAVE
      CMP     #'UP,IOBUF  ;UPDATE?
      BNE     200
      CLR     UPDATE
      JMP     OPTOUT      ;LEAVE
200:    CMP     #'SM,IOBUF  ;SMOOTH DISPLAYED DATA?
      BNE     210
      CALL    SMOOTH      ;GET INPUT
      JMP     OPTOUT      ;LEAVE
210:    CMP     #'SR,IOBUF  ;SCROLL WINDOW RIGHT?
      BNE     220
      MOV     #1,SLRFLG
      CALL    SLR
      JMP     OPTOUT
220:    CMP     #'SL,IOBUF  ;SCROLL WINDOW LEFT?
      BNE     230
      MOV     #-1,SLRFLG
      CALL    SLR
      JMP     OPTOUT
230:    CMP     #'NO,IOBUF  ;CHANGE SCANNING CONDITION?
      BNE     240
      CMP     LOCKEY,LOCKEY+2 ;ARE PROGRAM VARIABLES LOCKED?
      BEQ     10220       ;BRANCH IF UNLOCKED
      JMP     OPTLOC      ;LOCKED! LEAVE WITH MESSAGE
10220:  CALL    DISHLT     ;HALT DISPLA
      CALL    NOTHN
10230:  JMP     OPTOUT      ;LEAVE
240:    CMP     #'IN,IOBUF  ;START PULSE SEQUENCE?
      BNE     250
      .PRINT  #M55        ;PULSE SEQUENCE INIT.
      .PRINT  #M48        ;ARE YOU SURE?
      CALL    READ        ;YES OR NO
      CMPB    #'Y,IOBUF
      BEQ     10240
      JMP     OPTOUT
10240:  MOV     #1,R1
      CALL    MOTOR2      ;SEND ONE PULSE
      JMP     OPTOUT      ;LEAVE
250:    CMP     #'PR,IOBUF  ;PRINT OPTIONS
      BNE     260
      CALL    PR
      JMP     OPTOUT      ;LEAVE
260:    CMP     #'SF,IOBUF  ;SCROLL FASTER
      BNE     270
      CALL    SF
      JMP     OPTOUT
270:    CMP     #'SS,IOBUF  ;SCROLL SLOWER
      BNE     280
      CALL    SS
      JMP     OPTOUT
280:    CMP     #'TY,IOBUF  ;TYPE TO CONSOLE
      BNE     300
      CALL    TY
      JMP     OPTOUT      ;LEAVE
300:    CMP     #'NC,IOBUF  ;SET NUMBER OF DATA CYCLES PER CHANN

```

```

EL?      BNE      31$
          CMP      LOCKEY,LOCKEY+2
          BEQ      1030$
          JMP      OPTLOC
1030$:    CALL     NOCYCL
          JMP      OPTOUT
31$:      CMP      $'FU,IOBUF
          BNE      32$
          CMP      $'CK,IOBUF+2
          BNE      32$
          .PRINT   $M44
          JMP      OPTOUT
32$:      CMP      $'LO,IOBUF
          BNE      33$
          CMP      $'CK,IOBUF+2
          BNE      33$
          MOV      $0,LOCKEY
          .PRINT   $M52
          JMP      OPTOUT
33$:      CMP      LOCKEY+2,IOBUF
          BNE      34$
          MOV      IOBUF,LOCKEY
          .PRINT   $M53
          JMP      OPTOUT
34$:      CMP      $'HE,IOBUF
          BNE      35$
          CALL     HEADER
          JMP      OPTOUT
35$:      CMP      $'UP,IOBUF
          BNE      36$
          CMPB     $'Q,SCCODE
          BNE      36$
          MOV      $'QP,SCCODE
          CALL     DISHLT
          CALL     QUAD
          JMP      OPTOUT
36$:      CMP      $'MC,IOBUF
          BNE      37$
          CMP      LOCKEY,LOCKEY+2
          BEQ      360$
          JMP      OPTLOC
360$:     CALL     MCS
          JMP      OPTOUT
37$:      MOV      $WL,DISCOM
          CMP      $'WL,IOBUF
          BEQ      38$
          MOV      $WR,DISCOM
          CMP      $'WR,IOBUF
          BEQ      38$
          MOV      $WI,DISCOM
          CMP      $'WI,IOBUF
          BEQ      38$
          MOV      $WA,DISCOM
          CMP      $'WA,IOBUF

```

#ARE PROGRAM VARIABLES LOCKED?
 #BRANCH IF UNLOCKED
 #LOCKED! LEAVE WITH MESSAGE
 #LEAVE
 #FOUL LANGUAGE USAGE?
 #WATCH YOUR LANGUAGE!!
 #LEAVE
 #LOCK MACHINE CONDITION?
 #LOCK IT!
 #'LOCKED' MESSAGE
 #LEAVE
 #UNLOCK PROGRAM VARIABLES?
 #ENTER KEY
 #'UNLOCKED' MESSAGE
 #LEAVE
 #ENTER HEADER?
 #LEAVE
 #SCAN FROM PEAK TO PEAK?
 #IS THE FIRST LETTER A 'Q'?
 #BRANCH IF NO
 #CODE FOR PEAK TO PEAK SCANNING
 #HALT DISPLAY
 #MCS UNIT
 #ARE PROGRAM VARIABLES LOCKED?
 #BRANCH IF UNLOCKED
 #LOCKED! LEAVE WITH MESSAGE
 #LEAVE
 #ENTER COMMAND CODE
 #SHIFT WINDOW LEFT?
 #WINDOW SHIFT RIGHT
 #
 #DEFINE INITIAL WINDOW CHAN.
 #
 #DEFINE WINDOW APERTURE

	BEQ	38%	
	MOV	#WB,DISCOM	
	CMP	#*WB,I0BUF	#WINDOW BRIGHTNESS
	BEQ	38%	
	MOV	#AB,DISCOM	#ACTIVE CHAN. BRT.
	CMP	#*AB,I0BUF	
	BNE	39%	-
38%:	CALL	DISDAT	
	JMP	OPTOUT	
39%:	CMP	#*DH,I0BUF	#DISPLAY(DMA) HALT?
	BNE	40%	
	CALL	DISHLT	
	JMP	OPTOUT	
40%:	CMP	#*PL,I0BUF	#FULL PLOT?
	BEQ	41%	
	CMP	#*FP,I0BUF	#PLOT POINTS ONLY?
	BNE	42%	
41%:	CALL	PLOT	
	JMP	OPTOUT	
42%:	CMP	#*PC,I0BUF	#PLOT CHANNELS ONLY?
	BNE	43%	
	CALL	PLOTPC	
	JMP	OPTOUT	
43%:	CMP	#*PM,I0BUF	#MOVE PLOT
	BNE	44%	
	CALL	PLOTPH	
	JMP	OPTOUT	
44%:	CMP	#*PH,I0BUF	#PLOT HORIZONTAL LINE?
	BNE	45%	
	CALL	PLOTPH	
	JMP	OPTOUT	
45%:	CMP	#*PV,I0BUF	#PLOT VERTICAL LINE?
	BNE	46%	
	CALL	PLOTPV	
	JMP	OPTOUT	
46%:	CMP	#*PB,I0BUF	#DRAW BOX ONLY
	BNE	47%	
	CALL	PLOTIT	
	JMP	OPTOUT	
47%:	CMP	#*ND,I0BUF	#NEW DATE?
	BNE	48%	
	.DATE		
	MOV	RO,DATE	#SAVE
	CALL	DATES	#DECODE
	JMP	OPTOUT	
48%:	CMP	#*ER,I0BUF	#SET RUN NUMBER?
	BNE	49%	
	CALL	ER	
	JMP	OPTOUT	
49%:	CMP	#*RR,I0BUF	#RECALL PRESENT RUN #
	BNE	50%	
	MOV	RUN+2,RUN	
	JMP	OPTOUT	
50%:	CMP	#*US,I0BUF	#UPDATE SCALE
	BNE	51%	

```

CALL      US
51%:      JMP      OPTOUT
        CMP      #'SZ,I0BUF      ;SHIFT ZERO?
        BNE      52%
        CALL     SZ              ;SHIFT ZERO OF DISPLAY
52%:      JMP      OPTOUT
        CMP      #'ST,I0BUF      ;AUTO RESTART
        BNE      54%
        CMP      LOCKEY,LOCKEY+2 ;LOCKED?
        BEQ      53%
        JMP      OPTLOC          ;LOCKED!
53%:      CLR      ACCFLG        ;HALT
        CALL     RESET
        CALL     CLEAR
        CLR      UPDATE
        MOV      #1,ACCFLG       ;START ACCUM.
        JMP      OPTOUT
54%:      CMP      #'CU,I0BUF      ;CLOCK UNITS
        BNE      55%
        CALL     CU
55%:      JMP      OPTOUT
        CMP      #'RT,I0BUF      ;RE-TAKE MODE?
        BNE      56%
        CMP      LOCKEY,LOCKEY+2 ;LOCKED?
        BEQ      550%
        JMP      OPTLOC          ;OPTION LOCKED!
550%:     TST      RETAKE
        BEQ      555%
        CLR      RETAKE
        .PRINT    #M77           ;ACCUM. MODE
        JMP      OPTOUT
555%:     INC      RETAKE
        .PRINT    #M76           ;RE-TAKE MODE MSG.
        JMP      OPTOUT
56%:      CMP      #'KM,I0BUF      ;KEY MODE
        BNE      59%
        CALL     KM
59%:      JMP      OPTOUT
        CMP      #'SE,I0BUF      ;SET DEVICE
        BNE      60%
        CMP      LOCKEY,LOCKEY+2 ;ARE PROGRAM VARIABLES LOCKED?
        BEQ      590%            ;BRANCH IF UNLOCKED
        JMP      OPTLOC          ;LOCKED! LEAVE WITH MESSAGE
590%:     CALL     SE
        JMP      OPTOUT          ;LEAVE
60%:      .PRINT    #M51          ;NONEXISTENT OPTION
        JMP      OPTOUT          ;LEAVE
OPTLOC:   .PRINT    #M50          ;OPTION LOCKED MESSAGE
OPTOUT:   CALL     CRLF
        MOV      #'>,R0
        .TTYOUT
        JMP      DISPLA
;
;
;

```



```

;      THIS IS THE INTERRUPT SERVICE ROUTINE SECTION
;
;
DATAIN: MOV      R1,R1DATA      ;SAVE R1
        MOV      R4,R4DATA      ;2 R4
        CMP      #1,ACCFLG      ;ACCUMULATE??
        BEQ      1%             ;BRANCH IF YES
        JMP      DATOUT         ;DON'T ACCUMULATE!!!
1%:     MOVWB    #1,0*166040     ;READ MOTOR1 STATUS WORD
        BIT      #1,DATALO      ;IS MOTOR1 LAM SET?
        BNE      5%            ;BRANCH IF NOT BUSY
        JMP      DATOUT         ;BUSY--BRANCH OUT
5%:     CMP      0ACYCL,#1       ;CYCLE COUNTDOWN OVER?
        BLE      8%            ;BRANCH IF YES
        DEC      DACYCL         ;DECREMENT CYCLE COUNTER
        MOVWB    #0,A2DCON      ;SET LAM DOWN
        JMP      CYCOUT         ;NO DATA READ
8%:     MOV      DACYCL+2,DACYCL ;RE-LOAD CYCLE COUNTER
        TST      UPDATE        ;IF NOT ZERO,DEC. UPDATE
        BEQ      9%            ;
        DEC      UPDATE
9%:     MOV      SBBUF,R4        ;S+B BUFFER POINTER TO R4
        ADD      BUFOFF,R4      ;ADD OFFSET TO THE POINTER
        MOVWB    #0,SCALO       ;READ SCALER ZERO
        MOVWB    #2,SCALO
        ADD      DATALO,(R4)+    ;ADD DATA VALUE
        ADC      (R4)
        ADD      DATAHI,(R4)
        MOV      BABUF,R4      ;PLACE BAC-GRD POINTER INTO R4
        ADD      BUFOFF,R4      ;ADD IN BUFFER OFFSET
        MOVWB    #0,SCAL2       ;READ SCALER TWO
        MOVWB    #2,SCAL2
        ADD      DATALO,(R4)+    ;ADD VALUE TO DATA
        ADC      (R4)
        ADD      DATAHI,(R4)
        MOV      POBUF,R4      ;PLACE POWER BUF. POINTER IN R4
        ADD      BUFOFF,R4      ;ADD BUFFER OFFSET
        MOVWB    #0,A2DCON      ;READ A-2-D CONVERTER,CLEAR LAM
        ADD      DATALO,(R4)+    ;ADD VALUE TO BUFFER
        ADC      (R4)
        CMP      DIRFLG,#1      ;SCANNING WHICH WAY?
        BNE      30%
        CMP      LCHAN,BUFOFF   ;AT LAST CHANNEL YET?
        BNE      20%           ;BRANCH IF NO
        CMP      #*BI,SCITYPE    ;BIDIRECTIONAL SCANNING??
        BNE      10%           ;BRANCH IF NO
        MOV      #-1,DIRFLG
        JMP      CYCOUT
10%:    CLR      DIRFLG
        CLR      BUFOFF         ;SET BUFFER OFFSET TO ZERO
        CLR      UPDATE        ;UPDATE DISPLAY
        INC      NSCAN          ;KEEP TRACK OF NUMBER OF SCANS COMPL
ETEDD:  CMP      NSCAN,NSCAN+2    ;FINISHED YET?
        BMI      15%           ;BRANCH IF NO

```

```

        CLR      ACCFLG      ;STOP ACCUMULATING DATA
        CLR      RUNFLG      ;MESSAGE FLAG
        INC      RUN         ;NUMBER OF RUNS FOR THE DAY
        MOV      RUN,RUN+2    ;COPY
15%:    CALL     @SCFUNC      ;CALL SCAN FUNCTION
        JMP      CYCOUT       ;LEAVE
20%:    ADD      #4,BUFOFF    ;BUF OFFSET TO NEXT CHANNEL
        CALL     @SCFUNC
        JMP      CYCOUT
30%:    CMP      BUFOFF,#0     ;FIRST DATA CHANNEL?
        BNE      40%          ;BRANCH IF NO
        CLR      UPDATE      ;UPDATE DISPLAY
        INC      NSCAN        ;INCREMENT SCAN COUNTER
        CMP      NSCAN,NSCAN+2 ;TAKE MORE SCANS?
        BMI      35%          ;BRANCH IF NO
        CLR      ACCFLG      ;STOP ACCUMULATING DATA!
        CLR      RUNFLG      ;RUN COMPLETED MESSAGE FLAG
        INC      RUN         ;NUMBER OF RUNS COMPLETED
        MOV      RUN,RUN+2
35%:    MOV      #1,DIRFLG    ;GO FORWARD NOW
        JMP      CYCOUT       ;LEAVE
40%:    SUB      #4,BUFOFF
50%:    CALL     @SCFUNC      ;GO TO FUNCTION
        BR       CYCOUT
;
DATOUT: MOVB     #9.,SCAL0    ;CLEAR SCALER ZERO
        MOVB     #9.,SCAL2    ;CLEAR SCALER TWO
        MOVB     #0,A2DCON    ;LAM DOWN
CYCOUT: BIS      #300,STATU1   ;SET INE AND REIN
        MOV      R1DATA,R1    ;UNSAVE R1
        MOV      R4DATA,R4    ;$ R4
        BIT      #1,SCMODE    ;WHICH MODE?
        BNE      10%
        RTI
10%:    RETURN                ;RETURN FROM INTERRUPT
;                                ;SUBROUTINE RETURN
;
;DISPLAY DMA INTERRUPT SERVICE ROUTINE
;
;
DMAINT: MOV      R0,RODMA      ;SAVE REGS
        MOV      R1,R1DMA
        MOV      R2,R2DMA
        MOV      R3,R3DMA
        .INTEN    DMAPRI
        MOV      RODMA,R0     ;UNSAVE
        MOV      R1DMA,R1
        MOV      R2DMA,R2
        MOV      R3DMA,R3
        TST      EXPFLG       ;EXPAND DISPLAY?
        BEQ      10%          ;BRANCH IF YES
        DEC      WINFLG       ;WINDOW BRIGHTNESS
        BGE      10%          ;BRANCH IF YES
        DEC      ACTIVE       ;ACTIVE CHAN. BR'NESS
        BGE      20%
        MOV      DIRUF,DMACAR ;LOAD DMA REGISTERS

```

```

MOV     NCHAN,DMAPCR
NEG     DMAPCR
MOV     ACTIVE+2,ACTIVE
MOV     WINBRT,WINFLG
BR      DMAOUT
10%:    MOV     DISWIN,DMACR
MOV     WINSIZ,DMAPCR
BR      30%
20%:    MOV     BUFOFF,DMACR
ADD     DIBUF,DMACR
MOV     #1,DMAPCR
30%:    NEG     DMAPCR
DMAOUT: TST     DMAHLT
        BNE    10%
        CLR    ADCSR
        RTS    PC
10%:    BIS     #102,ADCSR
        BIS     #1,ADCSR
        RTS    PC
;
;
CLKINT: BIS     #20000,KWCSR
        RTI
;
;MCS INTERRUPT SERVICE ROUTINE
;
MCSINT: MOV     R1,K1DATA
MOV     R4,R4DATA
BIC     #1,STATU1
MOV     MCSA2,OVL
BIT     #3,OVL
BEQ     1%
JMP     MCSOUT
1%:     MOV     MCSBUF,R1
MOV     #377,R4
2%:     ADD     ##MCSA0,(R1)+
        ADC     (R1)+
        SOB    R4,2%
        CLR    UPDATE
        BIS     #1,STATU1
        MOVB   #9,MCSA0
        INC    NSCAN
        MOV     #100,R4
3%:     SOB    R4,3%
        BIT     #4,OVL
        BNE    MCSOUT
        MOVB   #26,MCSA6
MCSOUT: MOV     R1DATA,R1
MOV     R4DATA,R4
        BIS     #300,STATU1
        BIT     #1,SCMODE
        BNE    10%
        RTI
;
;2'S COMPLEMENT
;ACTIVE CHAN. BRT.
;DISPLAY WINDOW VALUES
-
;ACTIVE CHAN. POSITION
;2'S COMPLEMENT
;HALT DMA?
;BR IF NO
;RETURN FROM INTERRUPT
;START DMA
;RETURN FROM INTERRUPT
;RETURN FROM INTERRUPT
;SAVE REGS
;CLEAR DII BIT
;READ OVL AND STOPRUN
;CHECK FOR OVL
;255 CANNELS
;TRANSFER DATA TO LSI-11 DATA BUFFER
;UPDATE DISPLAY
;SET DII BIT
;F9A0 CLEAR RAM
;NUMBER OF "SWEEPS"
;WAIT LOOP FOR RAM CLEAR
;? IS RUN FINISHED
;YES, THEN RETURN
;NO, SET ACCUMULATE
;SET INE,REIN
;WHICH MODE?
;RETURN FROM INTERRUPT

```



```

      ADD      DELINC,DELTOT
      MOV      DELTOT,KWBPR
      NEG      KWBPR
      RETURN
10$:  CMP      DIRFLG,#0          ;RESET THE ION TRAP?
      BEQ      20$
      SUB      DELINC,DELTOT    ;BACKWARDS
      MOV      DELTOT,KWBPR
      NEG      KWBPR
      RETURN
20$:  MOV      DELOFF,DELTOT    ;RESET
      MOV      DELTOT,KWBPR
      NEG      KWBPR
      MOV      #1,DIRFLG      ;SET FOR FORWARD SCANNING
      RETURN
;
;
ND$:  CMP      DIRFLG,#1        ;NO OPERATION!!
      BNE      10$             ;SCAN FORWARD
      RETURN
10$:  CMP      DIRFLG,#0        ;RESET THE SCAN POINTERS?
      BEQ      20$
      RETURN
20$:  MOV      #1,DIRFLG        ;SET SCAN DIRECTION FLAG:FORWARD
      RETURN
;
;
QP$:  MOV      BUFOFF,R4        ;BUFFER OFFSET TO R4
      ASR      R4              ;DIVIDE BY TWO
      ADD      #MASBUF,R4      ;R4 HAS MASS POINTER
      CMP      DIRFLG,#1        ;QUADRUPOLE--SCANNING WHICH WAY?
      BNE      10$
      MOV      (R4),MDAC        ;SET QUADRUPOLE TO MASS PEAK
      RETURN
10$:  CMP      DIRFLG,#0        ;RESET THE QUADRUPOLE?
      BEQ      20$
      MOV      (R4),MDAC        ;SET QUADRUPOLE TO MASS PEAK
      RETURN
20$:  MOV      (R4),MDAC        ;RESET QUAD
      MOV      #1,DIRFLG
      RETURN
;
;
;END PAGE ONE

```

```

;PAGE TWO
;
;
;SUBROUTINE TO HALT DMA DRIVEN DISPLAY
;
DISHLT: CLR      DMAHLT           ;HALT DMA
10%:  BIT      #100,ADCSR        ;HALTED?
      BNE     10%              ;LOOP TILL YES
      RETURN
;
;
;SUBROUTINE "BUFINIT" GENERATES DATA BUFFER ADDRESSES GIVEN THE
;NUMBER OF DATA CHANNELS IN USE.
;
BUFINIT:MOV      R1,R1BUF        ;SAVE REGISTERS
      MOV      R2,R2BUF
      MOV      NCHAN,R1         ;R1 GETS # OF CHANNELS
      MOV      NCHAN,D1CHNS      ;NUMBER OF DISPLAYED CHANNELS
      CMP      NCHAN,WINSIZ      ;WINDOW TOO LARGE?
      BPL      10%
      MOV      NCHAN,WINSIZ      ;MAX WINDOW SIZE
10%:  ASH      #2,R1             ;MULTIPLY BY FOUR
      SUB      #4,R1
      MOV      R1,LCHAN         ;# OF ADDRESS LOCATIONS TO LAST CHAN
NEL   MOV      #DATBUF,R2        ;STARTING ADDRESS OF DATA BUFFER IN
R2    ADD      #1000,R2          ;500 HEADER WORDS
      MOV      R2,SBBUF         ;STARTING LOC. FOR SIGNAL+BACKGROUND
BUF.  ADD      #4,R1             ;# OF ADDRESSES IN R1
      ADD      R1,R2            ;STARTING LOC. FOR BACKGROUND BUFFER
      MOV      R2,BABUF         ;LOAD BACKGROUND BUFFER POINTER
      ADD      R1,R2            ;STARTING LOCATION FOR POWER BUFFER
      MOV      R2,POBUF         ;LOAD POWER BUFFER POINTER
R     ADD      R1,R2            ;STARTING LOCATION FOR DISPLAY BUFFE
      MOV      R2,DIBUF         ;LOAD DISPLAY BUFFER POINTER
      MOV      R2,DISTR1        ;STARTING LOCATION FOR DISPLAY
      MOV      R2,D1SWIN        ;WINDOW POINTER
      ADD      R1,R2
      MOV      R2,D1SMAX        ;DISPLAY BUFFER LAST ADDRESS +2
      MOV      #1,EXPFLG        ;DON'T EXPAND DISPLAY
      MOV      #1,D1RFLG        ;SCAN FORWARD FIRST
      CLR      BUFOFF           ;CLEAR BUFFER OFFSET
      CALL     XJUMP            ;CALCULATE XJUMP
      CLR      UPDATE           ;UPDATE DISPLAY
      BIC      #2,RUNFLG        ;RUN NOT IN PROGRESS
      MOV      R1BUF,R1         ;UNSAVE REGISTERS
      MOV      R2BUF,R2
      RETURN
;
;
;
;RETURN TO CALLER

```

!THIS SUBROUTINE LOADS 'DIFUNC' AND 'DICODE' WHICH ARE WORDS THAT DIRECT
!THE MAIN PROGRAM: MODULE DISPLAY ROUTINE.

```

DISOPT: MOV    IOBUF+2,IOBUF      !MOVE IN SECOND COMMAND IF ANY
        CHPB   IOBUF,#15         !IS IT A CARRIAGE RETURN?
        BEQ    1%               !IF YES,ASK FOR SECOND PART OF COMMA

ND      BR     3%               !GO CHECK THE COMMAND
        .PRINT #M10             !WHICH OPTION?
        CALL   READ
5%:     MOV     IOBUF,DICODE      !STORE RESPONSE IN DISPLAY CODE
        CMP    #'SB,IOBUF        !DISPLAY SIGNAL+BACKGRD.?
        BEQ    15%              !BRANCH IF YES
        CMP    #'SI,IOBUF        !DISPLAY SIGNAL BUFFER?
        BEQ    20%              !BRANCH IF YES
        CMP    #'BA,IOBUF        !DISPLAY THE BACKGRD. BUFFER?
        BEQ    30%              !BRANCH IF YES
        CMP    #'PD,IOBUF        !DISPLAY THE POWER BUFFER?
        BEQ    40%              !BRANCH IF YES
        CHPB   #'?,IOBUF        !PRINT OPTIONS?
        BEQ    50%              !BRANCH IF YES
        MOV     DICODE+2,DICODE  !INSERT OLD CODE
        CMP    #'DA,IOBUF        !DISPLAY DATE?
        BNE    6%
        CALL   TYDATE
6%:     BR     DISOUT
        CMP    #'PA,IOBUF        !DISPLAY PARAMETERS?
        BNE    8%
        CALL   DP
8%:     BR     DISOUT
        CMP    #'EX,IOBUF        !EXPAND DISPLAY?
        BNE    9%
        CALL   DE
9%:     BR     DISOUT
        CMP    #'PN,IOBUF        !POWER NORMALIZE?
        BNE    10%
        CALL   PN
10%:    BR     DISOUT
        CMP    #'RE,IOBUF        !DISPLAY REVERSE?
        BNE    DISOUT
        CALL   RE
15%:    BR     DISOUT
        MOV     #'SB,DIFUNC      !LOAD FUNCTION CODE WORD
        BR     60%              !GET OUT
20%:    MOV     #'SI,DIFUNC      !GET OUT
        BR     60%
30%:    MOV     #'BA,DIFUNC      !GET OUT
        BR     60%
40%:    MOV     #'PD,DIFUNC      !GET OUT
        BR     60%
50%:    .PRINT  #M7              !PRINT OPTIONS
        .PRINT  #M11
        CALL   CRLF
        JMP    1%
60%:    MOV     DIFUNC,DIFUNC+2  !TRY AGAIN
        !SAVE FUNCTION CODE

```

```

        MOV     DICODE,DICODE+2      ;SAVE NEW DISPLAY CODE
        CLR     UPDATE               ;UPDATE DISPLAY
DISOUT: RETURN                       ;RETURN TO CALLER
;
;SUBROUTINE 'DISCAL' SCALES THE NUMBERS IN THE DISPLAY BUFFER SO
;THAT THE LARGEST VALUE RESULTS IN FULL SCALE DEFLECTION OF THE
;DISPLAY SCOPE
DISCAL: CALL    DISHLT              ;HALT DISPLAY
        MOV     R1,R1DIS            ;SAVE THE REGISTERS
        MOV     R2,R2DIS
        MOV     R3,R3DIS
        MOV     R4,R4DIS
        MOV     R5,R5DIS
        MOV     @DIBUF,R1           ;STARTING ADDRESS OF BUFFER IN R1
        CMP     FLGDIS,#1           ;FORWARD OR REVERSE?
        BLE     10%
        ADD     LCHAN,R1            ;DISPLAY BUFFER MAXIMUM
        MOV     NCHAN,R4            ;NUMBER OF CHANNELS IN R4
        JMP     @DIFUNC             ;GO TO DISPLAY FUNCTION
;
;DISPLAY SIGNAL---S+B BUFFER MINUS B BUFFER= SIGNAL BUFFER
SI:     MOV     @SABUF,R3           ;ADDRESS OF BACKGRD. BUFFER
        MOV     @SBBUF,R2           ;ADDRESS OF S+B BUFFER
        MOV     @POBUF,R0           ;ADDRESS OF POWER BUF.
        BIT     #1,FLGDIS           ;POWER NORM.?
        BNE     30%
        BIT     #2,FLGDIS           ;FORWARD OR REVERSE
        BNE     20%
10%:    MOV     (R2)+,(R1)           ;MOVE DOUBLE WORD
        MOV     (R2)+,2(R1)
        SUB     (R3)+,(R1)+         ;DO SUBTRACTION
        SBC     (R1)
        SUB     (R3)+,(R1)+
        SOB     R4,10%              ;DO THEM ALL
        JMP     @SCALE
20%:    MOV     (R2)+,(R1)
        MOV     (R2)+,2(R1)
        SUB     (R3)+,(R1)
        SBC     2(R1)
        SUB     (R3)+,2(R1)
        SUB     #4,R1
        SOB     R4,20%
        JMP     @SCALE
30%:    MOV     R1,R5SMO
        MOV     NCHAN,SMOPTR
        MOV     @POBUF,R1           ;POWER BUFFER ADDRESS
        CALL    MAXFND
        MOV     @ARG2,@POWMAX
        MOV     @ARG2+2,@POWMAX+2
        TST     @POWMAX             ;IS IT ZERO?
        BNE     35%
        MOV     #1,@POWMAX
35%:    MOV     R5SMO,R1            ;RESTORE DIBUF ADDRESS IN R1

```



```

MOV    @#BABUF,R3          ;ADDRESS OF BACKORD. BUFFER
MOV    @#SBBUF,R2          ;ADDRESS OF S+B BUFFER
MOV    @#POBUF,R0          ;ADDRESS OF POWER BUF.
40$:   MOV    (R2)+,@#ARG1
      MOV    (R2)+,@#ARG1+2
      SUB    (R3)+,@#ARG1
      SBC    @#ARG1+2
      SUB    (R3)+,@#ARG1+2
      MOV    @#POWMAX,@#ARG2
      MOV    @#POWMAX+2,@#ARG2+2
      MOV    (R0)+,@#POVALU
      MOV    (R0)+,@#POVALU+2
      MOV    #LIST,R5      ;ARG. LIST
      MOV    R0,R0SM0      ;SAVE
      MOV    R1,R1SM0      ;SAVE
      MOV    R2,R2SM0      ;SAVE
      MOV    R3,R3SM0      ;SAVE
      MOV    R4,R4SM0      ;SAVE
      CALL   JMUL
      CMP    R0,#-2        ;OVERFLOW?
      BNE    50$
      .PRINT #M68         ;OV FLO!!
50$:   MOV    @#RESULT,@#ARG1
      MOV    @#RESULT+2,@#ARG1+2
      MOV    @#POVALU,@#ARG2
      MOV    @#POVALU+2,@#ARG2+2
      TST    @#ARG2        ;ZERO?
      BNE    53$
      MOV    #1,@#ARG2
53$:   MOV    #LIST,R5
      CALL   JDIV
      MOV    R4SM0,R4      ;UNSAVE
      MOV    R3SM0,R3
      MOV    R2SM0,R2
      MOV    R1SM0,R1
      MOV    R0SM0,R0
      MOV    @#RESULT,(R1)+ ;LOAD DIBUF
      MOV    @#RESULT+2,(R1)+
      BIT    #2,FLGDIS     ;FOR. OK REV.?
      BEQ    55$
      SUB    #8,R1
55$:   DEC    R4           ;LOOP COUNTER
      BEQ    60$
      JMP    40$
60$:   JMP    @#SCALE
;
;DISPLAY SIGNAL+BACKGROUND BUFFER
SB:    MOV    @#SBBUF,R2   ;ADDRESS OF S+B BUFFER
      BR     MW
;
;DISPLAY THE POWER BUFFER
PD:    MOV    @#POBUF,R2   ;ADDRESS OF POWER BUFFER
      BR     MW
;

```

```

;DISPLAY THE BACKGROUND BUFFER
BA:  MOV    @BABUF,R2          ;ADDRESS OF BACKGROUND BUFFER
     BR     MW
;
;DISPLAY THE SMOOTHED BUFFER(I.E. DUN'T SCALE AND DON'T UPDATE)
SM:  JMP    @SCAOUT           ;NO SCALING --GET OUT
;
;
MW:  BIT     @2,FLGDIS         ;WHICH WAY?
     BEQ     MOVDAT           ;FORWARD
     BR     DATMOV           ;REVERSE
;
;
MOVDAT: MOV    (R2)+,(R1)+      ;FORWARD
        MOV    (R2)+,(R1)+
        SOB    R4,MOVDAT      ;TRANSFER UNTIL DONE
        JMP    @SCALE
;
;
DATMOV: MOV    (R2)+,(R1)      ;REVERSE
        MOV    (R2)+,2(R1)
        SUB    #4,R1
        SOB    R4,DATMOV      ;TRANSFER UNTIL DONE
        JMP    @SCALE
;
;
MINFND: MOV    #177777,@ARG2   ;SEARCH FOR THE SMALLEST
        MOV    #77777,@ARG2+2 ;VALUE IN THE ARRAY
10$:  MOV    (R1)+,@ARG1
        MOV    (R1)+,@ARG1+2
        MOV    @LIST,R5
        MOV    R1,@R1SHO
        CALL   JCMP
        MOV    @R1SHO,R1
        CMP    #-1,R0
        BNE    15$
        MOV    @ARG1,@ARG2
        MOV    @ARG1+2,@ARG2+2
15$:  DEC    @SMOPTH           ;DEC. LOOP COUNTER
        BNE    10$
        RETURN
;
;
MAXFND: MOV    #0,@ARG2        ;SEARCH FOR THE LARGEST
        MOV    #0,@ARG2+2      ;ABSOLUTE VALUE IN THE ARRAY
10$:  MOV    (R1)+,@ARG1
        MOV    (R1)+,@ARG1+2
        BGE    20$
        COM    @ARG1+2
        COM    @ARG1
        ADD    #1,@ARG1
        ADC    @ARG1+2
20$:  MOV    @LIST,R5
        MOV    R1,@R1SHO
        CALL   JCMP

```

```

MOV      @R1SM0,R1          ;UNSAVE R1
CMP      #1,R0
BNE      25$
MOV      @*ARG1,@*ARG2
MOV      @*ARG1+2,@*ARG2+2
25$:     DEC      @*SHOPTR    ;DEC. LOOP COUNTER
BNE      10$
RETURN

;
;
;DISPLAY BUFFER HAS BEEN LOADED--NOW SCALE THEM FOR OUTPUT.
SCALE:   TST      RETAKE      ;ACCUMULATING?
BEQ      1$
CALL     CLEAR              ;CLEAR DATA
1$:      CMP      #1,ZERFLG    ;WHICH ZERO?
BLT      20$                ;YMIN = 'ENTERED VALUE'
BGT      MAXIE              ;YMIN = 0
MOV      @*DISTRT,R1        ;DISPLAY START
MOV      @*DICHNS,@*SHOPTR
CALL     MINFND              ;FIND MINIMUM
MOV      @*ARG2,@*YMIN       ;MOVE BUFMIN
MOV      @*ARG2+2,@*YMIN+2
20$:     MOV      @*YMIN,R3
MOV      @*YMIN+2,R2
MOV      @*DIBUF,R1
MOV      NCHAN,R4
25$:     SUB      R3,(R1)+
SBC      (R1)
SUB      R2,(R1)+
SOB      R4,25$
MAXIE:   MOV      @*DIBUF,R1  ;ADDRESS OF DISPLAY BUFFER
CMP      DISFLG,#1          ;AUTO-SCALE OR WINDOW SCALE?
BEQ      4$
BLT      4$
CMP      DISFLG,#2          ;CHANNEL OR ABSOLUTE SCALING?
BNE      30$
ADD      C$CHAN,R1          ;CHANNEL SCALE
MOV      (R1),YMAX
MOV      (R1),YMAX+2
BR       30$
4$:      MOV      @*NCHAN,@*SHOPTR ;AUTO SCALE
BR       8$
6$:      MOV      DISWIN,R1     ;WINDOW SCALE
MOV      WINSIZ,SHOPTR
8$:      CALL     MAXFND        ;GET MAX. OF ARRAY
MOV      @*ARG2,@*YMAX
MOV      @*ARG2+2,@*YMAX+2
30$:     MOV      @*YMAX,R3
MOV      @*YMAX+2,R2
CLR      @*SHIFT
CMP      #0,R2
BNE      35$
MOV      #15,@*SHIFT
35$:     CMP      #0,R3        ;LOW WORD ZERO?
BNE      37$

```

```

MOV      #1,R3
MOV      #30,,@#SHIFT
BR       40%
37%:     SWAB      R3
BNE      38%
MOV      #23,,@#SHIFT
38%:     SWAB      R3
40%:     ASHC      @#SHIFT,R2
BIT       #40000,R2
BNE      43%
MOV      @#YMAX,R3
MOV      @#YMAX+2,R2
INC       @#SHIFT
BR       40%
43%:     MOV      R3,@#ARG1
MOV      R2,@#ARG1+2
MOV      @#YSCALE,ARG2
CLR       @#ARG2+2
MOV      @LIST,R5
CALL      JDIV
MOV      @#RESULT,@#ARG2
MOV      @#RESULT+2,@#ARG2+2
MOV      @#DISTRT,R1
MOV      @#DICHNS,@#SMOPTR
45%:     MOV      (R1)+,R3
MOV      (R1)+,R2
ASHC      @#SHIFT,R2
BVS      47%                ;SIGN CHANGE?
MOV      R3,@#ARG1
MOV      R2,@#ARG1+2
MOV      @LIST,R5
MOV      R1,@#R1SMO
CALL      JDIV                ;SAVE R1
MOV      @#R1SMO,R1          ;UNSAVE R1
ADD      #3777,@#RESULT
CMP      #7777,@#RESULT
BPL      50%
47%:     MOV      #7777,@#RESULT
50%:     MOV      @#RESULT,-2(R1)
DEC      SMOPTR                ;DEC. LOOP COUNTER
BNE      45%
SCADOUT: CALL      XLOAD
MOV      @#R1DIS,R1
MOV      @#R2DIS,R2
MOV      @#R3DIS,R3
MOV      @#R4DIS,R4
MOV      @#R5DIS,R5
MOV      #1,DMA/ILT          ;DMA GO
MOV      DIBUF,,MACAR        ;LOAD DMA REGISTERS
MOV      NCHAN,DMAPCR
NEG      DMAPCR                ;2'S COMPLEMENT
BIS      #102,ADCSR           ;ENABLE DMA INT
BIS      #1,ADCSR             ;START DMA
RETURN                                ;RETURN TO CALLER

```

```

/
/
;THIS SUBROUTINE DEFINES AND LOADS CODE VALUES INTO THE WORDS
;'SCTYPE' AND 'SCFUNC'. SCTYPE DETERMINES THE 'SCAN TYPE' TO
;BE PERFORMED DURING DATA TAKING--BIDIRECTIONAL OR UNIDIRECTIONAL.
;SCFUNC DETERMINES THE 'SCAN FUNCTION'; THAT IS, WHICH DEVICE IS
;TO BE SCANNED--THE DYE LASER, THE OPD, ETC..
/
SC:  CALL    DISHLT                ;HALT    DISPLAY
      MOV     #1,DIRFLG           ;SCAN  DIRECTION FLAG
      MOV     IOBUF+2,IOBUF        ;MOV IN SECOND COMMAND, IF ANY
      CMPB    IOBUF,#15           ;IS IT A CARRIAGE RETURN?
      BEQ     1%                 ;IF YES, ASK FOR SECOND PART OF COMMA

ND:                                     ;WHAT COMMAND IS IT?
1%:  .PRINT   #M5
      CALL    READ
5%:  MOV      IOBUF,SCCODE
      CMP     #'LA',IOBUF         ;SCAN THE LASER?
      BEQ     10%
      CMP     #'QU',IOBUF         ;SCAN THE QUADRUPOLE?
      BEQ     20%
      CMP     #'TR',IOBUF         ;SCAN THE ION TRAP?
      BEQ     30%
      CMP     #'MA',IOBUF         ;SCAN THE MAGNET?
      BEQ     40%
      CMP     #'MC',IOBUF         ;THE MCS UNIT?
      BEQ     50%
      CMP     #'NO',IOBUF         ;SCAN NOTHING?
      BEQ     60%
      CMPB    #'?',IOBUF          ;PRINT OPTIONS AVAILABLE?
      BEQ     SC05

      .PRINT   #M4
      BR      1%
10%: MOV      #LA,SCFUNC
      CALL    DYELAS              ;DYE LASER SUBROUTINE
      CALL    BUFINIT             ;GENERATE NEW BUFFER POINTERS
      CALL    CLEAR               ;CLEAR DATA BUFFER
      JMP     SCOUT
20%: MOV      #QU,SCFUNC
      CALL    QUAD                 ;CALL QUADRUPOLE SUBROUTINE
      CALL    BUFINIT             ;GENERATE NEW BUFFER POINTERS
      CALL    CLEAR               ;CLEAR DATA BUFFER
      JMP     SCOUT
30%: MOV      #TR,SCFUNC
      CALL    TRAP                 ;LEAVE
      JMP     SCOUT
40%: MOV      #MA,SCFUNC
      CALL    MAGNET              ;CALL MAGNET SUBROUTINE
      CALL    BUFINIT             ;GENERATE NEW BUFFER POINTERS
      CALL    CLEAR               ;CLEAR DATA BUFFER
      JMP     SCOUT
50%: .PRINT   #M98                ;ACTIVATE MCS UNIT?
      .PRINT   #M48                ;ARE YOU SURE?

```

```

CALL      READ      ;GET RESPONSE
CMPB      0'Y,IOBUF ;IS IT YES?
BNE       SCOUT     ;IF NO,GET OUT
MOV       #377,NCHAN ;255. CHANNELS
CALL      BUFINIT
CALL      CLEAR
.PRINT    #M85      ;MCS ACTIVE MESSAGE
MOVB      #24.,A2DCON ;DISABLE A2DCUN INTERRUPT
CLR       ACTIVE+2   ;NO ACTIVE CHANNEL BRT.
MOV       S88UF,MCSBUF ;DATA INTO S+B BUFFER (DEFAULT)
CALL      MCSIN
JMP       SCOUT
609:      MOV        #ND,SCFUNC
          MOVB       #15,IOBUF+2 ;'NOTHIN' LOOKS FOR THIS CARRIAGE RE
TURN
NOTHIN:   MOVB       0'0,IOBUF    ;ZERO TO THE FIRST TWO BYTES
          MOVB       0'0,IOBUF+1
          CMPB       #15,IOBUF+2 ;A CARRIAGE RETURN?
          BEQ        109         ;BRANCH IF YES
          BR         209         ;CONVERT TO BINARY IF NO
109:      .PRINT     #M4
          CALL      READ
209:      CALL      ASCBIN
          BCC       479         ;BRANCH IF NO ERROR
          .PRINT     #M4        ;PRINT ERROR MESSAGE
          BR        109         ;TRY AGAIN
479:      TST       R1
          BEQ       559
          BGT       509
          NEG       R1          ;MAKE POSITIVE IF IT WAS NEGATIVE
509:      CMP       #1000.,R1
          BMI       559
          MOV       R1,NCHAN
          CALL      BUFINIT
          CALL      CLEAR
          JMP       SCOUT
559:      .PRINT     #M4
          BR        109
SC05:     .PRINT     #M7
          .PRINT     #M8
          JMP       SC
SCOUT:    CLR        UPDATE     ;UPDATE DISPLAY
          RETURN      ;RETURN TO CALLER
;
;SUBROUTINE TO 'SET' A DEVICE
;LOADS 'ROUTINE' WITH THE ADDRESS OF SUBROUTINE TO BE EXECUTED
;
SE:       MOV       IOBUF+2,IOBUF ;MOV IN SECOND COMMAND,IF ANY
          CMPB      IOBUF,#15     ;IS IF A CARRIAGE RETURN?
          BEQ       29           ;IF YES,ASK FOR SECOND PART OF COMMA
NP
          BR        39           ;WHAT COMMAND IS IT?
29:       .PRINT    #M5
          CALL      READ
39:       CMP       SCCODE,IOBUF  ;IS THE DEVICE BEING 'SCANNED'?

```

```

        BNE      5%
        .PRINT   #M91
        RETURN

5%:      CMP      #*LA,IOBUF      ;SET THE LASER?
        BNE      10%
        MOV      #LA,ROUTINE
        JMP      SEOUT           ;GO CALL THE ROUTINE
10%:     CMP      #*QU,IOBUF      ;SET THE QUADRUPOLE?
        BNE      20%
        MOV      #QU,ROUTINE
        JMP      SEOUT           ;GO CALL THE ROUTINE
20%:     CMP      #*TR,IOBUF      ;SET THE ION TRAP?
        BNE      30%
        MOV      #TR,ROUTINE
        JMP      SEOUT           ;GO CALL THE ROUTINE
30%:     CMP      #*MA,IOBUF      ;SET THE MAGNET?
        BNE      40%
        MOV      #MA,ROUTINE
        JMP      SEOUT           ;SECTOR MAGNET
                                ;GO CALL THE ROUTINE
40%:     .PRINT   #M51           ;NONEXISTENT OPTION
        RETURN
SEOUT:   .PRINT   #M96           ;KEY MODE READY
        CALL     KEYHOL
        RETURN
;
;
;SUBROUTINE TO IMPLEMENT 'KEY-MODE' OPERATION.
;
KEYHOL:  BIS      #10000,JSW      ;SPECIAL TTY MODE(NO CR/LF)
10%:     .TTINR
        BCS      30%             ;CHARACTER INPUT?
        CMPB     #'',R0          ;BRANCH IF NO
        BNE      15%             ;DECREASE?
        MOV      #-1,DIFFLG      ;SET DIRECTION FLAG
        BR       20%
15%:     CMPB     #'',R0          ;INCREASE?
        BNE      25%
        MOV      #1,DIFFLG
20%:     CALL     @ROUTINE        ;CALL THE ROUTINE
        BR       30%
25%:     CMPB     #'S,R0          ;STOP COMMAND?
        BEQ      35%
30%:     TST      UPDATE
        BNE      10%
        MOV      DICODE+2,DICODE ;GET RID OF POSSIBLE 'SM'
        MOV      DIFUNC+2,DIFUNC ;RESTORE FUNCTION CODE
        CALL     DISCAL          ;UPDATE
        MOV      UPDATE+2,UPDATE
        BR       10%
35%:     .TTINR
        BCC      35%
        BIC      #10000,JSW      ;RETURN TTY TO NORMAL MODE
        CALL     CRLF            ;TYPE CR-LF
        RETURN
;

```

```

)
;SUBROUTINE TO SET THE SCANNING PROCEDURE
)
SCNPRO: MOV     IOBUF+2,IOBUF           ;MOV IN SECOND COMMAND,IF ANY
        CMPB    IOBUF,#15             ;IS IT A CARRIAGE RETURN?
        BEQ     10%                  ;IF YES,ASK FOR SECOND PART OF COMMA
ND
        BR      20%                   ;WHAT COMMAND IS IT?
10%:    .PRINT   #M9                   ;TYPE OF SCANNING?
        CALL    READ
20%:    CMP      #'BI,IOBUF             ;BIDIRECTIONAL?
        BEQ     1010%
        CMP      #'UN,IOBUF            ;UNIDIRECTIONAL?
        BEQ     1010%
        .PRINT   #M4
        CALL    CRLF
        BR      10%
1010%:  MOV      IOBUF,SCTYPE           ;RETURN TO CALLER
SCNOUT: RETURN
)
;SUBROUTINE TO CLEAR DATA BUFFER AND RE-INIT
)
CLRQUE: .PRINT   #M49                 ;CLEAR MESSAGE
        .PRINT   #M48                 ;ARE YOU SURE MESSAGE
        CALL    READ                 ;GET RESPONSE
        CMPB    #'Y,IOBUF             ;IS IT YES?
        BNE     CLROUT               ;NO,GET OUT
CLEAR:  CLR      NSCAN                ;CLEAR SCAN COUNTER
        MOV      NCHAN,R1             ;NOW CLEAR BUFFER
        MUL      #6.,R1
        MOV      SBBUF,R2
10%:    MOV      #0,(R2)+             ;DATA BUFFER POINTER
        SOB     R1,10%
        MOV      DACYCL+2,DACYCL      ;UPDATE CYCLE COUNT
CLROUT: RETURN                       ;RETURN TO CALLER
)
;THIS SUBROUTINE SETS THE DEVICE BEING SCANNED TO ITS STARTING
;POINT,RESETS THE BUFFER OFFSET FLAG AND THE SCAN DIRECTION FLAG.
)
RESQUE: .PRINT   #M46                 ;RESET THE DEVICE?
        .PRINT   #M48                 ;ARE YOU SURE?
        CALL    READ                 ;GET REPLY
        CMPB    #'Y,IOBUF             ;YES OR NO
        BNE     RESOUT               ;NO,LEAVE
RESET:  CMP      #'LA,SCCODE           ;DYE LASER
        BEQ     10%
        CMP      #'QU,SCCODE          ;QUADRUPOLE
        BEQ     20%
        CMP      #'TR,SCCODE          ;ION TRAP
        BEQ     30%
        CMP      #'QP,SCCODE          ;QUAD SCANNING PEAK POSITION
        BEQ     40%
        CMP      #'MA,SCCODE          ;SECTOR MAGNET?

```



```

      BEQ      50%
      CMP      #'ND,SCCODE
      BEQ      60%
      BR       RESOUT
10%:   MOV      SHOWAV,RESULT
      MOV      SHOWAV+2,RESULT+2
      CALL     DYESET
      BR       60%
20%:   MOV      MDAC1,MDAC
      BR       60%
30%:   MOV      DELOFF,DELTOT
      MOV      DELTOT,KWBPR
      NEG      KWBPR
      BR       60%
40%:   MOV      MASBUF,MDAC
      BR       60%
50%:   MOV      MADAC1,MADAC
60%:   MOV      #1,DIFRLG
      CLR      BUFOFF
      BIC      #2,RUNFLG
      RESOUT: RETURN
      ;
      ;THIS SUBROUTINE CREATES AND WRITES A DATA FILE
      ;
WDISK: MOV      R2,R2DSK
      MOV      #DATBUF,R2
      MOV      NCHAN,(R2)+
      MOV      NCHAN+2,(R2)+
      MOV      SHOWAV,(R2)+
      MOV      SHOWAV+2,(R2)+
      MOV      LONWAV,(R2)+
      MOV      LONWAV+2,(R2)+
      MOV      WAVINC,(R2)+
      MOV      WAVINC+2,(R2)+
      MOV      SETWAV,(R2)+
      MOV      SETWAV+2,(R2)+
      MOV      CALWAV,(R2)+
      MOV      CALWAV+2,(R2)+
      MOV      MDAC1+2,(R2)+
      MOV      MDAC2,(R2)+
      MOV      HRES+2,(R2)+
      MOV      NSTEP,(R2)+
      MOV      DELINC,(R2)+
      MOV      DELOFF,(R2)+
      MOV      LASHOTS,(R2)+
      MOV      LASHOTS+2,(R2)+
      MOV      SCCODE,(R2)+
      MOV      SCFUNC,(R2)+
      MOV      NSCAN,(R2)+
      MOV      NSCAN+2,(R2)+
      MOV      A2DGNS,(R2)+
      MOV      DACYCL+2,(R2)+
      MOV      BUFOFF,(R2)+
      MOV      MADAC1+2,(R2)+
      ;SAVE R2
      ;STARTING LOCATION OF DATA BUFFER
      ;STORE PROGRAM VARIABLES
      ;SECROR MAGNRT

```

```

MOV     MADAC2,(R2)+
MOV     MARE+2,(R2)+
MOV     DATE,(R2)+
MOV     RUN,(R2)+           ;RUN NUMBER OF DATE
MOV     SCTYPE,(R2)+        ;SCANNING PROCEDURE
MOV     TRGBIN,(R2)+
CALL    WRDISK              ;WRITE THE DATA FILE
MOV     R2DSK,R2           ;RESTORE R2
RETURN                                ;RETURN TO CALLER

;
;SUBROUTINE TO READ A DATA FILE OFF THE DISK.
;
RDISK:  .PRINT    #M47           ;READ THE DISK?
        .PRINT    #M48           ;ARE YOU SURE?
        CALL      READ           ;GET REPLY
        CMPB      #'Y',IOBUF     ;YES?
        DNE       RDIOUT         ;NO,GET OUT
        CALL      DISHLT         ;HALT DISPLAY
        CALL      CRLF
        CLR       ACCFLG        ;STOP TAKING DATA
        MOV       R2,R2DSK       ;SAVE R2
        CALL      REDISK         ;READ THE FILE
        MOV       #DATABUF,R2   ;STARTING LOCATION OF DATA BUFFER
        MOV       (R2)+,NCHAN    ;RESTORE PROGRAM VARIABLES
        MOV       (R2)+,NCHAN+2
        MOV       (R2)+,SHOWAV
        MOV       (R2)+,SHOWAV+2
        MOV       (R2)+,LONWAV
        MOV       (R2)+,LONWAV+2
        MOV       (R2)+,WAVINC
        MOV       (R2)+,WAVINC+2
        MOV       (R2)+,SETWAV
        MOV       (R2)+,SETWAV+2
        MOV       (R2)+,CALWAV
        MOV       (R2)+,CALWAV+2
        MOV       (R2)+,MDAC1+2
        MOV       (R2)+,MDAC2
        MOV       (R2)+,MRES+2
        MOV       (R2)+,NSTEP
        MOV       (R2)+,DELINC
        MOV       (R2)+,DELOFF
        MOV       (R2)+,LASHOTS
        MOV       (R2)+,LASHOTS+2
        MOV       (R2)+,SCCODE
        MOV       (R2)+,SCFUNC
        MOV       (R2)+,NSCAN
        MOV       (R2)+,NSCAN+2
        MOV       (R2)+,A2DGNS
        MOV       (R2)+,DACYCL+2
        MOV       (R2)+,BUFOFF
        MOV       (R2)+,MADAC1+2
        MOV       (R2)+,MADAC2
        MOV       (R2)+,MARE+2
        MOV       (R2)+,DATE     ;FILE DATE
        MOV       (R2)+,RUN      ;FILE RUN NUMBER

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```

MOV      (R2)+,SCTYPE
MOV      (R2)+,TR0BIN
MOV      BUFOFF,R2          ;SAVE
CALL     BUFINIT
MOV      R2,BUFOFF
CALL     DATES
MOV      A2DONS,<IOBIN+2>
CALL     A2DAMP              ;SET GAIN SETTING
CMP      #'UN,SCTYPE        ;MISSING CODE?
BEQ      10%
CMP      #'BI,SCTYPE
BEQ      10%
CALL     TYSTAT              ;TYPE STATUS
.PRINT   #M74                ;WARNING TO USER
10%:     MOV      R2DSK,R2    ;RESTORE R2
RDIOUT:  RETURN
;
;
;SETS NUMBER OF SCANS TO BE MADE
;
NOSCNS:  MOV      R1,RINOS    ;SAVE R1
MOV      #00,IOBUF          ;PLACE ZEROES IN THE F. ST WORD
CMPB     #15,IOBUF+2        ;IS IT A CARRIAGE RETURN?
BEQ      10%                ;BRANCH IF YES
BR       15%                ;CONVERT TO BINARY IF NO
10%:     .PRINT   #M14        ;ASK FOR NUMBER OF SCANS TO BE MADE
CALL     READ               ;READ ENTRY
15%:     CALL     ASCBIN      ;CONVERT TO BINARY NUMBER
PCD      20%                ;ERROR?
.PRINT   #M4                ;BAD ENTRY MESSAGE
BR       10%                ;TRY AGAIN
20%:     MOV      R1,NSCAN+2  ;STORE ENTRY
MOV      RINOS,R1          ;RESTORE R1
NOSOUT:  RETURN            ;RETURN TO CALLER
;
;
;SUBROUTINE TO SET THE NUMBER OF DATA CYCLES PER CHANNEL.
;
NOCYCL:  MOV      R1,RINOC    ;SAVE R1
MOV      #00,IOBUF          ;PLACE ZEROES IN THE FIRST WORD
CMPB     #15,IOBUF+2        ;IS IT A CARRIAGE RETURN?
BEQ      10%                ;BRANCH IF YES
BR       15%                ;CONVERT TO BINARY IF NO
10%:     .PRINT   #M41        ;ASK FOR CYCLES
CALL     READ               ;GET THE REPLY
15%:     CALL     ASCBIN      ;CONVERT TO BINARY
BCC      20%                ;BRANCH IF OK
.PRINT   #M4                ;BAD ENTRY MESSAGE
BR       10%                ;TRY AGAIN
20%:     MOV      R1,DACYCL+2 ;SAVE IT
MOV      R1,DACYCL          ;LOAD CYCLE COUNTER
MOV      RINOC,R1          ;RESTORE R1
NOCOUT:  RETURN            ;RETURN TO CALLER
;
;

```

```

;
;SUBROUTINE TO SMOOTH DATA IN THE DISPLAY BUFFER
;
SMOOTH: MOV     R1,R1SMO                ;SAVE REGISTERS
        MOV     R2,R2SMO
        MOV     R3,R3SMO
        MOV     R4,R4SMO
        MOV     R5,R5SMO
        MOV     #SM,DIFUNC             ;SMOOTH FUNCTION CODE FOR DISPLAY
        MOV     #'SM,DICODE            ;"SMOOTH" BEING DISPLAYED
        MOV     #IDBUF,R0              ;BUFFER POINTER
        MOV     #'00,(R0)+             ;ZEROS IN FIRST WORD
10%:    CMPB     #15,(R0)               ;CR?
        BNE     20%
        CALL    ASCBIN
        BCC     15%
        BR      25%
15%:    MOV     R1,NPTAVG
        BR      45%
20%:    CMPB     #'X,(R0)+             ;X?
        BNE     10%
        MOVB     #15,-1(R0)            ;REPLACE X WITH CR
        CALL    ASCBIN
        BCC     30%
        BCC     30%                    ;ERROR?
25%:    .PRINT   #M4                   ;INVALID ENTRY
        BR      SMOOT
30%:    MOV     R1,NPTAVG                ;NUM. OF POINTS TO BE AVERAGED
        MOV     #IDBUF,R0
35%:    CMPB     #15,(R0)               ;CR?
        BEQ     40%
        MOVB     #'0,(R0)+            ;FILL WITH ZERO
        BR      35%
40%:    MOVB     #'0,(R0)               ;REPLACE CR WITH ZERO
        CALL    ASCBIN
        BCC     50%
        BCC     50%                    ;CONVERT
45%:    MOV     #1,TIMES
        BR      60%
50%:    MOV     R1,TIMES                ;NUM. OF TIMES TO SMOOTH
60%:    CALL    SMUZ                    ;SMOOTH DATA
        DEC     TIMES
        BNE     60%
SMOOT:  MOV     R1SMO,R1                ;UNSAVE REGISTERS
        MOV     R2SMO,R2
        MOV     R3SMO,R3
        MOV     R4SMO,R4
        MOV     R5SMO,R5
        RETURN
SMUZ:   CMP     #1,NPTAVG                ;DO NOT AVERAGE IF ONE
        BGE     SMOOT                  ;LEAVE
        CMP     NPTAVG,MCHAN            ;MUST BE LESS THAN NUM. OF CHANNELS
        BGT     SMOOT
        MOV     NPTAVG,R1
        MOV     MCHAN,R4
        MOV     #IDBUF,R5
        TST     (R5)+
        ;DATA AS X,Y PAIRS

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25%:  MOV      (R5),R3          ;GET A NUMBER
      SUB      #3777,R3        ;REMOVE D/A BIAS
      CLR      R2              ;CLEAR HIGH WORD
      DIV      NPTAVG,R2       ;DIVIDE BY NPTAVG
      MOV      R2,(R5)+        ;PLACE RESULT IN BUFFER
      TST      (R5)+
      SOB      R4,25%          ;DIVIDE THEM ALL
      BIT      #1,R1           ;IS THE NUMBER ODD?
      BEQ      30%             ;BRANCH IF NO
      SUB      #1,R1           ;MAKE EVEN
30%:  MOV      R1,OFFSET        ;BUFFER OFFSET VALUE
      MOV      NCHAN,R2        ;NUMBER OF CHANNELS TO R2
      SUB      R1,R2           ;CALCULATE LAST CHANNEL
      ASH      #2,R2
      SUB      #4,R2
      MOV      R2,LCHN         ;LAST CHANNEL
      CLR      SMOPTTR         ;CLEAR SMOOTH-POINTER
40%:  MOV      DIBUF,R2        ;DISPLAY BUFFER STARTING ADDRESS
      TST      (R2),
      MOV      NPTAVG,R4       ;NO. OF POINTS TO R4
      CLR      R1              ;SUM REGISTER
      ADD      SMOPTTR,R2       ;POINT TO CHANNEL
50%:  ADD      (R2)+,R1         ;ADD CHANNELS
      TST      (R2)+
      SOB      R4,50%          ;GET "NPTAVG" OF THEM
      ADD      #2777,R1        ;ADD D/A BIAS
      MOV      @IDUF,R2        ;RE-INIT
      TST      (R2)+
      ADD      SMOPTTR,R2       ;ADD POINTER
      MOV      R1,(R2)         ;PLACE SUM IN THE DATA BUFFER
      CMP      LCHN,SMOPTTR     ;DONE YET?
      BEQ      55%             ;BRANCH IF YES
      ADD      #4,SMOPTTR       ;INCREASE POINTER--CONTINUE
      BR       40%             ;DO MORE
55%:  MOV      OFFSET,R1       ;RE-INIT
      MOV      DIBUF,R2
      TST      (R2)+
      ADD      LCHN,R2
      ADD      #4,R2
60%:  MOV      #3777,(R2)+      ;THIS ZEROES UNUSED DATA CHANNELS
      TST      (R2)+
      SOB      R1,60%          ;
      MOV      OFFSET,R1       ;SHIFT THE DATA IN THE BUFFER
      MOV      DIBUF,R2        ;DISPLAY BUF LOCATION
      TST      (R2)+
      ADD      LCHN,R2         ;POINT TO LAST SMOOTHED DATA CHANNEL
      MOV      R2,R3
      ADD      R1,R3           ;SHIFT BY OFFSET
      ADD      R1,R3
      TST      (R2)+
      TST      (R3)+
      ASR      R1              ;DIVIDE OFFSET BY TWO
130%: MOV      -(R2),-(R3)      ;SHIFT!!
      TST      -(R2)
      TST      -(R3)

```

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SUB      #4,LCHN
BNE      130$      ;SHIFT THEM ALL
TST      -(R2)
140$:    MOV      #3777,(R2)+      ;ZERO THE FIRST OFFSET/2 CHANNELS
TST      (R2)+
SUB      R1,140$
SMOUT:   RETURN      ;RETURN TO CALLER
;
;
;SURROUTINE TO SET 'ION TRAP' PARAMETERS
;
TRAP:    MOV      R1,R1TRA      ;SAVE REGISTER ONE
10$:     .PRINT   #M17          ;ASK FOR DELAY OFFSET
MOV      DELOFF,R1            ;PRINT EXISTING VALUE
CALL     DECOU
MOV      #' ,R0              ;TYPE A SPACE
.TTYOUT
CALL     READ                ;READ IT IN
CHPB     #15,IOBUF          ;IS IT A CR?
BEQ      35$
CALL     ASCBIN              ;CONVERT TO BINARY
BCC      30$                ;ALL OK?
20$:     .PRINT   #M4          ;PRINT MESSAGE IF NOT OK
BR       10$                ;TRY IT AGAIN
30$:     TST      R1          ;NO NEGATIVES
BLT      20$                ;BAD ENTRY--GO BACK
MOV      R1,DELOFF          ;STORE VALUE
NEG      R1                  ;TWO'S COMPLEMENT
MOV      R1,KWBPR           ;MOVE TO BUFFER/PRESET REGISTER
35$:     CMP      SCCODE,#*TR  ;IS THE TRAP BEING SCANNED?
BNE      TRAOUT             ;BRANCH OUT IF NOT
40$:     .PRINT   #M18          ;ASK FOR DELAY INCREMENT
MOV      DELINC,R1          ;TYPE VALUE
CALL     DECOU
MOV      #' ,R0              ;THE SPACE
.TTYOUT
CALL     READ                ;GET IT
CHPB     #15,IOBUF          ;CR?
BEQ      65$
CALL     ASCBIN              ;CONVERT IT
BCC      50$                ;ERROR?
50$:     .PRINT   #M4          ;PRINT ERROR MESSAGE
BR       40$                ;TRY AGAIN
40$:     TST      R1          ;NO NEGATIVES
BLT      50$                ;GO BACK IF NEGATIVE
MOV      R1,DELINC          ;STORE ENTRY IN DELINC
65$:     MOV      DELOFF,DELTOT ;RESET TOTAL DELAY WORD
TRAOUT:  MOV      R1TRA,R1    ;RESTORE R1
RETURN      ;RETURN TO CALLER
;
;END OF PAGE TWO

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;PAGE THREE

;

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CU:      MOV      R1,RISAV      ;SAVE R1
        CLR      KWCSR         ;DISABLE CLOCK INTERRUPT
        MOV      #*00,I0BUF    ;PLACE A ZERO IN THE FIRST WORD
        CMPB     #15,I0BUF+2   ;IS IT A CARRIAGE RETURN?
        BEQ      10%          ;BRANCH IF YES
        BR       15%          ;CONVERT TO BINARY IF NO
10%:     .PRINT   #M75         ;ASK FOR CLOCK UNITS
        CALL     READ          ;READ ENTRY
15%:     CALL     ASCBIN        ;CONVERT TO BINARY NUMBER
        BCC      20%          ;ERROR?
        .PRINT   #M4          ;BAD ENTRY MESSAGE
        BR       10%          ;TRY AGAIN
20%:     CMP      R1,#4         ;LESS THAN 4?
        BGE      CUOUT        ;LEAVE IF NOT
        ASH      #1,R1         ;MUL BY EIGHT
        ADD      #8264,,R1
        MOV      R1,KWCSR      ;CLOCK CONTROL STATUS REGISTER
CUOUT:   MOV      RISAV,R1      ;USAVE R1
        RETURN

```

;SUBROUTINE TO SET 'RUN' NUMBER

;

```

ER:      MOV      R1,RISAV      ;SAVE R1
        MOV      #*00,I0BUF    ;PLACE A ZERO IN THE FIRST WORD
        CMPB     #15,I0BUF+2   ;IS IT A CARRIAGE RETURN?
        BEQ      10%          ;BRANCH IF YES
        BR       15%          ;CONVERT TO BINARY IF NO
10%:     .PRINT   #M67         ;ASK FOR RUN NUMBER
        CALL     READ          ;READ ENTRY
15%:     CALL     ASCBIN        ;CONVERT TO BINARY NUMBER
        BCC      20%          ;ERROR?
        .PRINT   #M4          ;BAD ENTRY MESSAGE
        BR       10%          ;TRY AGAIN
20%:     MOV      R1,RUN        ;SAVE ENTRY
        MOV      R1,RUN+2      ;COPY
        RETURN

```

;

;SUBROUTINE TO SET 'UPDATE' NUMBER

;

```

US:      MOV      R1,RISAV      ;SAVE R1
        MOV      #*00,I0BUF    ;PLACE A ZERO IN THE FIRST WORD
        CMPB     #15,I0BUF+2   ;IS IT A CARRIAGE RETURN?
        BEQ      10%          ;BRANCH IF YES
        BR       15%          ;CONVERT TO BINARY IF NO
10%:     .PRINT   #M72         ;ASK FOR UPDATE NUMBER
        CALL     READ          ;READ ENTRY
15%:     CALL     ASCBIN        ;CONVERT TO BINARY NUMBER
        BCC      30%          ;ERROR?
        .PRINT   #M4          ;BAD ENTRY MESSAGE
        BR       10%          ;TRY AGAIN
30%:     TST      R1           ;NEG OR ZERO?
        BLE      20%

```

```

MOV      R1,UPDATE
MOV      R1,UPDATE+2
RETURN

;
;
;PRINT OUT (LP) ROUTINE
;
PR:      MOV      IOBUF+2,IOBUF          ;OPTION TO FIRST WORD
        CMPB     IOBUF,#15             ;CR?
        BNE      10%
        .PRINT   #M10                  ;OPTION?
        CALL     READ
10%:     CMP      #'HE,IOBUF            ;PRINT HEADER?
        BNE      20%
        CALL     PRHEDR
        BR       50%
20%:     CMP      #'FU,IOBUF            ;PRINT FULL INFO?
        BNE      30%
        CALL     PRFULL
        BR       50%
30%:     CMP      #'DA,IOBUF            ;PRINT DATA
        BNE      40%
        CALL     PRDATA
        BR       50%
40%:     CMP      #'ST,IOBUF            ;PRINT STATUS?
        BNE      50%
        CALL     PRSTAT
50%:     RETURN
;
;
TY:      MOV      IOBUF+2,IOBUF          ;OPTION TO FIRST WORD
        CMPB     IOBUF,#15             ;CR?
        BNE      10%
        .PRINT   #M10                  ;OPTION?
        CALL     READ
10%:     CMP      #'HE,IOBUF            ;PRINT HEADER?
        BNE      20%
        CALL     TYHEDR
        BR       40%
20%:     CMP      #'ST,IOBUF            ;PRINT FULL INFO?
        BNE      30%
        CALL     TYSTAT
        BR       40%
30%:     CMP      #'DA,IOBUF            ;PRINT DATA
        BNE      40%
        CALL     TYDATA
40%:     RETURN
;
;
;SUBROUTINE TO ENTER THE HEADER TO DATA BUFFER.
;
HEADER:  MOV      R1,R1HEA              ;SAVE REGISTERS R1,R2
        MOV      R2,R2HEA
5%:      .PRINT   #M54                  ;NEW HEADER?
        CALL     READ
        CMPB     #'Y,IOBUF             ;LOOK FOR Y

```



```

      BEQ      10%           ;BRANCH IF YES
      BR      HEADUT        ;LEAVE OTHERWISE
10%:  MOV      $DATABUF,R2   ;DATA BUFFER STARTING LOCATION
      ADD      $100,R2      ;START OF HEADER SECTION
      MOV      $450,R1      ;MAX. LENGTH OF MESSAGE
15%:  CLR      (R2)+         ;CLEAR HEADER SECTION
      SOB      R1,15%       ;
      MOV      $DATABUF,R2   ;STARTING LOCATION
      ADD      $100,R2      ;START OF HEADER
      .PRINT   $M56         ;ENTER HEADER MESSAGE
      MOV      $'>,R0       ;PRINT PROMPT CHARACTER
      .TTYOUT
      MOV      $448,R1      ;NUMBER OF CHARACTERS PERMITTED
20%:  .TTYIN
      CNPB     $'>,R0       ;READ IN THE HEADER
      BEQ      40%         ;CHECK FOR HEADER TERMINATER
      DEC      R1           ;BRANCH IF AT THE END
      BEQ      30%         ;COUNT DOWN SPACE LEFT
      MOVB     R0,(R2)+     ;BRANCH IF NO SPACE LEFT
      BR      20%          ;PLACE CHARACTER INTO BUFFER
30%:  .TTYIN
      CNPB     $12,R0       ;GO GET MORE
      BNE      30%         ;EAT THE LEFT OVERS
      .PRINT   $M57         ;THRU EATING?
      BR      50%          ;IF NO GET MORE
40%:  .TTYIN
      CMP      $12,R0       ;TRUNCATION MESSAGE
      BNE      40%         ;CONTINUE
      MOV      $200,(R2)    ;EAT CR-LF
      HEADUT: MOV      R1HEA,R1 ;HAVE LINE FEED YET?
      MOV      R2HEA,R2     ;NO? WELL GO GET IT
      RETURN          ;HEADER TERMINATER SYMOL
                      ;RESTORE R1,R2
                      ;RETURN TO CALLER
;
;
;SUBROUTINE PRINT OUTPUTS DATA TO THE LINE PRINTER
;
PRFULL: MOV      R1,R1PRI    ;SAVE THE REGISTERS
      MOV      R2,R2PRI
      MOV      R3,R3PRI
      MOV      R4,R4PRI
      MOV      R5,R5PRI
      MOV      $14,R0
      CALL     LPOUT        ;FORM FEED TO LP
      CALL     PRHEDR       ;PRINT THE HEADER
      CALL     LPCR1F       ;SKIP A LINE
      CALL     PRSTAT       ;PRINT THE STATUS
      CALL     LPCR1F       ;SKIP A LINE
      BR      PRINT        ;GO PRINT DATA
PRDATA: MOV      R1,R1PRI    ;SAVE THE REGISTERS
      MOV      R2,R2PRI
      MOV      R3,R3PRI
      MOV      R4,R4PRI
      MOV      R5,R5PRI
      MOV      $14,R0
      CALL     LPOUT        ;FORM FEED TO LP

```

PRINT:	BIS	#10000,JSW	ISPECIAL TTY MODE
	MOV	#M21,R0	IAADDRESS OF ASCII STRING
	CALL	LPRINT	IOUTPUT TO LINE PRINTER
	CALL	LPCRLF	ICARRIAGE RETURN-LINE FEED
	MOV	DISTR1,R1	ICHANNEL COUNTER
	SUB	DIBUF,R1	
	MOV	SBBUF,R2	ISTARTING ADDRESS OF S+B BUFFER
	ADD	R1,R2	
	MOV	BABUF,R3	ISTARTING ADDRESS OF BACKGRD.BUFFER
	ADD	R1,R3	
	MOV	POBUF,R4	ISTARTING ADDRESS OF LASER POWER BUF
FER			
	ADD	R1,R4	
	ADD	#4,R1	ISTARTING CHANNEL NUMBER
	ASH	#-2,R1	
	MOV	DICHMS,R5	INUMBER OF DATA CHANNELS
10#:	CALL	LPDECO	IPRINT THE CHANNEL NUMBER(IN R1)
	MOV	#M22,R0	IASCII STRING
	CALL	LPRINT	IPRINT THE SPACES
	MOV	(R2),LOWORD	ILOAD SIG.+BACK. FOR OUTPUT
	MOV	2(R2),HIWORD	
	CALL	LPDCO2	IPRINT THE NUMBER
	MOV	#M22,R0	IPRINT THE SPACES
	CALL	LPRINT	
	MOV	(R3),LOWORD	ILOAD BACKGROUND
	MOV	2(R3),HIWORD	
	CALL	LPDCO2	IPRINT IT
	MOV	#M22,R0	IPRINT THE SPACES
	CALL	LPRINT	
	MOV	(R2)+,LOWORD	ICALLULATE THE SIGNAL
	MOV	(R2)+,HIWORD	ISUBTRACT BACKGROUND FROM SIG.+BACK.
	SUB	(R3)+,LOWORD	
	SBC	HIWORD	
	SUB	(R3)+,HIWORD	
	CALL	LPDCO2	IPRINT THE SIGNAL
	MOV	#M22,R0	IPRINT THE SPACES
	CALL	LPRINT	
	MOV	(R4)+,LOWORD	ILOAD LASER-POWER FOR OUTPUT
	MOV	(R4)+,HIWORD	
	CALL	LPDCO2	IPRINT IT!
	CALL	LPCRLF	ICARRIAGE RETURN-LINE FEED
	DEC	R5	ICOUNT THE LOOPS
	BEQ	30#	IBRANCH OUT IF DONE
	INC	R1	IINCREMENT CHANNEL NUMBER
	.TTINR		ICHECK FOR "STOP" COMMAND
	BCC	10#	INONE--GO AHEAD
	CMPB	#'S,R0	IS'S IS THE STOP COMMAND
	BNE	10#	ICONTINUE IF NOT 'S'
30#:	.TTINR		IEAT OTHER CHARACTERS
	BCC	30#	
	BIC	#10000,JSW	INORMAL TTY MODE
	MOV	R5PRI,R5	IRESTORE THE REGISTERS
	MOV	R4PRI,R4	
	MOV	R3PRI,R3	
	MOV	R2PRI,R2	

```

      MOV      R1PRI,R1
PRIOUT: RETURN                                ;RETURN TO CALLER
;
;
;THIS SUBROUTINE OUTPUTS THE 'STATUS' OF THE SPECTROMETER TO THE LINE PRINTER.
;
PRSTAT: MOV      R1,RIPRS                      ;SAVE R1
      CALL      PRDATE                          ;PRINT THE DATE
      MOV      #M67,R0                        ;RUN NUMBER
      CALL      LPRINT
      MOV      RUN,R1
      BIT      #2,RUNFLG                      ;RUN IN PROGRESS?
      BEQ      1$
      INC      R1
1$:    CALL      LPDECO
      CALL      LPCRLF
      CMP      #'LA,SCCODE                    ;IS THE LASER BEING SCANNED?
      BEQ      10$                             ;BRANCH IF YES
      CMP      #'QU,SCCODE                    ;IS THE QUADRUPOLE BEING SCANNED?
      BEQ      20$                             ;BRANCH IF YES
      CMP      #'TR,SCCODE                    ;IS THE ION TRAP BEING SCANNED?
      BEQ      30$                             ;BRANCH IF YES
      CMP      #'MA,SCCODE                    ;SECTOR MAGNET?
      BEQ      40$
      CMP      #'QP,SCCODE                    ;QUAD:PEAKS OPTION?
      BNE      3$
      JMP      50$
3$:    CMP      #'MC,SCCODE                    ;MCS UNIT?
      BNE      5$
      JMP      55$
5$:    JMP      60$                             ;NO DEVICE IS BEING SCANNED.
;
;
10$:   MOV      #M24,R0                      ;MESSAGE STRING TO R0
      CALL      LPRINT                          ;OUTPUT TO LP
      MOV      #M25,R0                      ;MESSAGE STRING
      CALL      LPRINT                          ;OUTPUT MESSAGE
      MOV      SHOWAV,LOWORD                  ;LOAD LOW WORD
      MOV      SHOWAV+2,HIWORD                ;LOAD HIGH WORD
      CALL      LPDC02                         ;SEND NUMBER TO LP
      CALL      LPCRLF                         ;CARRIAGE RETURN
      MOV      #M26,R0                      ;MESSAGE STRING
      CALL      LPRINT                          ;SEND IT
      MOV      LONWAV,LOWORD                  ;PRINT OUT LONG WAVELENGTH
      MOV      LONWAV+2,HIWORD
      CALL      LPDC02                         ;SEND IT TO LP
      CALL      LPCRLF                         ;CARRIAGE RETURN
      MOV      #M27,R0                      ;MESSAGE STRING
      CALL      LPRINT                          ;SEND TO LP
      MOV      WAVINC,LOWORD                  ;OUTPUT WAVELENGTH INCREMENT
      MOV      WAVINC+2,HIWORD
      CALL      LPDC02                         ;PRINT IT
      CALL      LPCRLF                         ;CARRIAGE RETURN
      MOV      #M28,R0                      ;MESSAGE STRING

```

```

CALL      LPRINT      ;SEND IT!!
MOV       NSTEP,R1    ;SEND NUMBER OF MOTOR STEPS
CALL      LPDECO      ;TO THE LP
CALL      LPCRLF      ;CARRIAGE RETURN
JMP       70%        ;KEEP GOING

;
;
20%:      MOV         #M30,R0      ;MESSAGE "QUAD. SCANNING"
CALL      LPRINT      ;SEND TO LP
MOV       #M31,R0      ;MESSAGE STRING
CALL      LPRINT      ;TO LP
MOV       MDAC1+2,R1    ;LOW MASS
CALL      LPDECO      ;OUTPUT TO LP
CALL      LPCRLF      ;CARRIAGE RETURN
MOV       #M32,R0      ;MESSAGE STRING
CALL      LPRINT      ;SEND TO LP
MOV       MDAC2,R1      ;HIGH MASS
CALL      LPDECO      ;TO THE LP!
CALL      LPCRLF      ;CARRIAGE RETURN
MOV       #M19,R0      ;MESSAGE STRING
CALL      LPRINT      ;SEND TO LP
MOV       HRES+2,R1    ;# OF CHANNELS PER UNIT MASS
CALL      LPDECO      ;SEND IT
CALL      LPCRLF      ;CARRIAGE RETURN
JMP       70%        ;GO ON

;
;
30%:      MOV         #M29,R0      ;ION TRAP MESSAGE
CALL      LPRINT      ;SEND MESSAGE TO LP
MOV       #M42,R0      ;DELINC MESSAGE
CALL      LPRINT      ;SEND IT
MOV       DELINC,R1    ;LOAD THE VALUE
CALL      LPDECO      ;PRINT NUMBER
CALL      LPCRLF      ;CARRIAGE RETURN
JMP       70%        ;CONTINUE

;
;
40%:      MOV         #M12,R0      ;SECTOR MAGNET
CALL      LPRINT      ;
MOV       #M13,R0      ;LOW CURRENT SETTING
CALL      LPRINT      ;
MOV       MADAC1+2,R1  ;
CALL      LPDECO      ;
MOV       #M15,R0      ;HIGH CURRENT
CALL      LPRINT      ;
MOV       MADAC2,R1    ;
CALL      LPDECO      ;
MOV       #M19,R0      ;CHANNELS/UNIT
CALL      LPRINT      ;
MOV       HRES+2,R1    ;
CALL      LPDECO      ;
CALL      LPCRLF      ;
BR        70%         ;
;
;

```

```

50%:  MOV    #M20,R0          #SQUAD PEAKS OPTION
      CALL  LPRINT
      CALL  LPCRLF
      BR    70%

;
;
55%:  MOV    #M85,R0          #MCS UNIT
      CALL  LPRINT
      MOV    #M97,R0          #TRIGGER COUNT=
      CALL  LPRINT            #TRIGGER COUNT
      MOV    TRGBIN,R1
      CALL  LPDECO
      CALL  LPCRLF
      BR    70%

;
;
60%:  MOV    #M34,R0          #NO DEVICE SCANNING!!
      CALL  LPRINT            #SEND MESSAGE
70%:  MOV    #M43,R0          #DELOFF MESSAGE
      CALL  LPRINT            #SEND IT
      MOV    DELOFF,R1        #LOAD VALUE
      CALL  LPDECO            #PRINT IT
      CALL  LPCRLF            #CARRIAGE RETURN
      MOV    #M35,R0          #LASER SETTING MESSAGE
      CALL  LPRINT            #SEND IT
      MOV    SETWAV,LOWORD     #LOAD THE NUMBER
      MOV    SETWAV+2,HIWORD
      CALL  LPDCO2
      CALL  LPCRLF            #PRINT IT
      MOV    #M36,R0          #CARRIAGE RETURN
      CALL  LPRINT            #NUMBER OF CHANNELS MESSAGE
      MOV    NCHAN,R1         #SEND
      CALL  LPDECO            #LOAD VALUE
      MOV    #M41,R0          #SEND IT OUT!
      CALL  LPRINT            #CYCLES MESSAGE
      MOV    DACYCL+2,R1      #SEND IT
      CALL  LPDECO            #LOAD VALUE
      CALL  LPCRLF            #SEND THE NUMBER
      MOV    #M37,R0          #CARRIAGE RETURN
      CALL  LPRINT            #NUMBER OF SCANS MESSAGE
      MOV    NSCAN,R1         #SEND IT
      CALL  LPDECO            #LOAD THE NUMBER
      CALL  LPCRLF            #PRINT IT
      MOV    #M38,R0          #CARRIAGE RETURN
      CALL  LPRINT            #CHANNEL NUMBER MESSAGE
      MOV    BUFOFF,R1        #SEND THE MESSAGE
      ASH    #-2,R1           #LOAD R1
      ADD    #1,R1            #DIVIDE BY FOUR
      CALL  LPDECO            #ADD 1 (ZERO=CHANNEL ONE)
      MOV    #M45,R0          #PRINT THE NUMBER
      CALL  LPRINT            #A2D GAIN SETTING MESSAGE
      MOV    A2DGNS,R0        #SEND IT
      CALL  LPOUT             #GET THE CHARACTER
      MOV    <A2DGNS+1>,R0    #SEND TO LP
      CALL  LPOUT             #GET THE OTHER ONE
      CALL  LPOUT             #SEND IT

```

```

MOV     #M39,R0                ;SCANNING PROCEDURE MESSAGE
CALL    LPRINT                 ;SEND TO LP
MOVB    SCTYPE,R0              ;GET THE FIRST CHARACTER
CALL    LPOUT                  ;SEND TO LP
MOVB    <SCTYPE+1>,R0          ;GET THE NEXT CHARACTER
CALL    LPOUT                  ;SEND IT
CALL    LPCRLF                 ;LP CARRIAGE RETURN-LINEFEED
MOV     RIPRS,R1               ;RESTORE R1
PRROUT: RETURN                 ;RETURN TO CALLER
;
;SUBROUTINE TO SEND MACHINE STATUS TO THE CONSOLE
;
TYSTAT: MOV     R1,R17S         ;SAVE R1
CALL     TYDATE                ;SEND THE DATE
.PRINT   #M67                  ;RUN NUMBER
MOV     RUN,R1
BIT     #2,RUNFLG              ;RUN IN PROGRESS?
BEQ     1$
INC     R1
1$: CALL    DECOU              ;
CALL    CRLF
CMP     #*LA,SCCODE            ;IS THE LASER BEING SCANNED?
BEQ     15$                    ;BRANCH IF YES
CMP     #*QU,SCCODE            ;IS THE QUADRUPOLE BEING SCANNED?
BEQ     20$                    ;BRANCH IF YES
CMP     #*TR,SCCODE            ;IS THE ION TRAP BEING SCANNED?
BEQ     30$                    ;BRANCH IF YES
CMP     #*MA,SCCODE            ;SECTOR MAGNET
BEQ     40$
CMP     #*QP,SCCODE            ;QUAD:PEAKS OPTION
BNE     3$
JMP     50$
3$: JMP     #*MC,SCCODE         ;MCS UNIT?
BNE     5$
JMP     55$
5$: JMP     60$                ;NO DEVICE IS BEING SCANNED.
;
;
15$: .PRINT   #M24              ;LASER SCANNING MESSAGE
.PRINT   #M25                  ;SHORT WAVELENGTH=
MOV     SHOWAV,LOWORD          ;LOAD LOW WORD
MOV     SHOWAV+2,HIWORD        ;LOAD HIGH WORD
CALL    DCOUT2                 ;SEND NUMBER TO TT
CALL    CRLF                   ;CARRIAGE RETURN
.PRINT   #M26                  ;LONG WAVELENGTH =
MOV     LONWAV,LOWORD          ;PRINT OUT LONG WAVELENGTH
MOV     LONWAV+2,HIWORD
CALL    DCOUT2                 ;SEND IT TO TT
CALL    CRLF                   ;CARRIAGE RETURN
.PRINT   #M27                  ;WAVELENGTH INCREMENT =
MOV     WAVINC,LOWORD          ;OUTPUT WAVELENGTH INCREMENT
MOV     WAVINC+2,HIWORD
CALL    DCOUT2                 ;PRINT IT
CALL    CRLF                   ;CARRIAGE RETURN

```

```

.PRINT      #M28      #NUMBER OF MOTOR STEPS =
MOV         NSTEP,R1  #SEND NUMBER OF MOTOR STEPS
CALL        DECOU     #TO THE TT
CALL        CRLF      #CARRIAGE RETURN
JMP         70%       #KEEP GOING

;
;
20%:        .PRINT    #M30      #MESSAGE "QUAD. SCANNING"
.PRINT      #M31      #LOW MASS =
MOV         MDAC1+2,R1 #LOW MASS
CALL        DECOU     #OUTPUT TO TT
CALL        CRLF      #CARRIAGE RETURN
.PRINT      #M32      #HIGH MASS =
MOV         MDAC2,R1  #HIGH MASS
CALL        DECOU     #TO THE TT
CALL        CRLF      #CARRIAGE RETURN
.PRINT      #M19      #TYPE MESSAGE
MOV         HRES+2,R1 # OF STEPS PER CHANNEL
CALL        DECOU     #SEND IT
CALL        CRLF      #CARRIAGE RETURN
JMP         70%       #GO ON

;
;
30%:        .PRINT    #M29      #ION TRAP MESSAGE
.PRINT      #M42      #DELINC MESSAGE
MOV         DELINC,R1 #LOAD THE VALUE
CALL        DECOU     #PRINT NUMBER
CALL        CRLF      #CARRIAGE RETURN
JMP         70%       #CONTINUE

;
;
40%:        .PRINT    #M12      #SECTOR MAGNET
.PRINT      #M13      #LOW CURRENT
MOV         MADAC1+2,R1
CALL        DECOU
.PRINT      #M15      #HIGH CURRENT
MOV         MADAC2,R1
CALL        DECOU
.PRINT      #M19      #CHANNELS/UNIT
MOV         HARES+2,R1
CALL        DECOU
CALL        CRLF
BR         70%

;
;
50%:        .PRINT    #M20      #QUAD:PEAKS OPTION
CALL        CRLF
BR         70%

;
;
55%:        .PRINT    #M85      #HCS UNIT
.PRINT      #M97      #TRIGGER COUNT=
MOV         TRGBIN,R1 #TRIGGER COUNT
CALL        DECOU     #DECIMAL OUTPUT
CALL        CRLF

```

```

BR      709

;
;
609:    .PRINT  #M34      ;NO DEVICE SCANNING
709:    .PRINT  #M43      ;DELOFF MESSAGE
      MOV    DELOFF,R1   ;LOAD VALUE
      CALL   DECOU      ;PRINT IT
      CALL   CRLF       ;CARRIAGE RETURN
      .PRINT #M35       ;LASER SETTING MESSAGE
      MOV    SETWAV,LOWORD ;LOAD THE NUMBER
      MOV    SETWAV+2,HIWORD
      CALL   DECOU      ;PRINT IT
      CALL   CRLF       ;CARRIAGE RETURN
      .PRINT #M36       ;NUMBER OF CHANNELS MESSAGE
      MOV    NCHAN,R1   ;LOAD VALUE
      CALL   DECOU      ;SEND IT OUT!
      .PRINT #M41       ;DATA CYCLES MESSAGE
      MOV    DACYCL+2,R1 ;LOAD THE NUMBER
      CALL   DECOU      ;TYPE IT TO CONSOLE
      CALL   CRLF       ;CARRIAGE RETURN
      .PRINT #M37       ;NUMBER OF SCANS MESSAGE
      MOV    NSCAN,R1   ;LOAD THE NUMBER
      CALL   DECOU      ;PRINT IT
      CALL   CRLF       ;CARRIAGE RETURN
      .PRINT #M38       ;CHANNEL NUMBER MESSAGE
      MOV    BUFOFF,R1  ;LOAD R1
      ASH    #2,R1      ;DIVIDE BY FOUR
      ADD    #1,R1      ;BUFOFF=0 IS CHANNEL ONE
      CALL   DECOU      ;PRINT THE NUMBER
      .PRINT #M45       ;A2D GAIN SETTING MESSAGE
      MOVB   A2DONS,R0  ;GET CHARACTER
      .TTYOUT ;TYPE IT
      MOVB   <A2DONS+1>,R0 ;GET THE OTHER ONE
      .TTYOUT ;TYPE IT
      .PRINT #M39       ;SCANNING PROCEDURE MESSAGE
      MOVB   SCTYPE,R0  ;GET THE FIRST CHARACTER
      .TTYOUT ;SEND TO CONSOLE
      MOVB   <SCTYPE+1>,R0 ;GET THE NEXT ONE
      .TTYOUT ;SEND IT
      .PRINT #M40       ;WHICH DATA BUFFER DISPLAYED
      MOVB   DICODE,R0  ;GET CHARACTER
      .TTYOUT ;SEND TO CONSOLE
      MOVB   <DICODE+1>,R0 ;GET THE OTHER ONE
      .TTYOUT ;SEND IT
      CALL   CRLF       ;CARRIAGE RETURN-LINEFEED
      MOV    R1TYS,R1   ;RESTORE R1
TYSOUT: RETURN
;
;
;SUBROUTINE TYDATA SENDS DISPLAYED DATA CHANNELS TO THE CONSOLE
;
TYDATA: MOV    R1,R1PRI  ;SAVE THE REGISTERS
      MOV    R2,R2PRI
      MOV    R3,R3PRI

```


	MOV R4,R4PRI	
	MOV R5,R5PRI	
	BIS #10000,JSW	ISPECIAL TTY MODE
	MOV D79TR7,R1	ISTART OF DISPLAY BUFFER
	SUB DIBUF,R1	IR1=BUFFER OFFSET
	MOV SDBUF,R2	ISTARTING ADDRESS OF S+B BUFFER
	ADD R1,R2	IADD OFFSET
	MOV BABUF,R3	ISTARTING ADDRESS OF BACKGRD.BUFFER
	ADD R1,R3	
FER	MOV POBUF,R4	ISTARTING ADDRESS OF LASER POWER BUF
	ADD R1,R4	
	MOV DICHNS,R5	INUMBER OF WINDOW CHANNELS
	.PRINT #M21	ITYPE HEADER
	CALL CRLF	ICARRIAGE RETURN-LINE FEED
	ADD #4,R1	ISTARTING CHANNEL NUMBER
	ASH #2,R1	
10%:	CALL DCOOUT	ITYPE THE CHANNEL NUMBER(IN R1)
	.PRINT #M22	ISPACES
	MOV (R2),LOWORD	ILOAD SIG.+BACK. FOR OUTPUT
	MOV 2(R2),HIWORD	
	CALL DCOOUT2	ITYPE THE NUMBER
	.PRINT #M22	ISPACES
	MOV (R3),LOWORD	ILOAD BACKGROUND
	MOV 2(R3),HIWORD	
	CALL DCOOUT2	ITYPE IT
	.PRINT #M22	ISPACES
	MOV (R2)+,LOWORD	ICALCULATE THE SIGNAL
	MOV (R2)+,HIWORD	ISUBTRACT BACKGROUND FROM SIG.+BACK.
	SUB (R3)+,LOWORD	
	SUB HIWORD	
	SUB (R3)+,HIWORD	
	CALL DCOOUT2	ITYPE THE SIGNAL
	.PRINT #M22	ISPACES
	MOV (R4)+,LOWORD	ILOAD LASER-POWER FOR OUTPUT
	MOV (R4)+,HIWORD	
	CALL DCOOUT2	ITYPE IT!
	CALL CRLF	ICARRIAGE RETURN-LINE FEED
	DEC R5	ICOUNT THE LOOPS
	BEQ 30%	IDRANCH OUT IF DONE
	INC R1	INCREMENT CHANNEL NUMBER
	.TTINR	ICHECK FOR 'STOP' COMMAND
	BCC 10%	INONE--GO AHEAD
	CMPE #S,R0	IS'S' IS THE STOP COMMAND
	BNE 10%	ICONTINUE IF NOT 'S'
30%:	.TTINR	IEAT OTHER CHARACTERS
	BCC 30%	
	BIC #10000,JSW	INORMAL TTY MODE
	MOV R5PRI,R5	IRESTORE THE REGISTERS
	MOV R4PRI,R4	
	MOV R3PRI,R3	
	MOV R2PRI,R2	
	MOV R1PRI,R1	
TYDOUT:	RETURN	IRETURN TO CALLER

```

;
;
;SUBROUTINE TO OUTPUT THE "HEADER" TO THE LINE PRINTER
;
PRHDR: MOV     R1,R1PRH           ;SAVE R1
        MOV     #DATBUF,R1       ;POINT TO DATA BUFFER
        ADD     #100.,R1         ;POINT TO HEADER
10$:    MOVB     (R1)+,R0         ;GET A CHARACTER
        CMPB     #200,R0         ;IS IT THE TERMINATOR?
        BEQ      20$            ;BRANCH IF YES
        CALL     LPOUT           ;SEND CHARACTER TO LINE PRINTER
        BR       10$           ;GET MORE
20$:    CALL     LPCRLF          ;RETURN CARRIAGE
        MOV     R1PRH,R1        ;RESTORE R1
PRHOUT: RETURN                   ;RETURN TO CALLER
;
;
;SUBROUTINE TO OUTPUT THE HEADER TO THE CONSOLE
;
TYHDR: MOV     R1,R1TYH           ;SAVE R1
        MOV     #DATBUF,R1       ;POINT TO DATA BUFFER
        ADD     #100.,R1         ;POINT TO HEADER
10$:    MOVB     (R1)+,R0         ;GET CHARACTER
        CMPB     #200,R0         ;TERMINATOR?
        BEQ      20$            ;BRANCH IF YES
        .TTYOUT                  ;CHARACTER OUT
        BR       10$           ;GET MORE
20$:    CALL     CRLF            ;SKIP A LINE
        MOV     R1TYH,R1        ;RESTORE R1
TYHOUT: RETURN                   ;RETURN TO CALLER
;
;
;SUBROUTINE TO SEND DATE TO CONSOLE
;
TYDATE: CALL     CRLF            ;SKIP LINE
        CMPB     #'N',DAY       ;IS THERE A DATE?
        BEQ      10$
        MOV     DAY,R1
        CALL     DECOU
        MOV     #' ',R0
        .TTYOUT
        .TTYOUT
        .PRINT     #M66          ;SEND MONTH
        MOV     YEAR,R1
        ADD     #1900.,R1
        CALL     DECOU
        BR       20$
10$:    .PRINT     #M64          ;NO DATE MESSAGE
20$:    CALL     CRLF
        RETURN
;
;
;SUBROUTINE TO SEND DATE TO PRINTER
;
PRDATE: CALL     LPCRLF          ;SKIP LINE

```

	CMPB	#'N, DAY	#NO DATE?
	BEG	10%	
	MOV	#M65, R0	
	CALL	LPRINT	#BACK SPACES
	MOV	DAY, R1	
	CALL	LPDECO	
	MOV	#'-, R0	
	CALL	LPOUT	
	MOV	#M66, R0	#MONTH
	CALL	LPRINT	
	MOV	#'-, R0	
	CALL	LPOUT	
	MOV	#M65, R0	#BACK SPACES
	CALL	LPRINT	
	MOV	YEAR, R1	
	CALL	LPDECO	
	BR	20%	
10%:	MOV	#M64, R0	#NO DATE MESSAGE
	CALL	LPRINT	
20%:	CALL	LCRLF	
	RETURN		
;			
#END OF PAGE THREE.			

IPAGE FOUR.

;
;SUBROUTINE TO DECODE SYSTEM DATE WORD (RETURNED BY .DATE) AND TO LOAD
;VALUE INTO 'DAY,MONTH,AND YEAR'.(MODIFIED 'DEC' PROGRAM--VOL3 PG 2-48)
;

```
DATES:  MOV     DATE,R0           ;COPY DATE WORD
        MOV     R0,R2
        BEQ     10%             ;BR IF NO DATE
        BIC     @^C37,R2        ;ISOLATE YEAR
        ADD     @72.,R2         ;ADD BIAS
        MOV     R2,YEAR
        ASH     @-2,R0
        MOV     R0,R1           ;COPY THE DATE
        SWAB    R1              ;MONTH IN LOW BYTE
        BIC     @^C37,R1        ;ISOLATE MONTH
        ASH     @-3,R0
        BIC     @^C37,R0        ;ISOLATE DAY
        MOV     R0,DAY
        SUB     #1,R1           ;MONTH STRING OFFSET
        ASL     R1
        ADD     @R50STR,R1
        MOV     (R1),MONTH      ;MONTH POINTER
        MOV     @DATLST,R5      ;ARGUMENT LIST FOR CALL
        CALL    R50ASC          ;LOAD 'MONTH' WITH ASCII
        BR      20%
10%:    MOVB    @'N,DAY         ;NO DATE FLAG
20%:    RETURN
```

;
;
;

;DISPLAY SUBROUTINES

```
;  
XLOAD:  MOV     DISTRT,R1
        MOV     DICHNS,R2
        MOV     XJMP,R3
        NEG     R3
XLOOP:  ADD     XJMP,R3
        MOV     R3,(R1)+
        TST     (R1)+
        SOB     R2,XLOOP
        RETURN
```

;
;

```
XJUMP:  MOV     #4096.,R1
        ASH     #2,R1
        CLR     R0
        DIV     DICHNS,R0
        ASH     @-2,R0
        MOV     R0,XJMP
        RETURN
```

;
;

;DISPLAY CONTROL SUBROUTINE

```
;  
DISDAT: CALL    DISHLT          ;HALT DISPLAY
```

	MOV	#00,IOBUF	!PLACE ZEROES IN FIRST WORD
	CMPB	#15,IOBUF+2	!CARIAGE RETURN?
	BEQ	10%	
	BR	15%	
10%:	.PRINT	#M5B	!ASK FOR VALUE
	CALL	READ	!READ REPLY
15%:	CALL	ASCBIN	!CONVERT TO BINARY
	BCC	20%	
	.PRINT	#M4	!ERROR MESSAGE
	BR	10%	
20%:	ASH	#2,R1	!TIMES FOUR
	MOV	R1,DISNUM	!SAVE DISPLAY NUMBER
	SUB	#4,DISNUM	!OFFSET
	TST	DISNUM	!POSITIVE?
	BPL	25%	
	MOV	#0,DISNUM	
25%:	JMP	@DISCOM	!GO TO COMMAND
WL:	SUB	R1,DISWIN	!SHIFT WINDOW LEFT
	CMP	DISWIN,DIBUF	!WITHIN BOUNDS?
	BPL	10%	
	MOV	DIBUF,DISWIN	
	CMP	#0,SLRFLG	!SCROLLING?
	BEQ	10%	
	NEG	SLRFLG	!SCROLL RIGHT
10%:	BR	DWCHK	
WR:	ADD	R1,DISWIN	
	MOV	WINSIZ,R2	
	ASH	#2,R2	
	ADD	DISWIN,R2	
	CMP	DISHAX,R2	
	BPL	10%	
	SUB	R1,DISWIN	
	CMP	#0,SLRFLG	!SCROLLING?
	BEQ	10%	
	NEG	SLRFLG	!SCROLL LEFT
10%:	BR	DWCHK	!CHECK WINDOW SIZE
WI:	ADD	DIBUF,DISNUM	!MEMORY POINTER
	CMP	DISHAX,DISNUM	!TOO LARGE?
	BPL	10%	
	MOV	DISHAX,DISNUM	
10%:	MOV	DISNUM,DISWIN	!STARTING ADDRESS
	BR	DWCHK	!CHECK WINDOW SIZE
WA:	ADD	#4,DISNUM	!SELECT WINDOW SIZE
	MOV	DISNUM,R1	
	ASH	#-2,R1	
	MOV	R1,WINSIZ	!NEW WINDOW SIZE
DWCHK:	MOV	DISHAX,R1	!CHECK WINDOW SIZE COMPATABILITY

```

SUB      DISWIN,R1
ASH      #-2,R1
CMP      R1,WINSIZ
BPL      J0%
30%:     MOV      R1,WINSIZ
CMP      #0,EXPFLG
BNE      DICOUT
MOV      #1,EXPFLG

;
;
DE:      CALL     DISHLT           ;HALT DISPLAY
TST      EXPFLG                  ;EXPAND OR CONTRACT?
BEQ      20%
CLR      EXPFLG                  ;EXPAND
MOV      WINSIZ,DICHNS
MOV      DISWIN,DISTR
CALL     XJUMP
CALL     XLOAD
BR       DICOUT
20%:     MOV      #1,EXPFLG       ;CONTRACT
MOV      NCHAN,DICHNS
MOV      DIBUF,DISTR
CALL     XJUMP
CALL     XLOAD
BR       DICOUT

;
;
WB:      ASH      #-2,R1           ;DISPLAY BRIGHTNESS
TST      R1
BGE      10%
CLR      R1
10%:     MOV      R1,WINBRT
BR       DICOUT

;
;
;
AB:      ASH      #-2,R1           ;ACTIVE DISPLAY BRIGHTNESS
TST      R1
BGE      10%
CLR      R1
10%:     MOV      R1,ACTIVE+2
BR       DICOUT

;
DICOUT:  MOV      #1,DMAHLT        ;DMA GO
MOV      DISTR,DMACAR            ;LOAD DMA REGISTERS
MOV      DICHNS,DMAPCR
NEG      DMAPCR                  ;2'S COMPLEMENT
BIS      #102,ADCSR              ;ENABLE DMA INT
BIS      #1,ADCSR                ;START DMA
RETURN

;
;
;SUBROUTINE TO SCROLL WINDOW

```

```

;
SLR:  MOV    #4,R1                ;SCROLL LEFT
      CALL  DISHLT                ;STOP DMA
      CMP   #1,SLRFLG            ;SCROLL RIGHT?
      BEQ   1$
      CALL  WL                    ;SHIFT DISPLAY LEFT
      BR    5$
1$:   CALL  WR                    ;SHIFT DISPLAY RIGHT
5$:   MOV    SCROLL,R1            ;WAIT LOOP
10$:  SOB    R1,10$
      BIS    #10000,JSW          ;SPECIAL TTY MODE
      .TTINR                      ;CHECK FOR 'STOP' COMMAND
      BCS    SLR                 ;NONE--GO AHEAD
      CMPB   #'S',R0             ;'S' IS THE STOP COMMAND
      BNE    SLR                 ;CONTINUE IF NOT 'S'
20$:  .TTINR                      ;EAT THE OTHER CHARACTERS
      BCC    20$
      BIC    #10000,JSW          ;NORMAL TTY MODE
      RETURN
;
;
;YAXIS PACKAGE SETS Y-AXIS SCALING OF DISPLAYED DATA.
;
YAXIS: JMP    @YFUNC              ;GO TO SCALING FUNCTION
;
;
;SUBROUTINE TO SET AUTO-SCALING OF DISPLAY OR ABSOLUTE SCALING.
;
AS:   MOV    #'00,I0BUF           ;ZERODES FIRST WORD
      CMPB   #15,I0BUF+2         ;CR?
      BEQ    10$
      CMP    #'AS,I0BUF+2        ;AUTO-SCALE?
      BEQ    30$
      BR     12$
10$:  .PRINT  $M59                ;Y-MAX
      CALL   READ
      CMP    #'AS,I0BUF         ;AUTO SCALE?
      BEQ    30$
12$:  CALL    ASCBIN
      BCC    20$
15$:  .PRINT  #M4                 ;BAD ENTRY
      BR     10$
20$:  TST     R2
      BLT    15$
      MOV    R1,YMAX             ;LOW WORD
      MOV    R2,YMAX+2           ;HIGH WORD
      MOV    #3,DISFLG          ;SCALING FLAG
25$:  MOV     #2048.,YSCALE
      CLR    UPDATE
      RETURN
30$:  MOV     #0,DISFLG
      BR     25$
;
WS:   MOV     #1,DISFLG          ;WINDOW SCALING
      MOV     #2048.,YSCALE

```

```

CLR      UPDATE
RETURN

;
;
;SCALE DOWN DISPLAY BY 1/2
;
SD:      ASR      YSCALE
        BNE      SEX
        MOV      #1,YSCALE
SEX:     .PRINT   #M60          ;YSCALE:
        MOV      YSCALE,R1
        CALL     DCOUT
        CALL     CRLF
        CLR      UPDATE
        RETURN

;
;SCALE UP DISPLAY BY 2
;
SA:      ASL      YSCALE
        BPL      SEX
        MOV      #32767.,YSCALE
        BR       SEX

;
;SCALE DISPLAY SO SPECIFIED CHANNEL=100.
;
CS:      MOV      #'00,I0BUF          ;ZER0ES IN FIRST WORD
        CHPB     #15,I0BUF+2          ;CR?
        BEQ      10%
        BR       12%
10%:     .PRINT   #M61          ;CHANNEL:
        CALL     READ
12%:     CALL     ASCBIN
        BCC      20%
15%:     .PRINT   #M4          ;BR IF OK
        BR       10%          ;BAD ENTRY
20%:     CMP      R1,#1
        BLT      15%
        CMP      NCHAN,R1
        BLT      15%
        DEC      R1          ;ADDRESS OFFSET
        ASH      #2,R1
        MOV      R1,CSCHAN
        CLR      UPDATE
        MOV      #2048.,YSCALE
        MOV      #2,DISFLG
        RETURN

;TYPE DISPLAY PARAMETERS
;
DP:      .PRINT   $M59          ;YMAX:
        MOV      YMAX,LOWORD
        MOV      YMAX+2,HIWORD
        CALL     DCOUT2
        CALL     CRLF
        .PRINT   #M73          ;YMIN:
        MOV      YMIN,LOWORD

```



```

MOV     YMIN+2,HIWORD
CALL    DCOUT2
CALL    CRLF
.PRINT  #M62                                ;WINDOW SILL
MOV     DISWIN,R1
SUB     DIBUF,R1                            ;FIND CHANNEL NUMBER
ADD     #4,R1
ASH     #-2,R1
CALL    DECOUT
CALL    CRLF
.PRINT  #M63                                ;WINDOW SIZE
MOV     WINSIZ,R1
CALL    DECOUT
CALL    CRLF
.PRINT  #M60                                ;YSCALE
MOV     YSCALE,R1
CALL    DECOUT
CALL    CRLF
BIT     #2,FLGDIS                           ;REVERSED DISPLAY?
BEQ     10%                                 ;DISPLAY REVERSED
.PRINT  #M78
BR      20%
10%:    .PRINT #M79                          ;DISPLAY NORMAL
20%:    BIT     #1,FLGDIS                    ;POWER NORMALIZED?
BEQ     30%
.PRINT  #M80                                ;YES
BR      40%
30%:    .PRINT #M81                          ;NO
40%:    RETURN
;
;
RE:     BIT     #2,FLGDIS                    ;DISPLAY FORWARD OR REVERSE?
BEQ     10%                                 ;CHANGE IT
BIC     #2,FLGDIS                           ;GO FORWARD
.PRINT  #M79
CLR     UPDATE                              ;CAUSE DISPLAY UPDATE
RETURN
10%:    BIS     #2,FLGLIS                    ;GO "BACKWARDS"
.PRINT  #M78
CLR     UPDATE
RETURN
;
;
PN1:    BIT     #1,FLGDIS                    ;POWER NORMALIZE
BEQ     10%                                 ;PRESENTLY?
BIC     #1,FLGDIS                           ;DO NOT POWER NORM.
.PRINT  #M81
CLR     UPDATE                              ;CAUSE DISPLAY UPDATE
RETURN
10%:    BIS     #1,FLGDIS                    ;POWER NORM.
.PRINT  #M80
CLR     UPDATE
RETURN
;
;

```

SUBROUTINE TO SET 'KEY' INTERRUPT MODE

```

%MACRO KEY_INT;
KEY_INT:
    MOV     $0,ACCUM
    MOV     $0,ACCFLG
    MOV     $0,A2DCON
    .PRINT  %M92
    .PRINT  %M96
    MOV     %DATAIN,ROUTINE
    CALL    KEYHOL
    BIC     $1,SCMODE
    MOV     $26,A2DCON
    MOV     ROSMO,ACCFLG
    .PRINT  %M93
    RETURN
%ENDMACRO

```

●

● ●

```

      INITIALIZE TO CALL FORTRAN PLOTTB SUBROUTINE

```

•

PLOTPH:	MOV	#0,PLMOV	DEFAULT VALUES
	MOV	#1,PLLINE	SOLID LINE
	BR	PLOTIT	
PLOTPV:	MOV	#0,PLMOV	X-COORD.(CHANNEL)
	MOV	#1,PLLINE	SOLID LINE
	BR	PLOTIT	
PLOTPC:	MOV	#12,PLMOV	Y-COORD.
	BR	PLOTIT	
PLOTPH:	MOV	#10,PLMOV	Y-COORD.
	BR	PLOTIT	

1

```

PLOTIT:  MOV      IOBUF,PLCTRL      #CONTROL WORD
        CMPB     #15,<IOBUF+2>      #CR?
        BEQ      PLOTEX
        MOV      #IOBUF,R3         #POINTERS
        MOV      #<IOBUF+2>,R0
10$:     MOVB     (R0),(R3)          #SHIFT
        CMPB     #15,(R3)          #CR?
        BNE      30$
15$:     CALL     ASCBIN            #CONVERT TO BINARY
        BCC      20$              #BR IF OK
        BR       PLOTEX            #DEFAULT
20$:     MOV      R1,PLMOV          #ENTERED VALUE
        BR       PLOTEX
30$:     CMPB     #54,(R0)+         #COMMA?
        BEQ      40$
        TSTB     (R3)+
        BR       10$
40$:     MOVB     (R0),PLLINE       #CONTINUE
        MOVB     #15,(R3)          #ENTERED VALUE
        BR       15$

```

3

```

PLOT:  MOV      IOBUF,PLCTRL      ;PLOTTR CONTROL
        CLR      PLMOV
        CLR      PLCHAR
        CLR      PLLINE

```

```

CMPB      IOBUF+2,*15      ;CR?
BEQ        10%             ;IF YES,DEFAULT
MOVB      IOBUF+2,PLCHAR   ;PLOT CHARACTER
CMPB      IOBUF+3,*15      ;CR?
BEQ        20%             ;YES-THEN DEFAULT
MOVB      IOBUF+3,PLLINE   ;LINE TYPE
BR         PLOTX           ;DEFAULTS
10%:      MOV      #'I,PLCHAR
20%:      MOV      #'0,PLLINE
PLOTX:    CALL     DISHLT   ;HALT DMA
          MOV      DISTRT,R1 ;STARTING-CHANNEL NUMBER
          SUB      DIBUF,R1
          ADD      #4,R1
          ASH      #2,R1
          MOV      R1,STCHAN
          MOV      #PLLIST,R5 ;ARGUMENT LIST FOR CALL
          CALL     PLOTTR
          MOV      #1,DMAHLT   ;ALLOW DMA TO START
          BIS      #103,ADCSR  ;START DMA DISPLAY DRIVER
          RETURN

;
;
;SUBROUTINE TO FIND THE INTEGRAL OF WINDOWED CHANNELS.
;
IW:        MOV      DISWIN,R1      ;POINT TO FIRST CHANNEL
          SUB      DIBUF,R1
          CLR      LOWORD
          CLR      HIWORD
          MOV      WINSIZ,R4      ;WINDOW SIZE
          CMP      #'SI,DICODE    ;SIGNAL DISPLAYED?
          BEQ      10%
          CMP      #'SB,DICODE    ;SIG.+BAK.?
          BEQ      20%
          CMP      #'BA,DICODE    ;BAK.?
          BEQ      30%
          CMP      #'PO,DICODE    ;POWER?
          BEQ      40%
          JMP      IWOUT
10%:      MOV      SBBUF,R2
          ADD      R1,R2
          ADD      SBBUF,R1
15%:      ADD      (R1)+,LOWORD
          ADC      HIWORD
          BVS      60%            ;OVERFLOW?
          ADD      (R1)+,HIWORD
          BVS      60%            ;OVERFLOW?
          SUB      (R2)+,LOWORD
          SBC      HIWORD
          BVS      60%            ;OVERFLOW?
          SUB      (R2)+,HIWORD
          BVS      60%            ;OVERFLOW?
          SOB      R4,15%
          BR       50%
20%:      ADD      SBBUF,R1
25%:      ADD      (R1)+,LOWORD

```

```

        ADC      HIWORD
        BVS      60%                ;OVERFLOW?
        ADD      (R1)+,HIWORD
        BVS      60%                ;OVERFLOW?
        SOB      R4,25%
        BR       50%
30%:    ADD      BABUF,R1
35%:    ADD      (R1)+,LOWORD
        ADC      HIWORD
        BVS      60%                ;OVERFLOW?
        ADD      (R1)+,HIWORD
        BVS      60%                ;OVERFLOW?
        SOB      R4,35%
        BR       50%
40%:    ADD      POBUF,R1
45%:    ADD      (R1)+,LOWORD
        ADC      HIWORD
        BVS      60%                ;OVERFLOW?
        ADD      (R1)+,HIWORD
        BVS      60%                ;OVERFLOW?
        SOB      R4,45%
        BR       50%
50%:    .PRINT   #M69                ;INTEGRAL=
        CALL     DCOUT2
        CALL     CRLF
        BR       INOUT
60%:    .PRINT   #M68                ;OVERFLOW
INOUT:   RETURN
;
;SCROLL SPEED UP BY 2
;
SF:      ASR      SCROLL
        BNE      SEXY
        MOV      #1,SCROLL
SEXY:    .PRINT   #M70                ;SCROLL:
        MOV      SCROLL,R1
        CALL     DCOUT
        CALL     CRLF
        RETURN
;
;SCROLL SPEED DOWN BY 1/2
;
SS:      ASL      SCROLL
        BPL      SEXY
        MOV      #32767.,SCROLL
        BR       SEXY
;
;
;SUBROUTINE TO SUBTRACT A CONSTANT FROM DATA
;
SZ:      CMPB     #15,IOBUF+2        ;CR?
        BEQ      20%
        MOV      #*00,IOBUF          ;ZEROS IN FIRST WORD
        MOV      #<IOBUF+2>,R0
1%:      CHPP     #'-(R0)            ;MINUS?

```



```

35%:  CMP    $'SB,IOBUF      ;PLACE DATA IN S+B BUFFER?
      BNE    40%            ;LOAD BUFFER LOCATION
      MOV    SBBUF,MCSBUF
      RETURN

40%:  CMP    $'BA,IOBUF      ;PLACE DATA IN BACK. GR'D. BEFFER?
      BNE    45%            ;LOAD MCSBUF POINTER
      MOV    BABUF,MCSBUF
      RETURN

45%:  CMP    $'CL,IOBUF      ;CLEAR MCS RAM?
      BNE    50%            ;CLEAR RAM?
      .PRINT 0M99           ;ARE YOU SURE?
      .PRINT 0M48
      CALL   READ           ;GET REPLY
      CMB    $'Y,IOBUF      ;YES?
      BEQ    450%
      RETURN

450%: JMP     MCSCL          ;GO DO IT
50%:  JMP     3%            ;TRY ANOTHER COMMAND
;
;
MCSIM: MOVB    09.,MCSA0     ;ALL CLEAR
      MOV     100.,R0        ;WAIT FOR MEMORY CLEAR
1%:    SDB     R0,1%
      MOVB    026.,MCSA0
      .PRINT 0M87           ;DWELL TIME
      CALL   MCSINP
      MOV     BCD,DWLBBCD
      MOV     DWLBBCD,DATAL0
      MOVB    018.,MCSA0
      MOV     BIN,DWLBIN
      .PRINT 0M88           ;TRIGGER COUNT
      CALL   MCSINP
      MOV     BCD,TRGBCD
      MOV     TRGBCD,DATAL0
      MOVB    018.,MCSA2
      MOV     BIN,TRGBIN
      .PRINT 0M89           ;SWEEP COUNT
      CALL   MCSINP
      MOV     BCD,SWPBCD
      MOV     BIN,SWPBIN
      CLR     DATAL0
      MOVB    018.,MCSA1
3%:    MOV     SWPBCD,DATAL0 ;LOAD INITIAL ADDRESS
      BIS     01,STATU1      ;LOAD SWEEP COUNTER
      MOVB    018.,MCSA3
      BIC     01,STATU1      ;LOAD SWEEP COUNT
      CMP     MCSA3,SWPBCD   ;CLR DII FOR COMPARE
      BNE    3%
      CLR     NSCAN
      BIS     01,STATU1      ;CLEAR SCAN COUNTER
      MOVB    018.,MCSA4
      RETURN                ;SET INTERNAL DWELL CLOCK
;
;
MCSZZ: MOV     DWLBBCD,DATAL0 ;TRY LOADING AGAIN

```

```

MOV B    #18.,MCSA0          ;LOAD DWELL
MOV      TRGBCD,DATALD
MOV B    #18.,MCSA2          ;LOAD TRIGGER
MOV      SWPBCD,DATALD
BIS      #1,STATU1          ;SET D11 BIT AFOK LOOP BACK AFTER CL
5%:
EARING
MOV B    #18.,MCSA3          ;F18A3 LOAD SWEEP COUNTER
BIC      #1,STATU1          ;CLEAR D11 BIT FOR CMP OPERATION
CMP      MCSA3,SWPBCD        ;FOA3 COMPARE SWEEP COUNTER
BNE      5%                  ;RELOAD L IL EQUAL
BIS      #1,STATU1          ;RESET D11
RETURN
;
;
MCSST:   MOV B    #26.,MCSA1   ;F26A1, ENABLE LAM
MOV      #26.,MCSA6          ;F26A6, SET ACCUMULATE
BIS      #301,STATU1         ;SET REIN,INE,D11
RETURN
;
;
MCSMS:   .PRINT    #M90       ;ADDITIONAL SWEEPS
MOV      #26.,MCSA0
CALL     MCSINP
MOV      BCD,SWPBCD
MOV      BIN,SWPBIN
3%:      MOV      SWPBCD,DATALD
BIS      #1,STATU1          ;SET D11 BIT FOR KLOOP BACK AFTER K C
LEARING
MOV B    #18.,MCSA3          ;F18A3 LOAD SWEEP COUNTER
BIC      #1,STATU1          ;CLEAR D11 FOR CMP OPERATION
CMP      MCSA3,SWPBCD        ;FOA3 COMPARE SWEEP COUNTER
BNE      3%                  ;CHECK FOR EQUALITY, RELOAD IF NOT
BIS      #1,STATU1          ;RESET D11 BIT
MOV B    #26.,MCSA6          ;SET ACCUM
RETURN
;
;
MCSHA:   MOV B    #26.,MCSA0   ;HALT MCS
RETURN
;
;
MCSCL:   MOV B    #26.,MCSA0   ;HALT MCS--BLOCK TRIGGERS
MOV      #9.,MCSA0          ;CLEAR RAM MEMORY
RETURN
;
;
MCSOF:   MOV B    #26.,MCSA0   ;HALT MCS UNIT
MOV      #26.,A2DCON        ;ENABLE A2D INTERRUPT
MOV      #4,ACTIVE+2        ;ACTIVE CHANNEL BR'NESS
MOV      #NO,SCCODE         ;RETURNS IN 'NOTHING' MODE
MOV      #NO,SCFUNC         ;'NOTHING' FUNCTION
.PRINT    #M95
RETURN
;
;

```

```

#MCS INPUT SUBROUTINE
;
MCSINP: CLR      NEGA
        CLR      FLN
        CLR      BCD
        CLR      R1
        CLR      CNT
10:     .TTYIN
        CMP      R0,#56
        BNE      20
        INC      FLN
        BR       10
20:     CMP      R0,#55
        BNE      30
        INC      NEGA
        BR       10
30:     CMP      R0,#15
        BEQ      40
        CMP      R0,#60
        BLT      10
        CMP      R0,#71
        BGT      10
        INC      CNT
        CMP      #5,CNT
        BLE      10
        MOV      BCD,P2
        ASH      #4,R2
        SUB      #60,R0
        ADD      R0,R2
        MOV      R2,BCD
        MUL      #12,R1
        ADD      R0,R1
        BR       10
40:     .TTYIN
        MOV      R1,BIN
        RETURN
;
;
EXIT:   CLR      DMAHLT          #HALT DMA
100:    BIT      #100,ADCSR      #HALTED?
        BNE      100           #WAIT TILL YES
        CLR      KWCSR          #DISABLE KVV11-A
        BIS      #4,STATU1      #CAMAC Z-CYCLE
        RETURN
;
;
;
;
;     THIS SECTION CONTAINS THIS MODULE'S MESSAGES TO THE USER
;
;
M1:     .ASCII<15><12>/LOW MASS = /<200>
M2:     .ASCII<15><12>/HIGH MASS = /<200>
M3:     .ASCII<15><12>/CHANNELS PER MASS UNIT = /<200>
M4:     .ASCII<15><12>/INVALID ENTRY!! TRY AGAIN./

```



```

M5:      .ASCII<15><12>/WHICH DEVICE? /<200>
M6:      .ASCII<15><12>/NUMBER OF DATA CHANNELS = /<200>
M7:      .ASCII<15><12>/YOUR CURRENT OPTIONS ARE THE FOLLOWING:/
M8:      .ASCII<15><12>/LASER, TRAP, QUADRUPOLE, MAGNET, MCS UNIT, AND NOTHING
G/
M9:      .ASCII<15><12>/BIDIRECTIONAL OR UNIDIRECTIONAL SCANNING? /<200>
M10:     .ASCII<15><12>/      OPTION: /<200>
M11:     .ASCII<15><12>/SIGNAL, BACKGROUND, SB (SIG.+ BAK.), POWER/
M12:     .ASCII<15><12>/      SECTUR MAGNET MASS /<15><12>
M13:     .ASCII<15><12>/LOW CURRENT FACTOR: /<200>
M14:     .ASCII<15><12>/NUMBER OF SCANS = /<200>
M15:     .ASCII<15><12>/HIGH CURRENT FACTOR: /<200>
M16:     .ASCII<15><12>/NUMBER OF POINTS TO BE AVERAGED = /<200>
M17:     .ASCII<15><12>/TRAP DELAY OFFSET = /<200>
M18:     .ASCII<15><12>/TRAP DELAY INCREMENT = /<200>
M19:     .ASCII<15><12>/STEPS PER CHANNEL: /<200>
M20:     .ASCII<15><12>/      QUAD: PEAKS OPTION/<15><12>
M21:     .ASCII<15><12>/      CHANNEL      SIG.+BACK.      BACKGROUND      SIGNAL      LASER
POWER/
M22:     .ASCII / /<200>
M23:     .ASCII<7> /<200>
M23A:    .ASCII<15><12>/**** RUN COMPLETED ****/<15><12>
M24:     .ASCII<15><12>/      DYE LASER FREQUENCY/<15><12>
M25:     .ASCII /THE SCAN STARTS AT WAVELENGTH: /<200>
M26:     .ASCII /THE SCAN ENDS AT WAVELENGTH: /<200>
M27:     .ASCII /WAVELENGTH INCREMENT PER CHANNEL:/<200>
M28:     .ASCII /NUMBER OF MOTOR STEPS PER INCREMENT: /<200>
M29:     .ASCII<15><12>/      ION TRAP STORAGE TIME/
M30:     .ASCII<15><12>/      QUAD, MASS SPEC./<15><12>
M31:     .ASCII /SCAN STARTS AT ABOUT MASS:/<200>
M32:     .ASCII /SCAN ENDS AT ABOUT MASS: /<200>
M34:     .ASCII<15><12>/      NO DEVICE/<15><12>
M35:     .ASCII /LASER WAVELENGTH SETTING:/<200>
M36:     .ASCII /NUMBER OF DATA CHANNELS: /<200>
M37:     .ASCII /NUMBER OF SCANS COMPLETED:/<200>
M38:     .ASCII /PRESENT CHANNEL NUMBER: /<200>
M39:     .ASCII<15><12>/SCANNING PROCEDURE: /<200>
M40:     .ASCII<15><12>/DISPLAY BUFFER: /<200>
M41:     .ASCII<15><12>/DATA CYCLES PER CHANNEL: /<200>
M42:     .ASCII<15><12>/ION TRAP DELAY INCREMENT: /<200>
M43:     .ASCII<15><12>/ION TRAP DELAY OFFSET: /<200>
M44:     .ASCII<15><12>/***** WATCH YOUR LANGUAGE!!! *****/
M45:     .ASCII<15><12>/A2D CONVERTER GAIN SETTING: /<200>
M46:     .ASCII<15><12>/RESET DEVICE: /<200>
M47:     .ASCII<15><12>/READ THE DISK: /<200>
M48:     .ASCII /ARE YOU SURE? /<200>
M49:     .ASCII<15><12>/CLEAR DATA BUFFER: /<200>
M50:     .ASCII<15><12>/THIS OPTION IS 'LOCKED'./
M51:     .ASCII<15><12>/NONE/STIENT OPTION./
M52:     .ASCII<15><12>/      *** LOCKED ***/
M53:     .ASCII<15><12>/      *** UNLOCKED ***/
M54:     .ASCII<15><12>/DO YOU WISH TO ENTER A HEADER MESSAGE? /<200>
M55:     .ASCII<15><12>/PULSE SEQUENCE INIT: /<200>
M56:     .ASCII<15><12>/ENTER HEADER MESSAGE./
M57:     .ASCII<15><12>/MESSAGE TOO LONG--MESSAGE WAS TRUNCATED./

```

[illegible]

BCD:	.WORD		IMCS UNIT
BIN:	.WORD		IMCS UNIT
BUFOFF:	.WORD		IBDATA BUFFER OFFSET
CALWAV:	.BLKW	2	ICALIBRATION WAVELENGTH
CNT:	.WORD		IMCS UNIT
CSCHAN:	.WORD		ISCALING CHANNEL
DACYCL:	.BLKW	2	IMOROS FOR NUMBER OF DATA CYCLES/CHA
NNEL			
DATE:	.WORD		IPROGRAM DATE WORD
DATLST:	.WORD	3	ILIST FOR 'R50ASC' SYSF4 CALL
	.WORD	<DATLST+8.>	
	.WORD	MONTH	
	.WORD	M46	
	.WORD	3	
DAY:	.WORD		IDAY OF THE MONTH(DATE)
DELINC:	.WORD		
DELOFF:	.WORD		ION STORAGE TIME OFFSET
DELTOT:	.WORD		ITOTAL ION STORAGE TIME
DIBUF:	.WORD		IDISPLAY BUFFER POINTER
DICHNS:	.WORD		
DIFUNC:	.BLKW	2	IDISPLAY FUNCTION WORD
DIRFLG:	.WORD		ISCAN DIRECTION FLAG
DICODE:	.BLKW	2	IDISPLAY CODE WORD
DISCOM:	.WORD		IDISPLAY COMMAND WORD
DISFLG:	.WORD		IDISPLAY YAXIS SCALE FLAG
DISMAY:	.WORD		IDISPLAY BUFFER MAX
DISNUM:	.WORD		IDISPLAY COMMAND NUMBER
DISTR:	.WORD		IDISPLAY START-FOR XLOAD
DISWIN:	.WORD		IDISPLAY WINDOW STARTING ADDRESS
DMAHLT:	.WORD		IDMA "HALT" WORD
DNLBCD:	.WORD		
DNLBIN:	.WORD		IMCS UNIT
EXPFLG:	.WORD		IDISPLAY EXPAND FLAG
FLGDIS:	.WORD		ISECOND DISPLAY FLAG.
FLN:	.WORD		IMCS UNIT
LASHOTS:	.BLKW	2	INUMBER OF LASER SHOTS
LCHAN:	.WORD		IOF ADDRESSES TO LASER CHANNEL
LCHN:	.WORD		ILAST AVERAGED DATA CHANNEL
LIST:	.WORD	3	IARRUMENT LIST FOR SYSF4 CALLS
	.WORD	ARG1	
	.WORD	ARG2	
	.WORD	RESULT	
LONGWAV:	.BLKW	2	ILONG WAVELENGTH
MASBUF:	.BLKW	100.	IBUFFER FOR MASS PEAKS
MADAC1:	.BLKW	2	ILOW VALUE FOR SECTOR MAGNET
MADAC2:	.WORD		IHIGH VALUE FOR SECTOR MAGNET
MARES:	.BLKW	2	ISECTOR MAGNET RESOLUTION WORD
MCSBUF:	.WORD		IMCS UNIT DATA BUFFER POINTER
MDAC1:	.BLKW	2	ILOW MASS FOR QUADRUPOLE
MDAC2:	.WORD		IHIGH MASS FOR QUADRUPOLE
MONTH:	.WORD		IMONTH(DATE)
MRES:	.BLKW	2	IQUAD. RESOLUTION WORD
NCHAN:	.BLKW	2	INUMBER OF DATA CHANNELS
NEGA:	.WORD		IMCS UNIT
NPTAVG:	.WORD		INUMBER OF POINTS AVERAGED

```

NSTEP: .WORD          ;NUMBER OF MOTOR STEPS
XJMP: .BLKW          2  ;X-AXIS INCREMENT VALUE
NSCAN: .BLKW          2  ;NUMBER OF DATA SCANS
OFFSET: .WORD          ;OFFSET IN SUBROUTINE SMOOTH
QVF: .WORD            ;MCS UNIT
PLCHAR: .WORD          ;PLOT CHARACTER
PLCTRL: .WORD          ;PLOTTER CONTROL WORD
PLMOV: .WORD           ;PLOT MOVEMENT
PLLINE: .WORD          ;PLOT LINE TYPE
PLLIST: .WORD          ;ARG. LIST FOR PLOTTER CALL
        .WORD          B.
        .WORD          PLCTRL
        .WORD          PLCHAR
        .WORD          PLLINE
        .WORD          DISTRT
        .WORD          DICMSN
        .WORD          STCMAN
        .WORD          PLMOV
        .WORD          YMAX

POBUF: .WORD           ;POWER BUFFER POINTER
POVALU: .BLKW          2  ;POWER CHANNEL VALUE
POWMAX: .BLKW          2  ;POWER BUFFER MAX.
RESULT: .BLKW          2  ;SYSF4 RESULT WORDS
RETAKE: .WORD          ;RETAKE MODE FLAG
ROUTINE: .WORD         ;CONTAINS SUB-RTN LOCATION FOR *KEYW
OL*

RUN: .BLKW             2  ;RUN NUMBER WORD
RUNFLG: .WORD          ;RUN COMPLETED FLAG
R1DATA: .WORD          ;SAVE WORDS FOR *DATAIN*
R4DATA: .WORD          ;
R0DMA: .WORD           ;SAVE WORDS FOR *DMAINT*
R1DMA: .WORD           ;
R2DMA: .WORD           ;
R3DMA: .WORD           ;
R1BUF: .WORD           ;REGISTER SAVE SUBROUTINE BUFINIT
R2BUF: .WORD           ;
R2DSK: .WORD           ;REG. SAVE FOR DISK INPUT/OUTPUT
R1HEA: .WORD           ;REG. SAVE SUBROUTINE *HEADER*
R2HEA: .WORD           ;
R1EXP: .WORD           ;REGISTER SAVE SUBROUTINE *EXPAND*
R1MD: .WORD            ;REGISTER SAVE *MD* SUBROUTINE
R1NOC: .WORD           ;REG. SAVE SUBROUTINE *NOCYCL*
R1NOS: .WORD           ;REG. SAVE SUBROUTINE *NOSCN*
R1PRI: .WORD           ;REG. SAVE SUBROUTINE *PRINT*
R2PRI: .WORD           ;AND SUBROUTINE *TYDATA*
R3PRI: .WORD           ;
R4PRI: .WORD           ;
R5PRI: .WORD           ;
R1PRH: .WORD           ;REG. SAVE FOR SUBROUTINE PRITIL
R1PRS: .WORD           ;REG. SAVE FOR SUBROUTINE PRSTAT
R1SAV: .WORD           ;REG. SAVE GENERAL USE
R0SMO: .WORD           ;REG. SAVE SUBROUTINE *SMOOTH*
R1SMO: .WORD           ;
R2SMO: .WORD           ;
R3SMO: .WORD           ;
R4SMO: .WORD           ;

```

```

R5SMO: .WORD
R1UPD: .WORD
R1DIS: .WORD
R2DIS: .WORD
R3DIS: .WORD
RADIS: .WORD
RSDIS: .WORD
R1TRA: .WORD
R1TYH: .WORD
R1TYS: .WORD
S8BUF: .WORD
SCCODE: .WORD
SCFUNC: .WORD
SCHODE: .WORD
SCROLL: .WORD
SCTYPE: .WORD
SETWAV: .BLKW 2
SHIFT: .WORD
SHOWAV: .BLKW 2
SLRFLG: .WORD
SMOPTR: .WORD
STCHAN: .WORD
SWPBCD: .WORD
SWPBIN: .WORD
TIMES: .WORD
TRGBCD: .WORD
TRGBIN: .WORD
UPDATE: .BLKW 2
WINBRT: .WORD
WINFLG: .WORD
WINSIZ: .WORD
WAVINC: .BLKW 2
YEAR: .WORD
YFUNC: .WORD
YMAX: .BLKW 2
YMIN: .BLKW 2
YSCALE: .WORD
ZERFLG: .WORD
/
LOCKEY: .ASCII /"X"/
/
/ DATA STRING FOR 'DATES' SUBROUTINE
/
R5OSTR: .RAD50 /JANFEBMARAPRMAJUNJULAUGSEP OCTNOVDEC/
/
/
/ INPUT/OUTPUT AND DATA BUFFER DEFINITIONS
IOBUF: .BLKB 100.
DATABUF: .BLKW 10000.
/
/
/ .END MCHSUB

```

IREG. SAVE SUBROUTINE 'UPDAT'
 IREGISTER SAVE SUBROUTINE DISCAL

 IREGISTER SAVE 'TRAP' SUBROUTINE
 IREG. SAVE FOR SUBROUTINE TYHEDR
 IREG. SAVE FOR SUBROUTINE TYSTAT
 IS+B BUFFER POINTER
 IDEVICE SCAN CODE
 ISCAN FUNCTION WORD
 ISCAN INTERRUPT MODE
 IWINDOW SCROLL SUBROUTINE
 ISCAN METHOD
 ITHE WAVELENGTH SET PRESENTLY
 IASHC FAC. IN SCALING ROUTINE
 ITHE SHORT WAVELENGTH OF SCAN
 IL-R SCROLL FLAG
 ISMOOTH-POINTER
 ISTARTING-CHANNEL OF DISPLAY
 IMCS UNIT
 IMCS UNIT
 I# OF TONES TO 'SMOOTH'
 IMCS UNIT
 IMCS UNIT
 IDISPLAY UPDATE COUNTER
 IDISPLAY WINDOW BRIGHTNESS
 IFLAG TO DISPLAY WINDOW
 IDISPLAY WINDOW SIZE
 I WAVELENGTH STEP SIZE
 I YEAR (DATE)
 IFUNCTION WORD FOR YAXIS SCALING
 IY-AXIS VALUE FOR 'FULL SCALE'
 IY-AXIS SUBTRACTION
 IY-AXIS EXTRA SCALE FACTOR
 IZERO SHIFT
 IKEY TO UNLOCK PROGRAM VARIABLES

```

      .TITLE  A2DAMP
;SUBROUTINE TO SET THE GAIN OF THE 3553-21A ANALOG-TO-DIGITAL CONVERTER'S
;AMPLIFIER. WHEN QUERIED ONE REPLIES "LOW" FOR A GAIN OF "1", "MEDIUM" FOR
;A GAIN OF "10", AND "HIGH" FOR A GAIN OF "100". GLOBAL IORUF
;MUST BE DEFINED BY THE CALLING PROGRAM. THIS ROUTINE IS USED BY A
;CALL A2DAMP INSTRUCTION.
;
;
;      SYSTEM MACRO
;      .MCALL  .PRINT
;
;      GLOBL  GLOBAL LIBRARY ROUTINE
;      .GLOBL  READ
;
;      GLOBAL DEFINED IN MAIN PROGRAM
;      .GLOML  IORUF
;
;      GLOBAL DEFINED BY THIS MODULE
;      .GLOBL  A2DAMP,A2DUNS
;
;
;
;
A2DCON=167100
A2DAMP:  MOV  #24.,A2DCON          ;A2D CONVERTER (BIN 18)
;DISABLE THE LAM REQUEST
MOV      IORUF+2,IORUF          ;GET SECOND COMMAND IF ANY
CMP      IORUF,#15              ;IS IT A CARRIAGE RETURN?
REQ      10%                   ;ASK FOR SECOND PART OF COMMAND:IF Y

ES
      BR      15%               ;GO DECODE COMMAND
10%:    .PRINT  #M1              ;WHAT SETTING IS WANTED?
      CALL  READ                ;READ THE REPLY
15%:    MOV      IORUF,A2DUNS     ;SAVE THE DESIRED GAIN SETTING
      CMP      #'L',IORUF        ;A GAIN OF "1"?
      BEQ      20%               ;YES,SET GAIN TO 1.
      CMP      #'E',IORUF        ;A GAIN OF "10"?
      BEQ      30%               ;IF YES,SET GAIN TO 10.
      CMP      #'H',IORUF        ;A GAIN OF "100"?
      BEQ      40%               ;IF YES,SET GAIN TO 100.
      .PRINT  #M2               ;INVALID RESPONSE--TELL USER
      .PRINT  #M3
      BR      10%               ;GO BACK--TRY AGAIN
20%:    MOVB     #25.,<A2DCON+2> ;SELECT GAIN OF 1.
      BR      50%               ;GO WAIT
30%:    MOVB     #25.,<A2DCON+4> ;SELECT GAIN OF 10.
      BR      50%               ;GO WAIT
40%:    MOVB     #25.,<A2DCON+6> ;SELECT GAIN OF 100.
50%:    MOV      #20000.,DELAY    ;LOAD DELAY WORD
60%:    DEC      DELAY            ;DELAY LOOP
      BNE      60%               ;WAIT FOR CONVERSION TO FINISH
      MOV      #0,A2DCON         ;CLEAR THE LAM
      MOV      #26.,A2DCON       ;ENABLE THE LAM REQUEST
      RETURN                     ;RETURN TO CALLER
;
;

```

```

A2DONS: .WORD          #WORD FOR GAIN SETTING
DELAY:  .WORD          #WORD FOR DELAY LOOP
;
;
M1:     .ASCII<15><12>/WHAT GAIN SETTING DO YOU WANT? /
        .BYTE 200
M2:     .ASCII<15><12>/ILLEGAL COMMAND--PLEASE USE "LO(W),ME(D),OR HI(BH)"/
M3:     .ASCII<15><12>/      LO = X1      ME = X10      HI = X100/
;
;
        .EVEN
        .END

```

```

        .TITLE  ASCBIN
;SUBROUTINE TO CONVERT ASCII CHARACTERS IN I/O BUFFER(TIOBUF) TO
;A BINARY NUMBER IN R1 (LOW WORD) AND R2 (HIGH WORD).
;IOBUF IS NOT CHANGED.
        .GLOBL  IOBUF,ASCBIN,JMUL
        .GLOBL  REGSAV,REGRES

;
ASCBIN:  MOV     R5,R5ASC                ;SAVE REGISTER
        CLR     R2                     ;CLR CHARACTER REGISTER
        MOV     #LIST,R5               ;TO USE SYSF4 JMUL
        MOV     #IOBUF,R1              ;STARTING ADDRESS IN R1
        MOV     #1,NEGFLG              ;NEGATIVE-VALUE FLAG UP
        CMPB    #'-',(R1)              ;IS FIRST CHARACTER A MINUS?
        BNE     10%                   ;BRANCH IF NO
        CLR     NEGFLG                 ;NEGATIVE-VALUE FLAG DOWN
        MOVB    #'0',(R1)              ;YES,REPLACE IT WITH ZERO
        BR      20%
10%:     CMPB    #'+',(R1)              ;IS FIRST CHARACTER A PLUS?
        BNE     20%                   ;BRANCH IF NO
        MOVB    #'0',(R1)              ;YES,REPLACE IT WITH A ZERO
20%:     MOV     #0,RESULT              ;CLEAR RESULT
        MOV     #0,RESULT+2
        MOV     #10,ARG2               ;PLACE TEN IN ARGUMENT TWO
        MOV     #0,ARG2+2
30%:     MOV     RESULT,ARG1            ;ARG1 TO BE MULTIPLIED BY TEN
        MOV     RESULT+2,ARG1+2
        MOVB    (R1)+,R2               ;MOVE CHARACTER TO R2
        CMPB    #'15',R2               ;IS IT A CARRIAGE RETURN?
        BEQ     60%                   ;BRANCH IF YES
        CMPB    #'60',R2               ;CHECK FOR LETTERS,ETC
        BGT     40%                   ;IF ANY FOUND,SET CARRY BIT
        CMPB    #'71',R2
        BGE     50%
40%:     SEC                          ;ERROR: SFT CARRY BIT
        BR      ASCOUT                ;GO TO CALLER
50%:     SUB     #'60',R2               ;SUBTRACT ASCII RIAS
        CALL    REGSAV                 ;SAVE REGISTERS R1-R5
        CALL    JMUL                   ;SYSF4 MULTIPLICATION
        CALL    REGRES                 ;RESTORE REGISTERS R1-R5
        CMP     #'-2',R0               ;CHECK ERROR CODE
        BEQ     40%                   ;BRANCH IF YES (OVERFLOW!)
        ADD     R2,RESULT              ;ADD TO RESULT
        ADC     RESULT+2
        BR      30%
60%:     CMP     #'0',NEGFLG           ;WAS IT NEGATIVE?
        BNE     130%                  ;NO SKIP NEGATION
        COM     RESULT
        COM     RESULT+2
        ADD     #1,RESULT
        ADC     RESULT+2
130%:    MOV     RESULT,R1              ;ANSWER IN R1
        MOV     RESULT+2,R2            ;AND R2
        CLC                          ;CLEAR CARRY! NO ERRORS
ASCBIN:  MOV     R5ASC,R5              ;UNSAVE REGISTER
        RETURN                        ;RETURN TO CALLER

```



```

;
;
LIST:  .WORD 3                      ;JMWL SYS. GLOBAL ARGUMENT LIST
        .WORD ARG1
        .WORD ARG2
        .WORD RESULT
ARG1:   .BLKW 2
ARG2:   .BLKW 2
RESULT: .BLKW 2
NEGFLG: .WORD
RSASC:  .WORD
;
;
        .END

```

```

      .TITLE  BINASC SUBROUTINE
;SUBROUTINE "BINASC" IS A ROUTINE TO CONVERT A SIGNED BINARY NUMBER
;IN R1 TO AN ASCII BYTE STRING WITH STARTING LOCATION "IOBUF". THE
;ASCII CODED STRING CONSIST OF SIX CHARACTERS. A MINUS SIGN FOR
;NEGATIVES WITH LEADING ZEROS SUPPRESSED;THE MINUS SIGN IS PLACED
;JUST BEFORE THE FIRST NONZERO DIGIT. USE WITH "CALL BINASC". THE
;BUFFER "IOBUF" MUST BE DEFINED AS A GLOBAL IN THE CALLING PROGRAM.
      .GLOBL  IOBUF,IBINASC
BINASC: MOV    R1,R1BIN      ;SAVE REGISTERS
        MOV    R2,R2BIN
        MOV    R3,R3BIN
        MOV    R4,R4BIN
        MOV    #IOBUF,R4    ;BUFFER STARTING LOCATION
        TST    R1           ;IS IT NEGATIVE?
        BPL    10%         ;NO
        NEG    R1           ;YES,TAKE ABS. VALUE
        MOVB   #'-(R4)+    ;PLACE MINUS SIGN IN BUFFER
        BR     15%         ;GO TO CONVERSION SECTION
10%:    MOVB   #'',(R4)+    ;PLACE A SPACE IN BUFFER
15%:    MOV    @BIN1,R2     ;POINTER TO DIVISOR TABLE
        MOV    #5,R3       ;FIVE DIVISORS
20%:    CLR    R0           ;CLEAR HIGH WORD
        DIV    (R2)+,R0     ;FIS DIVIDE
        ADD    #60,R0       ;ADD ASCII BIAS
        MOVB   R0,(R4)+    ;PLACE RESULT IN BUFFER
        SOB    R3,20%      ;DO IT FIVE TIMES
;NOW REPLACE LEADING ZEROS WITH SPACES AND MOVE THE "SIGN" ACCORDINGLY.
        MOV    #IOBUF,R4   ;BUFFER STARTING ADDRESS
        MOVB   IOBUF,R1    ;PLACE SIGN IN R1
        CLR    R3          ;CLEAR LOOP COUNTER
30%:    INCB   R4           ;GET NEXT BYTE LOCATION
        INCB   R3          ;INCREMENT LOOP COUNTER
        CMPB   #5,R3       ;IS IT THE FIFTH TIME?
        BEQ    40%        ;IF YES,EXIT
        CMPB   #'0,(R4)    ;IS THE CHARACTER A ZERO?
        BNE    40%        ;NO,EXIT ROUTINE
        MOVB   R1,(R4)     ;YES;REPLACE IT WITH SIGN
        MOVB   #' ,-(R4)   ;REPLACE FIRST SIGN WITH SPACE
        BR     30%        ;LOOK FOR MORE ZEROS
40%:    MOV    R4BIN,R4     ;UNSAVE REGISTERS
        MOV    R3BIN,R3
        MOV    R2BIN,R2
        MOV    R1BIN,R1
        RETURN            ;RETURN TO CALLING PROGRAM
BIN1:   .WORD   10000.,1000.,100.,10.,1
R1BIN:  .WORD
R2BIN:  .WORD
R3BIN:  .WORD
R4BIN:  .WORD
      .END

```

```

        .TITLE  BCD2BIN
;BCD2BIN SUBROUTINE CONVERTS BCD NUMBER
;IN R1 TO A BINARY NUMBER IN R1
        .GLOBL  BCD2BIN
BCD2BIN: MOV     R2,R2BCD
        MOV     R3,R3BCD
        MOV     R4,R4BCD
        MOV     R5,R5BCD
        MOV     R1,R5      ;COPY INTO R5
        MOV     #ASHIFT,R2 ;INIT.
        MOV     #AMUL,R3
        CLR     BIN
        MOV     #4,R4      ;FOUR OF THEM
BCD1:    MOV     R5,R1      ;GET THE NUMBER
        ASH     (R2)+,R1    ;MASK THE BITS
        BIC     #177760,R1
        MUL     (R3)+,R1    ;MULTIPLY BY POWER OF TEN
        ADD     R1,BIN
        SOB     R4,BCD1    ;FOUR TIMES
        MOV     BIN,R1     ;PLACE BINARY IN R1
        MOV     R2BCD,R2
        MOV     R3BCD,R3
        MOV     R4BCD,R4
        MOV     R5BCD,R5
        RTS      PC        ;RETURN
ASHIFT: .WORD   -12,-8,-4,0
AMUL:    .WORD   1000.,100.,10.,1
BIN:     .WORD
R2BCD:   .WORD
R3BCD:   .WORD
R4BCD:   .WORD
R5BCD:   .WORD
        .END

```

```

        .TITLE  DECOUT SUBROUTINE
;DECOUT SUBROUTINE OUTPUTS THE BINARY NUMBER CONTAINED IN R1
;IN DECIMAL FORMAT TO THE CONSOLE DEVICE. SIX CHARACTERS ARE
;OUTPUT; A MINUS SIGN IF THE NUMBER IS NEGATIVE AND WITH ANY
;LEADING ZEROES REPLACED BY SPACES. THE MINUS SIGN APPEARS
;NEXT TO THE FIRST NONZERO DIGIT.
        .MCALL  .TTYOUT
        .GLOBL  DECOUT,BINASC,I0BUF
DECOUT:  MOV     R1,R1DEC      ;SAVE REGISTERS
        MOV     R2,R2DEC
        CALL    BINASC        ;CONVERT R1 TO ASCII STRING
        MOV     #6,R1         ;SIX CHARACTERS OUTPUT
        MOV     #I0BUF,R2     ;BUFFER STARTING ADDRESS
10$:    MOVB     (R2)+,R0      ;OUTPUT CHARACTERS ONE BY ONE
        .TTYOUT
        SOB     R1,10$
        MOV     R2DEC,R2      ;UNSAVE REGISTERS
        MOV     R1DEC,R1
        RETURN                ;RETURN TO CALLING PROGRAM
R1DEC:  .WORD
R2DEC:  .WORD
        .END

```

```

        .TITLE  DCOU2 SUBROUTINE
;DCOUT2 SUBROUTINE OUTPUTS THE BINARY NUMBER CONTAINED IN WORDS
;LOWORD AND HIWORD IN DECIMAL FORMAT TO THE CONSOLE DEVICE. TEN CHARACTERS
;ARE OUTPUT; A MINUS SIGN IF THE NUMBER IS NEGATIVE AND WITH ANY
;LEADING ZEROS REPLACED BY SPACES. THE MINUS SIGN APPEARS
;NEXT TO THE FIRST NONZERO DIGIT.
        .MCALL  .TTYOUT
        .GLOBL  DCOU2,DPBASC,IDBUF
DCOUT2: MOV     R1,R1DEC      ;SAVE REGISTERS
        MOV     R2,R2DEC
        CALL    DPBASC       ;CONVERT "WORDS" TO ASCII STRING
        MOV     #11.,R1     ;ELEVEN CHARACTERS OUTPUT
        MOV     #IDBUF,R2    ;BUFFER STARTING ADDRESS
10$:    MOVB     (R2)+,R0     ;OUTPUT CHARACTERS ONE BY ONE
        .TTYOUT
        SOB     R1,10$
        MOV     R2DEC,R2     ;UNSAVE REGISTERS
        MOV     R1DEC,R1
        RETURN              ;RETURN TO CALLING PROGRAM
R1DEC:  .WORD
R2DEC:  .WORD
        .END

```

```

      ,TITLE  DISKIO INPUT-OUTPUT TO THE DISK
;
;
;THIS MODULE CONTAINS SUBROUTINES TO WRITE AND READ WITH THE DISK.
; "WRDISK" WRITES N WORDS TO THE DISK. N/4 IS PLACED INTO THE FIRST
; LOCATION OF "DATBUF" THE BUFFER WHICH HAS THE N WORDS TO BE SENT.
; THE FIRST 50 WORDS ARE RESERVED FOR "VARIABLES" AND THE NEXT
; 450 WORDS ARE FOR A HEADER IF DESIRED.
; "REDISK" READS N WORDS FROM THE SPECIFIED FILE (N IS THE FIRST
; WORD OF THE DATA FILE) AND PLACES IT INTO "DATBUF".
;
;
;      SYSTEM  MACROES
;
      .MCALL  .TTYIN,.TTYOUT,.PRINT,.CLOSE,.CSIGEN
      .MCALL  .WRITW,.READW
;
;      MAIN PROGRAM DEFINED GLOBALS
;
      .GLOBL  NCHAN,DATBUF,IOBUF
;
;      GLDLIB GLOBAL SUBROUTINE
;
      .GLOBL  READ
;
;      GLOBAL ENTRY POINTS OF THIS MODULE
;
      .GLOBL  WRDISK,REDISK
;
;
; "WRDISK" WRITES DATBUF TO THE DISK
WRDISK: MOV     R1,RISAV          ;SAVE REGISTER 1
        MOV     R2,R2SAV        ;SAVE REGISTER TWO
5%:     .PRINT  #M8             ;NEW HEADER?
        CALL    READ            ;YES OR NO?
        CMBF    %Y,IOBUF        ;YES?
        BEQ     10%             ;BRANCH IF YES
        CMBF    #N,IOBUF        ;NO?
        BEW     50%             ;BRANCH IF NO
        BR      5%             ;JUST ANSWER YES OR NO
10%:    MOV     #DATBUF,R2       ;DATA BUFFER STARTING LOCATION
        MOV     NCHAN,(R2)       ;STORE NUMBER OF CHANNELS
        ADD     #100.,R2        ;GO TO HEADER SECTION
        MOV     #450.,R1        ;MAX. HEADER LENGTH
15%:    CLR     (R2)+            ;CLEAN HEADER SECTION
        SOB     R1,15%          ;
        MOV     #DATBUF,R2       ;STARTING LOCATION IN R2
        ADD     #100.,R2        ;START OF HEADER SECTION
        .PRINT  #M6             ;ENTER HEADER MESSAGE
        MOV     #>,R0           ;PRINT PROMPT CHARACTER
        .TTYOUT
        MOV     #448.,R1        ;NUMBER OF CHARACTERS PERMITTED
20%:    .TTYIN                  ;READ IN THE HEADER

```

```

      CMPB    #1,R0          ;CHECK FOR END OF HEADER
      BEQ     40%           ;BRANCH IF AT END
      DEC     R1             ;COUNT DOWN SPACE
      BEQ     30%           ;BRANCH IF NO SPACE LEFT
      MOVB    R0,(R2)+      ;PLACE CHARACTER INTO BUFFER
      BR      20%           ;GO GET MORE
30%:   .TTYIN
      CMPB    #12,R0        ;EAT THE LEFT OVERS!
      BNE     30%           ;THRU EATING?
      .PRINT  #M3           ;GET MORE TO EAT IF NOT
      BR      50%           ;TELL USER TRUNCATION HAS OCCURRED
40%:   .TTYIN
      CMP     #12,R0        ;EAT CR-LF
      BNE     40%           ;HAVE LF IN MOUTH?
      MOV     #200,(R2)     ;GO GET IT!!
      .PRINT  #M7           ;HEADER TERMINATOR SYMBOL
      MOV     SP,SPSAV      ;ASK FOR FILE SPECIFICATIONS
      .CSIGEN #DEVSPC,#DEFEXT,#0 ;SAVE THE STACK POINTER
      MOV     SPSAV,SP      ;COMMAND STRING GENERATOR
      MOV     NCHAN,R1      ;RESTORE SP
      MUL     #6,R1         ;CALCULATE NUMBER OF WORDS
      ADD     #502,R1       ;TO BE TRANSFERED
      .WRITEW #AREA,#0,#DATABUF,R1,#0 ;WRITE THRU CHANNEL ZERO
      BCS     60%           ;BRANCH IF HARDWARE ERROR
      CMP     R1,R0         ;CORRECT NUMBER OF WORDS WRITTEN?
      BEQ     150%         ;BRANCH IF YES
      .PRINT  #M5           ;PRINT ERROR MESSAGE
60%:   CMPB    #0,#52       ;CHECK FOR THE ERROR
      BNE     130%         ;
      .PRINT  #M0           ;READ MESSAGES
      BR      150%         ;
130%:  CMPB    #1,#52       ;
      BNE     140%         ;
      .PRINT  #M1           ;
      BR      150%         ;
140%:  CMPB    #2,#52       ;
      BNE     150%         ;
      .PRINT  #M2           ;
150%:  .CLOSE  #0           ;CLOSE CHANNEL
      .PRINT  #M4           ;SUCCESS
      MOV     R1SAV,R1      ;
      MOV     R2SAV,R2      ;
      RETURN                    ;RETURN TO CALLER
;
;
;THIS SUBROUTINE READS THE DATA FROM THE DISK
;
REDISK: MOV     R1,R1SAV    ;SAVE R1
      .PRINT  #M7           ;WHICH FILE?
      MOV     SP,SPSAV      ;SAVE THE STACK POINTER
      .CSIGEN #DEVSPC,#DEFEXT,#0 ;GET COMMAND STRING GEN.
      MOV     SPSAV,SP      ;RESTORE SP
      .READW  #AREA,#3,#DATABUF,#5,#0
      BCS     20%           ;HARDWARE ERROR?
      CMP     R0,#5         ;CHECK NUMBER OF WORDS READ

```

```

      BEQ      10%
      .PRINT   %M5
      BR       20%
10%:  MOV      DATBUF,NCHAN      ;WHICH ERROR?
      MOV      NCHAN,R1         ;FIRST WORD= # OF DATA CHANNELS
      MUL      %6,R1            ;HOW MANY WORDS IN ALL?
      ADD      %$02,R1
      .READW   %WAREA,%3,%DATBUF,R1,%0
      BCS      20%
      CMP      R0,R1
      BEQ      50%
      .PRINT   %M5
20%:  CMPB     %0,%$52            ;CHECK THE ERROR CODES
      BNE      30%
      .PRINT   %M0
      BR       50%
30%:  CMPB     %1,%$52
      BNE      40%
      .PRINT   %M1
      BR       50%
40%:  CMPB     %2,%$52
      BNE      50%
      .PRINT   %M2
50%:  .CLOSE   %3                ;CLOSE CHANNE 3
      MOV      R1SAV,R1         ;RETURN TO CALLER
      RETURN

;
R1SAV: .WORD    0
R2SAV: .WORD    0
SPSAV: .WORD    0
;
;
DEFEXT: .RAD50   /DAT/
        .RAD50   /DAT/
        .WORD    0
        .WORD    0
WAREA:  .BLKW    5
DEVSPC: .WORD    0
M0:     .ASCIZ   /ATTEMPTED TO WRITE(READ) PAST END-OF-FILE/
M1:     .ASCIZ   /HARDWARE ERROR/
M2:     .ASCIZ   /CHANNEL WAS NOT OPEN/
M3:     .ASCIZ   /MESSAGE TOO LONG--TRUNCATED:NOT FATAL CONTINUE/
M4:     .ASCIZ   /DATA TRANSFER SUCCESSFUL/
M5:     .ASCIZ   /IMPROPER NUMBER OF WORDS WRITTEN(READ)/
M6:     .ASCIZ   /TYPE IN HEADER MESSAGE/
M7:     .ASCIZ   /GIVE FILE SPECIFICATIONS/
M8:     .ASCII<15><12>/DO YOU WISH TO ENTER A NEW HEADER MESSAGE? /
        .BYTE    200
        .EVEN
;
;
      .END

```



```

        .TITLE  DPBASC SUBROUTINE
;DOUBLE PRECISION INTEGER ASCII DECIMAL OUTPUT PROGRAM-WILL PLACE INTO A
;SPECIFIED BYTE STRING 10 ASCII NUMERALS AND A SIGN IF NEGATIVE. LEADING
;ZEROS ARE SUPPRESSED AND THE SIGN IS PLACED IMMEDIATELY BEFORE THE
;FIRST NON-ZERO DIGIT OF THE NUMBER.
;TO ENTER:
;      1. MOVE HIGH ORDER PART OF WORD TO BE OUTPUT TO HIWORD
;      2. MOVE LOW ORDER PART OF WORD TO BE OUTPUT TO LOWORD
;      3. CALLING PROGRAM MUST DEFINE "IOBUF" AS GLOBAL
;      4. CALLING PROGRAM MUST DEFINE LOWORD AND HIWORD AS GLOBALS
;      5. USE ROUTINE WITH "CALL DPBASC"
;ROUTINE WRITTEN BY SPARKS, MODIFIED BY BUSTAMANTE.
;
        .GLOBL  IOBUF,DPBASC,LOWORD,HIWORD
DPBASC:  MOV     R3,R3DPB          ;SAVE REGISTERS
        MOV     R5,R5DPB
        MOV     #IOBUF,R3        ;BUFFER ADDRESS IN R3
        CLR     NEGFLG           ;CLEAR NEGATIVE # FLAG
        CLR     LZSFLG           ;CLEAR LEADING ZERO SUPPRESS FLAG
        MOV     #-1,CNTR         ;INITIALIZE SUBTRACT LOOP COUNTER
        TST     HIWORD           ;IS INTEGER NEGATIVE
        BMI     NEGSET           ;YES, THEN CONVERT IT
POSOUT:  MOV     #DIG9,R5         ;LOAD BEGINNING ADDRESS OF 10^N LIST
MORYET:  INC     CNTR             ;COUNT # SUBTRACTION LOOPS
        SBC     2(R5),LOWORD      ;THREE STEP DOUBLE PREC. SUBTRACT
        SBC     HIWORD
        SUB     (R5),HIWORD
        BPL     MORYET           ;SUBTRACT AGAIN IF STILL POSITIVE
        ADD     2(R5),LOWORD      ;KILL LAST SUBTRACTION IF NEGATIVE
        ADC     HIWORD
        ADD     (R5),HIWORD
        ADD     #4,R5            ;READY FOR 10^N-1
        JSR     PC,ASCOUT        ;OUTPUT THE CHARACTER
        MOV     #-1,CNTR         ;RESET LOOP COUNTER
        CMP     R5,#<DIG1+4>    ;? LAST DIGIT YET
        BLT     MORYET          ;NO, DO ANOTHER
        MOV     LOWORD,CNTR      ;YES, SEND IT OUT
        INC     R5               ;TRACER FOR LAST DIGIT
        JSR     PC,ASCOUT
        MOV     R3DPB,R3        ;UNSAVE REGISTERS
        MOV     R5DPB,R5
        RTS     PC              ;RETURN TO CALLING PROGRAM
NEGSET:  BIS     #1,NEGFLG       ;SET FLAG FOR MINUS SIGN OUTPUT
        SUB     #1,LOWORD        ;4 STEP CONVERSION TO POSITIVE INTEG
ER
        SBC     HIWORD
        COM     HIWORD
        COM     LOWORD
        JMP     POSOUT          ;DECODE TO ASCII
        ;? GOT A ZERO
        BEQ     LZS
        BIS     #1,LZSFLG       ;YES, SEE IF NEEDS SUPPRESSED
        ;NO, PREVENT FURTHER SUPPRESSION
        LZSDN:  ADD     #60,CNTR  ;ADD ASCII BIAS
        BIT     #2,NEGFLG       ;IS SIGN OR SPACE ALREADY PRINTED?
        BGT     CHROUT         ;YES, JUST SEND CHARACTER

```

```

      BIT      #1,NEGFLG
      BGT      MINOUT
      MOVB     #40,(R3)+
      MOVB     CNTR,(R3)+
      BIS      #2,NEGFLG
      RTS      PC
MINOUT: MOVB     %35,(R3)+
      MOVB     CNTR,(R3)+
      BJC      #1,NEGFLG
      BIS      #2,NEGFLG
      RTS      PC
LZS:   TST      LZSFLG
      BGT      LZSDN
      CMP      R5,#<DIG1+4>
      BGT      LZSDN
      MOVB     #40,(R3)+
      RTS      PC
CHROUT: MOVB     CNTR,(R3)+
      RTS      PC
CNTR:   .WORD
NEGFLG: .WORD
HIWORD: .WORD
LOWORD: .WORD
LZSFLG: .WORD
DIG9:   .WORD 35632,145000
DIG8:   .WORD 2765,160400
DIG7:   .WORD 230,113200
DIG6:   .WORD 17,41100
DIG5:   .WORD 1,103240
DIG4:   .WORD 0,23420
DIG3:   .WORD 0,1750
DIG2:   .WORD 0,144
DIG1:   .WORD 0,12
R3DPB:  .WORD
R5DPB:  .WORD
.END

```

```

;NO, DO WE NEED A MINUS SIGN?
;YES, DO IT
;NO, SEND A SPACE
;THEN SEND CHARACTER
;NO MORE SPACES
;BACK TO CALLER
;SEND MINUS SIGN
;SEND CHARACTER
;MINUS SIGN DONE
;NO SPACES WANTED

;LEADING ZEROS OVER WITH?
;YES, DON'T SUPPRESS
;LAST DIGIT YET?
;YES, THEN PRINT EVEN IF ZERO
;NO, SEND A SPACE

;SEND CHARACTER

```

```
.TITLE CRLF
;CRLF SUBROUTINE INITIALIZES CONSOLE DEVICE CARRIAGE
.MCALL .TTYOUT
CRLF:: MOV #15,R0      ;PRINT CR
       .TTYOUT
       MOV #12,R0     ;PRINT LF
       .TTYOUT
       RTS    PC      ;RETURN
       .END
```

.TITLE PRINTER SUBROUTINES

```

;
LPRCSR=176500
LPRBUF=176502
LPXCSR=176504
LPXBUF=176506
;
;
;SUBROUTINE LPOUT
;
;LPOUT SUBROUTINE PRINTS CHARACTERS OUT ON THE LINE PRINTER
;CHARACTER TO BE PRINTED IS IN R0. USE WITH 'CALL LPOUT'.
;GLOBL LPOUT
;
LPOUT: BIT    $200,LPXCSR    ;READY TO PRINT?
      BEQ    LPOUT         ;NO
      BIT    $200,LPRCSR    ;CHARACTER RECEIVED?
      BEQ    20%           ;8R IF NO
5%:    MOVB   LPRBUF,LPIN    ;MOVE IN CHARACTER
      BIC    $200,LPIN      ;CLEAR PARITY BIT
      CMPB   $21,LPIN       ;TRANSMIT?
      BEQ    20%           ;8R IF YES
      CMPB   $23,LPIN       ;STOP TRANSMISSION?
      BNE    20%           ;
10%:   BIT    $200,LPRCSR    ;WAIT FOR 'RESUME'
      BEQ    10%           ;
      BR     5%            ;
20%:   NOP
      MOVB   R0,LPXBUF      ;CONTINUE
      RETURN                ;YES,PRINT IT
                              ;RETURN TO CALLING PROGRAM
;
;
;SUBROUTINE LPRINT
;
;SUBROUTINE LPRINT EMULATES THE MONITOR .PRINT REQUEST BUT SENDS
;OUTPUT TO THE PRINTER. IT IS ACCESSED BY PLACING THE BEGINNING
;ADDRESS OF THE BYTE BY BYTE ASCII STRING TO BE OUTPUT IN R0
;FOLLOWED BY THE INSTRUCTION 'CALL LPRINT'. CARRIAGE RETURN AND
;LINE FEED HANDLING ARE THE SAME AS THE MONITOR .PRINT REQUEST
;SUBROUTINE BY R.K.SPARKS MODIFIED BY S.W.BUSTAMANTE
;GLOBL LPRINT
;
LPRINT: CMPB   (R0),#200     ;?TERMINATOR FOR NO CRLF
      BEQ     2%            ;YES,THEN ARE FINISHED
      CMPB   (R0),#0        ;? TERMINATOR FOR CRLF
      BEQ     OUT           ;YES,THEN OUTPUT LF
1%:    BIT    $200,LPXCSR    ;READY FOR NEW CHARACTER?
      BEQ    1%            ;NO,THEN LOOP
      BIT    $200,LPRCSR    ;CHARACTER RECEIVED?
      BEQ    20%           ;8R IF NO
5%:    MOVB   LPRBUF,LPIN    ;MOVE IN CHARACTER
      BIC    $200,LPIN      ;CLEAR PARITY BIT
      CMPB   $21,LPIN       ;TRANSMIT?

```

```

      BEQ      20%
      CMFB    #23,LPIN      ;BR IF YES
      BNE     20%          ;STOP TRANSMISSION?
10%:  BIT     #200,LPRCSR    ;WAIT FOR "RESUME"
      BEQ     10%
      BR      5%
20%:  NOP
      MOVB    (R0)+,LPXBUF   ;CONTINUE
      BR      LPRINT        ;SEND CHARACTER
2%:   RETURN          ;GO FOR ANOTHER
OUT:  BIT     #200,LPCXSR    ;RETURN WITH NO CRLF
      BEQ     OUT          ;READY?
      BIT     #200,LPRCSR    ;NO,LOOP
      BEQ     20%          ;CHARACTER RECEIVED?
5%:   MOVB    LPRBUF,LPIN    ;BR IF NO
      BIC     #200,LPIN      ;MOVE IN CHARACTER
      CMFB    #21,LPIN      ;CLEAR PARITY BIT
      BEQ     20%          ;TRANSMIT?
      CMFB    #23,LPIN      ;BR IF YES
      BNE     20%          ;STOP TRANSMISSION?
10%:  BIT     #200,LPRCSR    ;WAIT FOR "RESUME"
      BEQ     10%
      BR      5%
20%:  NOP
      MOVB    #12,LPXBUF     ;CONTINUE
      RETURN          ;SEND LF,GET AUTO CR
                          ;RETURN TO CALLER
;
;
;
;SUBROUTINE LPCRLF
;
;
;THIS SUBROUTINE CAUSES THE LINE PRINTER TO EXECUTE A
;LINEFEED-CARRIAGE RETURN SEQUENCE WHEN CALLED. USE
;WITH 'CALL LPCRLF'.
      .GLOBL LPCRLF
;
LPCRLF: BIT     #200,LPCXSR    ;READY?
      BEQ     LPCRLF        ;NO,LOOP
      BIT     #200,LPRCSR    ;CHARACTER RECEIVED?
      BEQ     20%          ;BR IF NO
5%:   MOVB    LPRBUF,LPIN    ;MOVE IN CHARACTER
      BIC     #200,LPIN      ;CLEAR PARITY BIT
      CMFB    #21,LPIN      ;TRANSMIT?
      BEQ     20%          ;BR IF YES
      CMFB    #23,LPIN      ;STOP TRANSMISSION?
      BNE     20%
10%:  BIT     #200,LPRCSR    ;WAIT FOR "RESUME"
      BEQ     10%
      BR      5%
20%:  NOP
      MOVB    #12,LPXBUF     ;CONTINUE
      RETURN          ;SEND LF,GET AUTO CR
                          ;RETURN TO CALLER
;
;
```

```

;
;SUBROUTINE LPDECO
;
;LPDECO SUBROUTINE OUTPUTS THE BINARY NUMBER CONTAINED IN R1
;IN DECIMAL FORMAT TO THE LINE PRINTER. SIX CHARACTERS ARE
;OUTPUT: A MINUS SIGN IF THE NUMBER IS NEGATIVE AND WITH ANY
;LEADING ZEROES REPLACED BY SPACES. THE MINUS SIGN APPEARS
;NEXT TO THE FIRST NONZERO DIGIT.
;       .GLOBL LPDECO,BINASC,I0BUF,LP0UT
;
LPDECO: MOV     R1,R1DEC      ;SAVE REGISTERS
        MOV     R2,R2DEC
        CALL    BINASC       ;CONVERT R1 TO ASCII STRING
        MOV     %6,R1        ;SIX CHARACTERS OUTPUT
        MOV     #I0BUF,R2    ;BUFFER STARTING ADDRESS
10$:     MOVB    (R2)+,R0      ;OUTPUT CHARACTERS ONE BY ONE
        CALL    LP0UT
        SOB     R1,10$
        MOV     R2DEC,R2     ;UNSAVE REGISTERS
        MOV     R1DEC,R1
        RETURN               ;RETURN TO CALLING PROGRAM
;
;
;SUBROUTINE LPDC02
;
;LPDC02 SUBROUTINE OUTPUTS THE BINARY NUMBER CONTAINED IN WORDS
;LOWORD AND HIWORD IN DECIMAL FORMAT TO THE CONSOLE DEVICE. ELEVEN CHARACTER
;S
;ARE OUTPUT: A MINUS SIGN IF THE NUMBER IS NEGATIVE AND WITH ANY
;LEADING ZEROES REPLACED BY SPACES. THE MINUS SIGN APPEARS
;NEXT TO THE FIRST NONZERO DIGIT.
;
;       .GLOBL LPDC02,DPBASC,I0BUF,LP0UT
;
LPDC02: MOV     R1,R1DEC      ;SAVE REGISTERS
        MOV     R2,R2DEC
        CALL    DPBASC       ;CONVERT "WORDS" TO ASCII STRING
        MOV     #11,R1       ;ELEVEN CHARACTERS OUTPUT
        MOV     #I0BUF,R2    ;BUFFER STARTING ADDRESS
10$:     MOVB    (R2)+,R0      ;OUTPUT CHARACTERS ONE BY ONE
        CALL    LP0UT
        SOB     R1,10$
        MOV     R2DEC,R2     ;UNSAVE REGISTERS
        MOV     R1DEC,R1
        RETURN               ;RETURN TO CALLING PROGRAM
R1DEC:  .WORD
R2DEC:  .WORD
LPIN:   .WORD
        .END

```



```

CALL      READ                                ;CHECK FOR "SKIP" WORD
CMPB      #'Y',IOBUF                          ;SKIP THIS PART?
BEQ        10%                               ;DO NOT SKIP IF NOT EQUAL
JMP        210%                              ;SKIP IF EQUAL
10%:      .PRINT #M2                          ;GET SHURT WAVELENGTH
CALL      REWAVE
MOV        RESULT,SHOWAV
MOV        RESULT+2,SHOWAV+2
30%:      .PRINT #M3                          ;ASK FOR LONG WAVELENGTH
CALL      REWAVE
MOV        RESULT,LONWAV
MOV        RESULT+2,LONWAV+2
MOV        RESULT,ARG2                      ;COMPARE SHORT TO LONG WAVELENGTH
MOV        RESULT+2,ARG2+2
MOV        SHOWAV,ARG1
MOV        SHOWAV+2,ARG1+2
MOV        $LIST,R5
CALL      JCMF
CMF        #-1,R0
BEQ        40%
.PRINT     #M6
BR         30%
40%:      .PRINT #M4                          ;GET STEP SIZE
CALL      REWAVE
MOV        RESULT,ARG1
MOV        RESULT+2,ARG1+2
MOV        #48.,ARG2                       ;ONE STEP=48 UNITS
MOV        #0.,ARG2+2
MOV        $LIST,R5
CALL      JDIV
CMF        #1,R0                            ;ANY NEGATIVES OR ZEROES?
BEQ        50%
.PRINT     #M5                               ;MESSAGE
.PRINT     #M16
BR         40%
50%:      MOV        RESULT,ARG1
MOV        RESULT+2,ARG1+2
MOV        #32767.,ARG2
MOV        $LIST,R5
CALL      JCMF
TST        R0
BLE        160%
.PRINT     #M7                               ;STEP SIZE TOO LARGE
JMP        40%
160%:     MOV        ARG1,NSTEP              ;NUMBER OF STEPS PER CHANNEL
MOV        #48.,ARG2                       ;MAKE WAVINC=48*NSTEP
MOV        #0.,ARG2+2
MOV        $LIST,R5
CALL      JMWL
MOV        RESULT,WAVINC
MOV        RESULT+2,WAVINC+2
MOV        LONWAV,ARG1
MOV        LONWAV+2,ARG1+2
SUB        SHOWAV,ARG1
SBC        ARG1+2

```



```

SUB      SHOWAV+2,ARG1+2
MOV      WAVINC,ARG2
MOV      WAVINC+2,ARG2+2
MOV      #LIST,R5
CALL     JDIV
TST      RESULT+2
BEQ      180%
170%:    .PRINT  #M8           ;RESULTS IN IMPROPER # OF CHANNELS
        BR      40%           ;GET NEW STEP SIZE
180%:    CMP     #1000.,RESULT ;#OVER 1000. CHANNELS?
        BGE     190%
        BR      170%
190%:    CMP     RESULT,#0      ;ZERO CHANNELS?
        BGT     200%
        BR      170%
200%:    MOV     RESULT,NCHAN
        ADD     #1,NCHAN
        MOV     SHOWAV,RESULT
        MOV     SHOWAV+2,RESULT+2
        CALL    DYESSET
        BR      230%
210%:    .PRINT  #M9           ;ENTER NUMBER OF MOTOR STEPS
        CALL    READ
        CALL    ASCBIN
        BCC     212%           ;CONVERT TO BINARY NUMBER
        .PRINT  #M12          ;BRANCH IF NO ERROR
        BR      210%           ;PRINT ERROR MESSAGE
212%:    TST     R1
        BGE     215%
        .PRINT  #M5
        BR      210%
215%:    CMP     #20800.,R1     ;LESS THAN 20800.?
        BPL     220%           ;YES,BRANCH AWAY
        .PRINT  #M7           ;NO! PRINT MESSAGE
        BR      210%           ;GO BACK
220%:    MOV     R1,NSTEP
        MOV     R1,ARG1
        MOV     #0,ARG1+2
        MOV     #48.,ARG2
        MOV     #0,ARG2+2
        MOV     #LIST,R5
        CALL    JMUL
        MOV     RESULT,WAVINC
        MOV     RESULT+2,WAVINC+2
        MOV     SETWAV,SHOWAV
        MOV     SETWAV+2,SHOWAV+2
        MOV     RESULT,ARG1
        MOV     RESULT+2,ARG1+2
        MOV     NCHAN,ARG2
        MOV     #0,ARG2+2
        MOV     #LIST,R5
        CALL    JMUL
        MOV     RESULT,LONWAV
        MOV     RESULT+2,LONWAV+2
230%:    MOV     R5DL,R5       ;UNSAVE REGISTER

```

```

MOV      R1DL,R1
DLOUT:   RETURN                                ;RETURN TO CALLER
;
;
;
;
;DYESET SUBROUTINE SETS THE DYE LASER GRATING TO THE GIVEN VALUE. THE
;VALUE IS PASSED TO DYESET THROUGH RESULT(LOW WORD) AND RESULT+2 (THE
;HIGH WORD).
;
DYESET:  MOV      R1,R1DS                      ;SAVE REGISTERS
MOV      R2,R2DS
MOV      R3,R3DS
MOV      R4,R4DS
MOV      R5,R5DS
MOV      RESULT,R1
MOV      RESULT+2,R2
SUB      SETWAV,RESULT
SBC      RESULT+2
SUB      SETWAV+2,RESULT+2
MOV      R1,SETWAV                            ;NEW SET VALUE
MOV      R2,SETWAV+2
MOV      RESULT,ARG1
MOV      RESULT+2,ARG1+2
MOV      #48.,ARG2
MOV      #0,ARG2+2
MOV      #LIST,R5
CALL     JDIV
MOV      R0,NEGFLG
CMP      #-1,R0
BNE      10%
COM      RESULT+2
COM      RESULT
ADD      #1,RESULT
ADC      RESULT+2
10%:     MOV      #32767.,ARG1
MOV      #0,ARG1+2
20%:     MOV      RESULT,ARG2
MOV      RESULT+2,ARG2+2
MOV      #LIST,R5
CALL     JCHP
TST      R0
BGT      30%
MOV      #32767.,R1
MUL      NEGFLG,R1
CALL     MOTOR1
SUB      #32767.,RESULT
SBC      RESULT+2
BR       20%
30%:     MOV      RESULT,R1
MUL      NEGFLG,R1
CALL     MOTOR1
MOV      R5DS,R5
MOV      R4DS,R4

```

```

        MOV     R3DS,R3
        MOV     R2DS,R2
        MOV     R1DS,R1
DSOUT:  RETURN                                ;RETURN TO CALLER
;
;
;
;SURROUTINE REMAVE READS ASCII CODED NUMBER INTO SYSTEM. A DECIMAL
;MAY BE USED, FOR EXAMPLE 4567.234 WILL BE READ CORRECTLY, BUT NO
;MORE THAN THREE PLACES PAST THE DECIMAL ARE ALLOWED. THE ENTRIES
;4567,4567.,4567.0,4567.00,4567.000 ARE ALL READ CORRECTLY. NUMBERS
;FROM 0.000 TO 7200 ARE READ. LARGER NUMBERS ARE VOIDED.
;BINARY NUMBER IS RETURNED IN RESULT(LOW WORD) AND RESULT+2(HIGH WORD).
;
REMAVE: MOV     R1,R1REW                      ;SAVE REGISTERS
        MOV     R2,R2REW
        MOV     R3,R3REW
        MOV     R4,R4REW
        MOV     R5,R5REW
10%:    CLR     R1                            ;CHARACTER COUNTER
        MOV     #IOBUF,R2                    ;I/O BUFFER POINTER IN R2
        MOV     #MULFAC,R4                  ;MULTIPLICATION FACTORS
        CLR     R3                            ;DECIMAL POINT FLAG
20%:    .TTYIN                                ;GET CHARACTER
        CMPB    #12,R0                       ;IS IT A LINE FEED?
        BEQ     60%                          ;IF YES, LEAVE
        CMP     R1,#8.                       ;ONLY EIGHT CHARACTERS PASS
        BNE     30%                          ;
        .PRINT  #M10                          ;TOO MANY CHARACTERS!!!
25%:    .TTYIN                                ;SWALLOW OTHER CHARACTERS
        CMPB    #12,R0
        BNE     25%
        BR      10%
30%:    CMPB    #'.,R0                        ;BRANCH TO START
        BNE     40%                          ;LOOK FOR DECIMAL
        MOV     #1,R3                        ;DECIMAL FLAG UP
        BR      20%
40%:    CMP     #1,R3                        ;HAS THERE BEEN A DECIMAL?
        BNE     50%                          ;
        CMP     #15,R0                       ;SKIP THE CARRIAGE RETURN
        BEQ     50%
        TST     (R4)+                         ;GET DIFFERENT MULTIPLIER
50%:    MOVB    R0,(R2)+                      ;PLACE CHARACTER INTO BUFFER
        INC     R1                            ;INCREMENT CHARACTER COUNTER
        BR      20%                          ;GET MORE
60%:    CALL    ASCBIN                        ;CONVERT TO 32 BIT BINARY NO.
        BCC     130%                         ;BRANCH IF NO ERRORS
        .PRINT  #M12                          ;
        BR      10%                          ;TRY AGAIN
130%:   MOV     R1,ARG1
        MOV     R2,ARG1+2
        MOV     (R4),ARG2
        MOV     #0,ARG2+2
        MOV     #LIST,R5

```

```

CALL      REGSAV          ;SAVE REGISTERS R1-R5
CALL      JMUL
CALL      REGRES          ;RESTORE REGISTERS R1-R5
CMP       #-2,R0          ;WAS THERE AN OVERFLOW?
BNE       135$            ;IF NO,BRANCH
.PRINT    #M17
.PRINT    #M11            ;PRINT OVERFLOW MESSAGE
BR        10$             ;START OVER
135$:     MOV      RESULT,ARG1      ;IS THE RESULT TOO LARGE?
MOV      RESULT+2,ARG1+2
MOV      #0,ARG2
MOV      #160,ARG2+2          ;7300.000 MAXIMUM
CALL     REGSAV              ;SAVE R1-R5
CALL     JCMP
CALL     REGRES              ;RESTORE R1-R5
CMP      #-1,R0
BEQ      140$
.PRINT    #M11
BR        10$
140$:     MOV      R5REW,R5
MOV      R4REW,R4
MOV      R3REW,R3
MOV      R2REW,R2
MOV      R1REW,R1

RWOUT:    RETURN            ;RETURN TO CALLER
;
;
;
;
;      THIS SUBROUTINE ALLOWS ONE TO 'CALIBRATE' THE DYE LASER
;BY SETTING THE GRATING TO A GIVEN POSITION AND ASSOCIATING A
;WAVELENGTH WITH THE POSITION.
;
DYECAL:   MOV      R1,R1DC          ;SAVE R1
.PRINT    #M13                ;NEW CAL WAVELENGTH??
20$:      CALL     READ
CMPB     #'Y,I0BUF            ;YES OR NO
BEQ      30$
CMPB     #'N,I0BUF
BEQ      DCOUT
.PRINT    #M13
BR        20$
30$:      .PRINT    #M14          ;GET NEW WAVELENGTH
CALL     REWAVE
MOV      RESULT,SETWAV
MOV      RESULT,CALWAV
MOV      RESULT+2,SETWAV+2
MOV      RESULT+2,CALWAV+2
.PRINT    #M18
.PRINT    #M19
DCOUT:    MOV      R1DC,R1
RETURN    ;RETURN TO CALLER
;
;
;

```

```

;
; MESSAGE SECTION
;
M1: .ASCII<15><12>/DESIRED WAVELENGTH = /
    .BYTE 200
M2: .ASCII<15><12>/SHORT WAVELENGTH = /
    .BYTE 200
M3: .ASCII<15><12>/LONG WAVELENGTH = /
    .BYTE 200
M4: .ASCII<15><12>/STEP SIZE = /
    .BYTE 200
M5: .ASCII<15><12>/PLEASE! NO NEGATIVES!/
M6: .ASCII<15><12>/LONG WAVELENGTH MUST BE GREATER THAN SHORT WAVELENGTH
/
M7: .ASCII<15><12>/STEP SIZE TOO LARGE!! ENTER SMALLER VALUE/
M8: .ASCII<15><12>/VALUES ENTERED RESULT IN IMPROPER NO. OF DATA CHANNEL
S/
M9: .ASCII<15><12>/NUMBER OF MOTOR STEPS = /
    .BYTE 200
M10: .ASCII<15><12>/TOO MANY CHARACTERS. TRY AGAIN: /
    .BYTE 200
M11: .ASCII<15><12>/WAVELENGTH TOO LONG. TRY AGAIN: /
    .BYTE 200
M12: .ASCII<15><12>/PLEASE ENTER A NUMBER! TRY AGAIN: /
    .BYTE 200
M13: .ASCII<15><12>/DO YOU WISH TO CHANGE THE CALIBRATION WAVELENGTH? /
    .BYTE 200
M14: .ASCII<15><12>/ENTER CALIBRATION WAVELENGTH: /
    .BYTE 200
M15: .ASCII<15><12>/AUTO SET? /
    .BYTE 200
M16: .ASCII<15><12>/PLEASE!! NO ZEROES!!/
M17: .ASCII<15><12>/MULTIPLICATION OVERFLOW !!!/
M18: .ASCII<15><12>/SET THE DYE LASER DIAL TO READ/
M19: .ASCII<15><12>/FIVE TIMES THE CALIBRATION WAVELENGTH./
    .EVEN
;
;
; LABEL DEFINITIONS
;
R1DC: .WORD
R1DL: .WORD
R5DL: .WORD
R1DS: .WORD
R2US: .WORD
R3DS: .WORD
R4DS: .WORD
R5DS: .WORD
R1RFW: .WORD
R2REW: .WORD
R3REW: .WORD
R4REW: .WORD
R5REW: .WORD
NEGFLG: .WORD

```

```
MULFAC: .WORD 1000,,100,,10,,1  
;  
;  
;  
      .END
```

```

      .TITLE  MAGNET
;
;SUBROUTINE TO CONTROL THE MAGNETIC SECTOR MASS SPECTROMETER UNDER SCAN MODE
;
;
;      SYSTEM MACROS
;
;      .MCALL  .PRINT,.TTYOUT
;
;      GLOLIB  LIBRARY GLOBALS
;
;      .GLOBL  READ,ASCBIN,DECOUT,BUFINIT,CLEAR
;
;      GLOBALS DEFINED IN CALLING PROGRAM
;
;      .GLOBL  SICCODE,NSTEP,NCHAN,MADAC,MADAC1,MADAC2,MARES
;      .GLOBL  SCFUNC,IOBUF,UPDATE
;
;      THIS IS GLOBAL ROUTINE 'MAGNET'
;      .GLOBL  MAGNET
;
MAGNET:  MOV     R1,R1MAG           ;SAVE REGISTERS
        MOV     R2,R2MAG
        MOV     R3,R3MAG
        MOV     R4,R4MAG
        MOV     R5,R5MAG
        CMP     #MA,SCCODE       ;IS THE MAGNET BEING SCANNED?
        BEQ     4$
        .PRINT  #M6              ;DEVICE NOT ACTIVE
        CLR     UPDATE           ;CAUSE DISPLAY UPDATE
        JMP     MAGOUT
4$:      .PRINT  #M1
        MOV     MADAC1+2,R1      ;TYPE PRESENT VALUE
        CALL    DECOUT
        MOV     #' ',R0         ;TYPE A SPACE
        .TTYOUT
        CALL    READ
        CMPR    #15,IOBUF       ;A CR?
        BEQ     15$
        CALL    ASCBIN          ;REPLY IN R1
        BCC     5$
        .PRINT  #M4
        BR      4$
5$:      RST R1
        BMI     10$
        CMP     #99,R1
        RPL 15$
10$:     .PRINT  #M4
        BR      4$              ;TRY AGAIN
15$:     MOV     R1,MADAC1+2     ;SAVE LOW VALUE
18$:     .PRINT  #M2

```

```

MOV      MADAC2,R1          ;TYPE PRESENT VALUE
CALL     DECDUT
MOV      #' ,R0             ;TYPE A SPACE
        .TTYOUT
CALL     READ
CHPB     #15,I0BUF          ;A CR?
BEQ      20%
CALL     ASCBIN              ;HIGH VALUE IN R1
BCC      20%
.PRINT   #M4
BR       18%
20%:     CMP      R1,MADAC1+2  ;HIGH VALUE>LOW VALUE?
BLE      25%
CMP      #100.,R1           ;HIGH VALUE<100?
BPL      30%
25%:     .PRINT   #M4
BR       18%
30%:     MOV      R1,MADAC2    ;TRY AGAIN
MOV      MADAC1+2,R1         ;SAVE HIGH VALUE
MUL      #34.,R1             ;MULT. BY 34.
MOV      R1,MADAC           ;34. #'S PER UNIT
MOV      R1,MADAC1          ;SET A-2-D TO LOW CURRENT
MOV      MADAC2,R3          ;SAVE COPY
SUB      MADAC1+2,R3         ;HIGH CURRENT VALUE TO R3
35%:     .PRINT   #M3        ;CURRENT SPAN
MOV      RARE+2,R1           ;TYPE PRESENT VALUE
CALL     DECDUT
MOV      #' ,R0             ;TYPE A SPACE
        .TTYOUT
CALL     READ
CHPB     #15,I0BUF          ;A CR?
BEQ      35%
CALL     ASCBIN              ;REPLY IN R1(BINARY)
BCC      40%
.PRINT   #M4
BR       35%
40%:     TST      R1
BLE      45%                 ;MUST BE GREATER THAN ZERO
CMP      #35.,R1            ;AND LESS THAN 35.
BPL      50%
45%:     .PRINT   #M4
BR       35%
50%:     MOV      R1,MARE+2    ;TRY AGAIN
MOV      R1,MARE            ;SAVE ENTERED VALUE
MUL      #34.,R3            ;INCREMENT VALUE
CLR      R2                 ;R3 CONTAINS MASS SPAN
DIV      MARE,R2
CMP      #1000.,R2          ;IS IT LESS THAN 1000.?
BGE      60%                ;BRANCH IF YES
.PRINT   #M5
BR       35%
60%:     MOV      R2,NCHAN
MAINIT:  CALL     BUFINIT     ;GENERATE PROPER BUFFER POINTERS
CALL     CLEAR              ;CLEAR DATA BUFFERS
MAGOUT:  MOV      R5MAG,R5    ;RESTORE REGISTERS

```



```

        MOV     R4MAG,R4
        MOV     R3MAG,R3
        MOV     R2MAG,R2
        MOV     R1MAG,R1
        RETURN
;
;
;      LABELS
R1MAG:  .WORD
R2MAG:  .WORD
R3MAG:  .WORD
R4MAG:  .WORD
R5MAG:  .WORD
;
;
M1:     .ASCII<15><12>/LOW VALUE(0-100) =/<200>
M2:     .ASCII<15><12>/HIGH VALUE      =/<200>
M3:     .ASCII<15><12>/STEPS PER CHANNEL=/<200>
M4:     .ASCIZ<15><12>/INVALID REPLY!! TRY AGAIN./
M5:     .ASCIZ<15><12>/RESULTS IN TOO MANY CHANNELS: ONLY 1000 ARE ALLOWED,/
M6:     .ASCIZ<15><12>/DEVICE IS NOT ACTIVE/
        .EVEN
;
;
        .END

```

```

        .TITLE    MOTOR1
;MOTOR SUBROUTINE SENDS "R1" PULSES TO STEPPING MOTOR.
;POSITIVE NUMBER FOR CLOCKWISE ROTATION AND A NEGATIVE
;NUMBER FOR COUNTERCLOCKWISE ROTATION. USE WITH A
;*CALL MOTOR1*STATEMENT.
        .MCALL    .PRINT
        .GLOBL    MOTOR1
DATALO=166000
MOTOR1:  MOVB     #1,0#166040    ;READ MOTOR STATUS WORD
        BIT      #1,DATALO      ;IS LAM SET?
        BEQ      MOTOR1         ;NO, WAIT
        BIT      #2,DATALO      ;IS CCWL SET?
        BEQ      10$            ;NO
        .PRINT    #M1           ;YES-PRINT WARNING
10$:     BIT      #4,DATALO      ;IS CWL SET?
        BEQ      20$            ;NO
        .PRINT    #M2           ;YES-PRINT WARNING
20$:     TST      R1             ;IS R1 NEGATIVE?
        BGE      30$            ;NO
        NEG      R1             ;YES-MAKE POSITIVE
        BIS      #100000,R1      ;SIGN BIT = 1
30$:     BEQ      40$            ;DO NOT LOAD A ZERO
        MOV      R1,0#166040    ;LOAD COUNTER
40$:     RETURN
M1:      .ASCIZ<15><12>/WARNING!! CCW LIMIT OF MOTOR 1 REACHED!/
        .EVEN
M2:      .ASCIZ<15><12>/WARNING!! CW LIMIT OF MOTOR 1 REACHED!/
        .EVEN
        .END

```

```

        .TITLE  MOTOR2
#MOTOR SUBROUTINE SENDS 'R1' PULSES TO STEPPING MOTOR.
#POSITIVE NUMBER FOR CLOCKWISE ROTATION AND A NEGATIVE
#NUMBER FOR COUNTERCLOCKWISE ROTATION. USE WITH A
#CALL MOTOR2*STATEMENT.
        .MCALL  .PRINT
        .GLOBL  MOTOR2
DATA0=166000
MOTOR2: MOVB    #1,0#166040      ;READ MOTOR STATUS WORD
        BIT     #20,DATA0        ;IS LAM SET?
        BEQ     MOTOR2          ;NO, WAIT
        BIT     #40,DATA0        ;IS CCWL SET?
        BEQ     10%             ;NO
        .PRINT  #M1             ;YES-PRINT WARNING
10%:     BIT     #100,DATA0       ;IS CWL SET?
        BEQ     20%             ;NO
        .PRINT  #M2             ;YES-PRINT WARNING
20%:     TST     R1              ;IS R1 NEGATIVE?
        BGE     30%             ;NO
        NEG     R1              ;YES-MAKE POSITIVE
        BIS     #100000,R1       ;SIGN BIT = 1
30%:     BEQ     40%             ;DO NOT LOAD A ZERO
        MOV     R1,0#166042      ;LOAD COUNTER
40%:     RETURN
M1:      .ASCIIZ<15><12>/WARNING!! CCW LIMIT OF MOTOR 2 REACHED!/
        .EVEN
M2:      .ASCIIZ<15><12>/WARNING!! CW LIMIT OF MOTOR 2 REACHED!/
        .EVEN
        .END

```

```

      .TITLE   QUAD
;
;SUBROUTINE TO CONTROL THE QUADRUPOLE MASS SPECTROMETER UNDER SCAN MODL.
;
;
;      SYSTEM MACROS
;
;      .MCALL   .PRINT,.TTYOUT
;
;      GLOLIB   LIBRARY GLOBALS
;
;      .GLOBL   READ,ASCBIN,DECOU,BUFINIT,CLEAR
;
;
;      GLOBALS DEFINED IN CALLING PROGRAM
;
;      .GLOBL   SCCODE,NSTEP,NCHAN,MDAC,MDAC1,MDAC2,MRES
;      .GLOBL   HASBUF,SCFUNC,QP,IOBUF,UPDATE
;
;      THIS GLOBAL ROUTINE "QUAD"
;      .GLOBL   QUAD
;
QUAD:  MOV      R1,R1QUA                ;SAVE REGISTERS
      MOV      R2,R2QUA
      MOV      R3,R3QUA
      MOV      R4,R4QUA
      MOV      R5,R5QUA
      CMP      #'QU,SCCODE              ;IS THE QUAD. BEING SCANNED?
      BEQ      4%
      CMP      #'QP,SCCODE              ;SCAN PEAK TO PEAK?
      BNE      1%
      MOV      #'QP,SCFUNC
      JMP      QUPKS
1%:    .PRINT   #'N9                    ;DEVICE NOT ACTIVE
      CLR      UPDATE                  ;CAUSE A DISPLAY UPDATE
      JMP      QUADUT
4%:    .PRINT   #'M1                    ;PRINT EXISTING VALUE
      MOV      MDAC1+2,R1
      CALL     DECOU
      MOV      #' ,R0                  ;TYPE A SPACE
      .TTYOUT
      CALL     READ
      CMPB     #'S,IOBUF                ;IS IT A CR?
      BEQ      10%                     ;IF YES GO TO NEXT QUESTION
      CALL     ASCBIN                   ;REPLY IN R1
      BCC      5%
      .PRINT   #'M4
      BR       4%
5%:    TST     R1
      BMI      10%
      CMP      #200.,R1
      BPL      15%
10%:   .PRINT   #'M4

```

```

15%: BR      4%      ;TRY AGAIN
      MOV     R1,MDAC1+2 ;SAVE LOW MASS VALUE
18%: .PRINT  #M2
      MOV     MDAC2,R1   ;PRINT EXISTING VALUE
      CALL    DECOUT
      MOV     #' ,R0     ;TYPE A SPACE
      .TTYOUT
      CALL    READ
      CMFB    #15,I0BUF  ;A CR?
      BEQ     20%
      CALL    ASCBIN     ;HIGH MASS IN R1
      BCC     20%
      .PRINT  #M4
      BR      18%
20%: CMP     R1,MDAC1+2  ;HIGH MASS>LOW MASS?
      BLE     25%
      CMP     #200.,R1   ;HIGH MASS<200?
      BPL     30%
25%: .PRINT  #M4
      BR      18%
30%: MOV     R1,MDAC2    ;TRY AGAIN
      MOV     MDAC1+2,R1 ;SAVE HIGH MASS VALUE
      MUL     #20.,R1    ;MUL BY 20.
      MOV     R1,MDAC    ;20. #'S PER UNIT MASS
      MOV     R1,MDAC1    ;SET A-2-D TO LOW MASS
      MOV     MDAC2,R3    ;SAVE COPY
      SUB     MDAC1+2,R3  ;HIGH VALUE TO R3
      .PRINT  #M3        ;MASS SPAN
35%: MOV     MRES+2,R1    ;EXISTING VALUE
      CALL    DECOUT
      MOV     #' ,R0     ;TYPE A SPACE
      .TTYOUT
      CALL    READ
      CMFB    #15,I0BUF  ;A CR?
      BEQ     55%
      CALL    ASCBIN     ;REPLY IN R1(BINARY)
      BCC     40%
      .PRINT  #M4
      BR      35%
40%: TST     R1
      BLE     45%
      CMP     #21.,R1    ;MUST BE GREATER THAN ZERO
      BPL     50%        ;AND LESS THAN 21.
45%: .PRINT  #M4
      BR      35%
50%: MOV     R1,MRES+2    ;TRY AGAIN
55%: MOV     R1,MRES      ;SAVE ENTERED MRES VALUE
      MUL     #20.,R3    ;INCREMENT VALUE
      CLR     R2         ;R3=MASS SPAN*20.
      DIV     MPES,R2
      CMP     #1000.,R2  ;IS IT LESS THAN 1000.?
      BGE     60%        ;BRANCH IF YES
      .PRINT  #M5
      BR      35%
60%: MOV     R2,NCHAN

```

```

QUINIT: CALL    BUFINIT           ;GENERATE PROPER BUFFER POINTERS
        CALL    CLEAR            ;CLEAR DATA BUFFERS
QUADUT: MOV     R5QUA,R5          ;RESTORE REGISTERS
        MOV     R4QUA,R4
        MOV     R3QUA,R3
        MOV     R2QUA,R2
        MOV     R1QUA,R1
        RETURN

;
;
QUPKS:  .PRINT  #M6              ;ASK FOR NUMBER OF SEGMENTS
        CALL    READ             ;GET RESPONSE
        CALL    ASCBIN           ;CONVERT TO BINARY
        BCC     5%              ;BRANCH IF NO ERROR

1%:     .PRINT  #M4              ;ZERO?
        BR      QUPKS

5%:     TST     R1               ;ZERO?
        BEQ     1%
        MOV     R1,R5           ;LOOP COUNTER
        CLR     NCHAN           ;CLEAR CHANNEL COUNTER
        MOV     #1,R4           ;SEGMENT COUNTER
        MOV     #M$BUF,R3       ;MASS BUFFER STARTING LOCATION
10%:    .PRINT  #M7              ;ASK FOR STARTING CHANNEL NUMBERS
        MOV     R4,R1
        CALL    DECOUT
        MOV     #' ,R0          ;TYPE A SPACE
        .TTYOUT
        MOV     #'=,R0          ;TYPE =
        .TTYOUT
        MOV     #' ,R0          ;TYPE ANOTHER SPACE
        .TTYOUT
        CALL    READ            ;GET REPLY
        CALL    ASCBIN           ;CONVERT TO BINARY
        BCC     12%            ;BRANCH IF NO ERROR

12%:    .PRINT  #M4              ;TRY AGAIN
        BR      10%

15%:    TST     R1               ;ZERO?
        BEQ     12%
        SUB     #1,R1           ;CHANNEL 1 = ZERO OFFSET
        MUL     MRES,R1         ;"MRES" UNITS PER CHANNEL
        ADD     MDAC1,R1        ;STARTING A-2-D VALUE
        MOV     R1,(R3)+        ;PLACE IN MASS BUFFER
20%:    .PRINT  #M8              ;NUMBER OF CHANNELS IN SEGMENT?
        CALL    READ            ;GET REPLY
        CALL    ASCBIN           ;CONVERT TO BINARY(REPLY IN R1)
        BCC     23%            ;BRANCH IF NO ERROR

22%:    .PRINT  #M4              ;TRY AGAIN
        BR      20%

23%:    TST     R1               ;ZERO?
        BEQ     22%
        MOV     -2(R3),(R3)     ;CREATE SCAN ARRAY
        ADD     MRES,(R3)+      ;COUNT NUMBER OF CHANNELS
        INC     NCHAN
        CMP     #100,,NCHAN     ;ALLOW ONLY 100 CHANNELS
        BPL     30%
30%:

```

```

30$:   BR      35$
      SGB     R1,25$
      INC     R4
      DEC     R5
      BEQ     35$
      JMP     10$
35$:   MOV     MASBUF,MDAC
      JMP     QUINT
      ;
      ;
      ;
      LABELS
R1QUA: .WORD
R2QUA: .WORD
R3QUA: .WORD
R4QUA: .WORD
R5QUA: .WORD
      ;
M1:    .ASCII<15><12>/LOW MASS =/<200>
M2:    .ASCII<15><12>/HIGH MASS =/<200>
M3:    .ASCII<15><12>/STEPS PER CHANNEL=/<200>
M4:    .ASCIZ<15><12>/INVALID REPLY!! TRY AGAIN./
M5:    .ASCIZ<15><12>/RESULTS IN TOO MANY CHANNELS: ONLY 1000 ARE ALLOWED./
M6:    .ASCII<15><12>/NUMBER OF MASS SEGMENTS = /<200>
M7:    .ASCII<15><12>/STARTING CHANNEL NUMBER OF SEGMENT/<200>
M8:    .ASCII<15><12>/NUMBER OF CHANNELS IN THE SEGMENT = /<200>
M9:    .ASCIZ<15><12>/DEVICE IS NOT ACTIVE/
      .EVEN
      ;
      ;
      .END

```

```

        .TITLE  READ
;READ SUBROUTINE READS  CHARACTERS ON CONSOLE DEVICE
;LOADS BUFFER STARTING AT LOCATION 'IOBUF'
        .MCALL  .TTYIN
        .GLOBL READ,IOBUF
READ:    MOV     R2,R2REA
        MOV     R1,R1REA
        MOV     #IOBUF,R2
        CLR     R1                                ;LOOP COUNTER
10$:     .TTYIN
        CMP     #100.,R1                        ;ONLY 100. CHARACTERS ARE ALLOWED
        BEQ     20$                             ;IF YES,EXIT
        CHPB    #12,R0
        BEQ     RE2
        MOVB    R0,(R2)+
        BR      10$
20$:     .TTYIN                                ;EAT THE REST
        CHPB    #12,R0
        BEQ     RE2
        BR      20$
RE2:     MOV     R2REA,R2                        ;UNSAVE REGISTERS
        MOV     R1REA,R1
        RTS    PC
R1REA:   .WORD
R2REA:   .WORD
        .END

```



```
C
C
SUBROUTINE PLOTTR(PLCTRL,PLCHAR,PLLINE,DISTR',DICHNS,STCHAN,PLMOV,
1YMAX)
INTEGER PLCTRL,DISTR,DICHNS,STCHAN
INTEGER PLLINE,PLCHAR,PLMOV,CTRLC,PLMOVE
EXTERNAL RUN
INTEGER*4 YMAX
REAL*8 DJFLT
DIMENSION ITDCK(9)

C
C
DEFINE SPECIAL CHARACTERS
CTRLC=3

C
C
TURN PLOTTER ON.
CALL      ON
CALL      ONMODE
CALL      XONOFF

C
C
INITIALIZE.
TYPE      100
FORMAT (' IN;PU;IP704,1850,10306,8103;')
IF(PLCTRL.EQ.'PP'.OR.PLCTRL.EQ.'PM') GO TO 850
IF(PLCTRL.EQ.'PC') GO TO 1510
IF(PLCTRL.EQ.'PH') GO TO 2110
IF(PLCTRL.EQ.'PV') GO TO 2200
IF(PLCTRL.EQ.'PB') GO TO 2300

C
C
DRAW THE BOX.
TYPE      200
FORMAT (' VS10;PA10306,C103;PU;')
TYPE      250
FORMAT (' PA10306,1135,704,1135,704,8103,10306,8103;FU;VS;')

C
C
CHANGE SCALE--DRAW THE Y-AXIS TICKS.
TYPE      300
FORMAT (' SC0,101,0,105;PA0,-10;TL1,0;')
TYPE      350,CTRLC
FORMAT (' YT;CP-3.5,-.25;LB-10',A1)
DO        500,I=0,100,10
TYPE      450,I,I,CTRLC
FORMAT (' PA0,'I3','YT;CP-3.5,-.25;LB',I3,A1)
CONTINUE
TYPE      550
FORMAT (' TL0,1;')
DO        600I=-10,100,10
TYPE      575,I
FORMAT (' PA101,',I3,'YT;')
```

```

600      CONTINUE
C
C
C
C      LABEL THE AXES.
      TYPE      700,CTRLC
700      FORMAT (' SC;SI.25,.5;PA4275,583;LBCHANNEL NUMBER',A1)
      TYPE      800,CTRLC
800      FORMAT (' DIO,10;PA232,3733;LBCOUNTS/CHANNEL',A1,'D1;')
C
C
C
C      PLOT THE DATA
850      PLMOVE=PLMOV*20+PLMOV/2
      TYPE      900,PLLINE,PLCHAR
900      FORMAT (' LT',A1,'ISH',A1;')
      TYPE      1000,DICHNS+1
1000     FORMAT (' SCO,',I3,',',0,2150;S1;')
      JADDR=DISTR+2
      DO        1500 I=1,DICHNS
      TYPE      1100,I,(IPEEK(JADDR)-2047)+PLMOVE
1100     FORMAT (' PA',I3,',',I4;')
      JADDR=JADDR+4
      IF(1.NE. 1) GO TO 1500
      IF(PLLINE.EQ. 32) GO TO 1400
      TYPE      1200
1200     FORMAT (' PD;')
      GO TO 1500
1400     TYPE      1450
1450     FORMAT (' PU;')
1500     CONTINUE
      IF(PLCTRL.EQ. 'PP' .OR. PLCTRL.EQ. 'PM') GO TO 9999
C
C
C
C      MAKE THE X-TICKS
1510     ITICK=DICHNS
      ITICK=ITICK/10
      DO        1520 I=1,5
      ITOCK(I+2)=I*5
1520     CONTINUE
      ITOCK(1)=1
      ITOCK(2)=2
      ITOCK(8)=50
      ITOCK(9)=100
      DO        1590 I=0,50
      DO        1550 J=1,9
      IF(ITICK.EQ. ITOCK(J)) GO TO 1600
1550     CONTINUE
      ITICK=ITICK+1
1590     CONTINUE
C

```

```

C
C      PLOT THE X-AXIS TICKS AND CHANNEL NUMBERS
C
1600   TYPE      1700
1700   FORMAT    (' PU;SM;LT;TL1.6;0;')
      TYPE      1750,DICHNS+1
1750   FORMAT    (' SC0;','I3;','0,105;SI;')
      IR=0
      IS=0
      ID=5
      IL=DICHNS-1
      IF(ITICK.LT.5)ID=ITICK
      ISAV=MOD(STCHAN,ID)
      IF(ITICK-ISAV.GE.ITICK/2)GO TO 1760
      IS=ITICK
      IR=ISAV
      IL=1L+ITICK
1760   DO        1900 IX=IS,IL,ITICK
      TYPE      1800,IX-IR+1,PLMOV-12,STCHAN+IX-IR,CTRLC
1800   FORMAT    (' PA;','I3;','','I3;','XT;CP-2,-1;LB;','I3,A1)
      IR=ISAV
1900   CONTINUE
      IX=IX-ITICK
      IF(DICHNS-IX+IR-1.LT.ITICK/2)GO TO 1950
      IX=DICHNS+IR-1
      TYPE      1800,IX-IR+1,PLMOV-12,STCHAN+IX-IR,CTRLC
1950   IF(PLCTRL.EQ. 'PC') GO TO 9999
      TYPE      2000
2000   FORMAT    (' TL0,1.6;')
      DO        2100,IX=0,DICHNS-1,ITICK
      TYPE      2050,IX+1
2050   FORMAT    (' PA;','I3;','105;XT;')
2100   CONTINUE
      TYPE      3000,DJFLT(YMAX),CTRLC
3000   FORMAT    (' PA1,-17;CP0,-2.0;LB;','F11.0 ' FULL SCALE;','A1)
      TYPE      3050,IPEEK(IADDR(RUN)),CTRLC
3050   FORMAT    (' CP;CP5,0;LB;','IS;',' RUN NUMBER;','A1)
      GO TO 9999

C
C      MAKE HORIZONTAL LINES
C
2110   TYPE      2150,PLMOV,PLLINE
2150   FORMAT    (' SC0,101,0,105;PA0;','I3;','LT;','A1;','PU;')
      TYPE      2175,PLMOV
2175   FORMAT    (' PA101;','I3;','')
      GO TO 9999

C
C      MAKE VERTICAL LINES.
C
2200   TYPE      2250,DICHNS+1,PLLINE,PLMOV
2250   FORMAT    (' SC0;','I3;','0,105;LT;','A1;','PA;','I3;','0;PD;')
      TYPE      2260,PLMOV
2260   FORMAT    (' PA;','I3;','101;')
      GO TO 9999

C

```

```

C      SUBROUTINE OM
      INTEGER ESCAPE
      ESCAPE=27
C      EMPTY RING
10     ICHAR=ITTINR(1)
      IF(ICHAR.GT. 0) GO TO 10
      TYPE    20,ESCAPE
20     FORMAT (1H ,A1,'.Y')
      RETURN
      END

C
C
C      SUBROUTINE OFF
      INTEGER ESCAPE
      ESCAPE=27
C      SEND 'ESC.L' BUFFER SIZE?
C      PLOTTER RESPONDS WHEN ITS BUFFER IS EMPTY.
      TYPE    10,ESCAPE
10     FORMAT (1H ,A1,'.L')
20     ICHAR=ITTINR(1)
      IF(ICHAR.LT. 0) GO TO 20
25     ICHAR=ITTINR(1)
      IF(ICHAR.GT. 0) GO TO 25
C      SEND 'ESC.Z' PLOTTER OFF COMMAND
      TYPE    30,ESCAPE
30     FORMAT (1H ,';',A1,'.Z')
      RETURN
      END

C
C
C      SUBROUTINE XONOFF
      INTEGER ESCAPE
      ESCAPE=27
      TYPE 20,ESCAPE
20     FORMAT (1H ,A1,'.I200;17:')
      TYPE    40,ESCAPE
40     FORMAT (1H ,A1,'.N0;19:')
      RETURN
      END

C
C
C      SUBROUTINE ONMODE
      INTEGER ESCAPE
      ESCAPE=27
      TYPE    20,ESCAPE
20     FORMAT (1H ,A1,'.0;2:')
      RETURN
      END

```

```
C      DRAW BOX ONLY
C
2300   TYPE      2310
2310   FORMAT    (' VS10;PA10306,8103;PB;')
      TYPE      2315
2315   FORMAT    (' PA10306,1850,704,1850,704,8103,10306,8103;PU;')
      GO TO 9999
C
C
C      EXIT THE PROGRAM
C
9999   TYPE      10010
10010  FORMAT    (' PU;SH;SC0,101,0,101;S1;PA101,101;')
      CALL      OFF
      RETURN
      END
```