BNL-105770-2014-TECH

EP&S No. 57;BNL-105770-2014-IR

Computer control of the AGS beams

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August 1972

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U.S. Department of Energy

USDOE Office of Science (SC)

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Upton, New York

EP&S DIVISION TECHNICAL NOTE
No. 57

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Introduction

I was asked to help Bryan Culwick in planning a system of computer control of the AGS beams. Since my time here was limited, I decided that I would be most useful if I worked on an overall plan, rather than on some specific items. The only specific item that I spent some time on was position control devices.

This is an informal report based on my observations. It starts with a general survey of the current status, followed by a section on position control devices. After that, there is a discussion on various problems associated with the current status, followed by a description of an overall system of computer control. Finally it ends with a discussion of organizational problems and possible re-organization to expedite the implementation of the AGS beam control.

Current Status

I have checked around to see what has been done or being done around the AGS to control various beam components. I did not make a complete or very systematic survey, but what I found out may be of interest to those involved in the AGS operation, and is certainly necessary in order to make an overall plan for the immediate future.

1. 80-in. Bubble Chamber Beam

The RF and DC separated beams are somewhat computer controlled and monitored. The computer is PDP-8 and it currently reads the scalers, DECITRAK encoders (for counter positions) and RF timing. The computer can control the motion of the beam profile counters, and can produce plots of DECITRAK positions vs scaler reading. There is a BCD to binary converter, and all readings both from scalers and DECITRAK are converted to binary for inputting into the computer.

The scalers are not controlled by the computer in a sense that gating or triggering is done by the usual method with predets.

The RF timing is controlled by the computer.

The magnet currents are not read by the computer yet, but a device is being made to read the shunt voltages brought out to the trailer. The computer, however, will merely scan the shunt voltages and logs them in some fashion. It does not control the magnet currents.

The RF system except for timing, and the DC separators are not monitored or controlled at all. Also other pieces of information such as the beam intensity, bubble chamber magnet current and other operating conditions which seem pertinent to the users are not monitored.

After the magnet current monitoring and perhaps control, some of the items mentioned above are to be tackled, but not much thought has gone into it yet. The current system is not designed to be compatible with the DATACOM system. The reason for this seems that the DATACOM (DATACOM II) system is regarded to be still in the developmental stage, and its use as the standard communication link is still far into the future. So the system mentioned here is regarded as an interim measure.

2. Slow Extracted Beam (SEB)

Nearly everything is manually remote controllable, but nothing is computer controlled. The items that are controlled are: six radius shifter levels, six SEB spill servo levels, F5-F10 upstream and downstream positions, A, B and C target turret, C20 and C85 collimators, and flag and split plate control. DECITRAKs are used for F5-F10 position control readouts.

A cross-bar control exists for connecting many things to many things (sixty signals to ten output channels), but is in bad shape in that labels, etc. always don't indicate what they say.

3. Fast Extracted Beam (FEB)

The A10 and I10 septums are remote controlled manually. The vertical pitching magnet should be controlled, but is not.

4. New Fast Extracted Beam (New FEB) to the North Area

This beam is not finished yet. Remote position control units exist, but not installed. These units are based on a design by J. Curtiss* and were built quite some time ago.

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* R20 (now called C20) Variable Aperture Collimator Mechanical Construction and Manual Control, L.B. Repeta and J.A. Curtiss, AGS Internal Report, AGS DIV 70-5. Also Master's thesis by J.A. Curtiss, June 1970.

Even though these units were primarily designed for the variable aperture collimators, they can easily be used for other position controls. Therefore, it seems appropriate to describe briefly these units. The basic units are shown in Fig. 1.

Manual control box consists of various switches to control the motion of SLO-SYN motors which move various components of the collimator and other devices. The selector lets the operator select a device he wishes to control. Distribution box relays the selector information to the particular device box chosen. There is a device box for each device. The complexity of a device box depends on the number of SLO-SYN's to be driven. There is one motor drive unit which controls the motion of SLO-SYN's. The number of SLO-SYN's which can be driven depends entirely on the power supply; so, many motors can be controlled simultaneously. Motors are driven by two-phase 60Hz AC. The phase relation determines the direction of the motor. The calibration device calibrates the potentiometer mechanically connected to a driven device so that the reading on the ratio-meter will come out in terms of mils from the beam center-line or whatever reference point is chosen.

The ratio-meter is a DVM which produces as an output ratio X/Y, where X = (potentiometer reading - common) / |Reference - Common|. Reference and common voltages are variable by means of the reference and zero potentiometers shown in Fig. 2. The denominator voltage has to be about ten volts for accurate operation of the ratiometer, and this requirement contains the resistance of these potentiometers as well as the applied DC voltage. The position of any device can be calibrated with respect to a known reference position and a known distance. If offset reading is desired (for example a collimator jaw may traverse only in the negative direction like 0 to-1.5 in.), an appropriate resistor can be inserted in series with the device potentiometer in one leg or the other to achieve this end.

The device pot is a ten-turn 10K Helipot which has minimum linearity of ± 0.05%, and is accurate enough for our purpose.

The control wires for these units for the new FEB have been installed except for those controlling copper splitter and collimator.

5. LINAC

The LINAC is controlled by PDP-8 which is being linked to PDP-10. The communication links are slow, and it is expected that DATACOM II will replace them.

6. DATACOM

A system called DATACOM has been designed to serve as communication links between the computer and various devices. There are two versions of DATACOM. The earlier version is DATACOM I, and the later one DATACOM II. The differences between DATACOM I and DATACOM II are:

a. The transmission rate for DATACOM I is 1 ms (at best .5 ms). For DATACOM II it is 120 μs per transmission.

b. DATACOM I is designed to be used with PDP-8, and uses a 12-bit word, but DATACOM II is designed to use a 16-bit word as PDP-11 is to be used.

c. Signals for the two systems are different (unipolar for DATACOM I and bipolar for DATACOM II).

The DATACOM I system has two central units, and currently controls low field correction magnets and the injection line including the inflector. There are still one-hundred twenty spare channels, and they go to the FEB area (E10 and H10 houses).

DATACOM II remote terminals are designed to control the ACME power supplies only so far, but other terminals will be designed and built as soon as specifications are set up to control other devices.

A more detailed description of DATACOM II is given in a memo by R. Frankel*, and several memos by B. Culwick**.

Since DATACOM I and DATACOM II are incompatible with each other, and since DATACOM II will be used for any future linkage, it is necessary to modify any extra cards, remote stations, etc. built for DATACOM I which are not currently in use so that they can function with DATACOM II.

<u>Position Control</u>

As mentioned in the previous section, a few types of position control (manual mainly) devices exist. The question is what sort of specifications are needed for a standardized position control device. Some of them are

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* R. Frankel, DATACOM System - Informal Report, AGS DIV Technical Note 88.

** EP&S CCN H3A, H2A, and memo dated June 26, 1972, also see EP&S Note 49 by V. Kovarik, May 1972 listed below.

1. Accuracy

It seems that $\pm$ 5 mils seems to be good enough for all positioning devices. This accuracy is easy to achieve.

2. Maximum Travel

Five inches total will be more than adequate. So coupled with the above requirement, we need .1% accuracy.

3. Position Monitoring

There are basically two ways of obtaining the position information. One is to use an absolute encoder like DECITRAK to obtain BCD or binary output. The other is to use a potentiometer to obtain analogue output. In either case, these monitoring devices must be coupled mechanically to SLO-SYN motors, and must be able to withstand radiation. So optical encoders and other encoders having solid state devices cannot be used. Also, magnetic type encoders will probably give trouble in the fringe field. Thus, we are left with DECITRAK or other brush type absolute encoders or potentiometers. DECITRAK type may be prefereable since it produces digital output, but the cost per encoder is very high. For example, a DECITRAK which has a range of 0 to 9999 in 100 turns costs about $600.00. A gate array for this encoder costs about $500.00, and more money is needed to multiplex many encoders to one gate array. A manufacturer representative will visit BNL later this month to discuss a possible package deal*.

Once we get away from the idea that the output should be digital, then the potentiometer is a very economical alternative. It is cheap, and with the scheme mentioned in the previous section it can be calibrated to suit any physical configuration. Since there are other analogue devices such as shunts to be checked by the computer control system, it does not seem all that important to adhere to the idea of digital output. Furthermore, the SLO-SYN motor will lock in within 1.5 cycles after the 60Hz AC power is applied, and will stop in 1.5 cycles when the power is removed. Therefore, the number of steps the SLO-SYN takes can be counted and controlled to three cycles. A proper selection of SLO-SYN will insure adequate accuracy. Therefore, I propose for position control the following.

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* See J. Curtiss for details of this meeting

a. Maximum travel of 5 in. with ± 5 mil accuracy. Since the SLO-SYN uncertainty will be about three cycles or three steps, this requirement will determine the pitch of the screw as well as the SLO-SYN characteristics.

b. Control the position by specifying the number of steps to be taken by the SLO-SYN. A counter can count the number of cycles of the applied voltage and compare it with the given number. The number of steps can be computed by knowing the current position from the potentiometer reading, and the distance through which the device is to be moved. In other words, the position should be monitored by the potentiometer, but the actual motion should be controlled digitally by the number of steps the SLO-SYN should take.

c. Use the Curtiss type units.

Current Problems

From the first section it must be apparent that the major problem facing the computer control of the AGS beams is a lack of uniformity in methods and devices of control and coordination among those who have been working on various parts and sections of the AGS beams. It seems that each piece of the AGS and its various beams has been, and still is, a separate entity, and each entity performs quite independently of others. Therefore, very few things are compatible with one another.

For example, the LINAC, which is an integral part of the AGS, is controlled separately, and DATACOM I controls the injection line. Also, why is it that the position control units designed by Curtiss have been gathering dust when they could have been very useful in checking the new FEB, had they been installed when they were made (Curtiss was put on some other assignment before he could install them)? Why is it that there seems to be very little communication between the 80-in beam and the other beams? Why is it that nobody but the authors seemed to know about the existence of the write-ups about the position control devices? I can go on citing many such examples.

These problems are the problems of communication and organization. The results of these problems of course are technical complications. In the next section I'll try to present some possible future alternatives by which the computer control of the AGS might be accomplished, and some of the features that the control systems should have.

Features of a New Control System

First let us assume that the world is perfect, and that we can get what we want. Then a possible system should have the following features.

1. It should be standardized so that the same communication links, some programming structure, same device controls and circuits can be used as much as possible. I'll say more about the philosophy of standardization later.

2. All AGS operations should be covered. This includes the LINAC, beams and even bubble chambers.

3. As far as the beams are concerned, those sections which are more or less permanent, such as the SEB and FEB, should be controlled by AGS staff, but information on these beams such as the collimator positions, magnet positions, and currents, etc. should be available to the experimenters on the floor. This can be accomplished by means of CRT displays upon request by the experimenters. These data are often very useful to them in logging their experimental conditions.

The user oriented beams such as the 80-in bubble chamber beam and any other which the experimenters "tune", should also be equipped with computer control. A sometime tedious process of tuning a beam can be minimized, if for example tuning curves of the counting rate versus the magnet setting can be obtained on a CRT display.

Even though bubble chambers are not really part of the beam operation, I would like to suggest that they too be equipped in such a way that their operating condition such as the magnetic field, chamber temperature and pressure, expansion stroke, etc. can be at least monitored, if not controlled. Again, these data are very useful to the experimenters in controlling the picture quality, etc.

Experimenters often bring their own computers for on-line experiments, and may wish to incorporate their computer into the AGS communication link system. For example, they may want to log in one of the magnet currents or some such beam data in their output magnetic data tape. If the experimenters are willing to make necessary interfaces, they should be able to hook into the AGS system.

4. For each major entity such as the LINAC, SEB, etc. a mini computer (such as PDP-11) should be assigned to handle it, and these mini computers are then hooked to a large computer such as PDP-10 for overall operation.

5. With arrangments such as indicated above, there is a danger of the large computer going bad and of not being able to run the AGS at all. The question is how much manual backup there should be. Some people I talked to felt that the manual backup was more a psychological crutch since once people get used to the computer control they wouldn't be able to face the manual control, and rather than resorting to manual control they would make every effort to fix the computer. This may be so, but I would want to see a complete manual backup through the communication links. The "off-computer" mode should be available for each device control so that any given device may be controlled manually at any given time. This is a desirable feature in preventing a possible "run-away" situation-- a situation when the computer is beyond your control (this has happened). Therefore, the links that connect the devices and computers should serve also as manual command links. If only the large computer is down, probably the mini-computers can still do some of the controls.

6. The next question is what should be monitored and/or controlled. I think the answer is, that everything that moves, is varied or whose value provides useful knowledge for proper operation of experiments. Also for the AGS operation, the operation of the SEB and FEB, and others such as bubble chambers, scope traces of beam spills, pressures, etc. are of paramount importance. There is no other way to monitor these signals but visually, and the new system should be able to display a number of such traces on a CRT with labels. These CRT display units should be equipped with hard copiers so that hard copies of the displays can be obtained. This will save a lot of time wasted in taking polaroid pictures of a number of oscilliscope traces.

7. I am not sure how the timing pulses are to be generated. In gating and/or triggering scalers and other devices it has been customary to use predets and digital delays for manual control. These devices can be computer controlled, or the computer can generate timing pulses. I tend to

favor the former, since these timing devices are needed for the backup systems anyway.

8. Some devices in the SEB and other beams need to be interlocked with the AGS safety system so that no one can accidentally walk into the switch yard area when the beam is extracted for example. This interlock can be accomplished by hardwires alone, but it will be good to have it via the computer also.

9. Many devices should have a record of what the computer has been doing over a certain time period. For example, take a DC separator. When it sparks off, the computer control should restore the DC voltage back. It may spark off a number of times, in which case a close look at the separator is needed, and the number of times the separator sparked off in a given period will be a very good diagnostic clue.

10. Finally we must consider what sort of software capability the system should have. The ideal situation will be to have the computer do everything. Tune the LINAC, AGS, all the beams, etc. all automatically. In reality, however, this will be a nearly impossible task. But I think at least for various beams, the operators or users should be able to tune the beam fairly automatically. For example, I'd like to see a single instruction specifying the magnet to be tuned, initial and final shunt values, step size, the scaler to be read, and scaler to normalize, and the normalizing counts. With this instruction a tuning curve can be produced on a CRT. A similar instruction for beam profile counters is necessary, and it actually exists for the 80-in bubble chamber beam.

I have sketched some main features of a possible new system. I think such a system should be designed in detail, at least in those common areas for all elements of the AGS, so that any future additions to the currently existing systems will be compatible with the new and standard system. I have received some comments which are not favorable to having a standard system, and making others to conform to this system. The major reason given is that such a system will retard progress since it will not permit people to experiment with new and better devices and ideas. I have no objection to people trying out new devices and ideas outside the system. As a matter of fact, there should be continued research to improve the computer control system. But progress for its own sake, is a dangerous concept as far as the AGS control is concerned. If it is working satisfactorily under a standardized system, then there seems to be no reason to destroy the uniformity of the system just because someone has a new, and perhaps more modern, way to control a particular beam which is not compatible with the standardized system. No doubt, whatever system is designed, it will have a finite life-time and will be replaced by another. There will be time enough for experimentation, and I do not feel that having a standard system will retard progress in any way.

There are very few alternatives in implementing computer control of the AGS beams. The neatest way is to scrap everyting, and install the new system in one go, but this is clearly impossible. Leaving the system the way it is, and connecting computers to various incompatible systems of control is undesirable.

The only practical way to improve the current situation is to insist on using DATACOM II as the communication link for all future installations, and scrap DATACOM I and other links as soon as possible, as it is clearly unwise to have many incompatible communication links. The position control units of Curtiss design are supposed to be installed in the new FEB. Even though the future position control units may be different from these (the current units employ many relays which may be replaced by solid state devices for example), they should be interfaced to be controlled via DATACOM II.

Whatever manual controls the SEB and FEB now have may not be easily interfaced to be computer controlled via DATACOM II, and they should be replaced by the new system as soon as practical.

The 80-in bubble chamber beam is the most advanced beam in terms of computer control, but it is totally independent of DATACOM II. Any addition to the current system should be DATACOM II compatible. The magnet monitor system being built is fine for monitoring the shunt voltages, but I don't think that it can remote control the magnet currents easily. If any plan is made to control the RF separator, a close liaison with the LINAC system seems desirable.

<u>Organizational Problems and Possible Reorganization</u>

I've stated before that many of the current problems and obstacles in developing a uniform computer control system of the AGS are due to the organizational structure and subsequent personnel problems. I don't even feel that the manpower shortage in this area is the major cause (it is true that having more digitally oriented engineers is very desirable). The major problem is a lack of coordination and communication among the various separate entities.

For example, I do not see why the 80-in bubble chamber beam, the SEB and FEB must function separately doing their own things as far as the controls are concerned. It seems wasteful to me to have two separate sets of DATACOM cables in E10 and H10 houses to control two beams separately. In order to avoid such a thing, the people involved in the SEB and FEB should work together. The same goes with the 80-in bubble chamber beam. This can be achieved by having cross-unit coordinators to see to it that people know what others are doing, and to minimize duplication of effort and manpower.

I'd also like to see better coordination among the designers of devices, their users, and maintenance people. There should be a lot of input from those who actually tune the beam or the LINAC; for example, to those who design the system and devices to control them. Those who maintain these devices and even the software should be familiar with the things they maintain before they take over the maintenance. For example, if EAO people are to maintain the position control units, then they should be in on the installation and testing of the units so as to avoid waste in the future.

I've given a very sketchy description of reorganization as I'm not familiar enough with the details of the current organizational situation. The essence of what I wish to recommend, is the strengthening of horizontal links connected with some vertical lines in the organizational chart rather than many parallel vertical lines which do not seem to cross paths.

I wish to thank the cooperation and assistance of many of the people in the Accelerator Department during my stay in the Department.

cc. Admin.
Electrical Engineers
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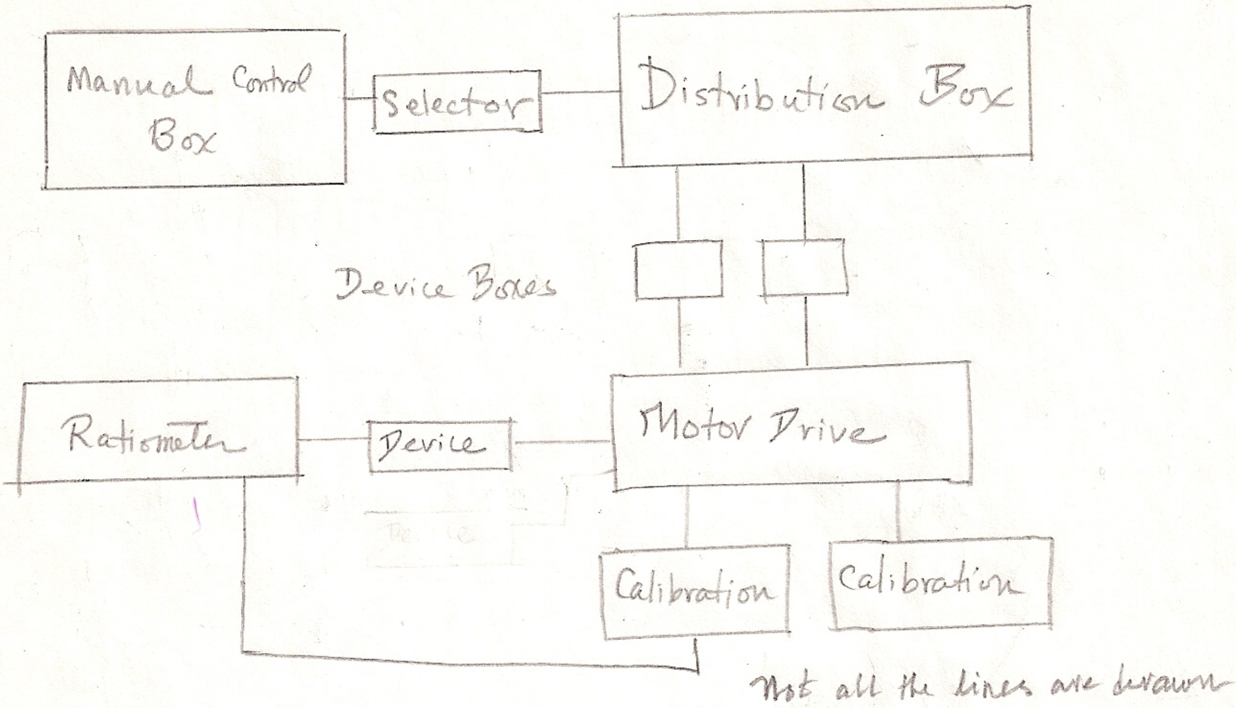
Manual Control Box
Selector
Distribution Box
Device Boxes
Ratiometer
Device
Motor Drive
Calibration
Calibration
Not all the lines are drawn

FIG. 1

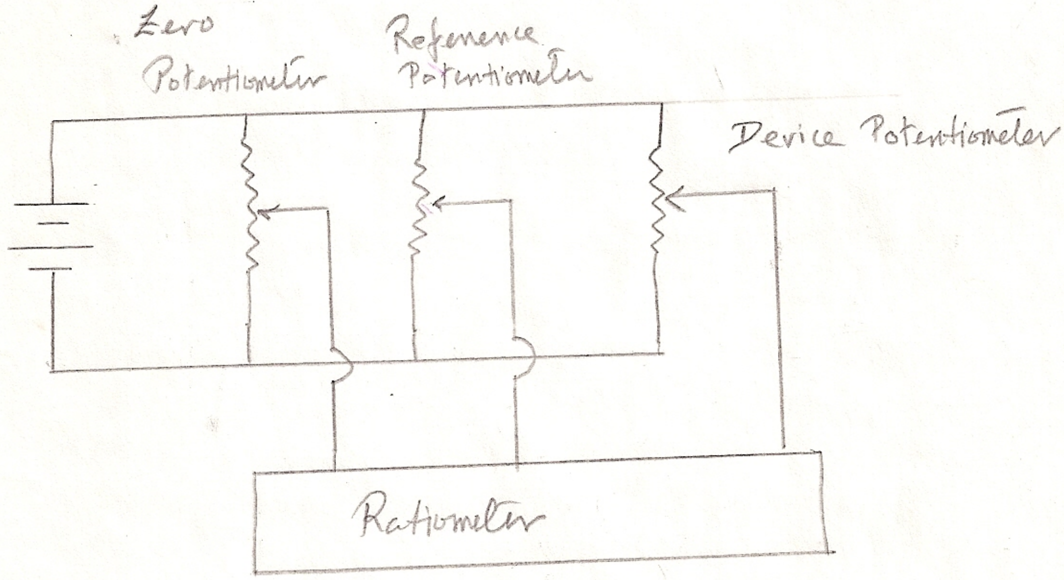
Zero Potentiometer
Reference Potentiometer
Device Potentiometer
Ratiometer

FIG. 2