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# Instrumentation and Control Equipment for Project M

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Some rather rough ideas will be laid down with a view to have a basis for further discussion. It is supposed that the accelerator will have 40 sections, nominally 250 ft. long each, and each such section will be driven by 6 klystrons, although these figures have only relative importance. The accelerator will be controlled: (1) As a whole from the main operation room. (2) Sectionwise in the klystron tunnel.

1) Control and Monitoring of the Accelerator -- as a whole will be performed from the main operation room under the direction of a Chief Operator and his 1 to 2 aides. The Chief Operator will have the overall supervision of the machine. The means of control and metering at his disposal will be the following:

a) A lighted board indicator, if any.

b) An automatic protection system.

c) Exclusive metering and control means of some of the main functions of the machine.

d) A complete control and metering setup for one 250 ft. section of the accelerator.

e) A digital telemetering system.

f) Control and metering means of the a.c. and d.c. power system.

The general outlay of the main control room is indicated in Fig. 1

2) Details

a) The lighted board represents the general outlay of the machine, klystron by klystron, sector by sector. It supplies visual indications by means of colored lights, or other more functional means, of the general performance of the various main components. Fig. 2 gives an idea of what such a board could be. The control board could be operated manually or automatically or in a mixed way. It is also possible to operate the board as a multi-input coincidence gate. This means that if any of the lights of a column relative to a sector, or part of it, is red (meaning abnormal operating conditions), the column is inhibited and that part of the machine is shut off or at least a warning signal is actuated. The lighted board in its above mentioned elementary form is not enough functional. It indicates extreme conditions, but not more than that. Another visual means of indication could be the following.

A D'Arsonval type instrument is used for the indication of each parameter of interest. Instead of being used as normally, with a graduated scale in front of the observer, it is placed with its side toward the onlooker, as in Fig. 3. Only the pointer can be seen. This pointer, although light, has a broad side, say 0.5" or more, and in the zero position it is vertical with its axis in the upper part of the case. Behind this broad pointer there is a uniform light source and this light is intercepted by the pointer in its zero position. If current passes through the moving coil, the light is uncovered and is maximum after a 90° deviation of the pointer. Although the cosine law, according to which light appears, is not an asset, there are several advantages in such a system.

(1) It gives a continuous monitoring of the parameter measure, like an oscilloscope.

(2) It supplies a visual image of its variations.

(3) It can indicate when the maximum and minimum values of the parameter are approached or reached.

(4) It could supply an electrical warning signal of these extreme conditions by means of auxiliary controls.

(5) It is not expensive, not much more than normal instruments.

Many of these instruments should be placed side by side behind a sanded white glass (on which the max. and min. areas are delineated by colored stripe) so that a continuous indication of each parameter along the whole accelerator could be observed. See Fig. 4. This same type of indication could be obtained by other means, such as a voltage sensitive neon column or a heated mercury or colored alcohol column, intercepting light coming from the background. These last two would be particularly suited as power indicators, being the column height proportional to $I^2$.

(b) Automatic protection can be obtained by means of a relay system linked to the vital points of the machine (gun, a.c. power, vacuum, interlocks, target radiation, etc).

(c) Beside the overall control board, the main control room will contain all the control and monitoring means of the gun, the oscillator chain, the first 4 - 5 drivers and power klystrons, their phasing, the target, the fire detecting equipment and possibly some others. These will be operated only by the Chief Operator, with the exception of the target area. Control over this can be taken over by the experimenters.

(d) One complete control desk, such as used for a 250 ft. section, will be located in the main control room. Its operation will be described later.

(e) The main control room will contain a digital voltmeter with the associated readout and a high speed printer. The printer, through the multi-channel input digital voltmeter, will supply a continuous record of the over-all operation of the machine. This will enable the personnel to locate possible sources of future trouble and in the same time this record will be the operational logbook of the accelerator. As to the readout, details as to the type to be used will be given later.

(f) The Chief Operator will have partial control of the a.c. power system, (possibly through one of his aides sitting in the main operating room before a separate control desk), The HV load centers will be operated from the same room by the same operator.

2) Control and Monitoring of Single Sections.

This will be accomplished by section operators. Being the number of klystrons only 6 in every 250 ft. section, i.e. only about 1/4 of the number employed along the same nominal length of Mark III, with improved means of control and monitoring it seems possible that one operator will be able to take appropriate care of 4 sections of 250 ft. each. In his operating space there will be somewhat less monitoring instruments than at present in the case of Mark III, both because the section operator will have no control of the injection gun and the driver system and because, whenever possible, manual multiplexing will be employed, i.e., one instrument will be used for more components of the same type. For example, one meter could be used for 6 klystron average current measurements. Still better, a visual display system could prove rather helpful, like the lighted board described under 1(e). Other possible means for multiple monitoring may be a digital voltmeter and its readout. This seems, if not the least expensive, but certainly the most reliable. A visual and/or an audio readout may be used, the latter being extremely versatile. By its nature, metering with an audio readout can be superimposed on the simultaneous visual reading of other instruments. In other words, the ears of the operator, which are normaly very little engaged, can be utilized for metering purposes. This reduces eye fatigue and thereupon increases the reliability of the operator.

The section operator will be in continuous communication with the Chief Operator through a P.A. system. Whenever he finds it necessary, he will be able to call him. A buzzer or a light will indicate that the section operator wants to communicate with the Chief Operator, and the latter, if not elsewhere engaged, will give him the line. In case of emergency, the section operator will be able to communicate with the Chief Operator either through a separate emergency communication system or by cutting off any other communication or by operating an emergency light or buzzer, instead of the normal call light. If the operation of the sections under the control of the section operator is such that he does not feel able to get along, the Chief Operator can take over the whole control and metering function of that section by means of the control desk mentioned in 1(d). This duplicate of a normal section control desk can be connected to any section of the accelerator or, in other words, the control and monitoring functions of any control and monitoring desk existing in the klystron tunnel can be transferred instantaneously to it through a bus and relay system. The buses extend along every single section and every section has its transfer relay panel. Fig. 5 represents schematically part of this transfer system.

This may seem a rather expensive system owing to the many buses, but it must be remembered that the section bus system is nothing else but the wiring going anyway toward the section control desk. Only the control bus system is a feature made on purpose, and, of course, the transfer relays. Virtually, this system gives control to the Chief Operator over the whole length of the accelerator.

The section bus system, besides being used for the two above mentioned purposes, may be employed for an important additional function. If, beside other means, digital voltmeters with audio readout are used for sector monitoring, these same instruments may be employed when tuning up a section or adjusting any part of it must be performed. In such a case the operator must be in continuous voice contact with his control room in order to see how a parameter under control varies. This may be done by telephone or through a P.A. system, but in a much better way and without the assistance of a second

person by using the digital voltmeter and the audio readout device. The operator switches the output of the readout from the control room to speakers in the klystron tunnel. At any point of the tunnel he can hear the results of his adjustment and can switch in, through channeling, any parameter he wishes. This system is schematically represented in Fig. 6. Instead of speakers, r.f. or magnetic paging can be used. This is a still better system because, with a small additional cost, it allows reading out in any point of a limited area. Different sections should use different wavelengths.

Some of the functions could be monitored on a go-non-go basis. For this purpose any type of limiter could be used and a warning light or buzzer, or a readout switched in if the parameter is not within the established limits. Extensive use of such max. - min. devices would greatly reduce the need of single instruments, while its cost would be rather negligible (2 diodes or 2 transistors for each go-non-go function and a common low voltage source for many of them.

It has been explained before that the Chief Operator can take over the complete control and monitoring of any sector or part of it. Sometimes this may not be necessary, but it could prove sufficient to connect his own digital voltmeter telemetering system to the parameter under investigation and give instructions to the sector operator. This latter, again through his sector's digital telemetering system, can follow the changes of that parameter. The audio readout used in connection with the digital telemetering system can be employed as a warning device too. Extreme operating conditions could be detected by any means, through the digital instrument itself or through separate transducers, and activate the audio readout which is much more effective than a warning light or a buzzer. Both the Chief Operator and the section operators could use a programmer. A small lighted board and a latched relay system could prevent the switching on of the different parts of the machine in an improper succession.

A public address system has been mentioned before as a means of communication. R.F. or carrier frequency or magnetic paging systems and telephone lines could complete the communication network. Closed circuit T.V. could

be used especially for monitoring the target area.

3) Proposals

In order to test the effectiveness of the proposed control and meter-systems, the construction and purchase of the necessary means seems advisable. They should be installed in a room adjacent to Mark IV and used in connection with it. The equipment to be built or bought is the following:

(1) a digital voltmeter, price range: $835 to 1250
(2) an audio readout, built here or bought
(3) a control board, built here
(4) a control desk, built here

In the same way as Mark IV is used for testing new parts, the proposed control setup could be employed as a test bench of new and gradually improved means of control and metering.