OPERATION AND CONTROL OF A
RADIOFREQUENCY ION SOURCE

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OPERATION AND CONTROL OF A
RADIOFREQUENCY ION SOURCE

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CHAPTER I

INTRODUCTION

Historical Development

The importance of accelerated deuterons and protons as tools in nuclear research prompted the initiation at North Texas State College of a project to construct a machine to produce such high energy particles. In its original design the unit was to consist of a radiofrequency ion source feeding a specially designed accelerator. The high voltage for the accelerator was to be supplied from a 100 kilovolt Cockroft-Walton voltage doubler power supply. These units, together with their associated electrical and mechanical circuitry, were put into operation for the initial test run in 1951. Unfortunately, during the initial test run the high voltage accelerator supply arced over through the vacuum system and destroyed the diffusion pump heater. Before a new heater could be obtained, the special accelerator tube was broken. As an ultimate result, the original ion source

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3Ibid., p. 35.
was rendered useless through corrosion from exposure to atmospheric moisture. During the research for this paper several other facts, which are to be discussed later, were noticed. These led, finally, to the decision to rebuild the entire unit incorporating in addition several of the refinements suggested by Windham. Since the special accelerator tube had been destroyed, a new one was designed in the more conventional cascade form. The design of the ion source was modified slightly; a palladium leak was developed; and the research and construction for this paper were thus started.

Basic Problems

Due to the fact that operation and control data on the ion gun and its associated equipment were needed before these units could be installed on an accelerator, and since the construction of such an accelerator was a major project in itself, the projects described in this paper were initiated. Basically there are two major categories into which the projects may be divided. First of all, the constructional problems must be solved. A test bench from which the aforesaid data might be taken was tentatively designed, and the primary problems were noted as follows:

(1) The electrical isolation from ground of the ion source together with its extracting and focusing supply.

(2) The electrical isolation of the radiofrequency exciter from the high potential at which the ion gun operates.

Ibid., pp. 34-36.
(3) The construction of a palladium leak for the metered admission of hydrogen or deuterium to the ionization chamber.

(4) The insulation from ground of the palladium leak, together with its heater current source.

(5) The design and construction of a power distribution system for the entire test bench.

(6) The redesign and construction of the ion source.

(7) Design and construction of a test accelerator.

(8) Installation of a target assembly and its associated beam metering circuits.

These problems and their solutions are discussed in Chapter II of this paper.

Due to the very high operating voltages existing on and around the ion source, the second project consisted of setting up and checking operating procedures for the protection of the equipment itself and for the safety of the operating personnel. This problem is taken up in Chapter III, and the operating procedure is outlined.
CHAPTER II

CONSTRUCTIONAL PROBLEMS

Redesign and Construction of a New Source

Design considerations.—During operational checks on the ion source as designed and built by Hannah, several facts were noted which indicated that a new ionization chamber and ion gun were needed. As noted in Chapter I of this paper, the unit had become rusted during an extended period of exposure to atmospheric moisture. Since much of the rust was on the interior surfaces which were to be exposed to extremely high vacuum, trouble was immediately encountered. Such rust spots contain many pores and expose a considerable surface area upon which much gas and vapor may be occluded. Because of this quality, a minute amount of rust will prevent the system from attaining high vacuum for a long period of pumping time since the occluded gases are given off very slowly and may never be entirely removed without baking the system at a high temperature. A second point that was noted was the fact that some of the lens dimensions of the ion gun were not precisely those developed by Bayly and Ward.


whose design was to be followed. In addition, it was thought that enlarged electrode plates should be tried in order to shield more completely the electrodes from the radiofrequency excitation which would be near them. For these reasons the ion source was redesigned as shown in Figure 1.

**Constructional detail.**—Figure 1 shows the detail of the new ion source. All the metal parts were machined from aluminum stock, and the glass insulator-spacers were cut from a 1000 ml. Pyrex graduated cylinder. For mechanical strength and to facilitate alignment, the gussets shown in Figure 1 were put in. These gussets, being out of the important field region, do not affect the operating characteristics. Plate 3 was designed larger than the other two since it was to be the seat for the O-ring vacuum seal and was to have mounting bolt holes for attaching the source to the accelerator. The mounting holes were enlarged to facilitate alignment of the source axis with the accelerator axis. The unit was assembled on a mandrel to insure internal alignment, and the vacuum seals were made with Apiezon W. The gas inlet was made through the top of Plate 1 rather than through the edge since the plate diameter was greater than that of the same plate in the original design.

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Fig. 1 — Detail of new source
Principles of Operation and Construction of the Test Accelerator

The test accelerator and target assembly, the detail of which is shown in Figure 2, was designed and built to operate at a maximum accelerating potential of twenty-five kilovolts. This voltage was the potential drop of the first accelerating gap of the high voltage accelerator into which the ion source was designed to work. The target electrode was a modified Faraday cage\(^5\) designed to suppress secondary electron emission. The small quartz plate was installed in order to allow visual observation of the beam as it strikes the target. Vacuum pump and vacuum gauge connections were made through the target electrode mounting plate. The groove for the O-ring vacuum seal in the mounting flange was designed for an AN6227-36 O-ring. Apiezon W was used for all other vacuum seals.

Detail of the Palladium Leak Assembly

The palladium leak assembly shown in Figures 3 and 4 was built to serve as a variable metering lead and gas storage chamber. When heated metallic palladium separates two regions of different hydrogen pressure, the hydrogen will diffuse through the metal from the higher pressure region to the lower pressure region at a rate proportional to the

Fig 2 -- Detail of test bench accelerator and target assembly.
Fig. 3.—Detail of palladium leak assembly
1. Inlet for palladium leak to ion source.
2. Palladium leak assembly.
4. Six volt storage battery.
5. Insulated lead to Kovar seal.
7. Ion source assembly.
8. Extraction voltage lead, 1/4 ID copper tube, 1500 volts.
9. Leak connection to source, 1/8 ID copper tube.
10. Extracting and focusing supply assembly.

Fig. 4.—Circuitry for palladium leak heater
temperature of the metal. In this case just such a system was set up. A palladium tube, Item 6, Figure 3, closed at its inner end with a brass plug, was inserted into the storage chamber, Item 2, Figure 3. A helical nichrome heater wire, Item 1, Figure 3, was installed around the palladium tube. This coil gains both mechanical support and electrical continuity through one of its leads which is silver soldered to the mounting plug, Item 3, Figure 3, of the palladium tube. Both the end plug and the mounting plug were silver soldered to the palladium tube. The storage chamber itself consisted of a copper cylinder closed on both ends with aluminum cover plates, Item 4, Figure 3. Through these cover plates, fittings were placed for a gas inlet and a pressure gauge. The palladium tube mounting plug was also seated in one end plate. A small Kovar-glass terminal, Item 5, Figure 3, was placed in the wall of the copper cylinder to provide a mounting point and an insulated electrical contact for the other end of the nichrome coil. Power for this heater was fed from a six volt battery, Item 4, Figure 4. As shown in Figure 4, one lead of this battery was the extraction voltage lead itself; the other lead, Item 5, Figure 4, was an insulated wire supported on this high voltage lead. The battery, the current controlling rheostat, Item 3, Figure 4, and an ammeter, Item 6, Figure 4, were mounted on the extraction supply support.

6John Strong, Procedures in Experimental Physics, p. 543.  
7Hoag, op. cit., p. 395.
Modification and Isolation of the Exciter.

Modification.--The radiofrequency exciter used to produce ionization of the hydrogen or deuterium in the ionization chamber was originally built by Hannah and was subsequently modified by Windham. In order to use this unit in the test bench operation of the new source, several additional modifications were necessary. The front panel of the exciter was moved to the rear of that chassis, and the minor changes of circuitry thus made necessary were completed. Since the final amplifier was not well balanced, four parasitic oscillation suppressors were installed, and the final amplifier plate lead was rearranged to give a better geometric balance. In addition to these changes, two neutralizing condensers were installed. Figure 5 is a corrected copy of the exciter circuit diagram. The parasitic suppressors have been designated $R_{16}$, $R_{17}$, $R_{18}$, $R_{19}$, $L_{6}$, and $L_{9}$; the neutralizing condensers have been designated as $C_{17}$ and $C_{18}$.

Isolation.--In order to operate this exciter at ground potential and yet prevent shorting the high voltage supply, a link coupling system, Figure 5, $L_{4}$ and $L_{5}$, was developed; and a twenty-seven megacycle per second tank circuit, Figure 5, $L_{6}$ and $C_{19}$, was built around the ionization chamber. The air

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8Hannah, op. cit., pp. 5-8.
10Ibid., p. 32. 11Hannah, op. cit., Figure 2, p. 15.
LIST OF COMPONENTS FOR FIGURE 5

R1, R5 .......................... 50,000 ohm, 1 watt, carbon
R2 .................................. 400 ohm, 1 watt, carbon
R3 .................................. 68,000 ohm, 1 watt, carbon
R4 .................................. 20,000 ohm, 10 watt, w.w.
R6 .................................. 400 ohm, 5 watt, w.w.
R7 .................................. 92 ohm, 1 watt, carbon
R8 .................................. 51,000 ohm, 2 watt, w.w.
R9, R10 ......................... 20,000 ohm, 2 watt, w.w.
R11 .................................. 25,000 ohm, 5 watt, w.w.
R12 .................................. 2000 ohm, 25 watt, w.w.
R13 .................................. 5000 ohm, 25 watt, w.w.
R14 .................................. 6200 ohm, 100 watt, w.w.
R15 .................................. 250 ohm, 20 watt, w.w.
R16, R17 .......................... 1500 ohm, 10 watt, w.w.
R18 .................................. 5 x 10^6 ohm, 1/2 watt, carbon.
R19, R20 .......................... 800 ohm, 2 watt, w.w.
C1 .................................. 0.005 μf mica.
C2, C7, C8 .......................... 0.01 μf, 600 volt, paper.
C3, C4, C11, C12, C20, C21 5000 μf mica.
C5 .................................. 100 μf, variable.
C6 .................................. 100 μf, mica.
C9, C13 .............................. 0.002 μf, mica.
C10 .................................. 260 μf per section, variable.
C14 .................................. 100 μf, mica.
C15 .................................. 0.001 μf, 5000 volt, mica
C16, C17 .......................... 6-12 μf, neutralizing.
C18, C19 .......................... 2-15 μf, neutralizing.
L1 .................................. 5 turns, #22 d.c.c., wound on
L2 .................................. 4 turns, 1/8 in. copper tubing,
L3 .................................. 4/2 turns, 1/8 in. dia., spaced to 3/4 in.
L4, L5 ................................ 1 1/2 turns, 1/4 in. dia., spaced to 1 1/2 in.
L6 ................. B & W, TVL10
RFC1, RFC2, RFC3, RFC5, RFC6, RFC8, RFC4 .......................... 2.5 mh. radio frequency.
RFC7 ................................. 4.5 mh., 600 ma., radio-
RFC9, RFC10 ........................ Parasitic choke; 7 turns,
X1 ................................. Crystal
S1 .................................. 4 position rotary switch.
J1, J2, J3 ........................ Metering jacks
gap between \( L_5 \) and \( L_6 \), and \( L_7 \) and \( L_8 \) proved to be sufficient insulation for the twenty kilovolt operating potential.

**Power Distribution and General Assembly**

**Power distribution.**—The circuit for the distribution of primary power for the entire test bench is shown in Figure 6. The system is fairly conventional. The abbreviations used for the wiring color code are shown in the figure. All the switches were of the twenty ampere circuit breaker type, and a fifteen ampere overload cutout, Figure 6, SGL, was installed in the primary lead of the final armature plate transformer of the exciter. A safety spark gap, Figure 6, SGL, was installed across the high voltage blower current meter. This gap consisted of a one inch diameter disc, insulated from the grounded copper backing of the control panel by a single sheet of cigarette paper. If the high voltage power supply should arc over, this gap would break down, shorting out the meter and thus protecting it from overload.

**General assembly.**—Each unit was checked carefully and set in position. The test accelerator was bolted to a bakelite sheet which was supported on two nice posts. The ion source was then bolted to the accelerator flange. A Pirani type vacuum gauge and the vacuum pump were sealed to the bottom of the target assembly with Apiezon W wax. The tank circuit, Figure 5, \( L_6 \) and \( C_{19} \), set on insulators, was installed around the ionization chamber; and the link loop from the exciter was supported on the top of the chamber.
A one-eighth inch inside diameter copper tube was used for the connection between the palladium leak and the ionization chamber. After the electrical connections were made to the ion source from the extracting and focusing supply chassis, the entire unit as shown in Figure 7 was ready for operation.
Fig. 7. -- Ion source test bench
CHAPTER III

OPERATING PROCEDURES

Starting Procedure

In putting a machine of this size into operation, care must be taken to follow particular procedures since the sequence of operations is important to the safety of the unit and of the operating personnel. In a test bench arrangement many of the features, which ordinarily would allow only the proper order of operations, are omitted because of the temporary nature of the bench. It is through the use of such a setup that the necessity for certain safety features may be seen and may be designed into the final product. In the following detailed procedure an effort will be made to give reasons for the sequence stated. Appendix A gives the starting procedure in outline form only for quick reference.

A line drawing of the various operating panels is given in Figure 8 showing the relative position of the controls and designating each with a number. To help locate the controls and thus to clarify the procedure, these numbers will be used in the text. The following is the recommended order of operations for starting the source from a complete shut down.

(1) Start the fore pump and Pirani gauge leaving the gauge set on the millimeter scale to protect it from overload.
Fig. 8.--Line drawing of source units showing locating operating controls
(2) After the Pirani gauge has warmed sufficiently, adjust the calibration control until the voltmeter reads three volts, as marked in red on the dial; this calibrates both of the pressure scales.

(3) When the pressure in the system has fallen to 150 microns, turn on the diffusion pump heater and the cooling water. About 400 ccs. per minute is sufficient to maintain the operating temperature of the pump. The diffusion pump heater Variac should be set at 100 volts; more voltage is unnecessary since no decrease in pressure will be gained.

(4) Check the palladium leak tank pressure gauge, M5, to insure that a sufficient quantity of gas is present for the desired duration of operation. A procedure for filling the tank is given later in this chapter.

(5) When the pressure in the accelerator and ion source system falls to twenty microns, turn on the exciter filament power switch, S5.

(6) Complete the palladium leak heater circuit; and using the rheostat control reel C3, set the current at 1.5 amperes as indicated on the heater current meter, M4. Twenty minutes are required for the temperature of the leak tank to come to equilibrium and thus for the leak rate to become stable. As discussed in Chapter IV, a heater current of 1.5 amperes corresponds to a leak rate of about fifteen ccs. per hour. If a higher or lower rate is desired, adjustment may be made after the unit is in full operation.
(7) When the leak rate becomes stable, turn on the oscillator-driver plate voltage, S6. It is now necessary to tune the oscillator and driver circuits. To do this, adjust oscillator control, C4, to obtain a maximum voltage at jack J1; and adjust driver control, C5, for maximum at J2. After these controls have been set, turn on the final plate voltage, S3; and adjust plate tuning control, C7, for maximum voltage at J3. Final loading is accomplished by setting condenser C8 for maximum brightness of the ionization chamber and by readjusting C4, C5, and C6. A well insulated screw driver must be used to operate C8. This chamber should now appear deep red; if a small leak is present in the system, the color will be a white or pale pink.¹

(8) The extracting and focusing supply may now be turned on by closing the knife switch S7. To check the operation of this unit, observe the vibrator output voltage, M7. If this reading is less than 125 volts, charge the twelve volt battery system before proceeding further.

(9) On the control panel turn on S1 to apply power to the rectifier filament Variac, VR1. Slowly turn the Variac control clockwise until meter M1 indicates forty volts; wait ten seconds; then advance control to its limit. M1 should now show about eighty volts.

(10) Switch S2 controls the input to the Variac, VR2, on the primary of the high voltage transformer. Turn this switch on, and slowly advance VR2 clockwise to the desired accelerator voltage. The reading of this meter, multiplied by $2 \times 10^5$, gives the output voltage of the accelerator supply.

(11) Advance reel C2 clockwise until voltmeter M8 indicates desired extracting voltage. Reel C1 controls the focusing voltage as read from voltmeter M9. Since the target current, M10, is controlled primarily by these two potentials, optimum voltages should be used to obtain the desired current. Discussion of these voltages is given in Chapter IV.

Operational Maintenance

Over an extended period of operation certain units need routine maintenance aside from the periodic adjustments necessary to retain the desired beam characteristics. This maintenance falls into two categories. Into the first category fall those things which limit the length of actual operating time; the second includes those things which may be put on a weekly or monthly schedule. The major items to be noted in the latter category are as follows:

(1) The oiling of all pump motors as indicated on the name plates.

(2) Checks to insure proper operation of the safety circuits and devices.

(3) Cleaning of high voltage insulators and all exposed parts which operate at high potentials.
At present, maintenance under the first category includes two items. The leak tank requires periodic filling. To perform this operation, pump out the glass lines leading to the storage chamber. If no leaks are present as witnessed by the sound of the pump, heat and open the stopcock leading to the chamber, and again wait until the system is pumped down. Turn off the pump and open valve of the supply tank. Allow the gas pressure to rise about twenty inches of mercury; close the stopcock; and pump the remaining gas from the leads.

Since the extracting and focusing supply and the palladium leak heater are both operated from storage batteries, periodic shutdown is necessary to charge these batteries. Operating conditions will determine how often this must be done. Charging rates are given on the batteries and charger.

Partial Shutdown Procedure

To shut off the ion accelerator for short periods, such as for maintenance or over night, repeat steps 7 through 11 in the starting procedure in reverse order. Caution should be exercised under step 9; be certain that the condensers of the high voltage supply have time to discharge before operating extracting supply power switch, S7. As a safety precaution, operate the high voltage shorting bar by opening the screen cage door. An outline of this procedure is given in Figure 12, Appendix B.
Emergency Shutdown Procedure

In case of power failure on fore pump line or for other emergency purposes, return high voltage Variac, VR2, to its counterclockwise limit, and turn off high voltage primary switch, S2. Turn off diffusion pump heater, and increase cooling water flow rate. At this point, either find out and repair trouble, or carry out short period shutdown procedure.
CHAPTER IV

RESULTS AND SUGGESTIONS FOR FURTHER STUDY

Ion Current

The utility of an ion source depends upon its capability to produce a required predetermined ion current. To this end operating characteristics were examined through a series of tests. Since the geometry of the particular accelerator with which the source was used would modify the characteristics, perhaps considerably, only a survey test was carried out. With the focusing voltage held constant, target current was measured for various extracting potentials, and this procedure was repeated for eleven values of focusing voltages between zero and 5000 volts. A graph showing the beam current as a function of focusing voltage is given in Figure 9. Visual observation at the quartz target showed that the peak current occurring at 1000 volts focusing potential represented a well focused beam. Above this voltage the beam became defocused as evidenced by a more diffuse fluorescence of the quartz. The increase in target current in this higher voltage region was due to a reduced bombardment of the accelerator elements. This peak, which represents the best focus, should migrate to higher
Fig. 9.—Ion source characteristics. Beam current plotted against focusing voltage for various extracting potentials.
potentials when the source is used with higher accelerating voltages.\textsuperscript{1, 2} Since the test accelerator was not stable at such higher voltages due to arcing, no data were taken to check this point.

When the source was operated at optimum focus, the target current was found to increase steadily with increasing hydrogen pressure until arc-discharge occurred. A palladium leak heater current of 1.5 amperes allowed the most stable operation. Under conditions of higher leak rate, beam currents as high as 200 microamperes were observed, and stable conditions might have been realized if the evacuating channel from the target assembly had been of a larger diameter. The pumping rate was seriously limited by this channel, and consequently the pressure in the accelerator was too high.

The operation of the exciter was entirely satisfactory, and little or no variation of beam current with excitation was observed as long as the gas in the chamber was ionized.

Palladium Leak

Flow rates were measured for the palladium leak assembly, and the results, plotted against heater current, are shown in Figure 10. As may be seen in this curve, the rate


\textsuperscript{2}C.D. Moak, H. Reese, Jr., and W.M. Good, "Design and Operation of a Radio-Frequency Ion Source for Particle Accelerators," \textit{Nucleonics}, IX (September, 1951), 20.
of diffusion approached saturation at a heater current of two amperes. The storage tank had a volume of approximately one liter; and, if initially filled to a pressure of twenty-five inches of mercury, it could supply hydrogen at a rate of fifteen cc. per hour for about twenty hours.

Suggestions

As discussed previously, the test bench upon which the new ion source was operated did not duplicate favorably the geometry of the accelerator for which the source was designed. Therefore the operating voltage characteristics as shown in Figure 9 will hold for the operation with the accelerator as to the form of the curve only and not with regard to the particular voltages and currents. These curves should be plotted again for each different geometrical arrangement and should be extended to include higher accelerating voltages.

The tank coil which was mounted around the ionization chamber was spaced to cover about four inches, and its physical position was never adjusted. A considerable increase in ion current might be realized if careful adjustments were made of both the length of the coil and its position with respect to the top of the extraction probes. These adjustments are independent of the accelerator geometry and, therefore, may be accomplished on the test bench.

The radiofrequency ion source is in complete operation, and although the beam current is somewhat low at present,
much higher currents may be realized when the source is completely adjusted and in operation on the final accelerator.
APPENDIX A

OUTLINE OF STARTING PROCEDURE

(1) Start forepump and Pirani gauge.

(2) Calibrate Pirani gauge.

(3) Turn on diffusion pump heater and cooling water.

(4) Check quantity of gas present in leak tank.

(5) Turn on exciter filaments.

(6) Turn on palladium leak current and set current at 1.5 amperes.

(7) Apply voltage to oscillator-driver plate circuit. Tune circuit. Turn on final plate voltage, and tune entire exciter circuit using insulated screwdriver on output tanks.

(8) Turn on extracting and focusing supply.

(9) Apply power to rectifier filaments slowly.

(10) Apply power to high voltage transformer, and set at desired accelerator voltage.

(11) Set extracting and focusing voltages for desired beam current.
APPENDIX B

OUTLINE OF PARTIAL SHUTDOWN PROCEDURE

(1) Return extracting and focusing voltages to zero.

(2) Return high voltage Variac to zero, and turn off power.

(3) Return filament Variac to zero, and turn off power.

(4) Allow high voltage condensers to discharge; open screen room door; and turn off extracting supply.

(5) Turn off exciter final voltage; then turn off oscillator-driver plate voltage.
BIBLIOGRAPHY


Chadwick, J., Nature, CXXIX (February, 1932), 51.


