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FACILITIES IMPROVEMENTS AND
ACTIVITY PROBLEMS ON THE 184" CYCLOTRON

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ABSTRACT

The new addition to the building, the new medical and physics caves, and improved equipment associated with the external beams are described. Some problems in working with an active machine are discussed.

Construction on the 184-inch Cyclotron was started in 1940, twenty-four years ago. Since that time the machine has undergone four distinct reincarnations. It is indeed remarkable that such a venerable antique is still considered worth improving!

Within the past few years the experimental facilities associated with the machine have been extensively enlarged and improved. An addition to the building has doubled the experimental area. A new cave for medical and biological research and a new physics cave have been erected. Various improvements and new items have been added to the equipment associated with the external meson beam and with the external proton-deuteron-alpha beams.

BUILDING ADDITION

The new addition to the building is shown in Figs. 1, 2, and 3. This measures approximately 40 feet by 210 feet, or 8,400 square feet net. This was built at a total cost of $283,000 or a unit cost of $34 per square foot. These are construction costs only and do not include design, inspection, the crane, or the cost involved in moving the mechanical vacuum pumps as required by the building addition.

For the greater part the building is of the usual steel frame construction sheathed with corrugated transite. At the back of the physics cave, however, the wall is of monolithic concrete with a smooth uninterrupted surface on both the inside and the outside. "Gun-ports" are provided in this wall at the level of the beam. With this construction the experimental area can be continued outside the building, the concrete wall providing shielding against which blocks can be neatly stacked.

A 30 ton crane, running along curved tracks conforming to the shape of the building, serves the entire area. This cost $50,000. The existing crane, pivoted at the center of the old part of the building, is still in service. Both cranes may be operated from the floor by pendant controls. In order to move items between the old and new areas an electrically powered truck rolling on rails flush with the floor is provided. When placing a shielding block in the awkward no-man's-land between the areas covered by the two cranes, a special handling device is employed. This consists of a beam with one end suspended from the hook of one crane and the other end suspended from the hook of the other crane. A hook may be moved along the beam by means of an electrically driven lead screw controlled from the floor.

PHYSICS CAVE

Full advantage of the addition to the building has been made with the back of the cave now extending to the new outside building wall. The cave is now almost three times longer in the direction of the beam than it was previously: 62 feet compared to 23 feet. The width remains the same. The side walls are 5 feet thick, the back wall 16 feet, and the roof 4 feet. With the exception of the common wall between the physics cave and the medical cave, all the physics cave shielding is at present of ordinary concrete.

However, new composite shielding blocks of steel and heavy concrete are on order. While the actual thickness will remain as shown in Fig. 1 the equivalent thickness in terms of ordinary concrete will be more than doubled.

Entrance to the cave was formerly through a maze. It will be now through a revolving barrel door. This consists of a steel shell, filled with steel plate and heavy concrete. It is mounted on roller bearings at the top and bottom and is driven by an airmotor. This door is $7\frac{1}{2}$ feet in diameter and weighs 30 tons. This type of door takes up little room and may be readily moved to other locations. It has, however, proven expensive to build.

MEDICAL CAVE

The new cave differs from the old one in that it (1) provides better shielding and (2) provides more space.

The previous medical cave shielding was adequate for alpha bombardment within the cave. The radiation background in the whole building, however, was too high when the full intensity proton beam was used in the medical cave. It is expected that there will be considerable whole-body proton irradiation of animals in connection with a contract with the National Aeronautics and Space Agency (NASA). Furthermore, the increased shielding thickness will now allow people to work in the medical cave in preparation for an experiment while the beam is on in the physics cave. The converse should also be true.

The original cave had a floor area of 17 by $18\frac{1}{2}$ feet. The new cave is 21 by 24 feet. The original walls were 5 feet thick, of ordinary concrete with a density of 150 lbs/ft^3. As indicated in Fig. 1, the new cave

shielding is partly ordinary concrete, partly heavy concrete of 300 lbs/ft^3 density, and partly steel. The north wall now has an equivalent thickness of 10 feet of ordinary concrete, the east wall (or common wall between the medical and physics caves) has an equivalent thickness of 12 feet, the south or back wall has an equivalent thickness of 20 feet, and thewest wall has a thickness of 9 feet. The original roof was 2 feet of ordinary concrete. The new roof is composite steel and ordinary concrete with an equivalent thickness of 8½ feet.

Entrance to the medical cave was formerly through a maze. Again with the thought of better shielding, entrance is now through a door plus maze. This may be seen in Fig. 4. This is a plug door which is moved up and down by a hydraulic cylinder. The door is so constructed that when it is open it is in a pit in the floor and the top of the door serves as the floor of the passageway into the cave. Such a door requires the minimum of floor space but is, of course, fixed in position by the pit in the floor.

The door block is of ordinary concrete, 9 feet thick, 4 feet wide, and 13 feet high. It weighs 34 tons. The cylinder is 8 inches diameter, has a 7 foot stroke, and operates at an oil pressure of 1350 psi. The hydraulic pump system is driven by a 30 hp electric motor which closes the door in about 30 seconds. Opening is simply by gravity, the rate of fall being determined by controlling the flow of oil through a metering valve.

PROTON-DEUTERON-ALPHA BEAM FACILITIES

The duty factor of the external beam has recently been substantially improved by the use of a second dee. This will be discussed at this

conference in a separate paper by Kenneth M. Crowe. The RF system is described in Ref. 4. There has been no change to the regenerative extraction system since it was installed seven years ago. A number of improvements have, however, been made in the external beam equipment.

As the deflected beam emerges from the tank it passes through a recently installed degrader. This is shown in Fig. 5. It consists of a box containing copper plates which may be inserted or removed from the beam path. Any total thickness may be achieved from 1/16 of an inch to 10 inches in increments of 1/16 of an inch. The individual plates are actuated by air cylinders remotely controlled from the control room. This degrader is used only when the beam is directed into the physics cave. Energy changes in the medical cave beam are made by another device to be described later.

The beam next goes through the new collimator shown in Fig. 5. This consists of two pairs of brass blocks 4 inches thick, one pair being movable in the vertical direction and the other pair in the horizontal direction. With each pair, both the width of the slit between the blocks and the position of the slit may be varied remotely from the control room. There has been a collimator in this spot for many years but the previous one did not have remote controls on the slit width.

The beam then goes through a steering magnet which steers it into either the physics cave or the medical cave. A new 8-inch quadrupole doublet replaces the 4-inch quadrupole previously installed in the beam to the physics cave. This increases the beam in the cave by a factor of 2. An existing remotely operated beam plug completes the equipment in the physics beam. The equipment along the beam line to the medical cave is

all new. The following description is taken largely from reference (2).

Referring again to Fig. 1, this new equipment includes – in the following order – a quadrupole, a beam plug, a scattering target, and a collimator. This array is also shown in Fig. 6.

In order to collect more particles and increase the available beam current in the medical cave, the beam tube diameter was increased from 6 to 8 inches. A new quadrupole doublet was designed to accommodate this; no quadrupoles were previously in this line. This change has been found to increase the beam current in the cave by a substantial but unknown factor (i.e., beam measurements are not complete). Available beam currents (internal and external for mesons, protons, deuterons, and alphas) are discussed by K. M. Crowe in the paper previously mentioned.

The beam plug is simply a safety device which cuts off the beam to the cave when the cave is not in use. It consists of a cylinder of steel and heavy concrete with two off-center holes parallel to the axis. The cylinder is remotely rotated by an air cylinder so that the holes may be in or out of the beam.

The beam vacuum tube is terminated in a thin vacuum window just ahead of the scattering target. The scattering target serves two pruposes: it provides (1) a means of controlling beam energy by placing various thicknesses of absorber in the beam path, and (2) a means of producing a diverging scattered beam for whole-body animal irradiation. This will explain one of the needs for a larger cave: space is needed to place the animal far enough away from the target so that it is entirely within the scattered beam cone. The scattering target is in the form of a turret resembling

the magazine of a Colt revolver. This turret is 30 inches in diameter by 42 inches long. It contains four 8 inch diameter holes at 90 degree intervals. Any one of these holes may be rotated into the beam path and various absorber thicknesses may be placed in the holes. The turret is rotated manually from within the cave.

Collimators of various kinds to fit particular experiments may be placed downstream from the scattering target.

MEDICAL CAVE EQUIPMENT

Figure 7 is a view of the inside of the medical cave. The beam enters the cave from the left at (a), (b) is the existing human positioner, (c) is a device for loading the scattering target turret, and (d) is the new animal rotator.

The human positioner shown has been used for many years for the irradiation of the pituitary gland. This is in connection with several diseases including, cancer of the breast, acromegaly, Cushing's disease, and Parkinson's disease. The patient is in a horizontal position with his head intersecting the beam. The bed and the head rest are not shown in this picture. In order to minimize the irradiation of surrounding tissue the bed may be placed at a variety of angles in the horizontal plane. The patient's head is also mechanically oscillated during irradiation.

The patient is viewed by two closed-circuit TV cameras. The TV receivers are located in three places; (1) in the nurse's sentry-box just outside the cave entrance (see Fig. 4), (2) in the main control room, and (3) in the new medical control room (Fig. 8). Facilities in the medical control room – in addition to the TV receivers – include dosimetry, remote controls for the positioner, and "off" control on the Cyclotron.

A new positioner to replace the existing one is currently being designed. Figure 9 is a picture of a model of this new positioner. The new positioner will have the following features. Instead of being designed for irradiation of the head only it is designed so that any part of the body may be irradiated. It will have three degrees of remotely controlled translation and two degrees of remotely controlled rotation. It is designed for a high degree of accuracy and rigidity; reproducibility within 0.010 inch is expected.

The animal rotator (Fig. 7) is for omnidirectional whole-body radiation to simulate conditions in space. The animal is placed in a hollow spherical or dumbbell-shaped shell made of styrofoam. This shell is rotated about a horizontal axis with a speed which may be varied from about 0.5 rpm to about 10 rpm. The shell is also roated about the vertical axis. In order to provide a uniform distribution of radiation it is necessary that this rotation about the vertical axis varies sinusoidally in time. This sinusoidal variation is provided by a Scotch yoke mechanism in the base. The time for one revolution about the vertical axis may be varied from less than 1 minute to about 15 minutes.

MESON BEAM FACILITIES

The meson facility has been in use for some years. Referring again to Fig. 1 this facility consists of: (1) an internal meson target which may be moved both radially and azimuthally, (2) a thin window through which the mesons emerge from the tank, (3) a meson focusing quadrupole, (4) a wheel in the shielding wall with a diametral hole which may be aligned with the meson beam, and (5) the meson cave. Changes have been made to the window and to the quadrupole.

The previous meson window was actually two separate windows in separate ports on the tank. Then it was found that one of the best positions was in between the two ports. Recently the two ports have been made into one large port and one large window has been installed in this. This window is of aluminum 0.025 inch thick, 8 inches wide and 82 inches long.

The meson focusing quadrupole which had been in service for some years had become quite radioactive. In addition it has to be located in an area which has the highest activity of any place within the shielding but outside the main vacuum tank. This is the area which is bombarded by that part of the beam which is only partially deflected and does not actually get through the magnetic channel. Positioning of this quadrupole for the various meson beams, both in translation and rotation, was previously done manually and was one of the biggest sources of radioactive exposure for the crew.

The new quadrupole has a remotely controlled mechanism which permits positioning of the magnet from the control room. This is shown in Figs. 10 and 11. The quadrupole may be translated parallel to the shielding wall both vertically and horizontally and also rotated about a vertical axis. Power is supplied by air motors. In addition to reducing radioactive exposure of the crew, more optimum meson beams can be generated since the quadrupole can be positioned during operation of the Cyclotron.

ACTIVITY PROBLEMS

"Improving a synchrocyclotron" somehow implies a rise in the activity level of the machine. At a conference on improving synchrocyclotrons it is therefore appropriate to say a few words about the present problems encountered in making repairs and alterations to an existing "unimproved" machine.

The 184-inch Cyclotron was rebuilt seven years ago in order to double the energy. At that time essentially all the then active parts were replaced. Since then it has been working steadily on a three-shift basis. The average internal beam current has been 1-2 microamperes. At least 95% of the running time has been with 730 MeV protons.

It is possible for the crew to enter the vault immediately after the beam is turned off to make quick changes or minor repairs. After cooling for a day or less, the radiation level in the cyclotron vault has dropped so that a person can safely spend an 8-hour day in it, provided he stays a few feet away from the one or two most active spots.

Two examples of repairs or alterations to the machine will serve to illustrate what can be done at the present levels of activity and what might be done at higher levels of activity.

Last year part of the dummy dee fell off. This was the result of eddy current force due to the collapse of the magnet field under fault conditions. To make the repairs it was, of course, necessary to enter the tank. The machine was cooled off for three days. However, after the first few hours the reduction in activity is very slow. Two men who had had little recent radioactive exposure were elected to do the work.

They each stayed in the tank for about ten minutes and during this time each received about 200 - 500 mR. If the annual allowable dose is 5 R and if this is spread evenly over the year, then the allowable weekly dose is 100 mR. On this basis they each received a maximum of a five-weeks' dose. It would have been possible for them to have remained in the tank six times longer (one hour) and still not have exceeded a "reportable incident" dose (3 R). At this time the hottest spot that was observed was on the stainless steel ion source tube, which was near the beam exit radius where it received splatter from the regenerator. The activity measured 50 R/hour. The ion source tube was removed during repairs.

Another example is the work which had to be done to change two ports into one port to accommodate the new meson window. As noted before, this is in the hottest spot inside the shielding but outside the tank. The work involved several days' effort in burning and welding in the active steel. In this case the work was done three weeks after the machine was shut down. A four-inch thick wall of lead bricks was stacked inside the tank to protect the workmen from the activity inside the tank. This reduced the activity in the working area by a factor of two. Each of seven welders worked eight - ten hours in the area. The maximum dose was 270 mR, the average dose was 140 mR. If one man had done all the work, he would have received about 1 R, still well within an acceptable limit.

It was considered advisable to prevent (1) the inhalation of the active iron vapor by the welders and (2) the spreading of active particles around the building. To achieve this, a wooden frame covered with sheet plastic was built around the immediate area, totally enclosing the welder

and the work. The welder wore a mask with a hose leading outside the enclosure. The atmosphere inside the enclosure was continually changed and was passed through a filter before being discharged into the building. The filter was monitored but no activity detectable with an ordinary Geiger counter was found.

It is apparent, then, that the present level of activities can be coped with in a very safe and conservative way. With extreme care and careful planning, activities up to say ten times the present levels could possibly be tolerated. Activities beyond this point, while not necessarily impossible, would require extraordinary measures and be extremely difficult to handle.

ACKNOWLEDGMENTS

I would like to thank J. T. V le, L. R. Glasgow, R. L. Fulton and N. W. Yanni for their kind permission to blatantly plagiarize from references (a) and (b). I would also like to thank H. W. Patterson for supplying information on activity levels.

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4. R. Smith, K. R. MacKenzie, J. Reidel, O. Kerns, W. R. Baker, C. W. Park, R. L. Thornton, The Electrical Aspects of the UCRL 740-MeV Synchrocyclotron, 1957 I. R. E. Wescon Convention Record

Figure Legends

Fig. 1. Schematic Plan View of the 184-inch Cyclotron and Building showing the new experimental facilities.

Fig. 2. Interior View of the New Addition to the Cyclotron Building. The "gun-ports" for extending particle-beams outside the building may be seen to the right.

Fig. 3. Exterior View of the New Addition to the Cyclotron Building. The portion of the wall which is concrete is to provide continuous shielding between the exterior and interior experimental areas.

Fig. 4. Entrance to Medical Cave. The hydraulically operated plug door is behind the folding safety door in the center of the picture. The nurses sentry-box to the left is provided with a TV receiver for viewing the patient.

Fig. 5. Degrader and Collimator for Deflected Beam. The beam enters at right. Reading from right to left: beam port, vacuum valve, degrader, collimator, steering magnet.

Fig. 6. Part of Beam Transport System for Medical Cave before Installation. Beam enters at left. (a) quadrupole. (b) beam tube. (c) beam plug. (d) vacuum window.

Fig. 7. Interior of Medical Cave. (a) beam entrance, (b) human positioner, (c) scattering-target loader, (d) animal rotator.

Fig. 8. Medical Control Room. Facilities include TV receivers for viewing patient, dosimetry, remote controls for positioner, and "off" control on the Cyclotron.

Fig. 9. Model of Proposed Human Positioner. This device is designed for irradiation of any part of the body.

Fig. 10. Meson Focusing Quadrupole before Installation. Quadrupole may be remotely rotated about a vertical axis, and remotely translated horizontally and vertically.

Fig. 11. Meson Focusing Quadrupole after Installation. The dee tank is on the left and the Meson Cave shielding wall is on the right.

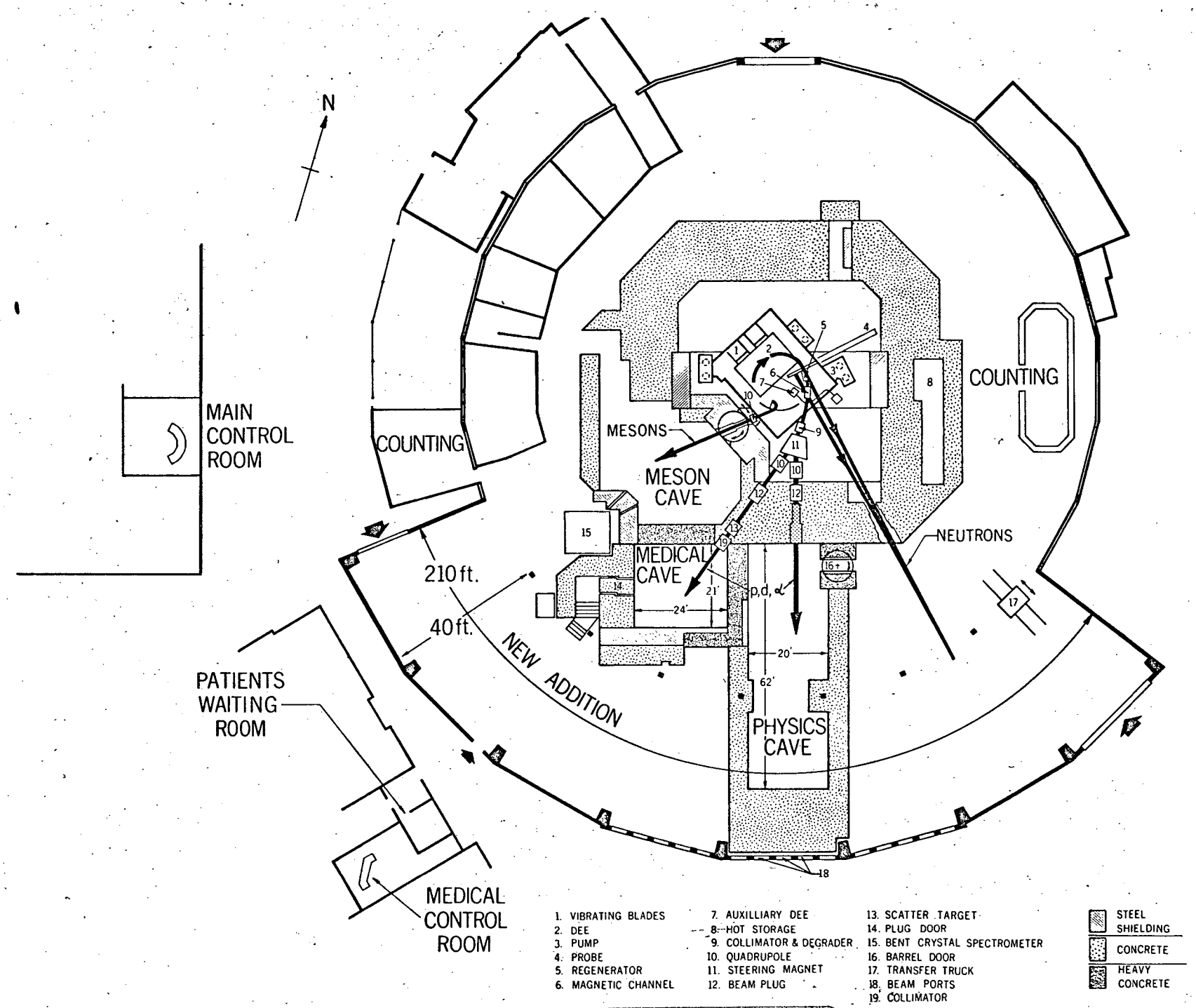
N
MAIN CONTROL ROOM
COUNTING
COUNTING
MESONS
MESON CAVE
MEDICAL CAVE
NEUTRONS
210 ft.
40 ft.
NEW ADDITION
PATIENTS WAITING ROOM
MEDICAL CONTROL ROOM
PHYSICS CAVE
p,d,α
21'
24'
20'
62'
1. VIBRATING BLADES
2. DEE
3. PUMP
4. PROBE
5. REGENERATOR
6. MAGNETIC CHANNEL
7. AUXILLIARY DEE
8. HOT STORAGE
9. COLLIMATOR & DEGRADER
10. QUADRUPOLE
11. STEERING MAGNET
12. BEAM PLUG
13. SCATTER TARGET
14. PLUG DOOR
15. BENT CRYSTAL SPECTROMETER
16. BARREL DOOR
17. TRANSFER TRUCK
18. BEAM PORTS
19. COLLIMATOR
STEEL SHIELDING
CONCRETE
HEAVY CONCRETE

Fig. 1

Fig. 2

Fig. 3

Fig. 4

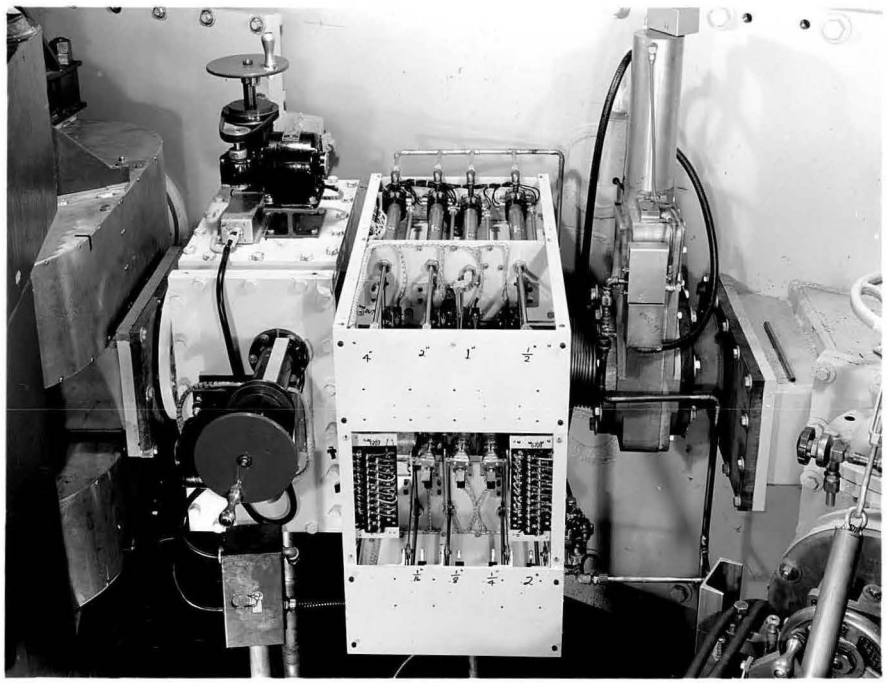

Fig. 5

Fig. 6

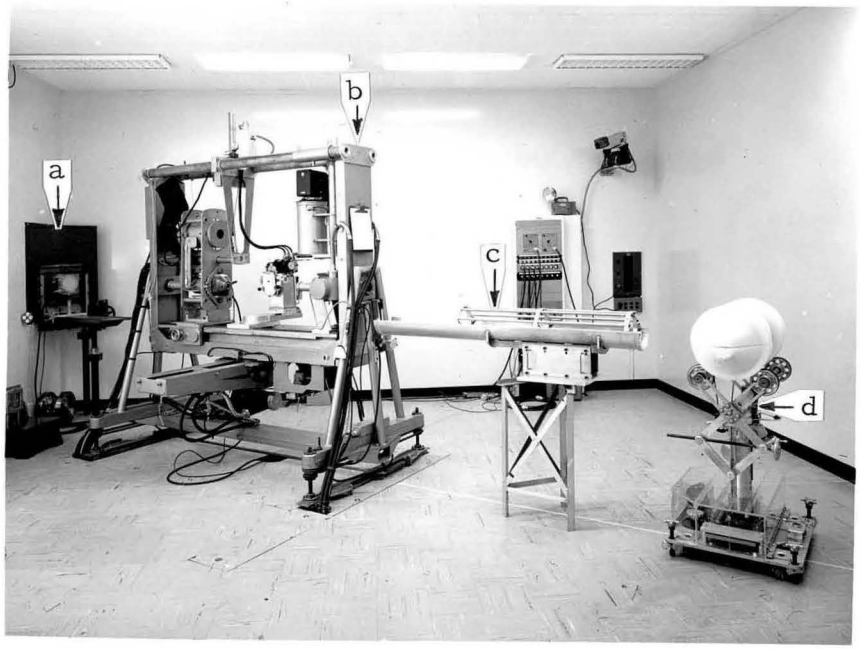

Fig. 7

MILLERS FALLS
BZIERASE
COTTON CONTENT

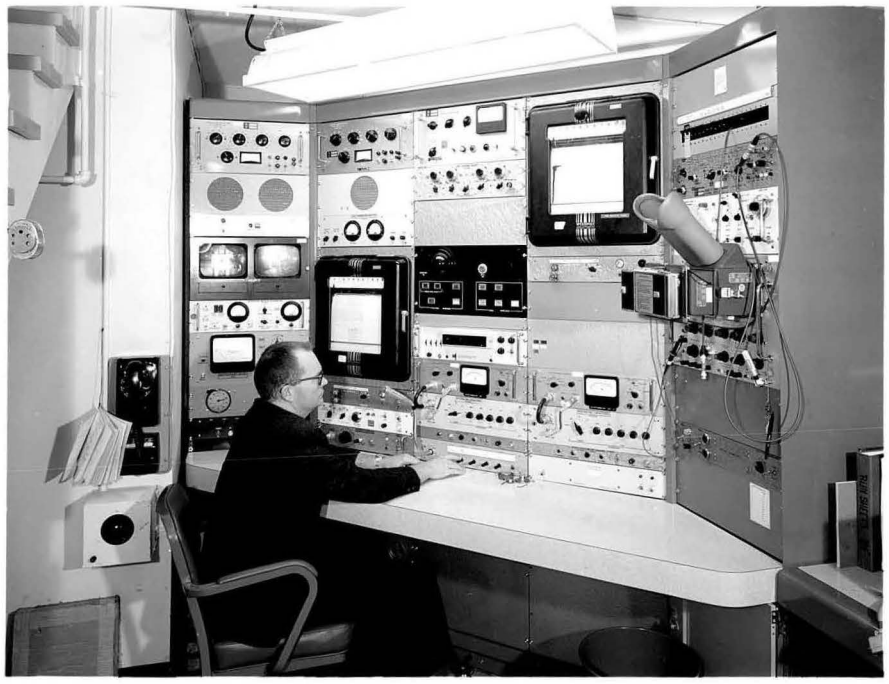

Fig. 8

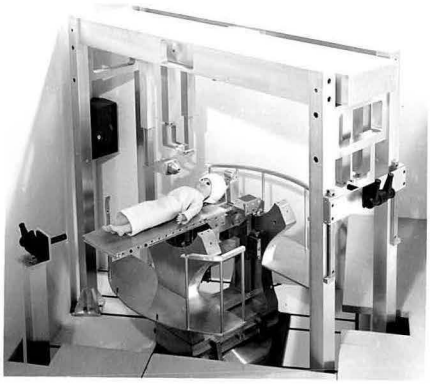

Fig. 9

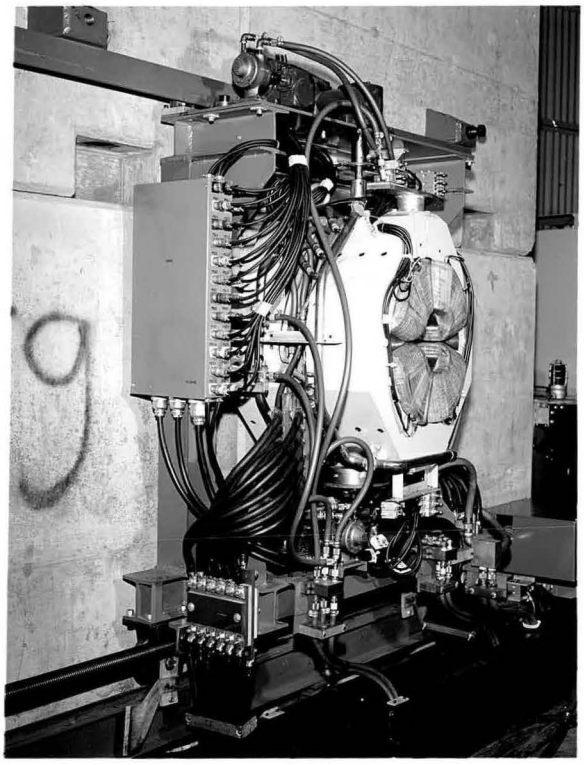

Fig. 10

Fig. 11

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