EVALUATION OF A COMMERCIAL APPLICATOR SYSTEM
FOR INTRAOPERATIVE RADIOTHERAPY

BY

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ABSTRACT

INTRAOPERATIVE RADIOTHERAPY (IORT) IS A TREATMENT MODALITY OF CURRENT INTEREST, PARTICULARLY THE USE OF ELECTRONS AS A BOOST DOSE IN CONJUNCTION WITH CONVENTIONAL FRACTIONATED EXTERNAL BEAM RADIATION. A MAJOR PROBLEM FACED BY INSTITUTIONS CONSIDERING INITIATING AN IORT PROGRAM IS THE DESIGN AND FABRICATION OF A SUITABLE APPLICATOR SYSTEM. A COMMERCIAL SYSTEM, INCLUDING PERISCOPIC VIEWER AND ELECTRON CONES, HAS RECENTLY BEEN MARKETED (RADIATION PRODUCTS DESIGN, INC.) AND IS ADAPTABLE TO EXISTING ACCELERATORS. WE HAVE INSTALLED THIS SYSTEM ON A VARIAN CLINAC 18 ACCELERATOR. DOSIMETRIC STUDIES HAVE BEEN MADE FOR CONE SIZES OF 4.5 TO 9.5 CM DIAMETER, WITH FLAT AND BEVELED ENDS, AND ELECTRON ENERGIES OF 12, 15, AND 18 MEV. PARAMETERS OF INTEREST, INCLUDING SURFACE DOSE, DEPTH DOSE, CONE RATIOS, ISODOSE CURVES, AND BEAM PROFILES WILL BE PRESENTED. CLINICAL EXPERIENCE IN USE OF THE SYSTEM AND DESIGN FEATURES WILL BE DISCUSSED.

DESIGN FEATURES

THE IORT ASSEMBLY, SHOWN IN FIGURES 1 TO 6, CONSISTS OF THE FOLLOWING MAJOR COMPONENTS:

1. ADAPTER PLATE IS CUSTOM MADE FOR EACH ACCELERATOR AND ALLOWS THE ASSEMBLY TO BE ATTACHED TO THE TREATMENT UNIT. SECURED BETWEEN PLATE AND VIEWER IS A SHEET OF .002" THICK MYLAR TO PREVENT POSSIBILITY OF FOREIGN MATTER ENTERING SITE.

2. ASSEMBLY BARREL IS MADE OF ALUMINUM WHICH IS ANODIZED TO OBTAIN SURFACE HARDNESS AND TO PREVENT DISCOLORATION DURING COLD GAS STERILIZATION.

3. VIEWING TUBE AND HIGHLY POLISHED STAINLESS STEEL MIRROR AND LEVER CONTROL ALLOWS VIEWING OF TUMOR PRIOR TO IRRADIATION. SPRINGS RETRACT MIRROR OUT OF BEAM DURING TREATMENT.

4. PEN LIGHT HOLDERS ON SWIVEL BRACKETS ALLOW ADJUSTMENT OF A FOCUSED LIGHT BEAM TO TREATMENT AREA. ASSEMBLIES ARE REMOVABLE FOR USE OF FIBER OPTICS LIGHT SOURCE IF DESIRED.

5. HINGED DOOR IN LOWER SECTION OF VIEWING ASSEMBLY ALLOWS ELECTRON CONES TO BE LATERALLY DOCKED INTO UNIT. THIS GREATLY FACILITATES THE DOCKING MANEUVER AND IS AN IMPORTANT SAFETY FEATURE.

6. ELECTRON CONES ARE MADE OF 1/8" THICK ACRYLIC, 12" LONG. THREE ACRYLIC SPACER RINGS ALLOW THE DIFFERENT SIZE CONES TO SLIDE INTO THE BARREL OF THE VIEWER. A 3/16" BRASS PLATE WITH A CENTRAL HOLE IS MOUNTED TO THE TOP OF EACH CONE TO PREVENT ELECTRON PENETRATION OF THE SPACER RINGS. THIRTEEN CONE SIZES WITH INSIDE DIAMETERS FROM 1.9 TO 9.5 CM ARE MANUFACTURED, WITH END ANGLES OF 0°, 15°, 30°, AND 45°. CONES UP TO 5.1 CM CAN ALSO BE SUPPLIED WITH OBTURATORS FOR USE AS INTRACAVITARY APPLICATORS. A SET OF DUMMY CONES IS AVAILABLE IN SURGERY FOR USE IN SELECTING THE PROPER CONE SIZE.

INTRODUCTION

INTRAOPERATIVE RADIOTHERAPY (IORT) IS OF CURRENT INTEREST IN RADIATION ONCOLOGY BECAUSE OF THE POTENTIAL IMPROVEMENT IN THE THERAPEUTIC RATIO OF LOCAL CONTROL VERSUS COMPLICATIONS. EARLY WORK BY INVESTIGATORS IN JAPAN, AS WELL AS RECENT STUDIES IN THE U.S. HAVE DEMONSTRATED THAT COMBINATIONS OF EXTERNAL BEAM PHOTONS, INTRAOPERATIVE ELECTRONS, AND SURGICAL RESECTION ARE FEASIBLE AND PRACTICAL, AND MAY SIGNIFICANTLY IMPROVE THE DURATION OF SYMPTOM-FREE OR OVERALL SURVIVAL OF CANCER PATIENTS.

BECAUSE OF SUCCESSES IN LOCAL CONTROL OF DISEASE THAT HAVE BEEN REPORTED IN THE LIMITED EXPERIENCE TO DATE, MANY RADIOTHERAPY CENTERS ARE INTERESTED IN INITIATING AN IORT PROGRAM. A MAJOR PROBLEM FACED BY THESE CENTERS IS THE DESIGN AND FABRICATION OF A SUITABLE APPLICATOR SYSTEM AND THE LARGE NUMBER OF ELECTRON CONES NEEDED TO FACILITATE TREATMENT. MOST RADIOTHERAPY DEPARTMENTS DO NOT HAVE ACCESS TO THE EXTENSIVE MACHINE-SHOP FACILITIES NEEDED TO PERFORM THIS TASK. FURTHERMORE, ACCELERATOR MANUFACTURERS DO NOT PRESENTLY SUPPLY THE ACCESSORIES NEEDED FOR IORT. IN ANSWER TO REQUESTS FROM THE RADIOTHERAPY COMMUNITY, A COMMERCIAL VENDOR (RADIATION PRODUCTS DESIGN, INC., BUFFALO, MN) HAS DESIGNED AND MANUFACTURED AN IORT APPLICATOR SYSTEM, COMPLETE WITH PERISCOPIC VIEWING ASSEMBLY AND VARIOUS SIZE ELECTRON CONES. THE SYSTEM IS SIMILAR IN DESIGN TO THAT USED AT THE MAYO CLINIC.[1]

AT THE OCHSNER FOUNDATION HOSPITAL, THE SYSTEM HAS BEEN INSTALLED ON A VARIAN CLINAC 18 ACCELERATOR IN THE DEPARTMENT OF RADIATION ONCOLOGY, WHERE AN IORT CLINICAL PROGRAM BEGAN IN JANUARY, 1984. IN ORDER TO MINIMIZE THE NUMBER OF ELECTRON CONES, IT WAS DECIDED TO LIMIT THE CONES TO FIVE DIAMETERS, BETWEEN 4.5 AND 9.5 CM AND THREE END ANGLES OF 0, 15, AND 30^o.

THE OBJECTIVE OF THE PRESENT WORK WAS 1) TO MEASURE AND EVALUATE THE DOSIMETRIC PARAMETERS OF THIS SYSTEM, 2) TO INVESTIGATE THE DESIGN FEATURES AND SPECIFICATIONS, AND 3) TO EVALUATE THE PERFORMANCE OF THE SYSTEM IN CLINICAL USE.

METHODS

Dosimetric data were taken for all cones at electron energies of 12, 15, and 18 MeV, the energies of interest for most unresectable cases. Extension of these measurements to 9 MeV, an energy of interest for intracranial irradiation and some cases involving resection, will be the subject of a later study.

Measurements of output factors (cone ratios), depth dose, surface dose, and x-ray contamination were made with a thin window, parallel plate ionization chamber (Capintec, Inc., model PS-033) in a polystyrene phantom. Polystyrene sheets of various thicknesses were used for build-up and attenuation. Ionization readings, recorded with a Keithly Model 616 digital electrometer, were corrected for beam divergence and converted to percent depth dose using appropriate C_E values. Cone ratios were determined by comparison of ionization readings with a "standard" 10 x 10 cm electron applicator. Photographs of the IORT system in the measurement arrangement are shown in Figures 7 and 8.

Measurements of isodose curves were recorded using type XV-2 x-ray film sandwiched in a large masonite film phantom. The processed films were scanned with an automatic film densitometer and the isodensity curves plotted. The central axis values were normilized to the ionization chamber results.

Measurements of beam profiles were taken in a water phantom with a silicon diode detector attached to a beam scanner. All scans were made at D_{MAX} depth. Check measurements were also made with films, with results essentially identical to those made with the diode.

RESULTS

Measurements of cone ratios (Fig. 7) show that for all energies, the output decreases with increasing cone diameter and decreasing cone angle. For the larger cone sizes, the cone ratio for 18 MeV electrons drops below that of the 15 MeV electrons.

Depth dose curves for the 9.5 cm cones (Figures 8-10) are typical of those observed for all the cones. Of particular interest is the decrease of % depth dose with increasing cone angle, an effect recently studied by Biggs[2]. Table I is a summary of the dosimetric properties of the intraoperative cones in which DMAX, surface dose, depths for 90%, 50%, and 30% dose, and average X-ray contamination are given for the smallest (4.5) and largest (9.5) cones studied. This table shows that at each energy:

1. There is no appreciable change in DMAX with cone angle due to the broad maxima that exist at 12-18 MeV.
2. There is a small (2-3%) decrease in surface dose with increasing cone angle for the large cones, but no change with the small ones.
3. The variation of % depth dose with cone angle is significant and is more pronounced for small cone diameters than for large ones.
4. The X-ray contamination is less than 4% in all cases.

Isodose curves for all the cones and energies are shown in Figures 11-13. The display of all 45 curves is helpful in cone selection, as well as to emphasize the distorted shape of the irradiated volume when using beveled cones.

Beam profiles for the 0^{o} and 30^{o} cones are shown in Figure 14 and 15. These show peaking (horns) at the edges of the field, which becomes more pronounced with decreasing cone diameter and increasing energy. The worse case of a 4.5 cm cone at 18 MeV shows about a 7% variation in flatness across the field. The beveled cones exhibit an asymmetry strongly dependent upon the cone diameter. Since dosimetric parameters are dependent on collimator setting, particularly cone ratios and beam profiles, studies were made to investigate these effects. Figure 16 shows the variation of cone ratio with collimator setting, while Figure 17 illustrates the effect of collimator setting on flatness. It was concluded that a fixed collimator setting of 10 x 10 cm was "optimal" for these cones.

CONCLUSIONS

THE DESIGN, DOSIMETRIC PROPERTIES AND SAFETY FEATURES OF THE SYSTEM DESCRIBED AND DOCUMENTED IN THIS STUDY ALL APPEAR TO BE ADEQUATELY SUITED FOR IORT. THE COMMERCIAL AVAILABILITY OF THESE COMPONENTS AND THE ADAPTABILITY OF THE ASSEMBLY TO EXISTING ACCELERATORS ALLOW INITIATION OF IORT PROGRAMS IN HOSPITALS LACKING THE EXPERTISE NEEDED TO FABRICATE SUITABLE APPLICATORS.

IN THE LIMITED CLINICAL EXPERIENCE TO DATE (6 PATIENTS TREATED WITH DOSES BETWEEN 12 AND 17.5 GY), THE APPLICATOR SYSTEM HAS FUNCTIONED WELL, WITH NO TECHNICAL PROBLEMS ENCOUNTERED. RADIOTHERAPISTS HAVE EXPRESSED SATISFACTION WITH THE DOSE CHARACTERISTICS AND WITH THE FLEXIBILITY AND EASE OF USE OF THE PERISCOPIC VIEWER AND INTRAOPERATIVE CONES.

REFERENCES

1. EDWIN C. MCCULLOUGH AND JOSEPH A. ANDERSON, MED. PHYS. 9 (2), 261 (1982)

2. PETER J. BIGGS, PHYS. MED. BIOL. (TO BE PUBLISHED)

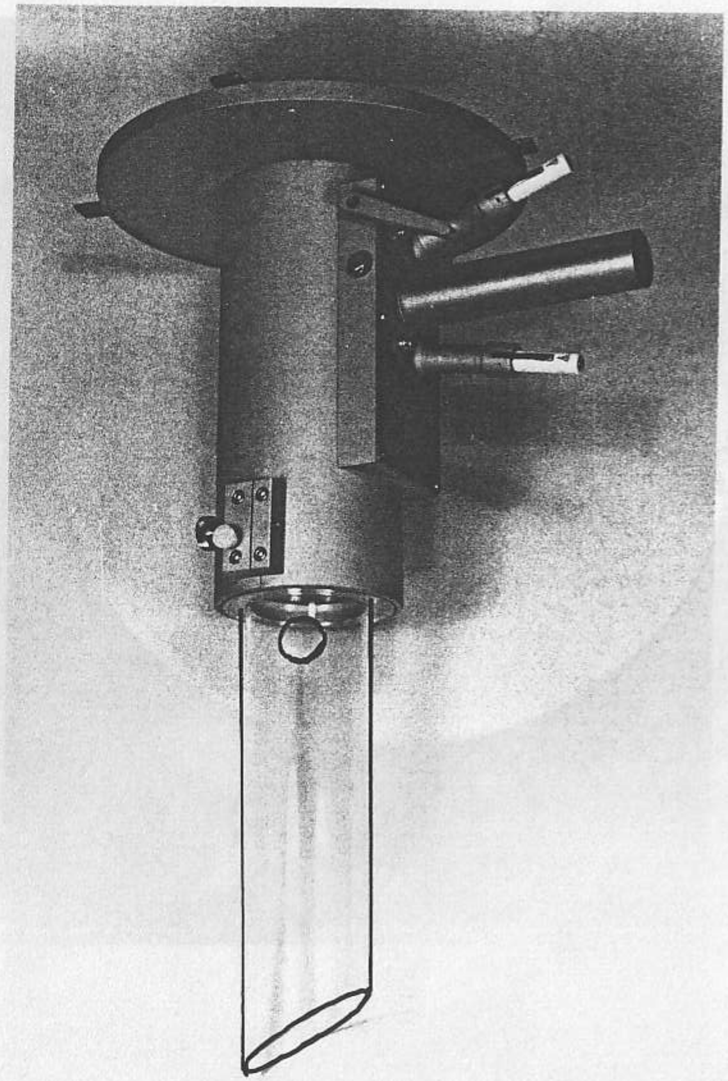

Fig. 1 Complete Periscopic Viewer and Electron Cone with adapter plate for Varian Clinac 18.

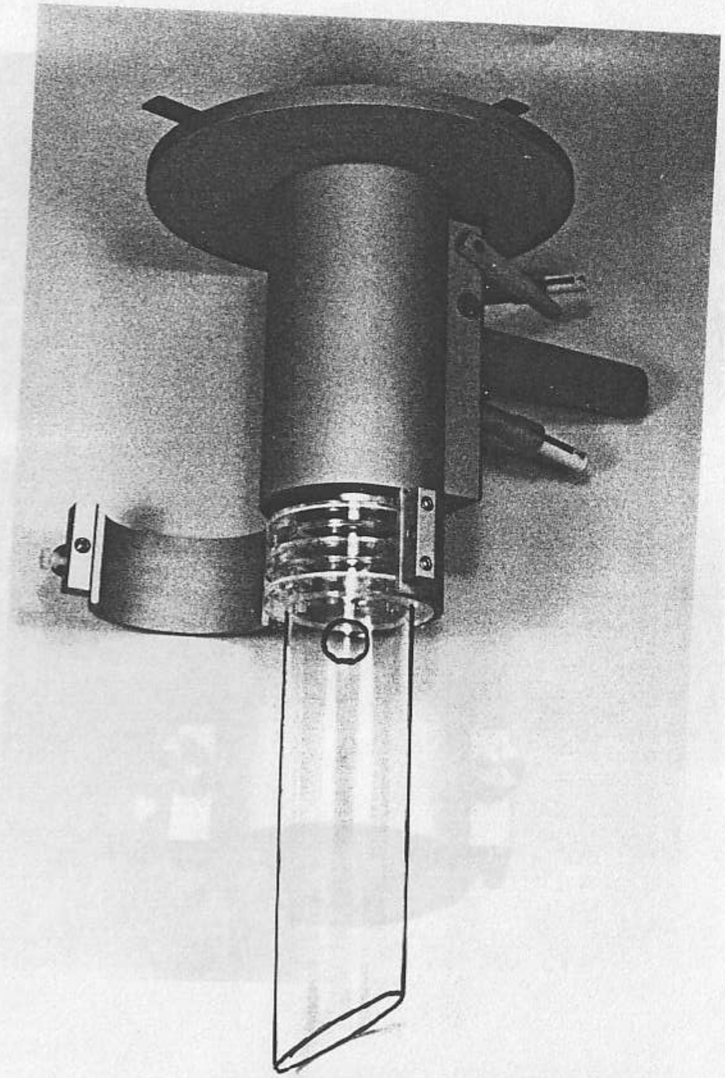

Fig. 2 Periscopic Viewer with hinged door in the open position, showing lateral docking of cone.

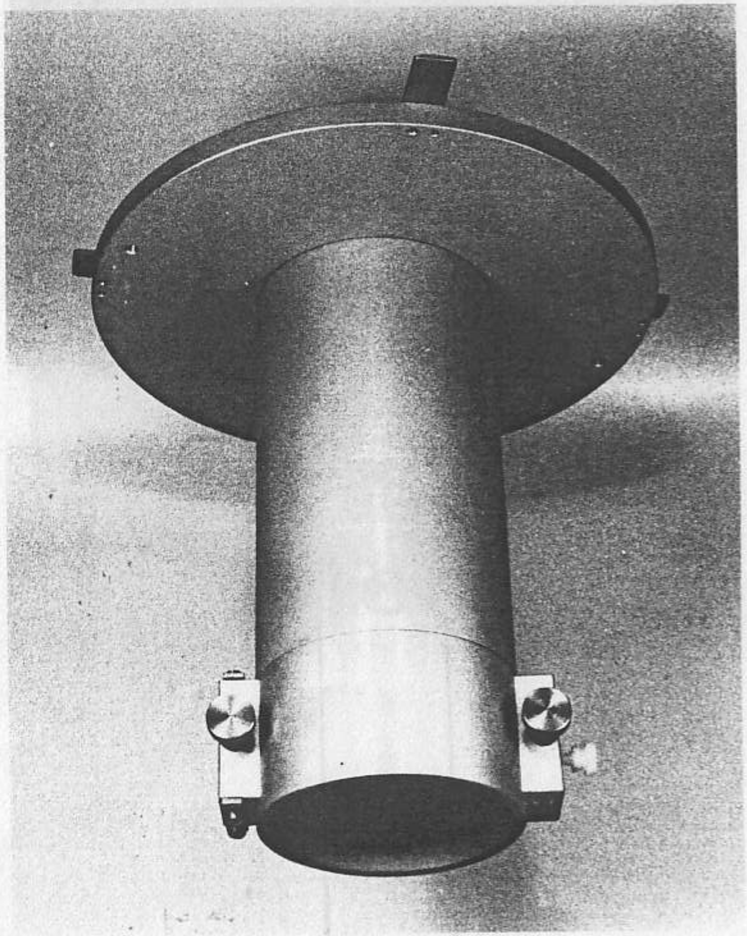

Fig. 3 Periscopic Viewer with hinged door in the closed position with two knobs securing the door.

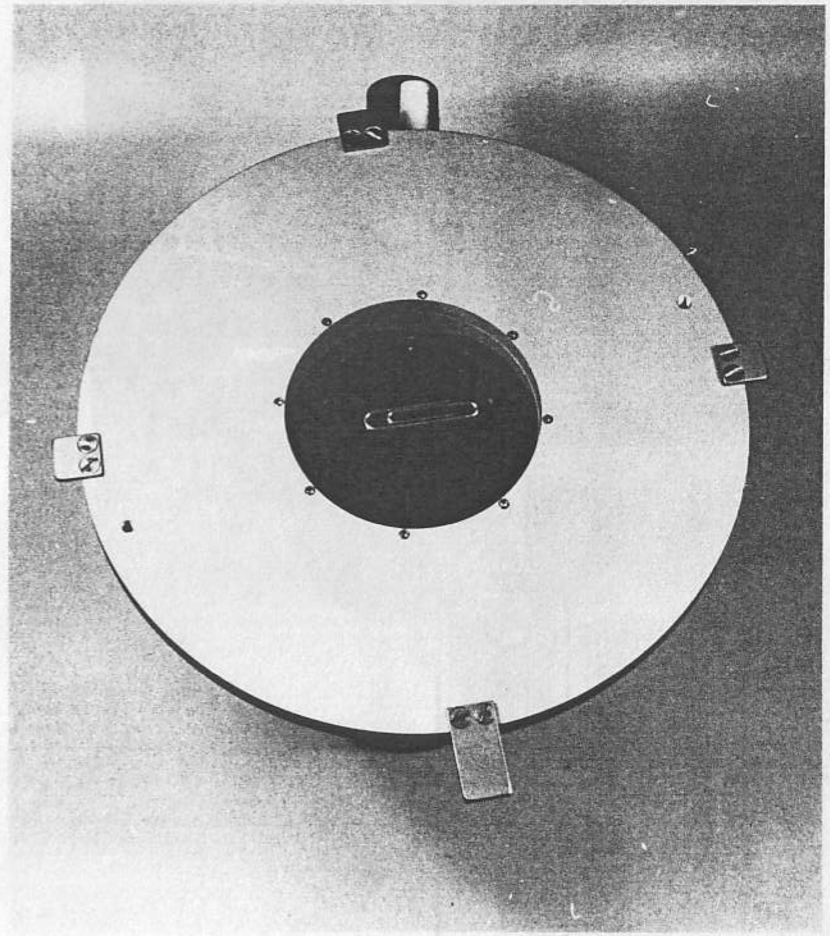

Fig. 4 View of adapter plate top and mylar window.

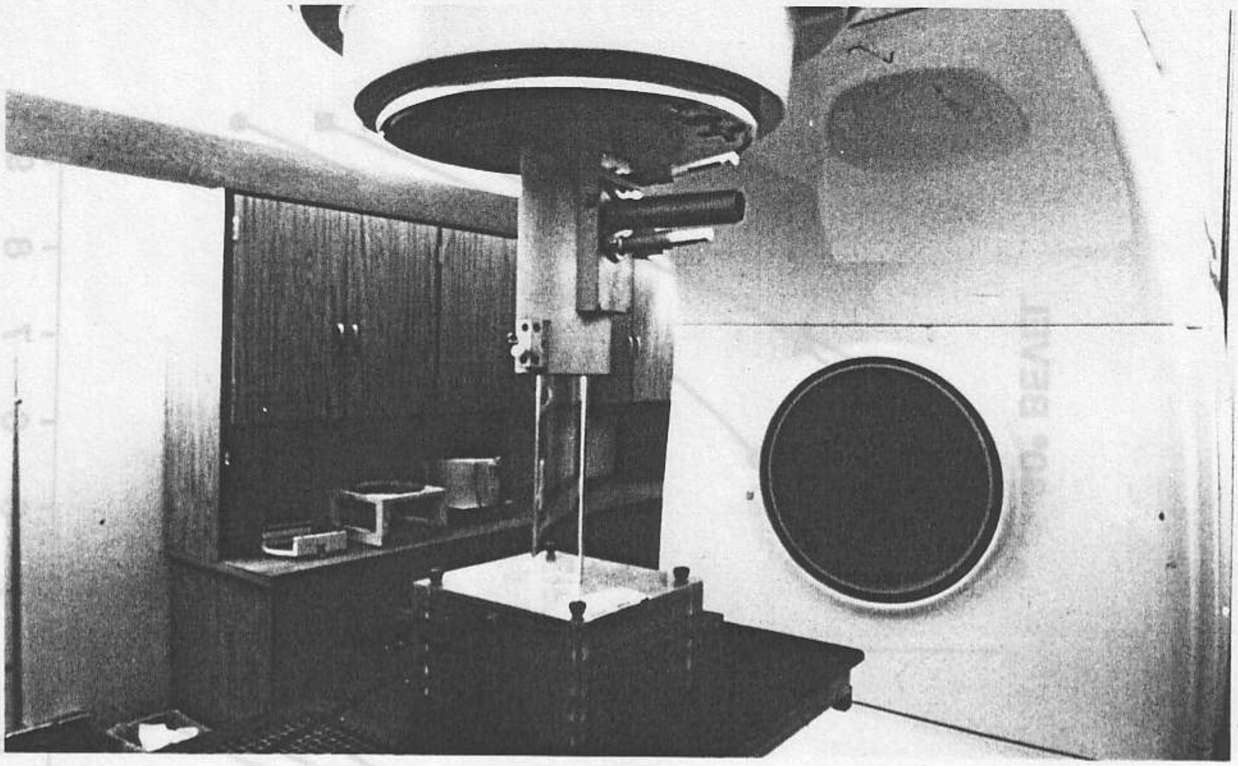

FIG. 5 EXPERIMENTAL ARRANGEMENT FOR DOSIMETRIC MEASUREMENTS WITH POLYSTYRENE PHANTOM.

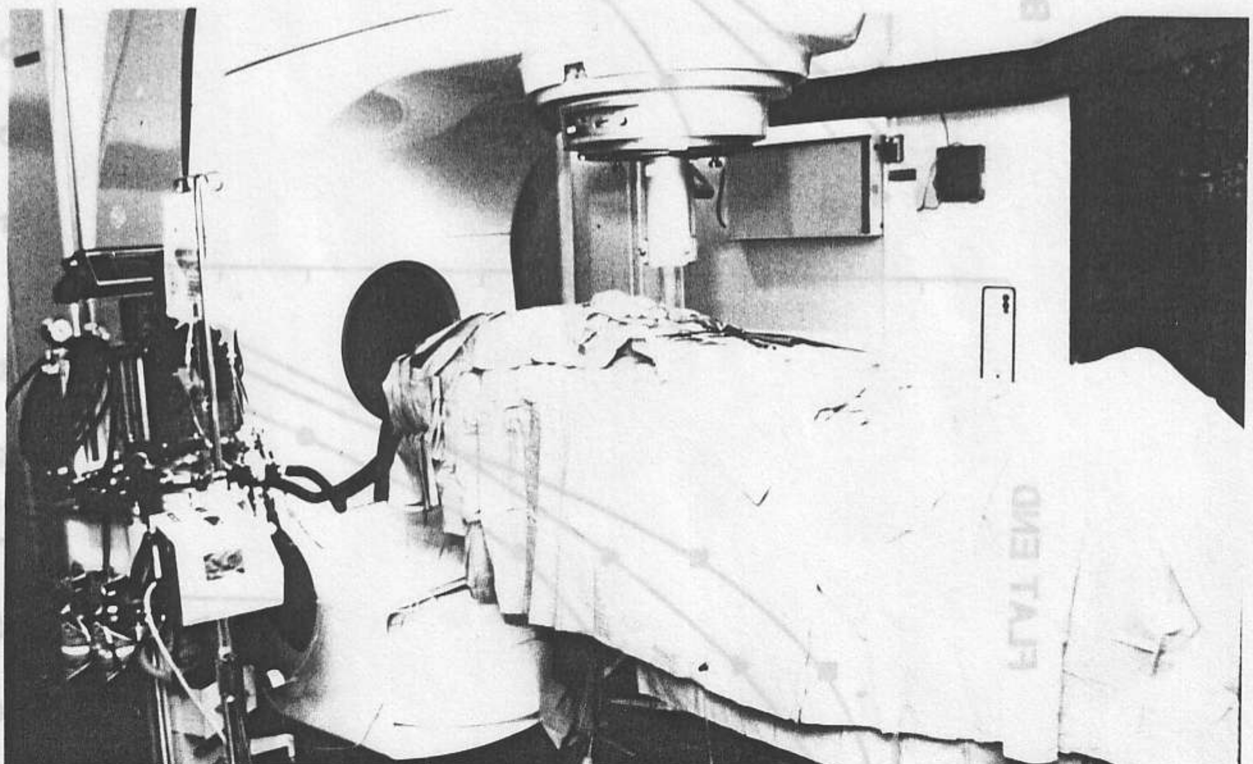

FIG. 6 APPLICATOR SYSTEM IN USE DURING PATIENT TREATMENT.

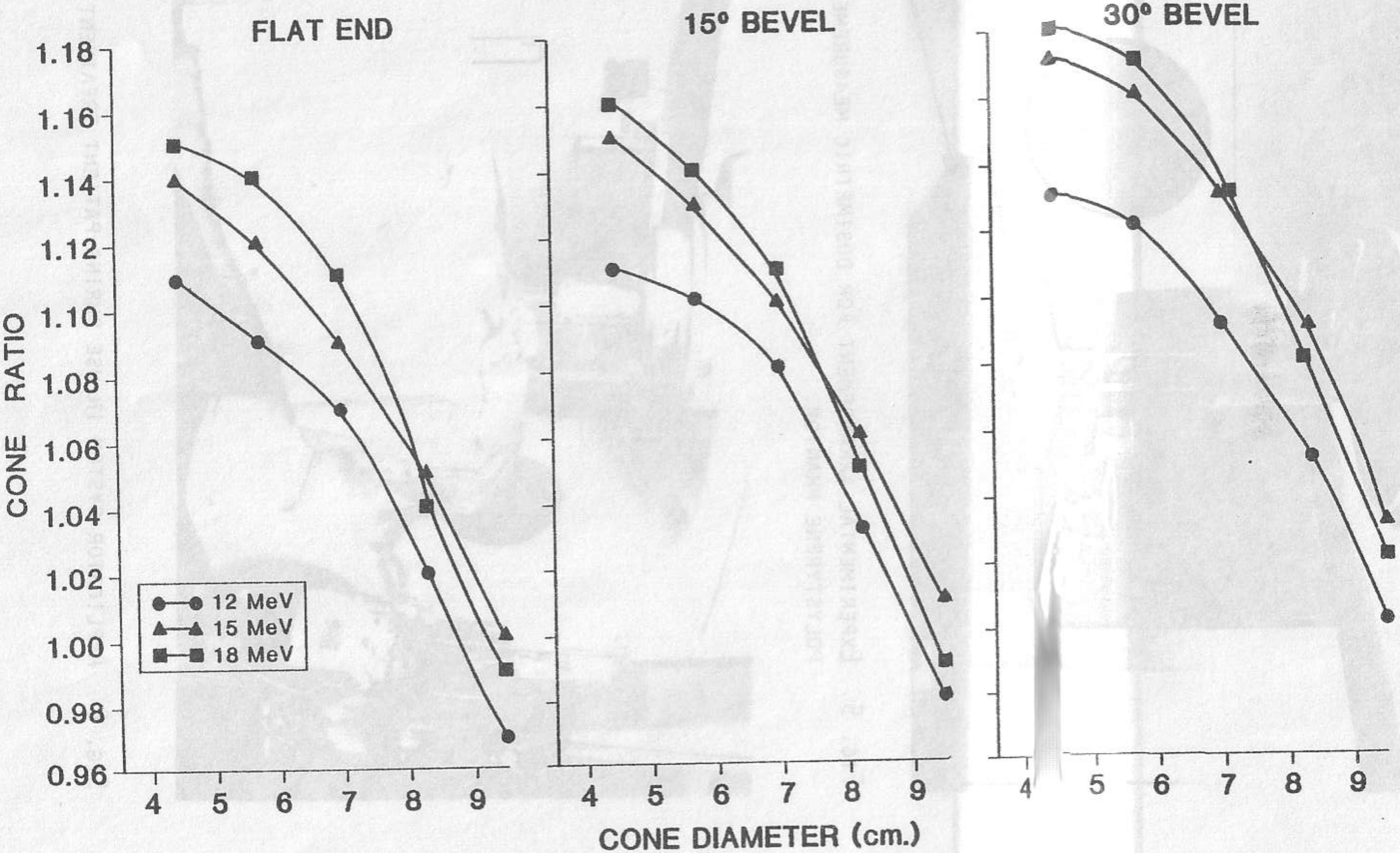

FIG. 7 CONE RATIOS VS CONE DIAMETER FOR COLLIMATOR SET NG OF 10 x 10 CM.

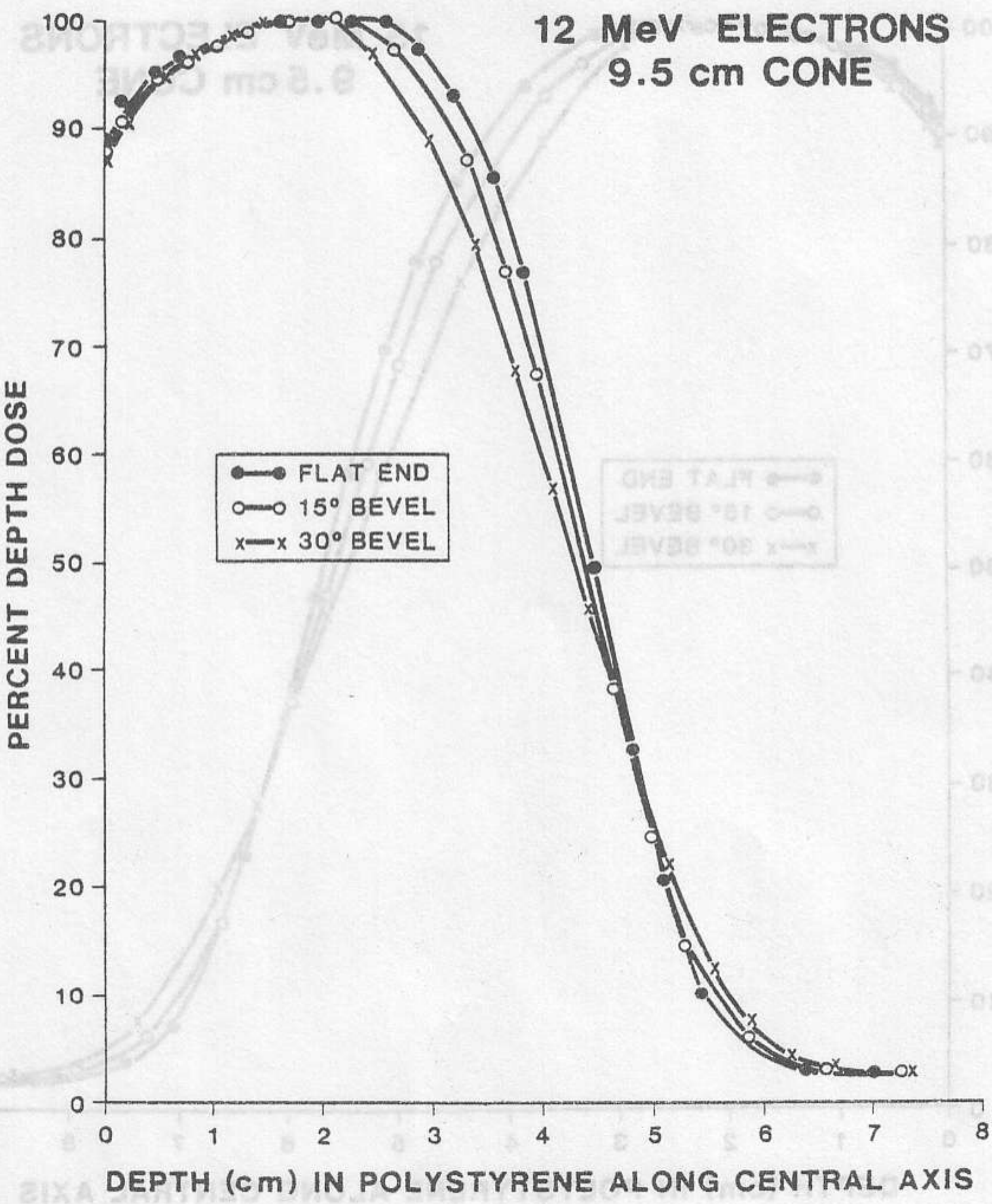

FIG. 8 PERCENT DEPTH DOSE CURVES IN POLYSTYRENE FOR 12 MEV ELECTRONS, 9.5 CM CONE, AND 10 X 10 CM COLLIMATOR SETTING. DEPTH IS MEASURED ALONG CENTRAL AXIS OF BEAM.

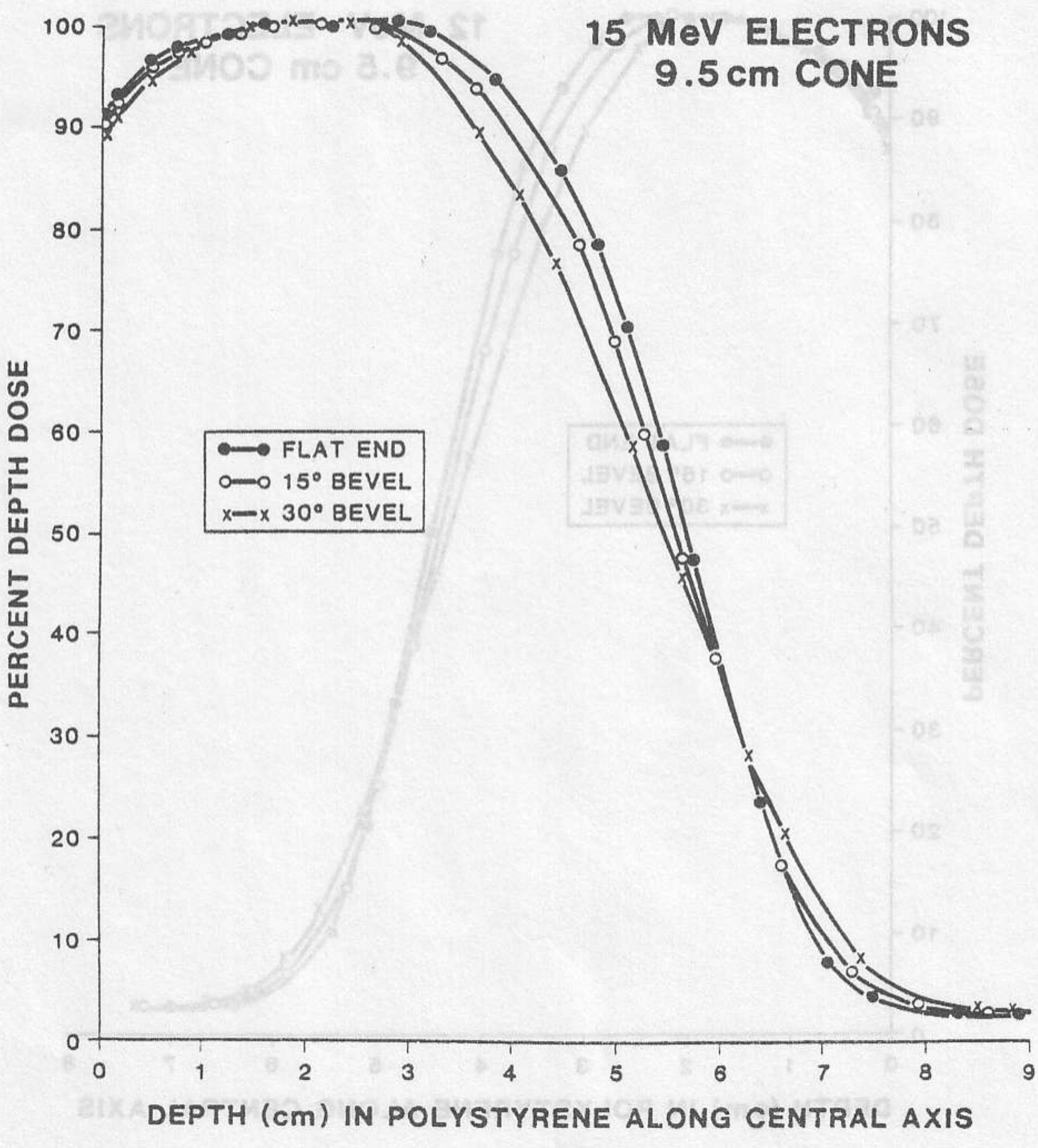

Fig. 9 Percent depth dose curves in polystyrene for 15 MeV electrons and 10 x 10 cm collimator setting. Depth is measured along central axis of beam.

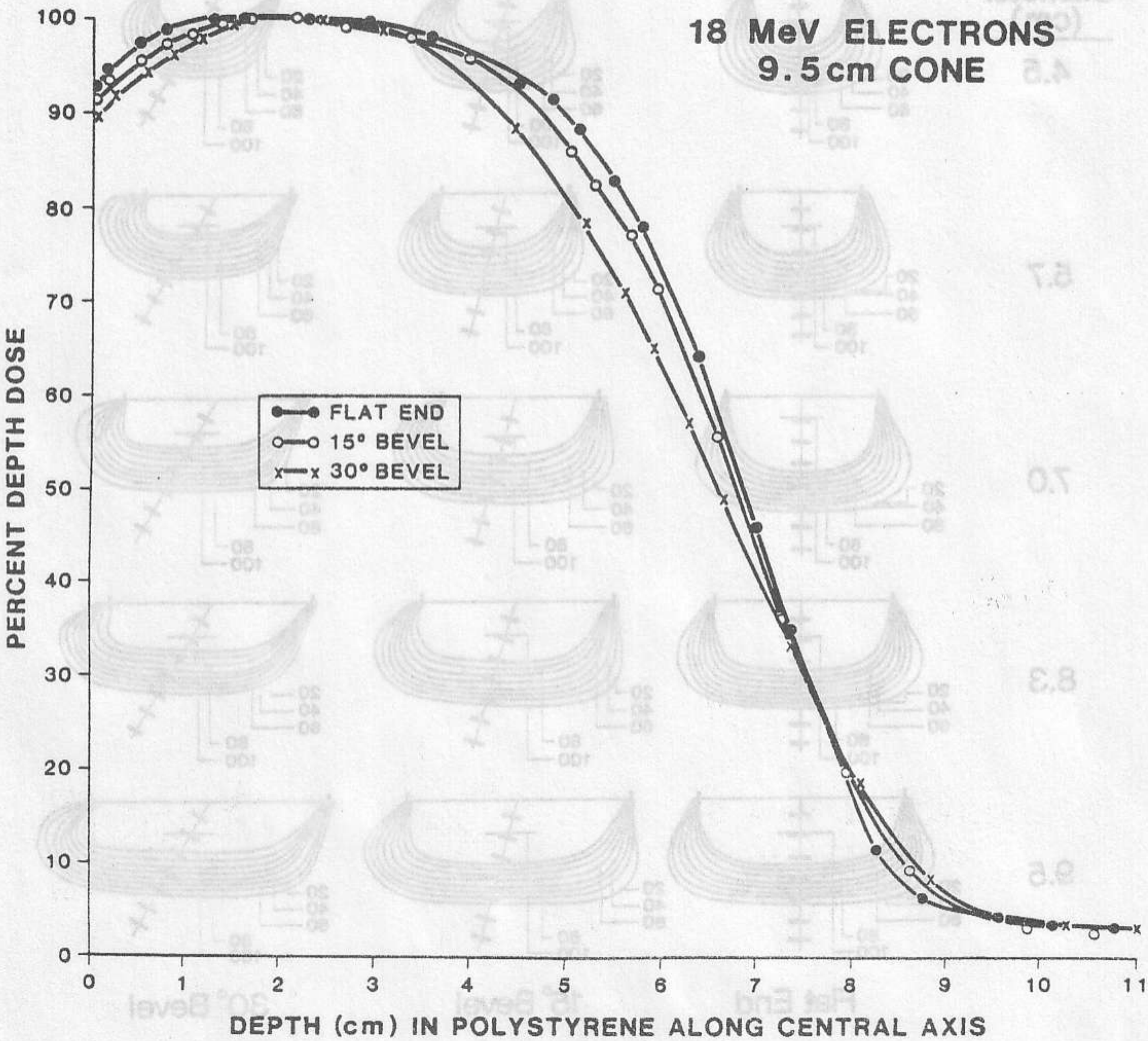

FIG. 10 PERCENT DEPTH DOSE CURVES IN POLYSTYRENE FOR 18 MEV ELECTRONS, 9.5 CM CONE, AND 10 x 10 CM COLLIMATOR SETTING. DEPTH IS MEASURED ALONG CENTRAL AXIS OF BEAM.

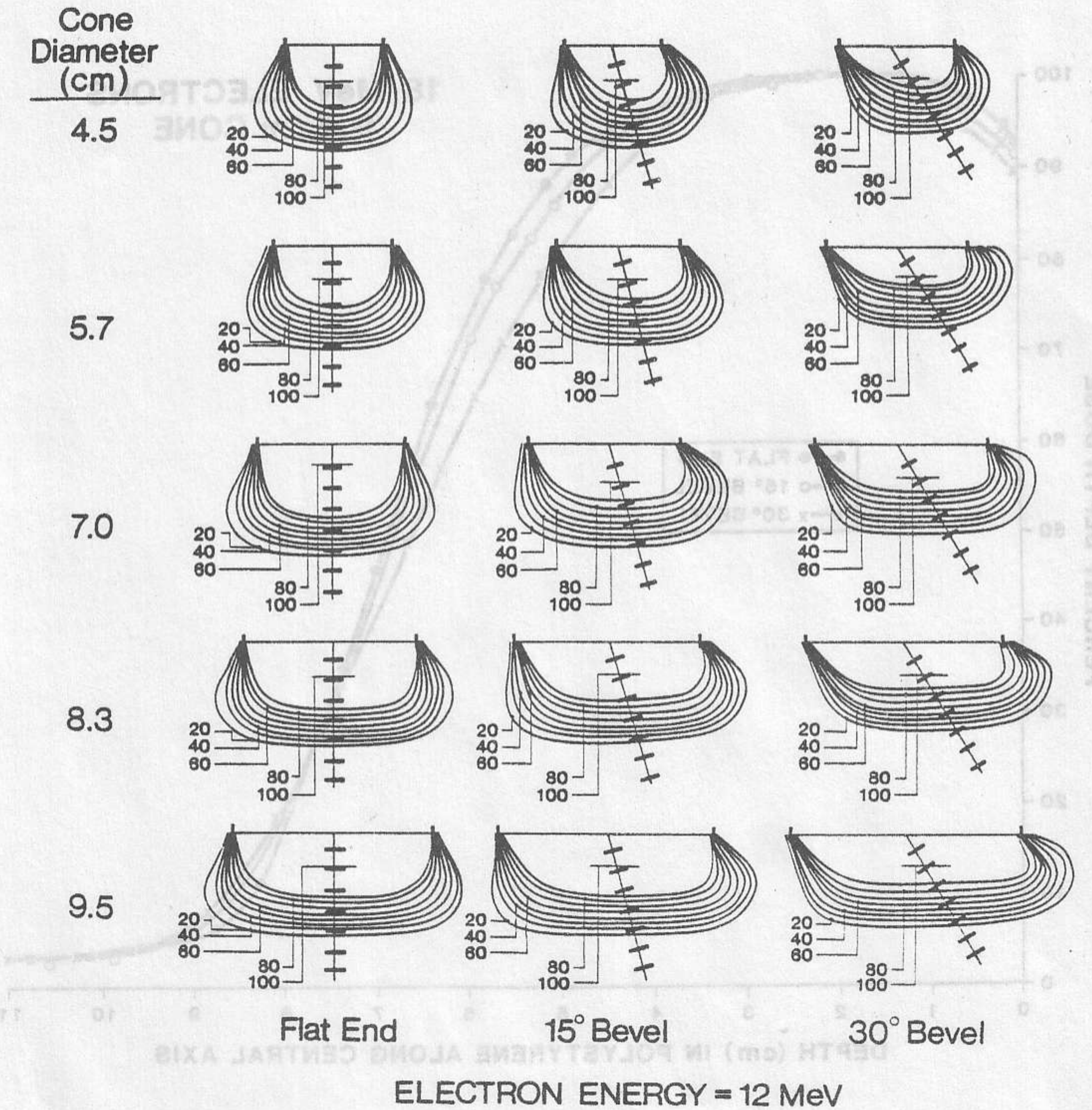

FIG. 11 ISODOSE CURVES AT ELECTRON ENERGY OF 12 MEV.

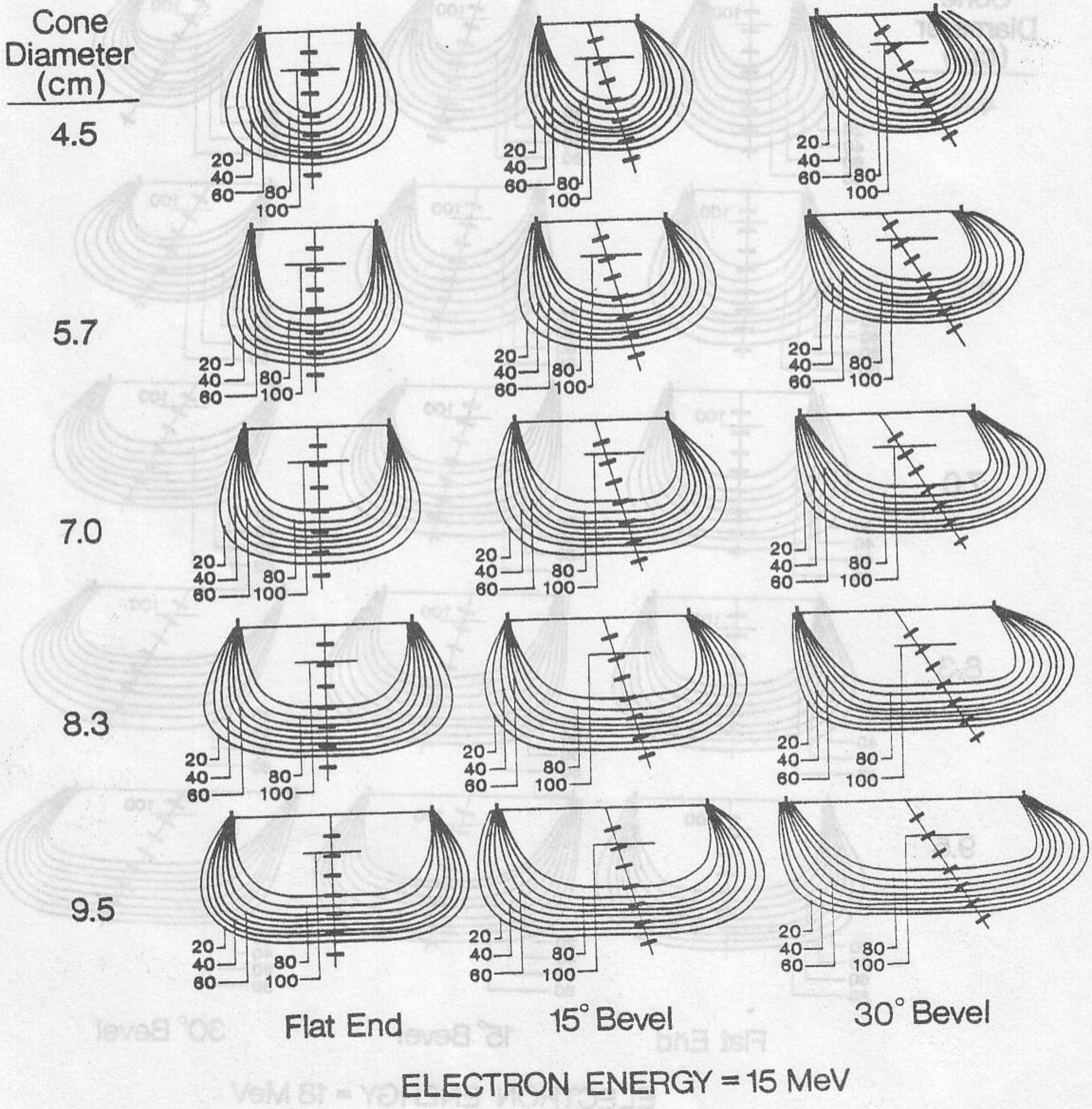

Fig. 12 Isodose curves at electron energy of 15 MeV.

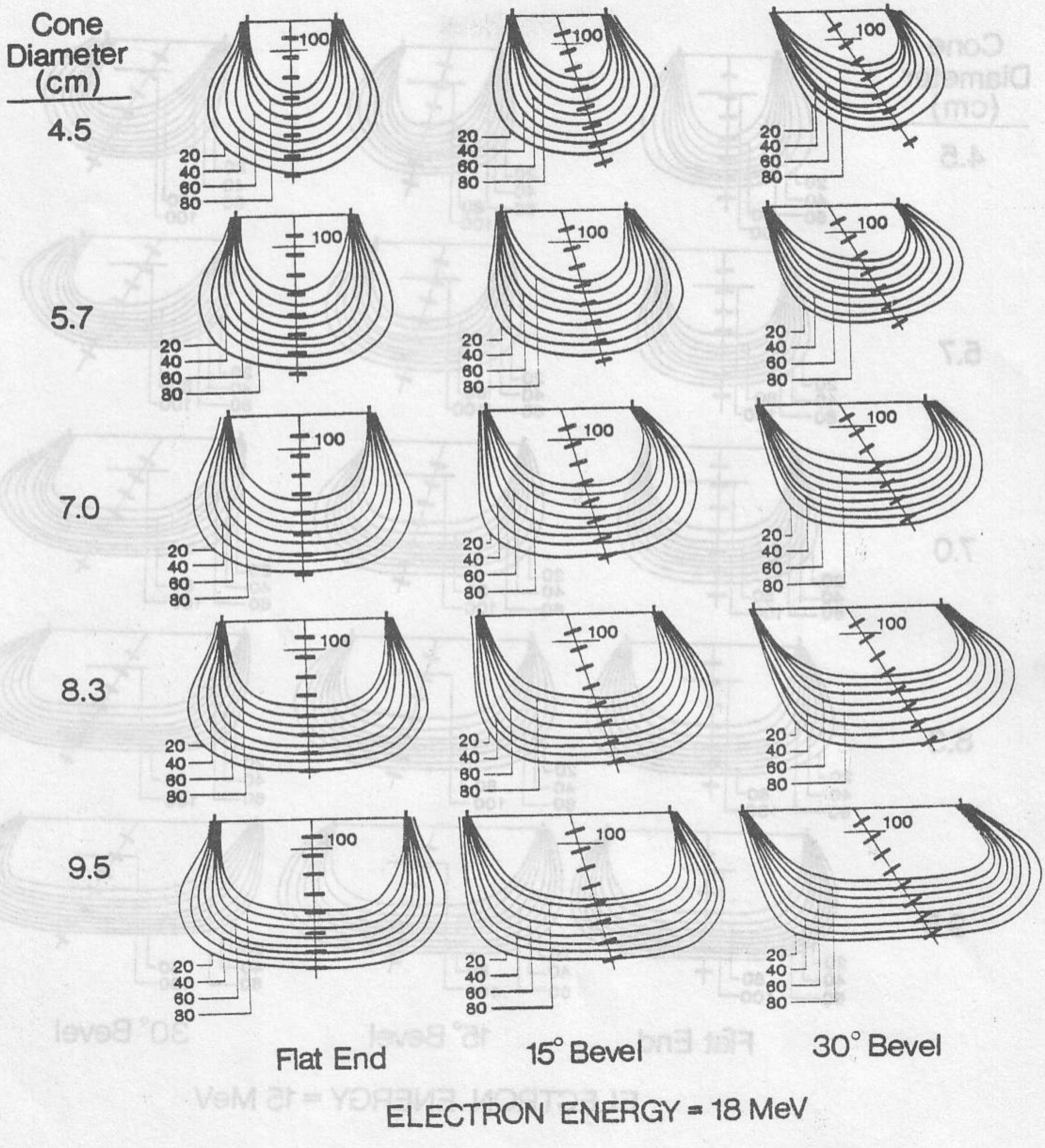

Fig. 13 Isodose curves at electron energy of 18 MeV.

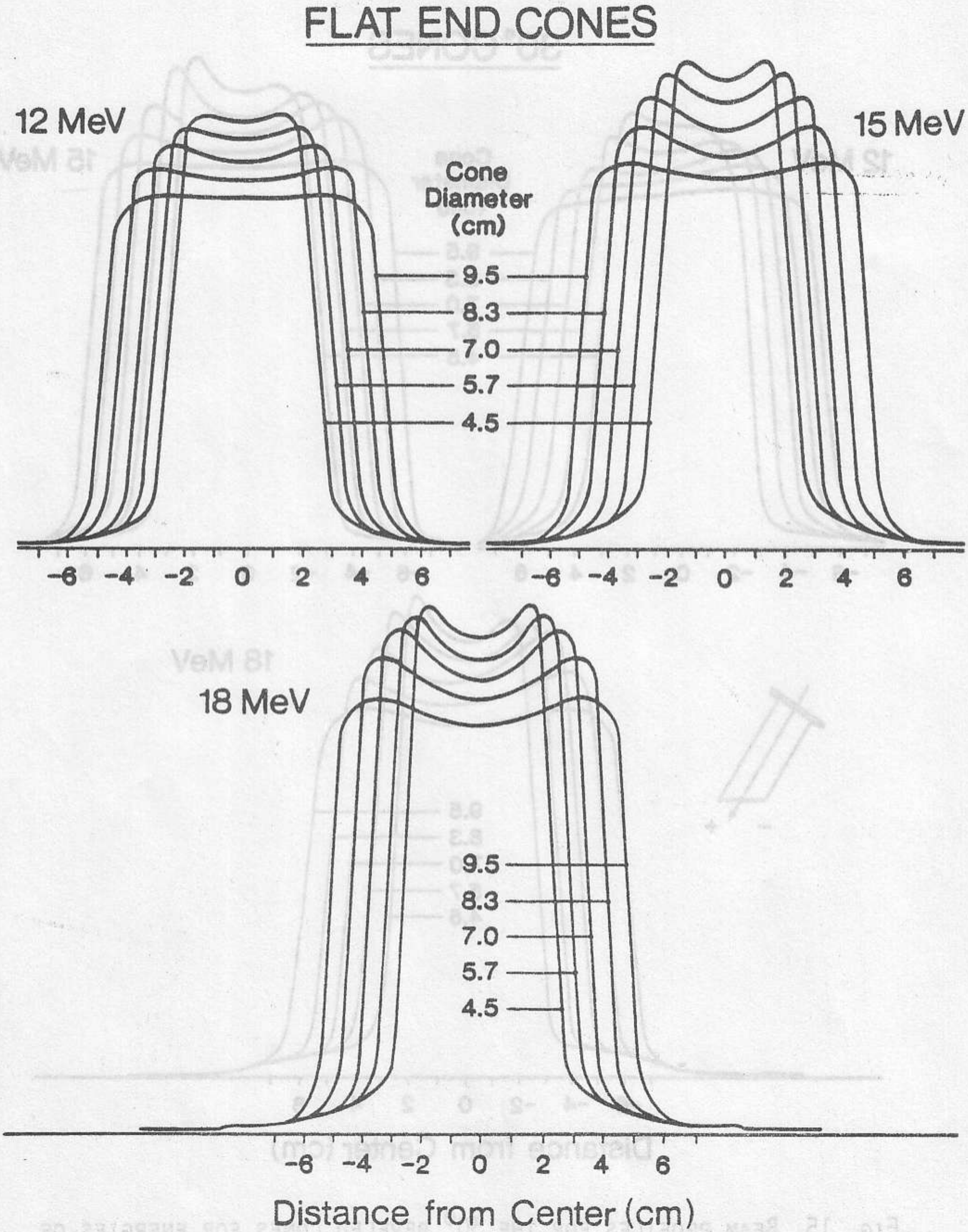

FIG. 14 BEAM PROFILES FOR THE 0^{0} (FLAT END) CONES FOR ENERGIES OF 12, 15, AND 18 MEV. COLLIMATOR SETTING IS 10 X 10 CM.

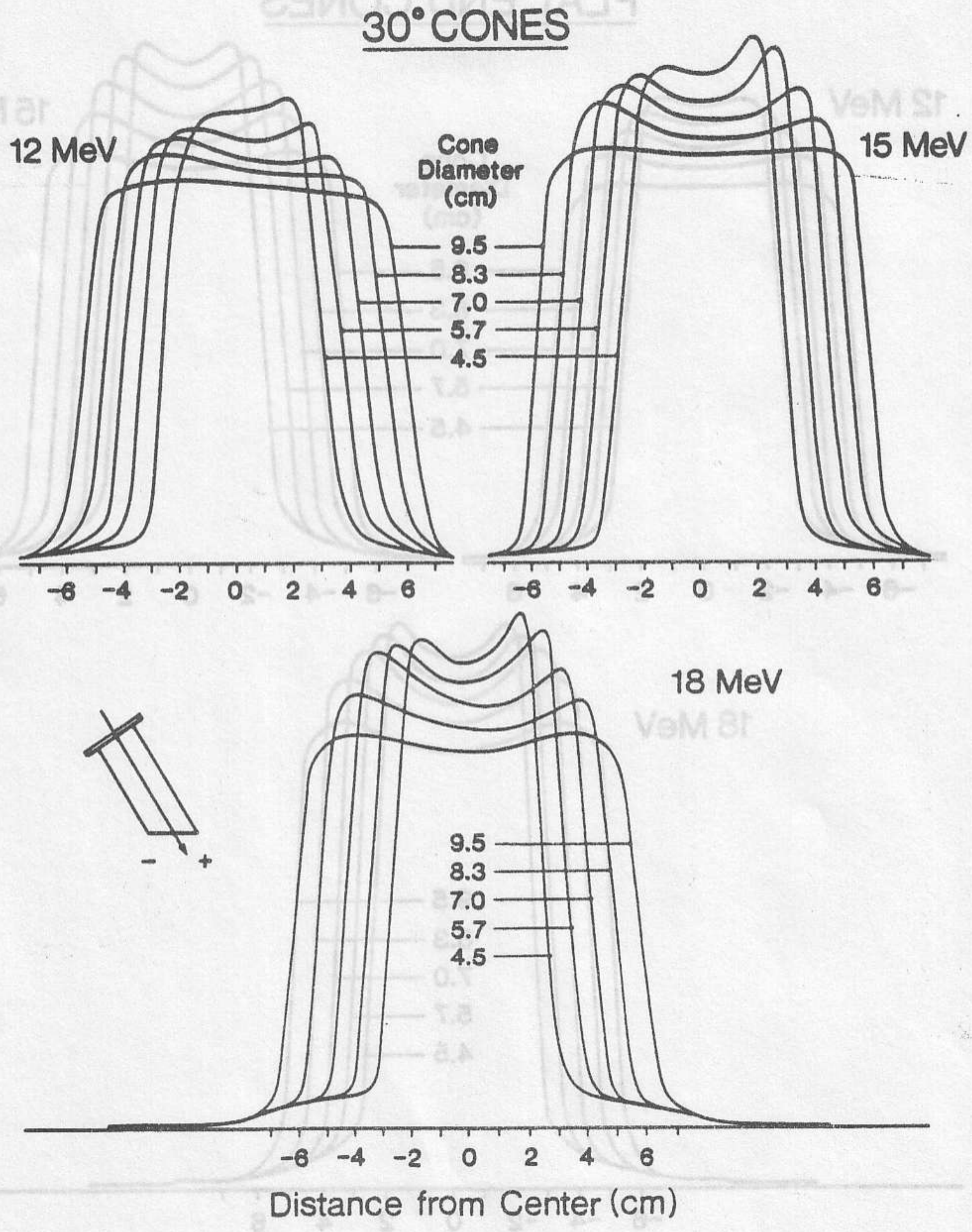

FIG. 15 BEAM PROFILES FOR THE 30° BEVELED CONES FOR ENERGIES OF 12, 15, AND 18 MEV. COLLIMATOR SETTING IS 10 x 10 CM.

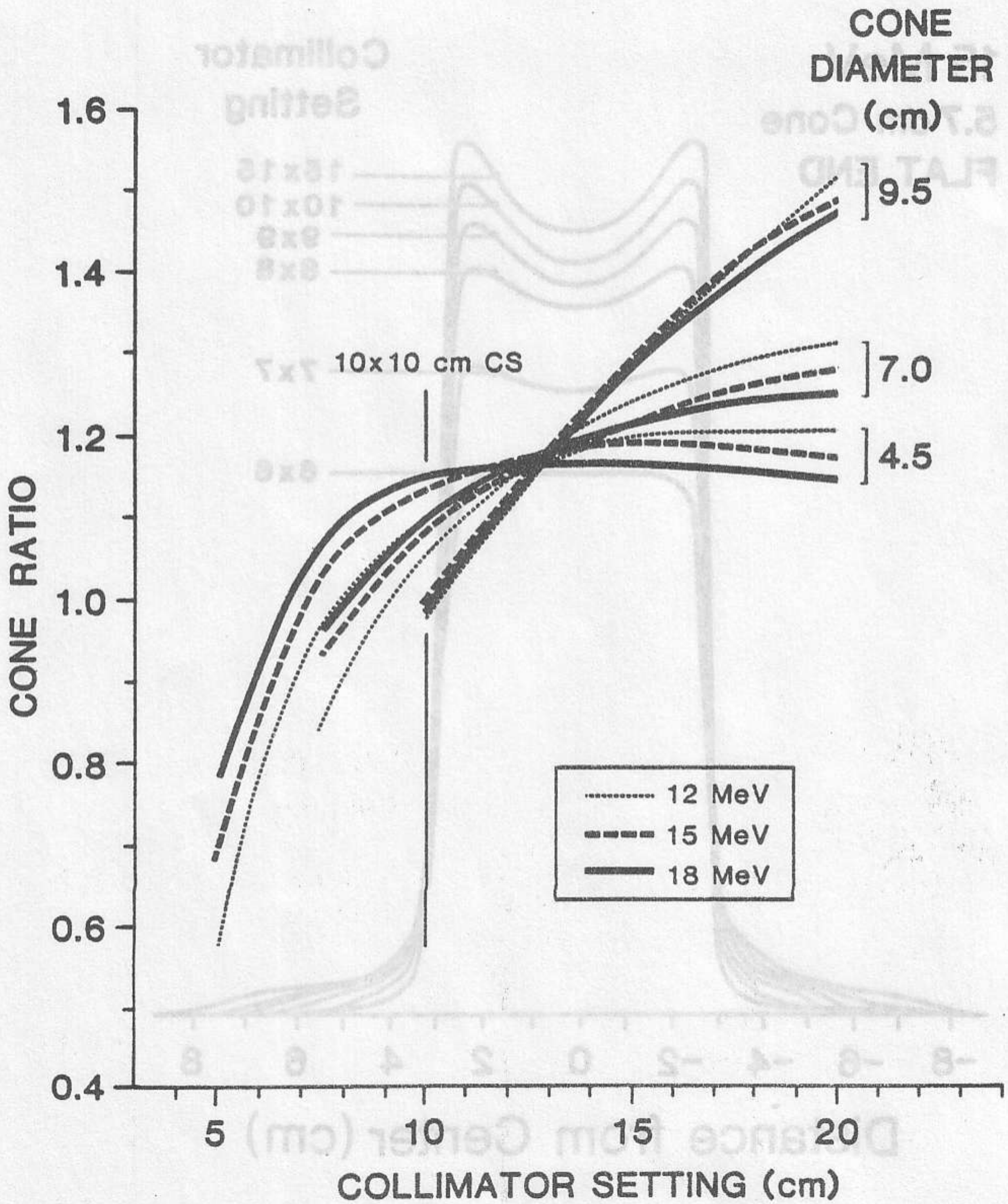

FIG. 16 VARIATION OF CONE RATIO WITH COLLIMATOR SETTING FOR 12, 15, AND 18 MEV ELECTRONS.

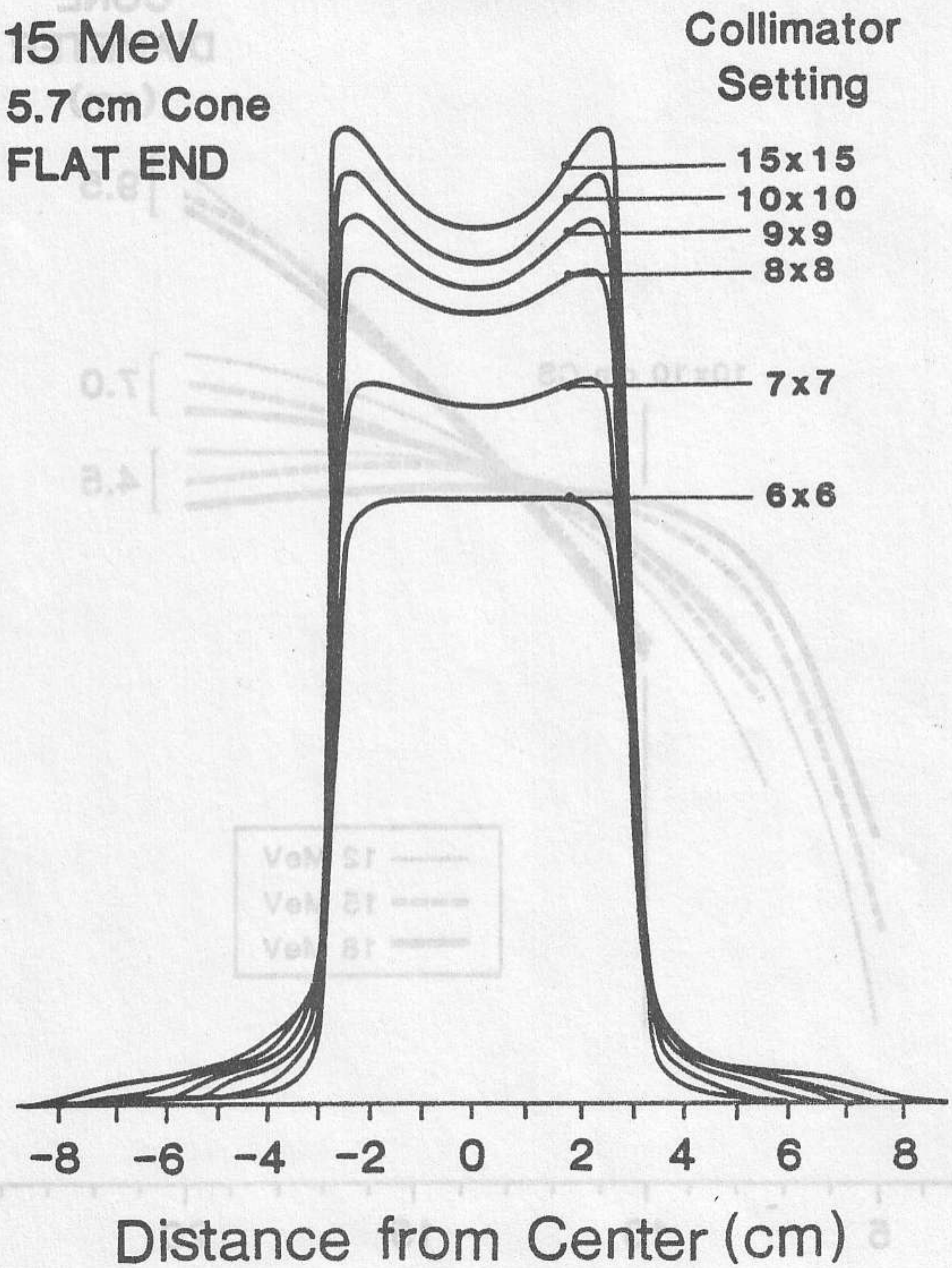

FIG. 17 BEAM PROFILES FOR 5.7 CM FLAT END CONE, 15 MEV ELECTRONS, SHOWING EFFECT OF COLLIMATOR SETTING ON FLATNESS AND OUTPUT.