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INHERENT SPIRAL STABILITY IN A FIXED WING AIRCRAFT BY MEANS OF A SIMPLIFIED PNEUMATIC WING TIP CONTROL SYSTEM

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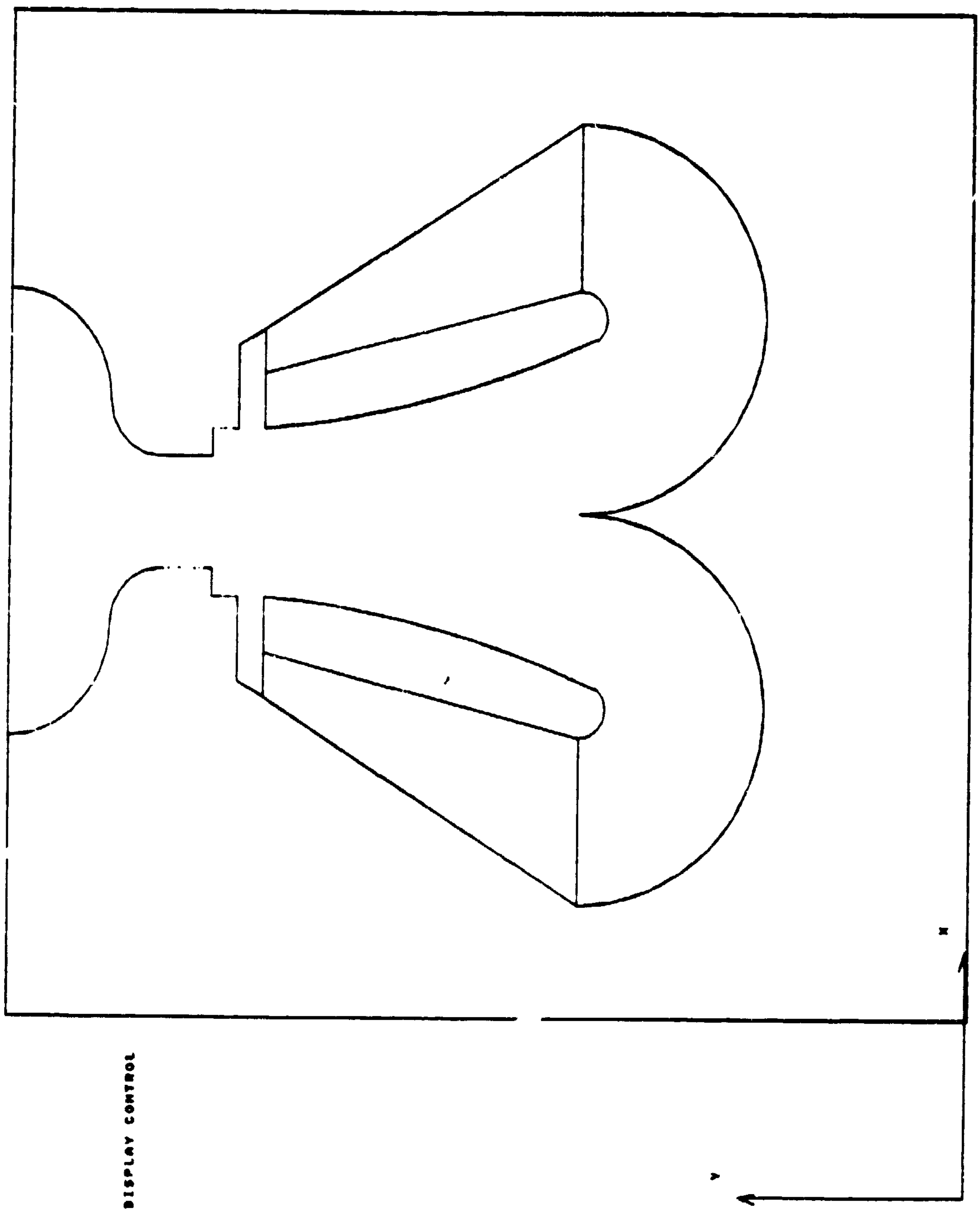

Figure 2. $\frac{1''}{8}$ amplifier.

INHERENT SPIRAL STABILITY IN A FIXED WING AIRCRAFT BY MEANS OF A SIMPLIFIED PNEUMATIC WING TIP CONTROL SYSTEM

By

G.L. Goglia[1] and B.K. Arunkumar[2]

INTRODUCTION

The lateralizer wings leveller system is an aerodynamic spiral stability signal system without a gyro. The lateralizer is simple, reliable and requires less maintenance and these are the reasons for its continued use over the last two decades.

The concept of the "lateralizer" device is to sense the difference in wing tip static pressures (differential pressures being created by wing tip venturis) produced when any deviation from straight to level flight occurs. In a steady state turn the low slow wing tip experiences less venturi suction than the high fast wing tip. This signal activates the appropriate servos connected to the ailerons to produce a wing leveling restoring moment. If the wing is subjected to rolling velocities due to changes of the local angle of attack at the tip, the downgoing wing tip operates at a higher angle than the upgoing one. If with an increase in the angle of attack the signal is such that it increases the venturi pressure, then the servos are activated to produce the most negative signal to an upgoing aileron which results in a wing leveling restoring moment. In other words, any deviation from straight and level flight in either roll or yaw is exploited and the difference signal from the differential pressures activates the servo to effect or produce the necessary corrective action to null the signal.

As mentioned earlier for the lateralizer to function it depends on pneumatic mechanical interconnect with the primary controls of the aircraft

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and depends on engine vacuum servo power. It is known that on the servo side of the system it uses moving parts which contribute to obvious disadvantages.

The principal object is to avoid the above mechanical difficulties by trying to get an all practical fluidics wings leveller system. In order to increase the inherent safety, simplicity and reliability of the lateraliser the magnitude of the pressures sensed should be amplified to such an extent that would permit them to drive a moderate size servo directly. The all practical fluidics wings leveller system should (1) provide acceptable roll out performance and fast response in turbulence; and (2) should provide reliability which matches the aircraft's primary control systems.

RAM TIP JET VORTEX ROLL CONTROL SYSTEM

In an effort to achieve the above mentioned all fluidics wings leveller system, Roger Griswold II did some flight investigations of the "Ram Tip Jet Vortex Roll Control System." A short span wing tip was modified to incorporate the leading edge which is circular in shape as the ram pressure inlet with internal ducting which lead to dual chordwise slots aft of midchord and having a vane normally open to direct the discharge overboard to discharge the jet inboard over the upper surface of the wing manual controls are provided in the cabin of the aircraft. The main function of the RTJ vortex roll control is to effect the spanwise control of the wing tip vortex. When the jet is discharged outwardly or overboard automatically low drag and high lift are automatically produced while effectively maintaining the geometric aspect ratio of the wing (ratio of the square of the span to its mean chord). When the jet is discharged inboard by manually operating the controls from the cabin, it moves the origin of the vortex appreciably inboard with resultant loss of wing lift and effective aspect ratio. This increases drag to provide differential roll with favorable yaw when operated asymmetrically. The switching of the jet from overboard (wings level, neutral position of the slot control vane) to inboard spoiler action can be done by manual operation from the cabin of the aircraft. As is evident the system is merely restricted to flight induced ram pressure. Higher or better performances will depend on mass flow. For the setup to be acceptable, a proporational amplifier of high flow gain type is needed.

For the application of RTJ Vortex roll control, an extended wing tip is preferred so as to avoid interference of aileron, to provide sufficient tip jet mass flow and for sufficient space for the fluidic valve components.

Investigations by Roger Griswold II (refs. 1,2) have yielded that the performance of the standardized lateralizer wings leveller system in cruise. It has yielded the validity of fluidic roll control (no gyro and potentially no moving parts) to provide inherent spiral stability. Indications are that provided with high flow gain and an on/off automatic signal actuation an all fluidic system may achieve adequate and perhaps acceptable wings leveller performance. However, the dynamic flight characteristics of a complete system, a prerequisite for satisfactory response in turbulence are yet to be proven in flight.

OBJECTIVE

TO DEVELOP A NON VENTED AMPLIFIER WHICH IS PROPORTIONAL AND HAS A HIGH FLOW GAIN

Different amplifiers were designed to observe the behaviour of various configurations. Two things are to be borne in mind while considering the design of the amplifiers. (1) Most conventional amplifiers are designed usually for pressure gain (we are looking for flow gain); and (2) most amplifiers have vents, the function of which is to minimize the effect of loading and provide air escape path for the excess fluid in the power stream The vents are usually at constant atmospheric pressure conditions. However during flight it is not possible to have a vented amplifier as there is no reference base.

DESIGN AND DEVELOPMENT OF THE AMPLIFIER

Operating Principle. Typically the power stream is issued through the throat of the amplifier and if not deflected the centerline of the powerstream will strike the splitter. Half of the powerstream exits out of the right output leg and the other half of the powerstream exits through the left output post. Now if a pressure or flow difference is applied through the control posts, the resulting momentum flow will deflect the power stream If the higher flow is applied to the right control post the stream will be deflected so that more flow goes out of the left output post than the right output post.

The angle of deflection of the power stream due to the resulting momentum flow is proportional to the differential flows and pressures applied between the control posts. The power stream can be deflected so that all of it goes out of the left output post and none goes out the right output post.

The basis for the amplifier develnpment has been the non vented value. The power jet velocity is directed by the momentum from the control jets. The receivers or the output legs are placed at the center of the straight sections so that the change of flow has a linear relation to the jet deflection.

The design variables are the nozzle size ratio, receiver position downstream, receiver width, and possibly the downstream load on file. The dimensions are normalized by relating these dimensions to the power nozzle width.

The design of a fluid amplifier can be determined by a trial and error process, however the usual embodiments of the device do not easily level themselves to variable geometry modeling which permits single variable experiments. A good experimental investigation requires a large number of relatively expensive models for each design change. For the above mentioned reason are first few amplifiers were made of foam material and the silhouette obtained by using a hot wire. The earlier testing was done using these these models the dimensions the dimensions of which were not really accurate compared to the drawings.

However these amplifiers when tested in the laboratory remained proportional and gave us further encouragement to get it fabricated.

In order to get the required flow amplification for precipitating the wing tip vortex appreciably inward, the amplifiers would have to be staged together. R.F. Hellbaum (ref.3) has known that cascading amplifiers (laminar, proportional) gave a very high pressure amplification (in the order of 2,000,000) and a similar principle is to be tried for flow amplification.

The staging of the amplifiers would make the drawing very complicated and does not clearly give a complete description for it to be fabricated. To get a better view and a clearer description of the three dimensional views of the amplifiers. Computer aided drafting was resorted to. The drawings were completed for all the different stages of the amplifiers. One of the main advantages of using computer aided drafting is it has the capability of not only displaying the different views but also to rotate and move the object enabling better comprehension by the designer and fabrications. Any changes in the design can be quickly accomplished. The concept of staging of the amplifiers can be very clearly viewed.

The amplifiers fabricated should be tested in the laboratory keeping in mind flow gain and proportionality. The following stages should be tested (1) 1/8" (fig.2) will be staged with 1/2" (fig.3), 2" (fig.4) and 8" (fig. 5). The control air will be supplied through the control posts of the 1/8" amplifier. The output of the 1/8" amplifier will act as the control air for the 1/2" amplifier and the output of 1/2" amplifier will be the con-air for the 2"amplifier. The output of the 2" amplifier will act as the control air for the 8" output stage. Based on the investigations done on the earlier foam models every stage would have an amplification factor of 4.

(2) Similar staging should be tried for the same amplifiers with a slight increase in the area of the separator ramp as shown in figure 10. Since every stage would have an amplification factor of 4, hence the need for an increased area for the passage of air from one stage to another.

To effect smoother transition from one stage to the other as a result of change in area, transition stages should be used between the amplifiers.

When the amplifiers are staged together, given a supply jet (ram air during flight) and a small control flow (operable from the cabin) the output of the I amplifier will be the control air for the II stage, the output of the II stage will be the control air for the III stage and so on. The output of the last stage should have a very high flow and therefore enough overall flow gain to move the wing tip vortex. When in operation (control signal from the cabin) coupled with a suitable angular rate sensor the output of the amplifier will keep the wings in steady level flight.

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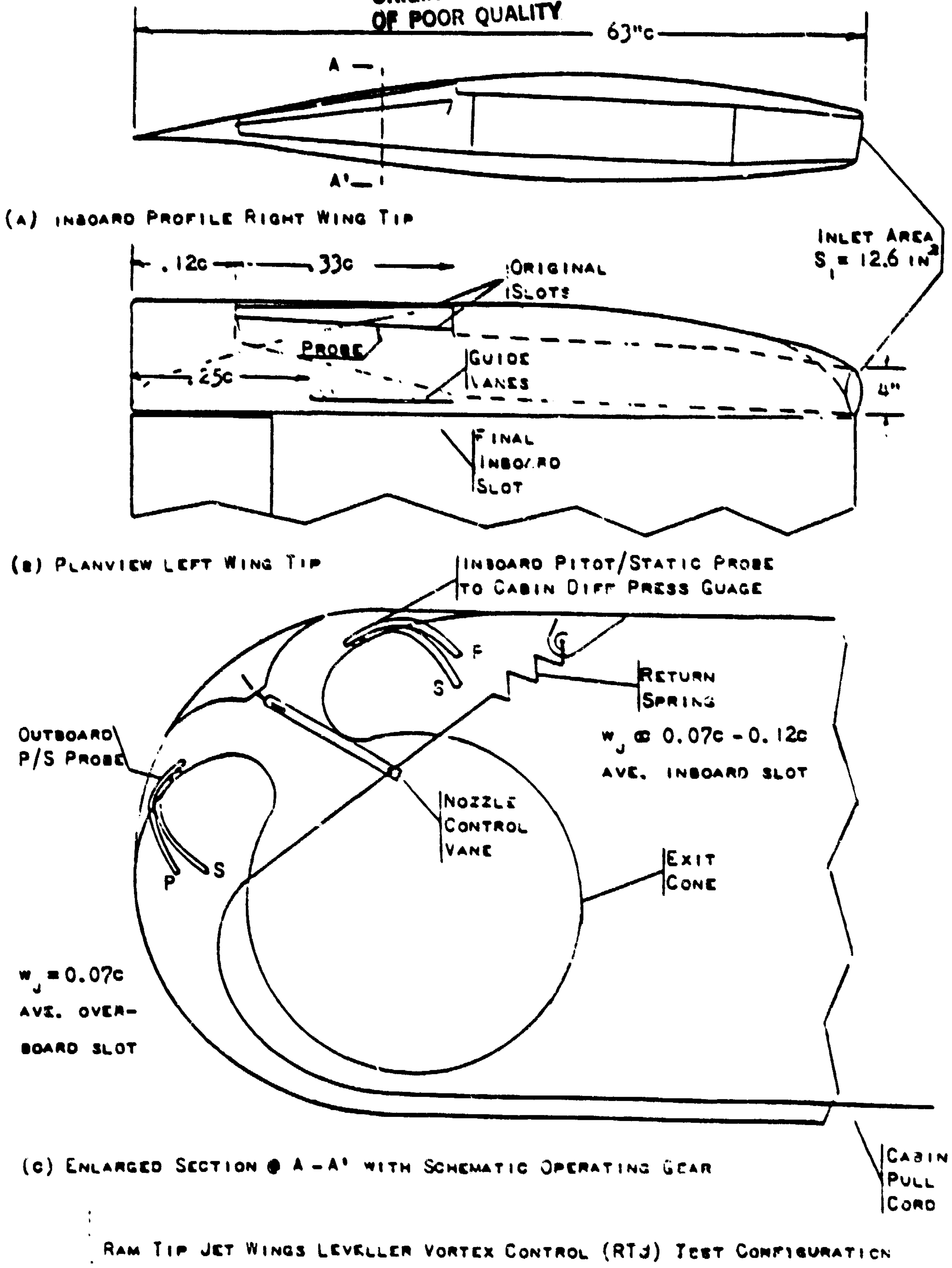

Figure 1. Borrowed from Roger Griswold's paper.

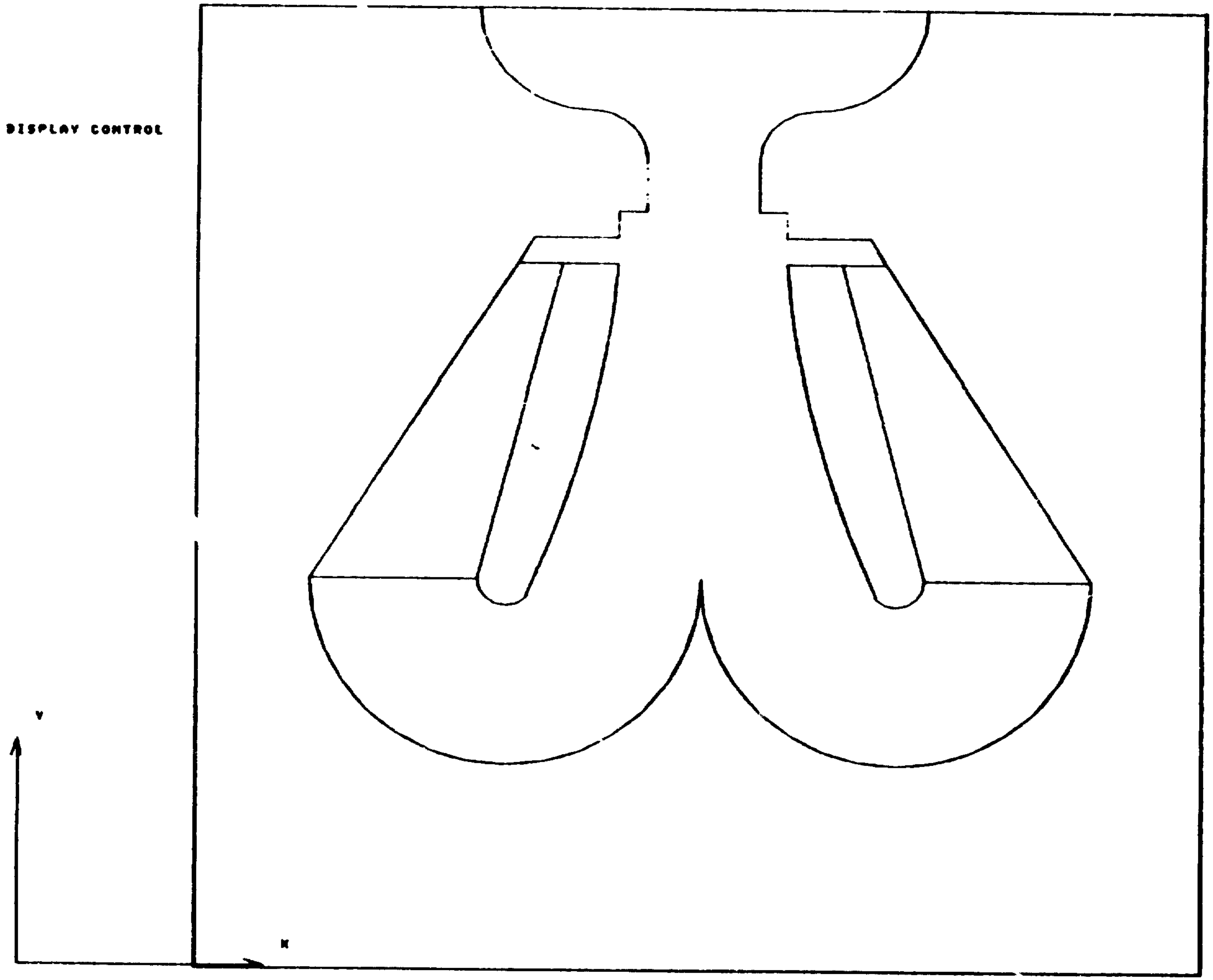

Figure 2. $\frac{1''}{8}$ amplifier.

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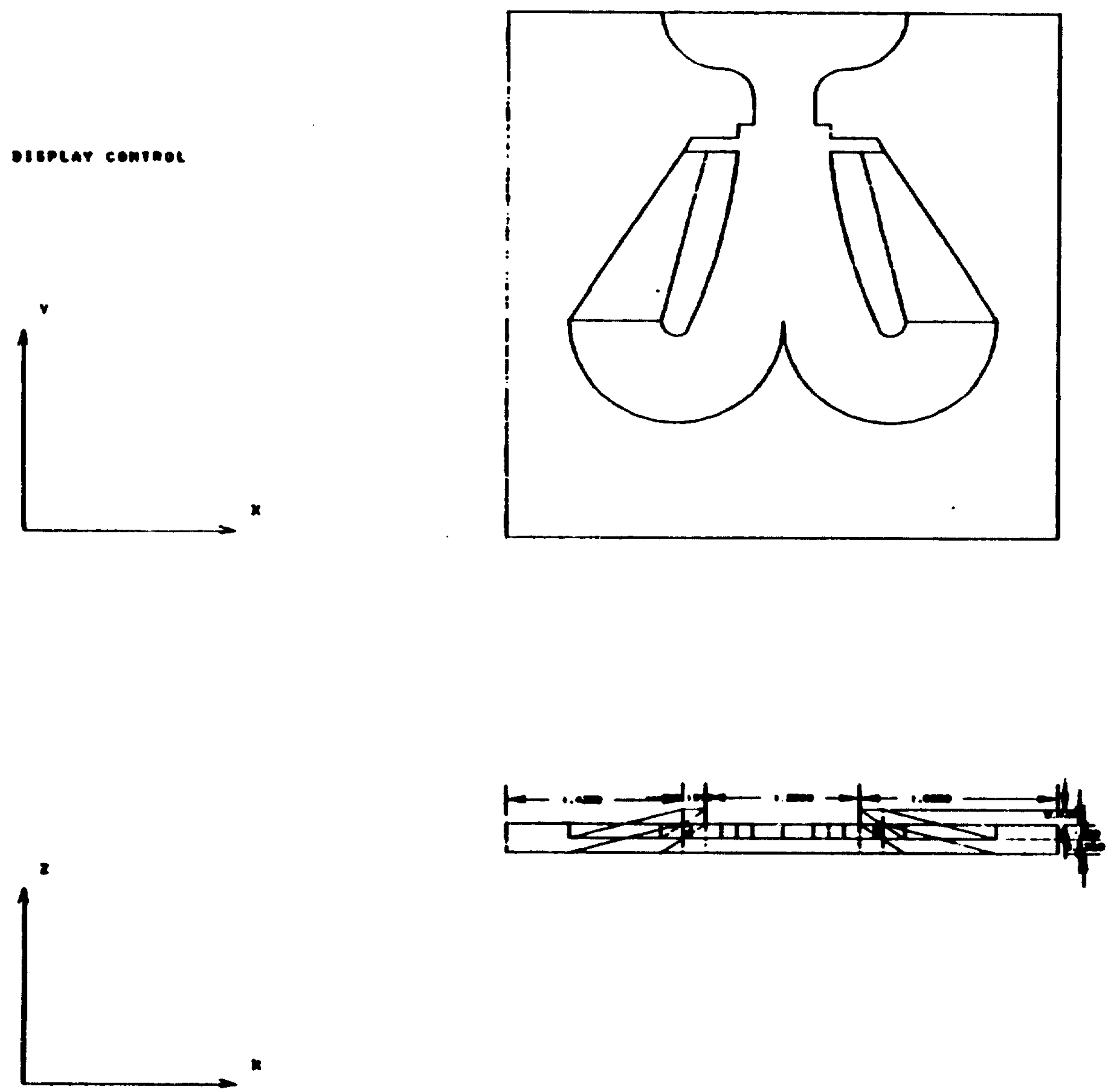

Figure 2(a). $\frac{1"}{8}$ amplifier with $\frac{1"}{8}$ plate.

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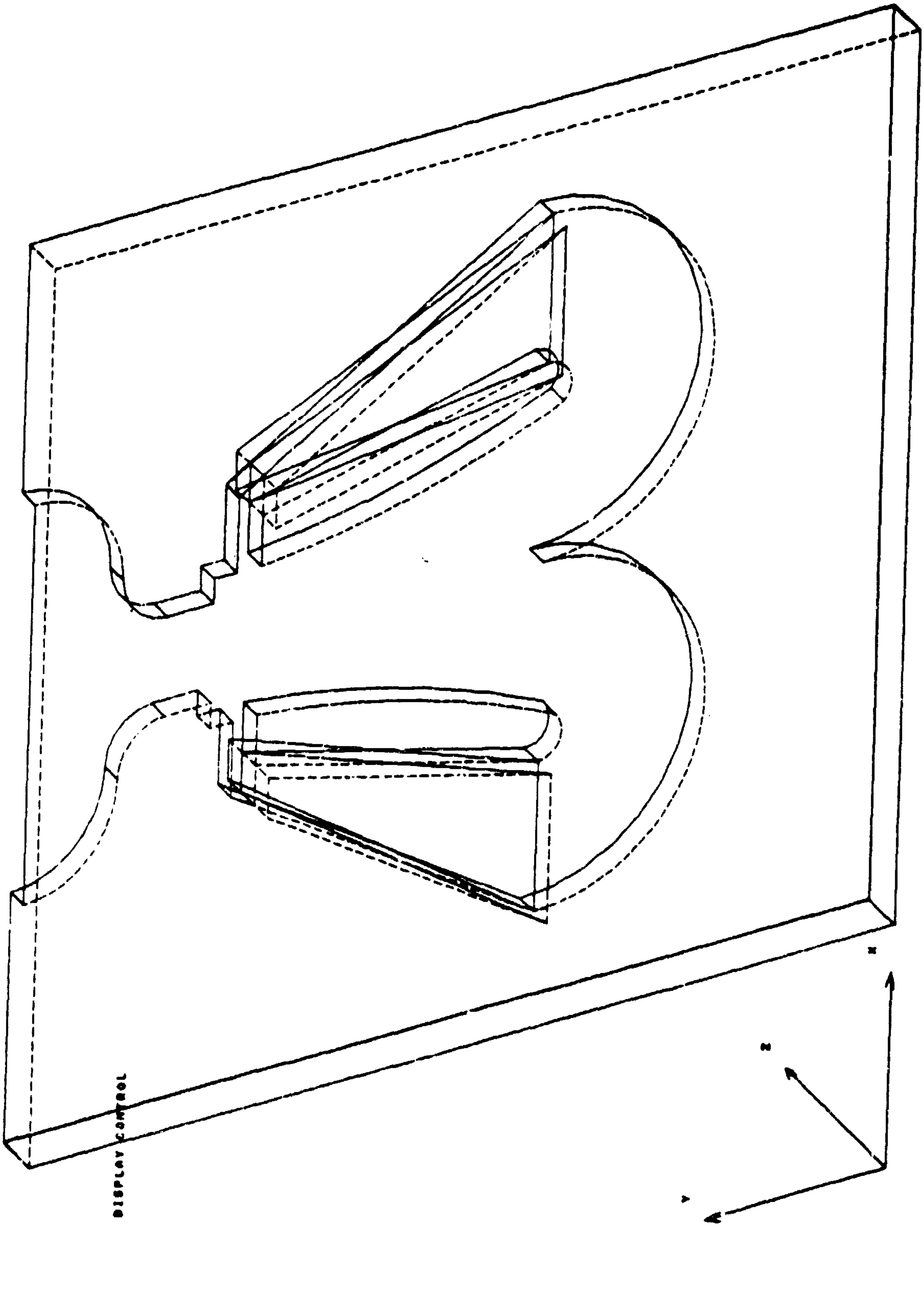

Figure 2 (b). Isometric view of $\frac{1}{8}$" amplifier.

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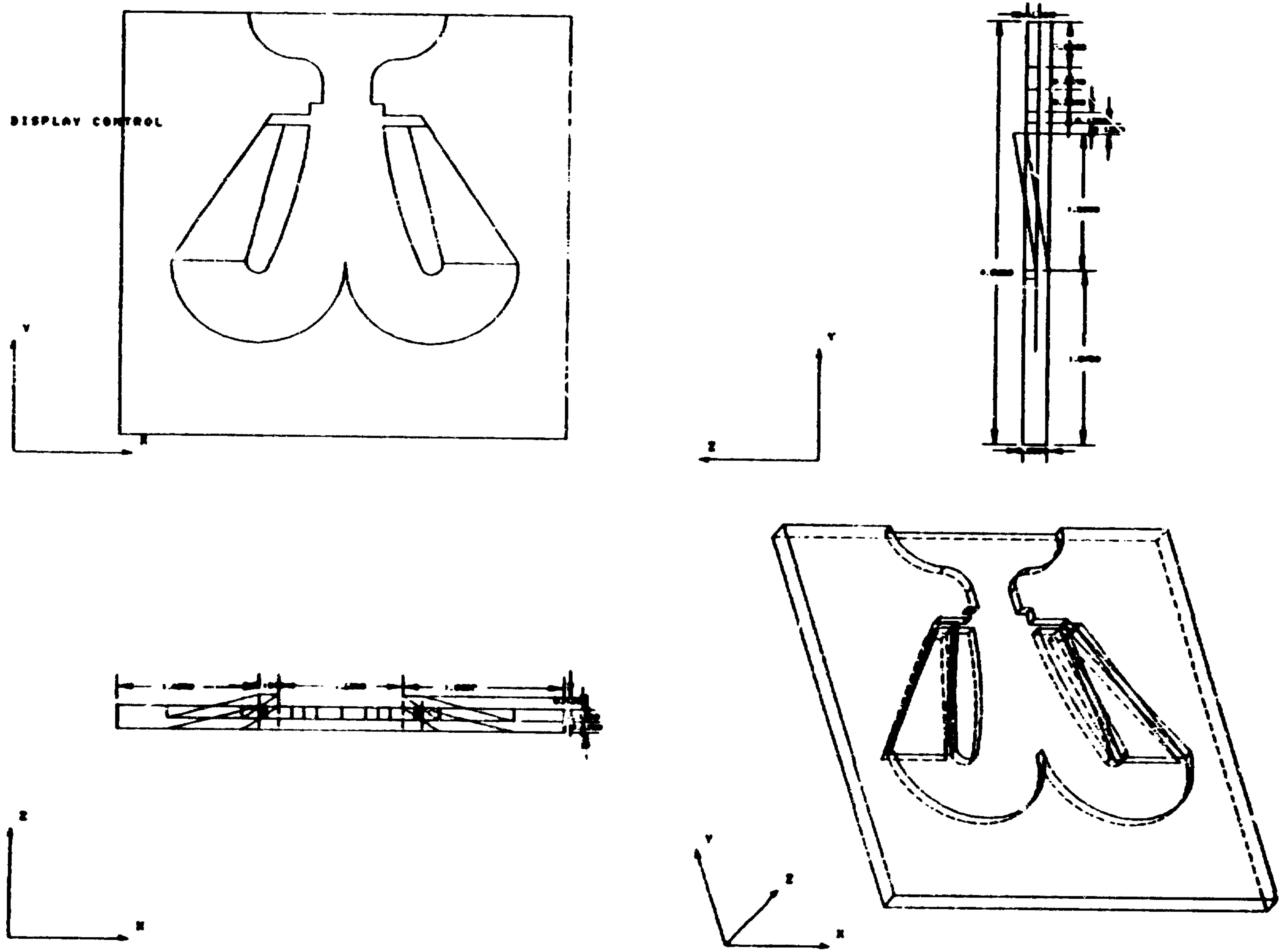

Figure 2(c). $\frac{1''}{8}$ amplifier.

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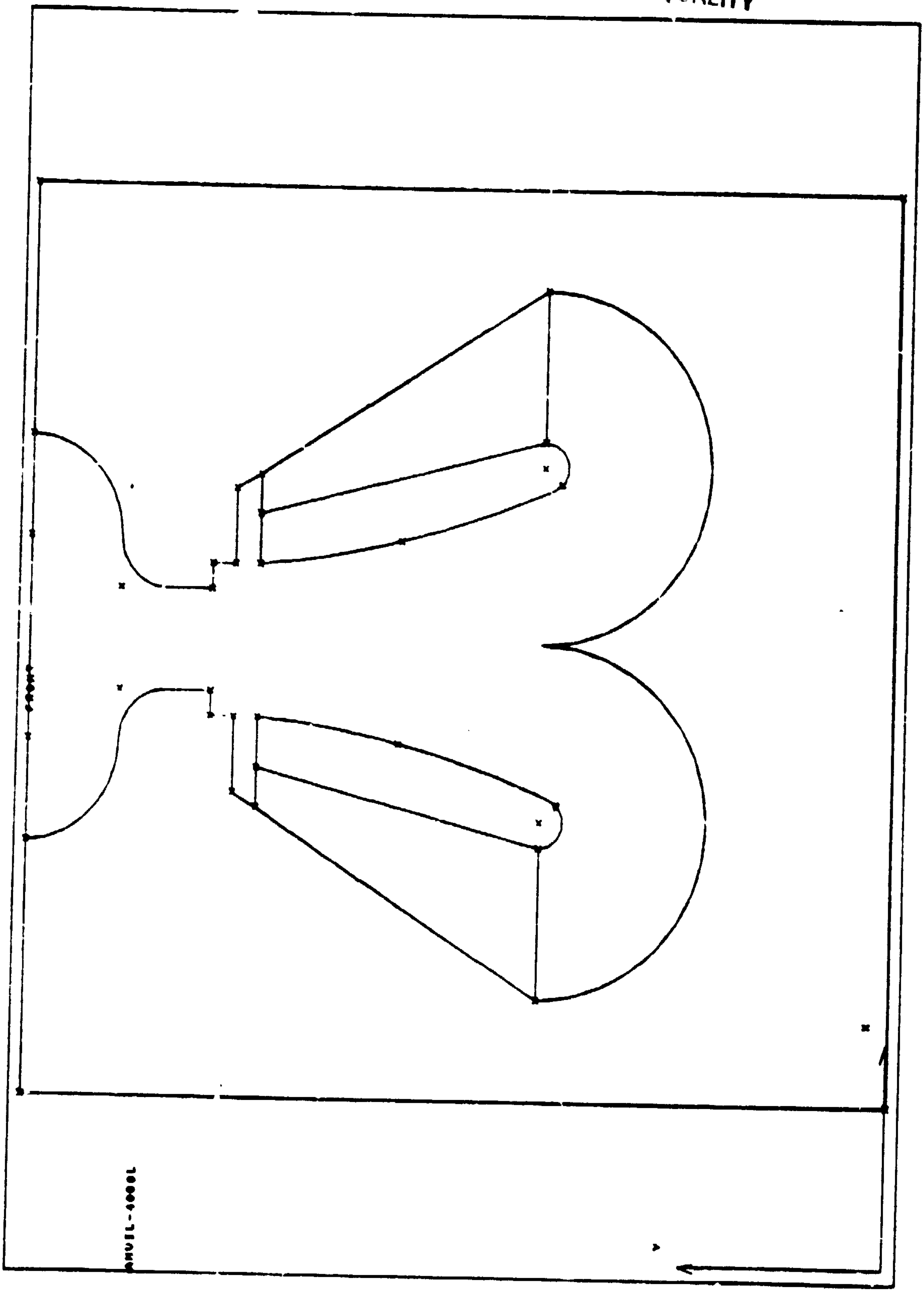

Figure 3. $\frac{1}{2}$" amplifier.

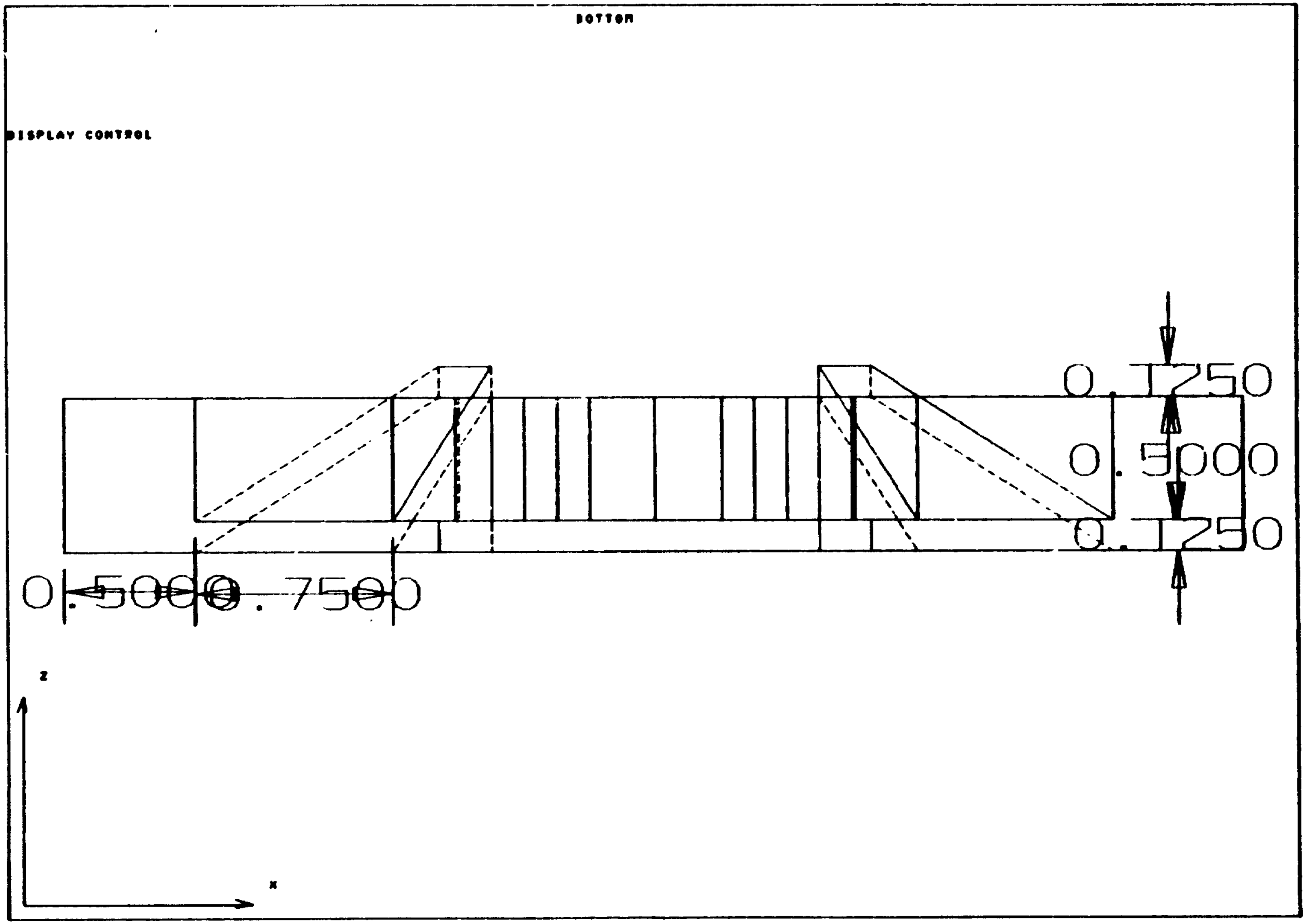

Figure 3(a). $\frac{1}{2}$" amplifier with $\frac{1}{8}$" bottom p ate.

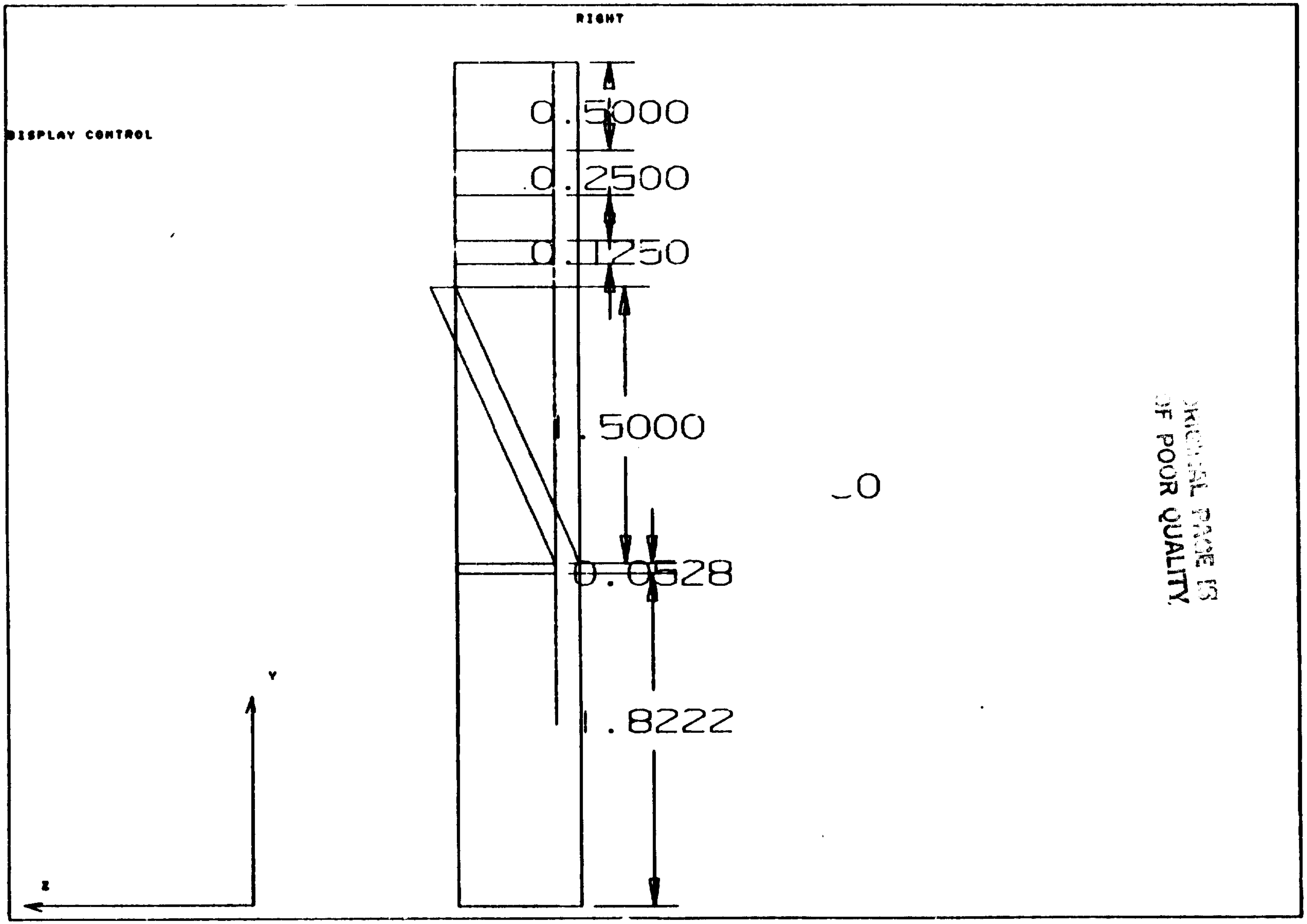

Figure 3 (b). 3D-view of $\frac{1}{8}''$ amplifier.

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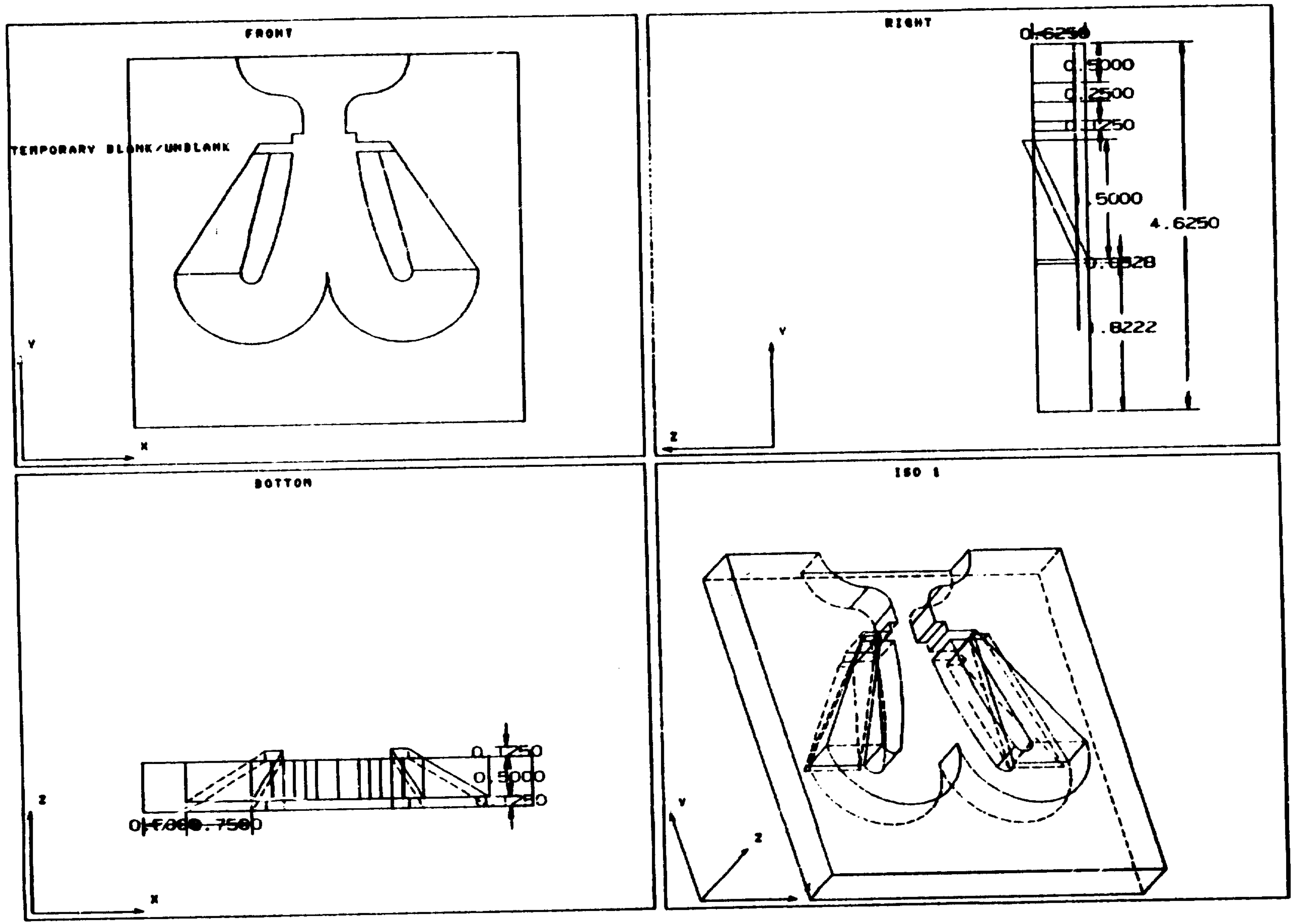

Figure 3(c). $\frac{1}{2}''$ amplifier.

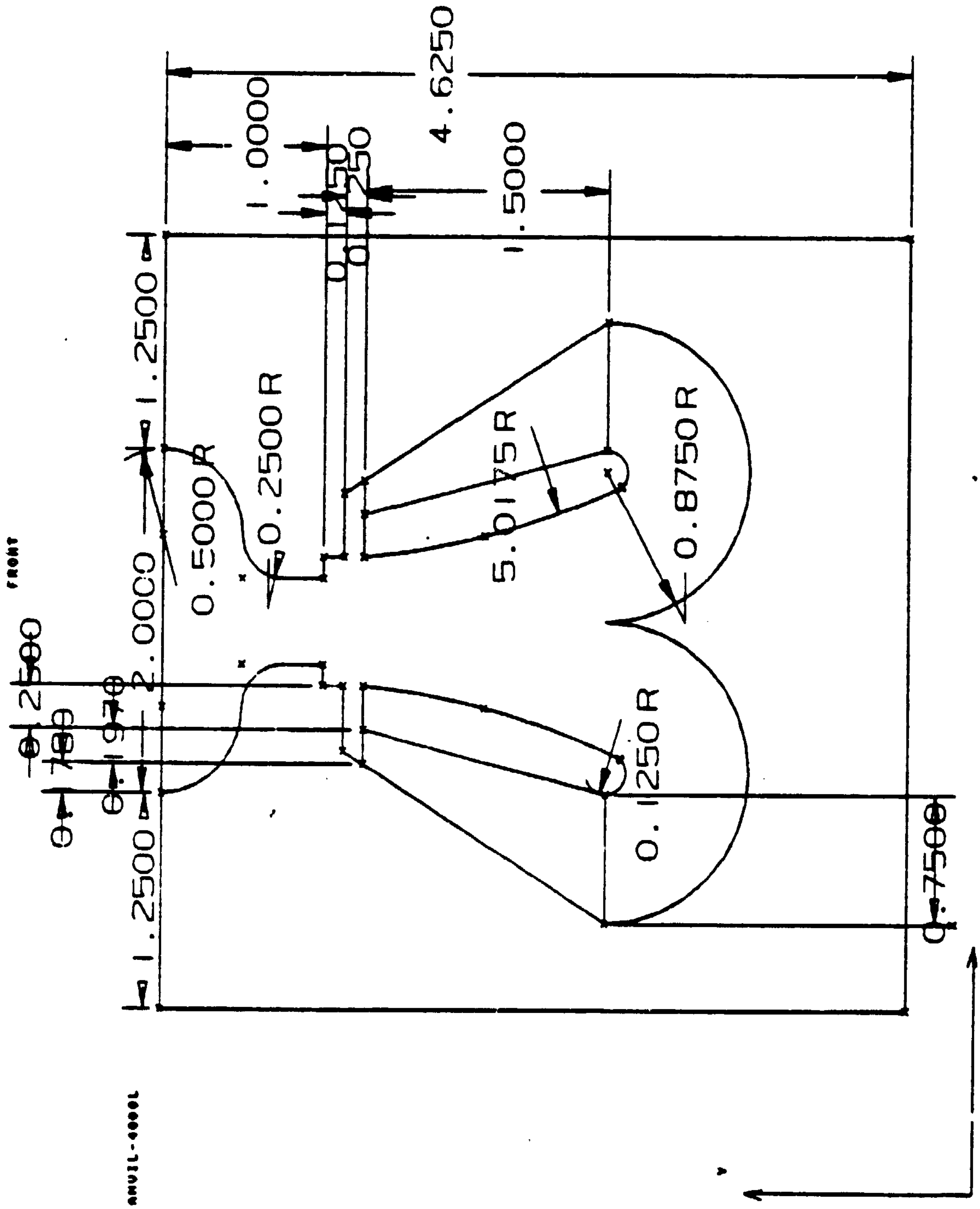

Figure 4. 2" amplifier.

DISPLAY CONTROL

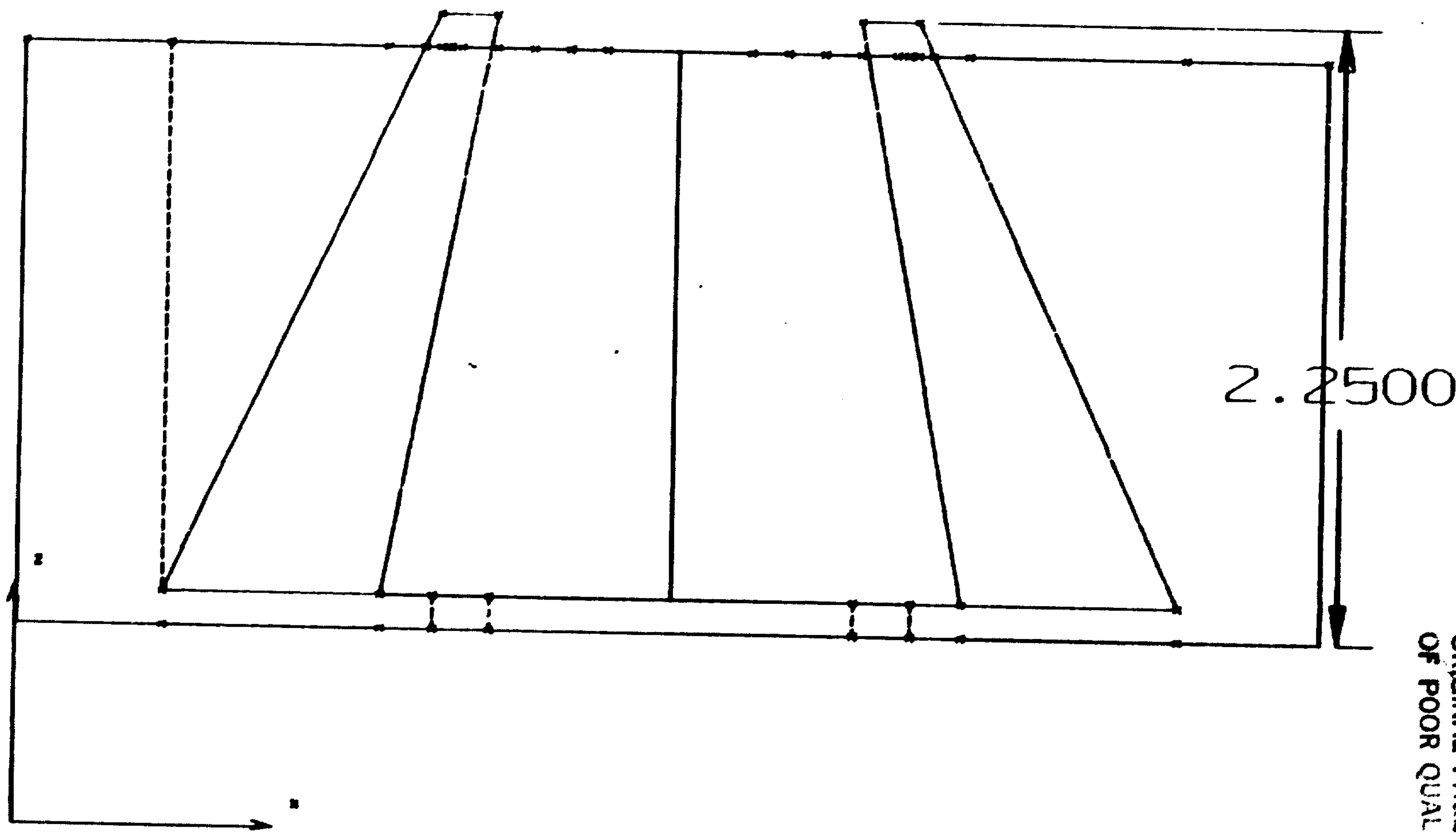

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Figure 4 (a). Bottom view of 2" amplifier with $\frac{1}{8}$" bottom plate.

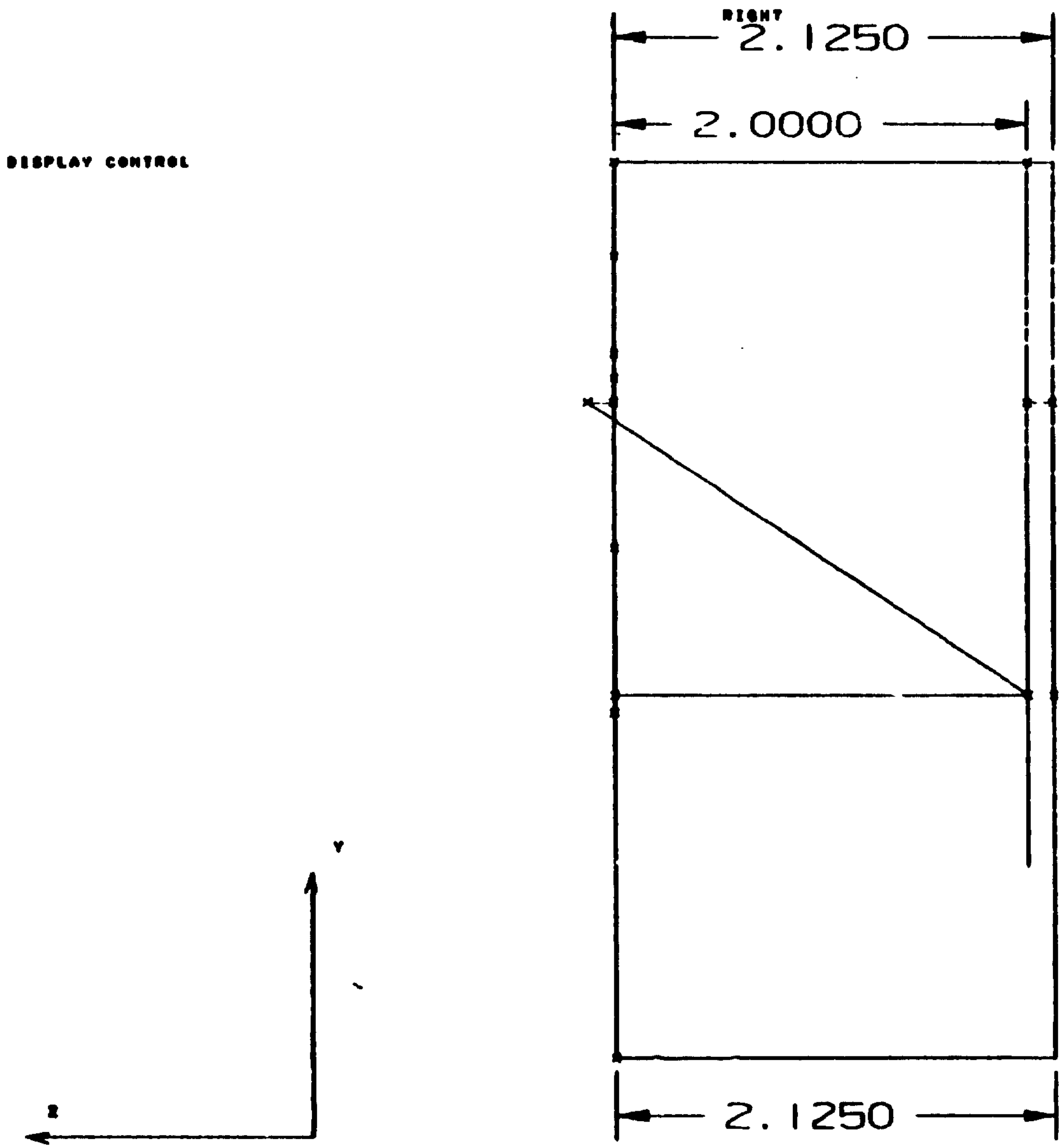

Figure 4(b). 2" amplifier.

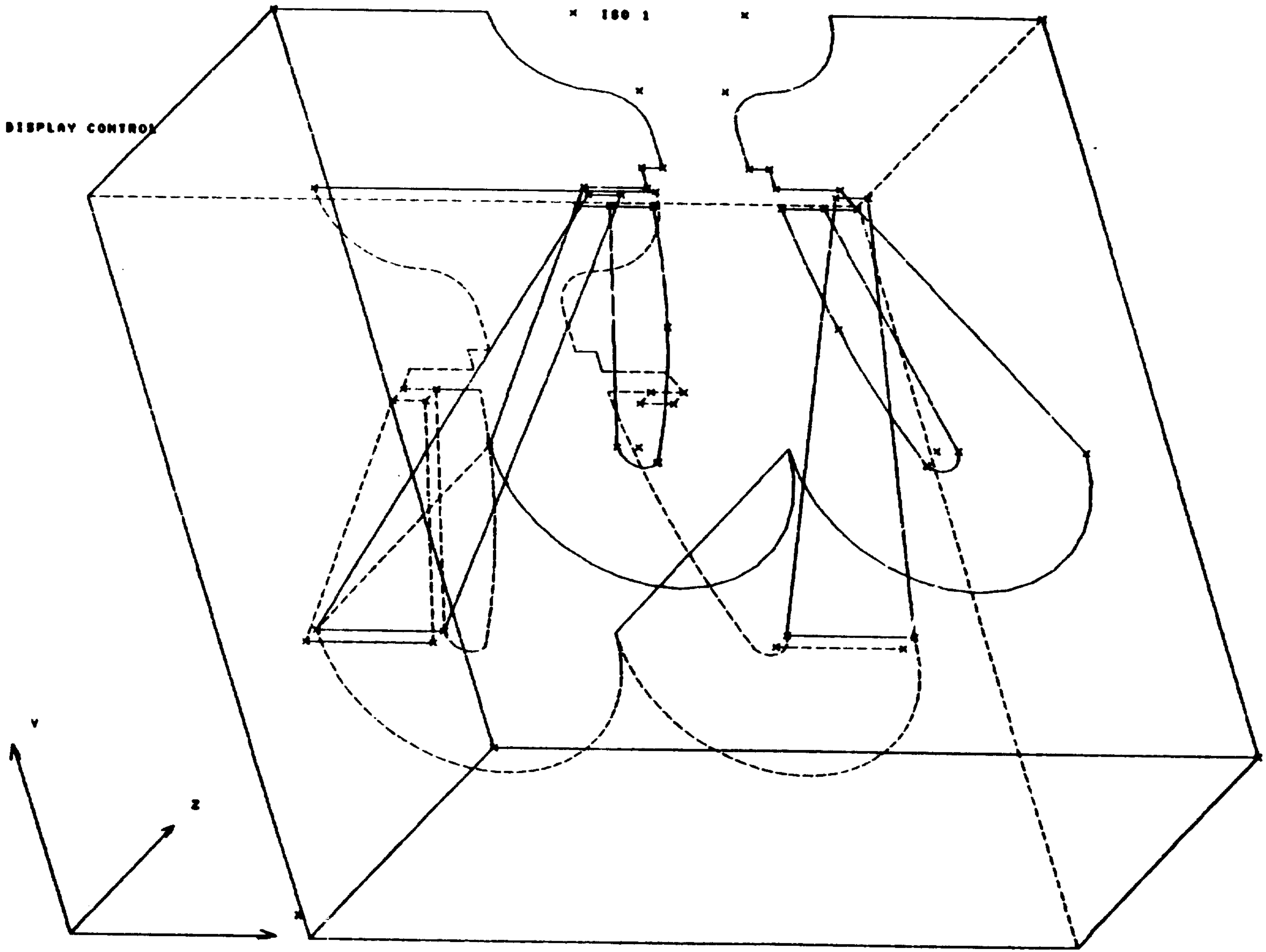

Figure 4 (c). Isometric view of 2" amplifier with some lines blanked for clearer physical understanding.

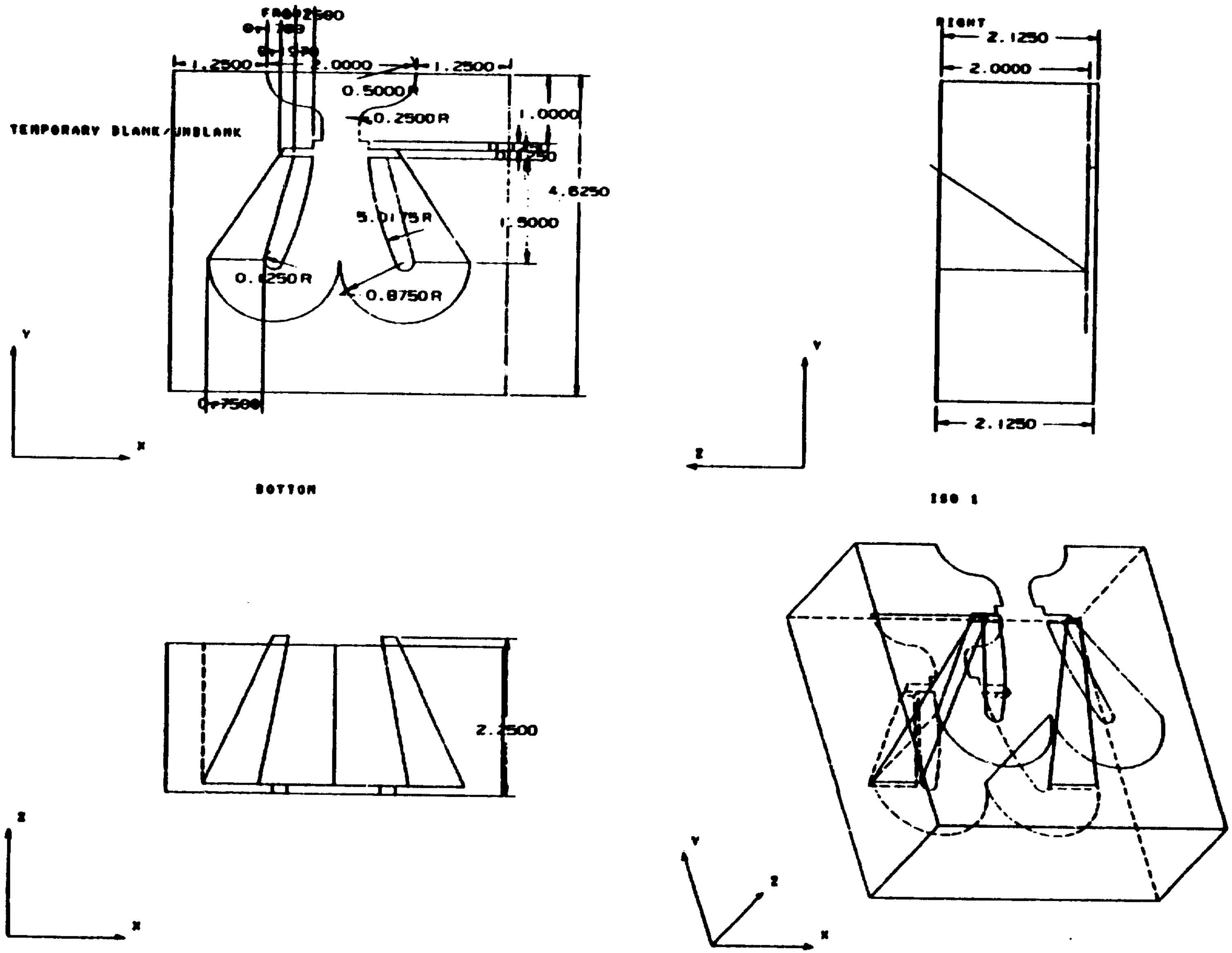

Figure 4(d). 2" amplifier.

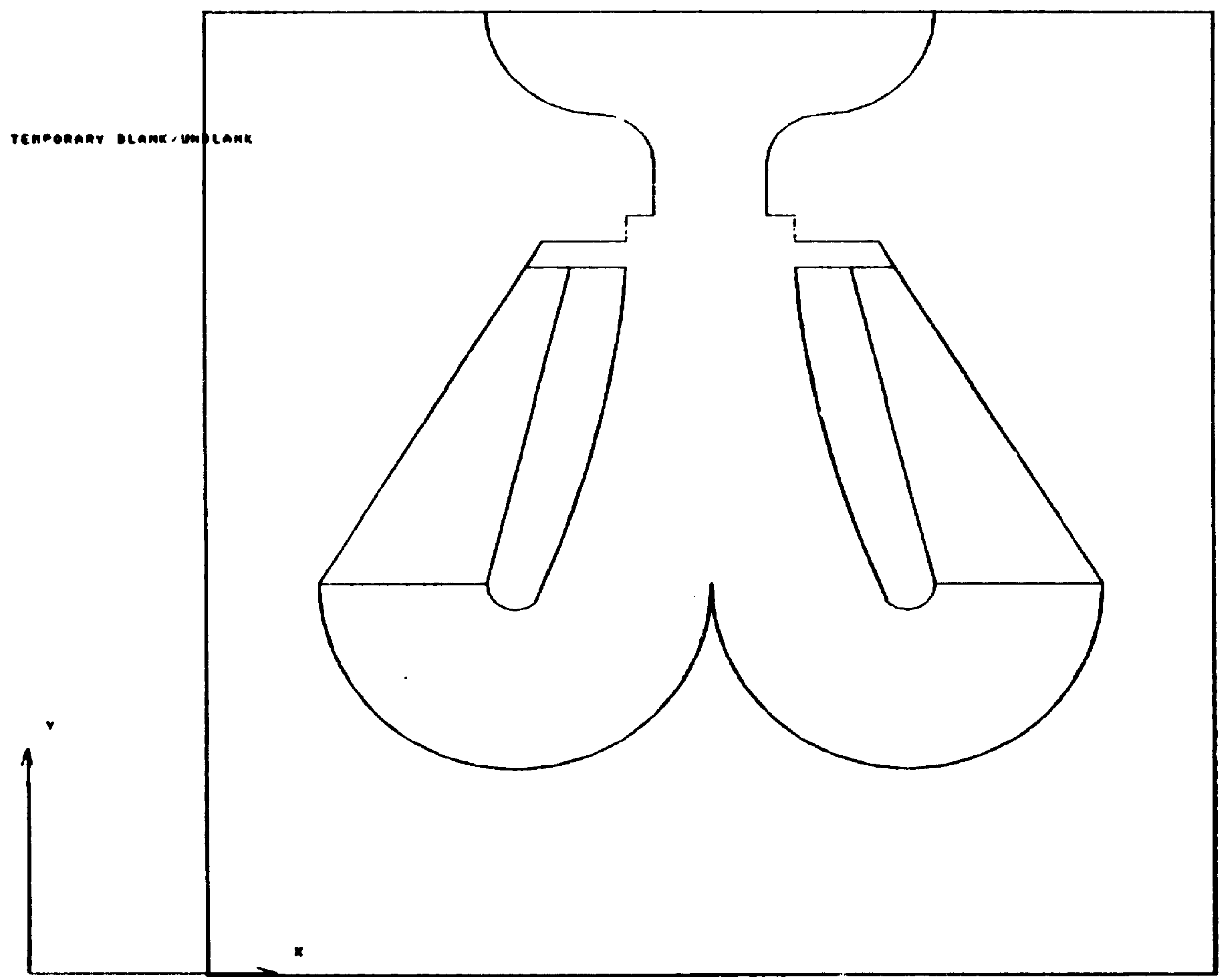

Figure 5. 8" amplifier, front view.

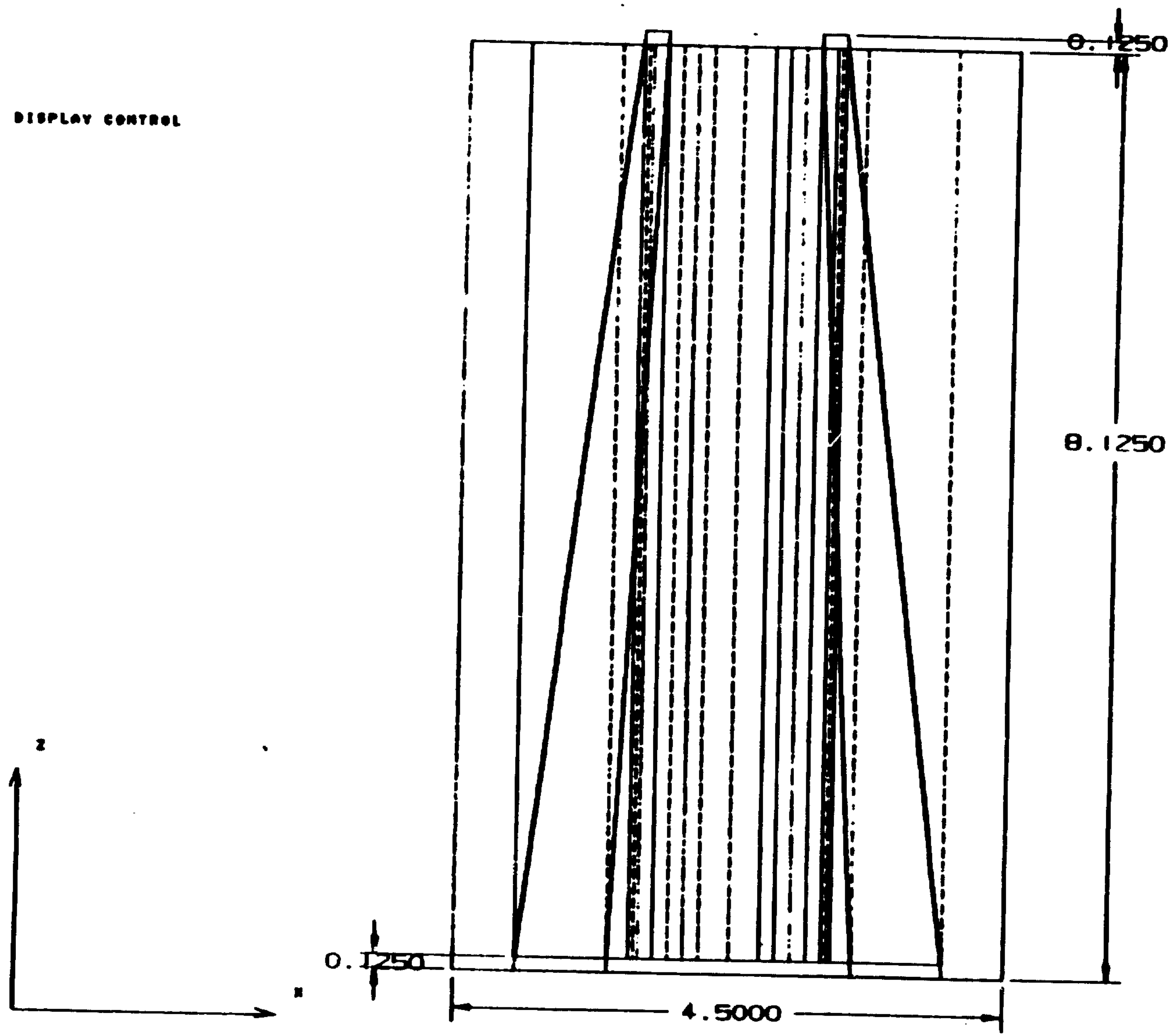

Figure 5 (a). Bottom view, 8" amplifier with 0.125" bottom plate.

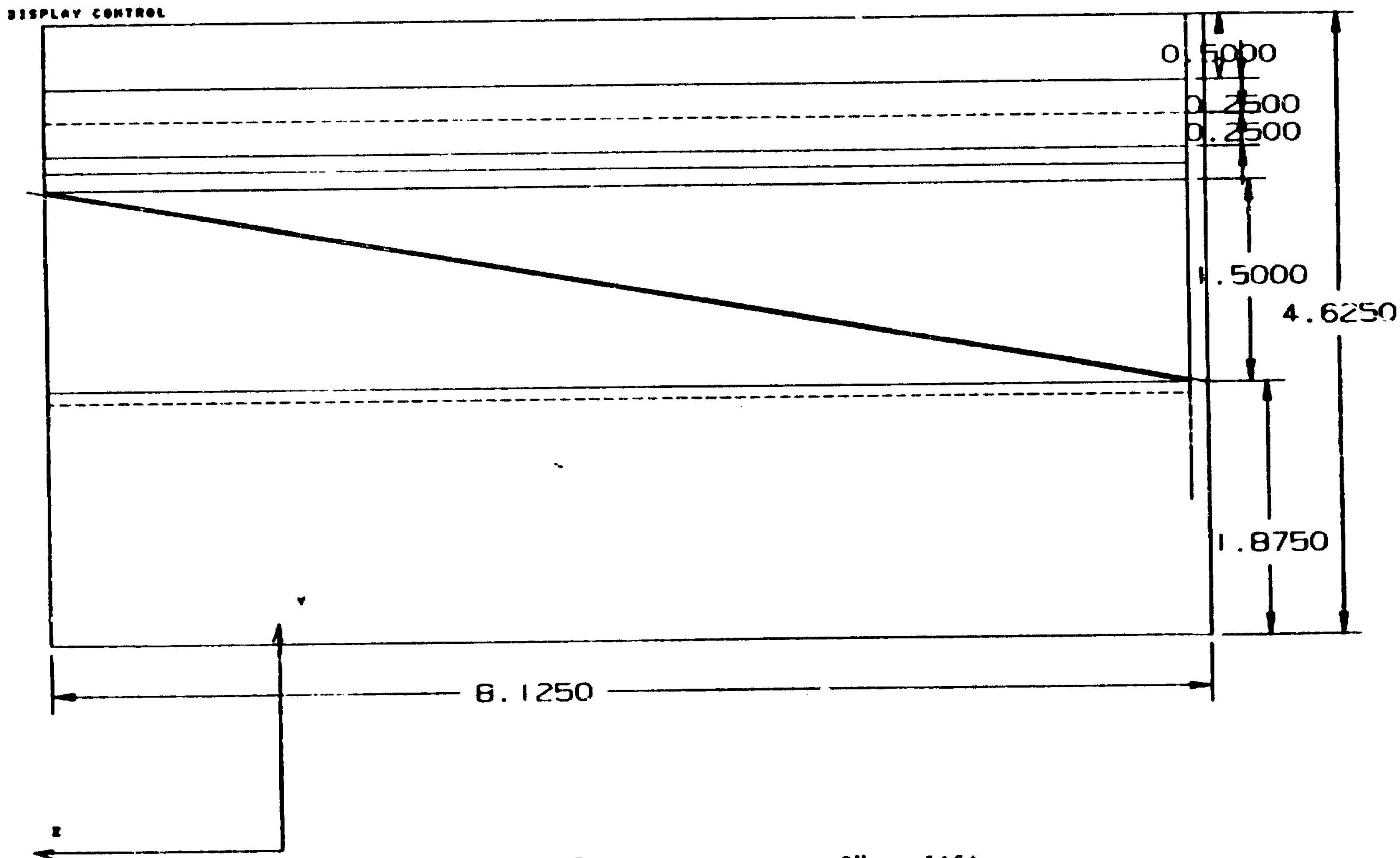

Figure 5(b). Right view, 8" amplifier.

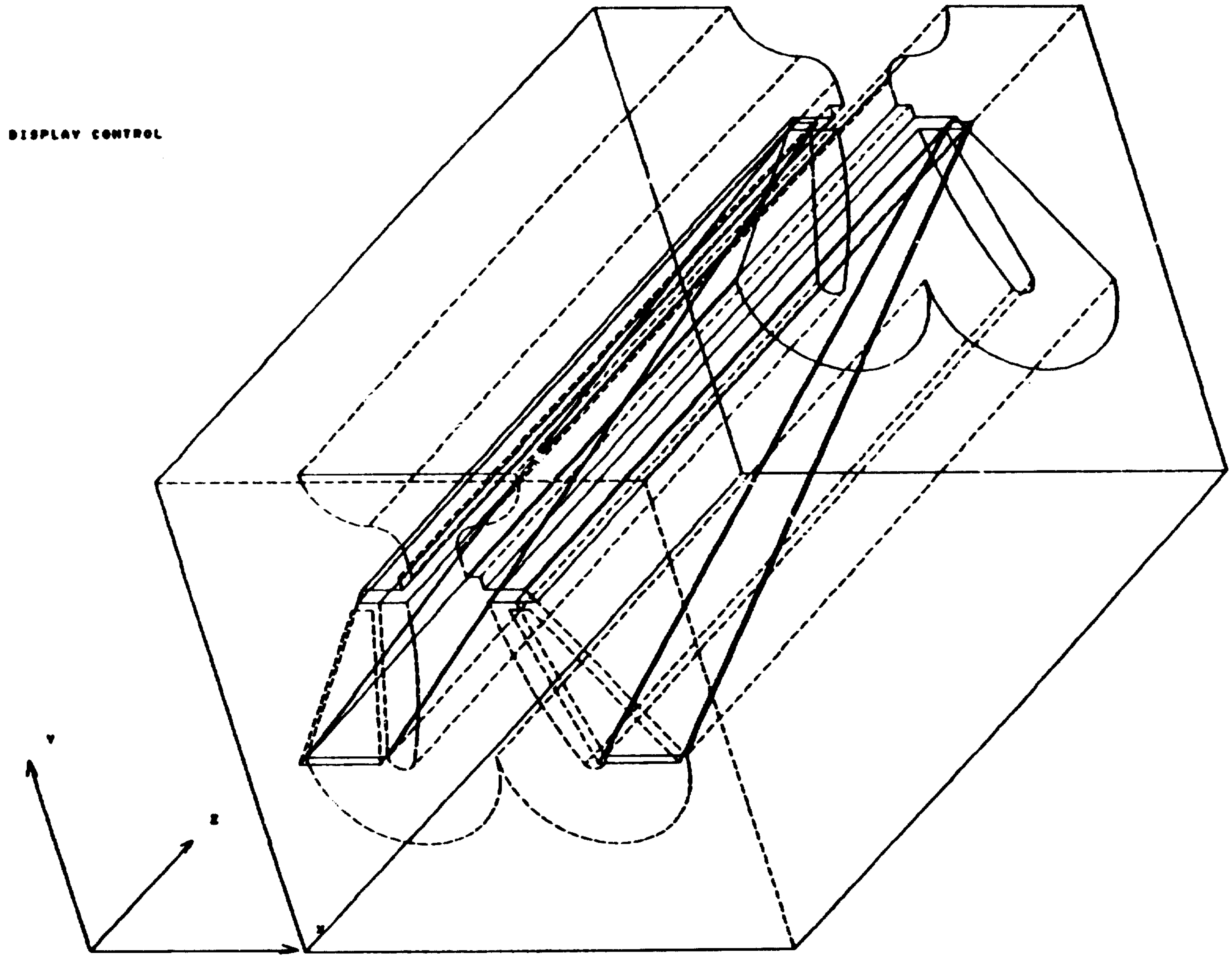

Figure 5 (c). Isometric view, 8" amplifier.

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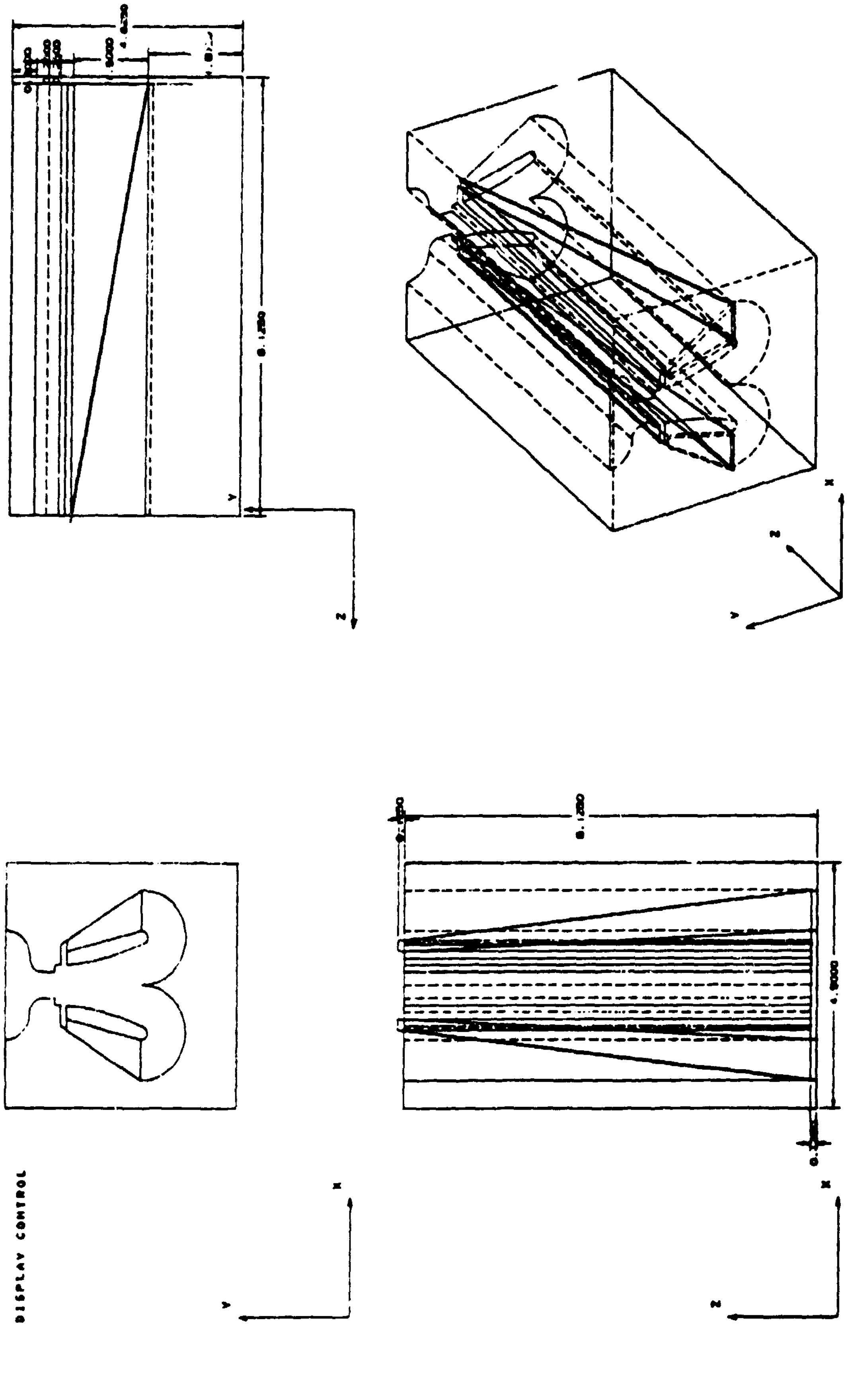

Figure 5(d). 8" amplifier.

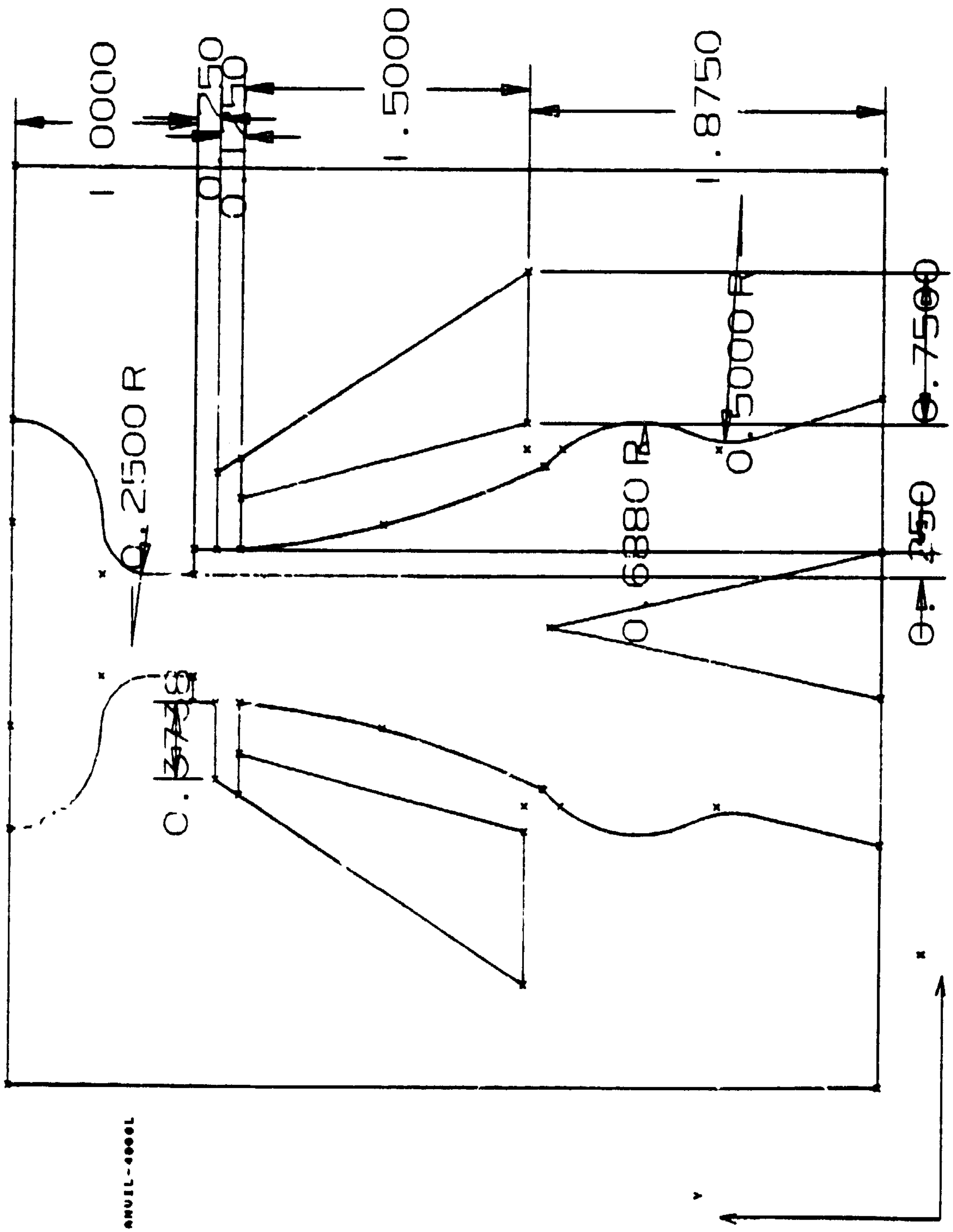

Figure 6. 32" output stage amplifier.

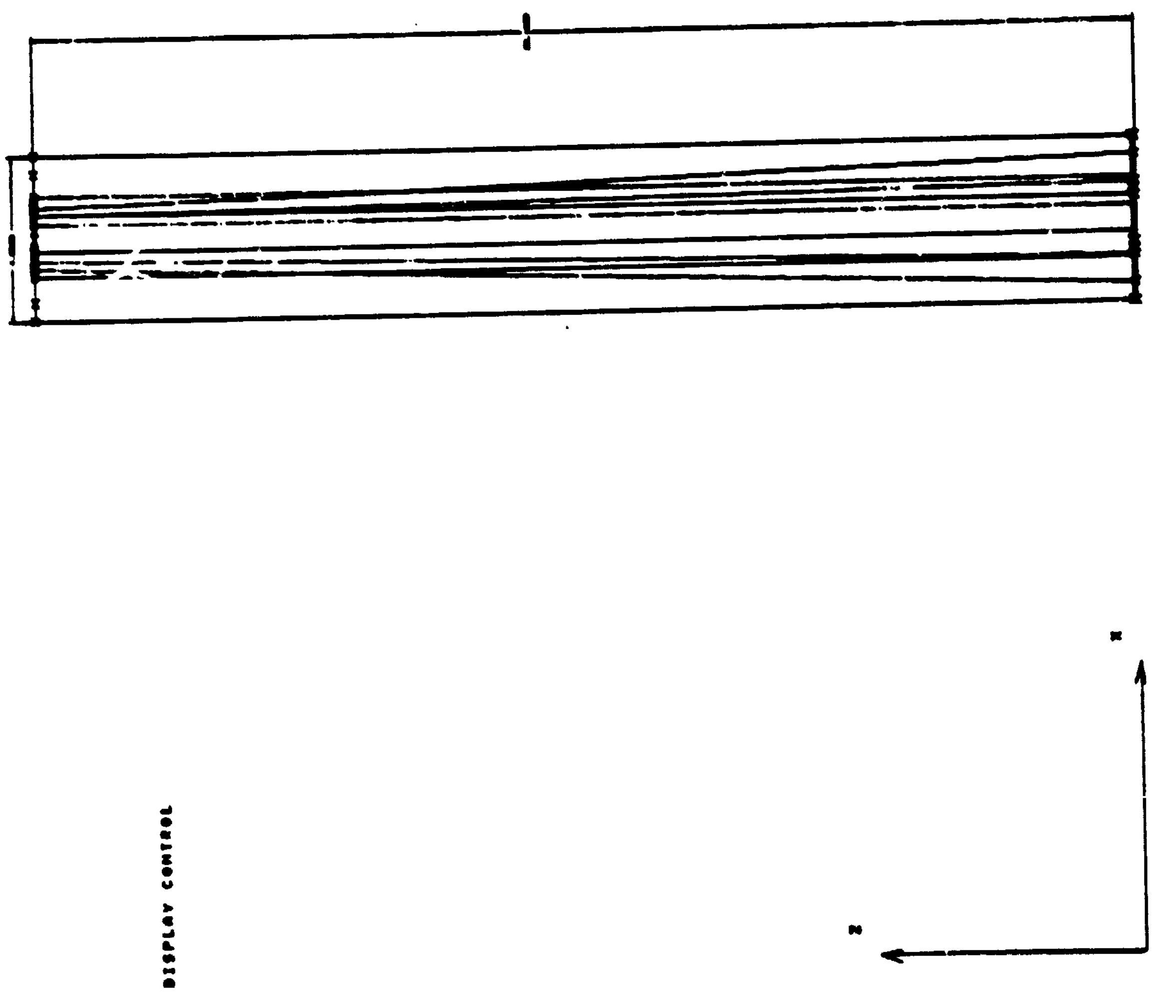

Figure 6(a). Bottom view of 32" amplifier.

DISPLAY CONTROL

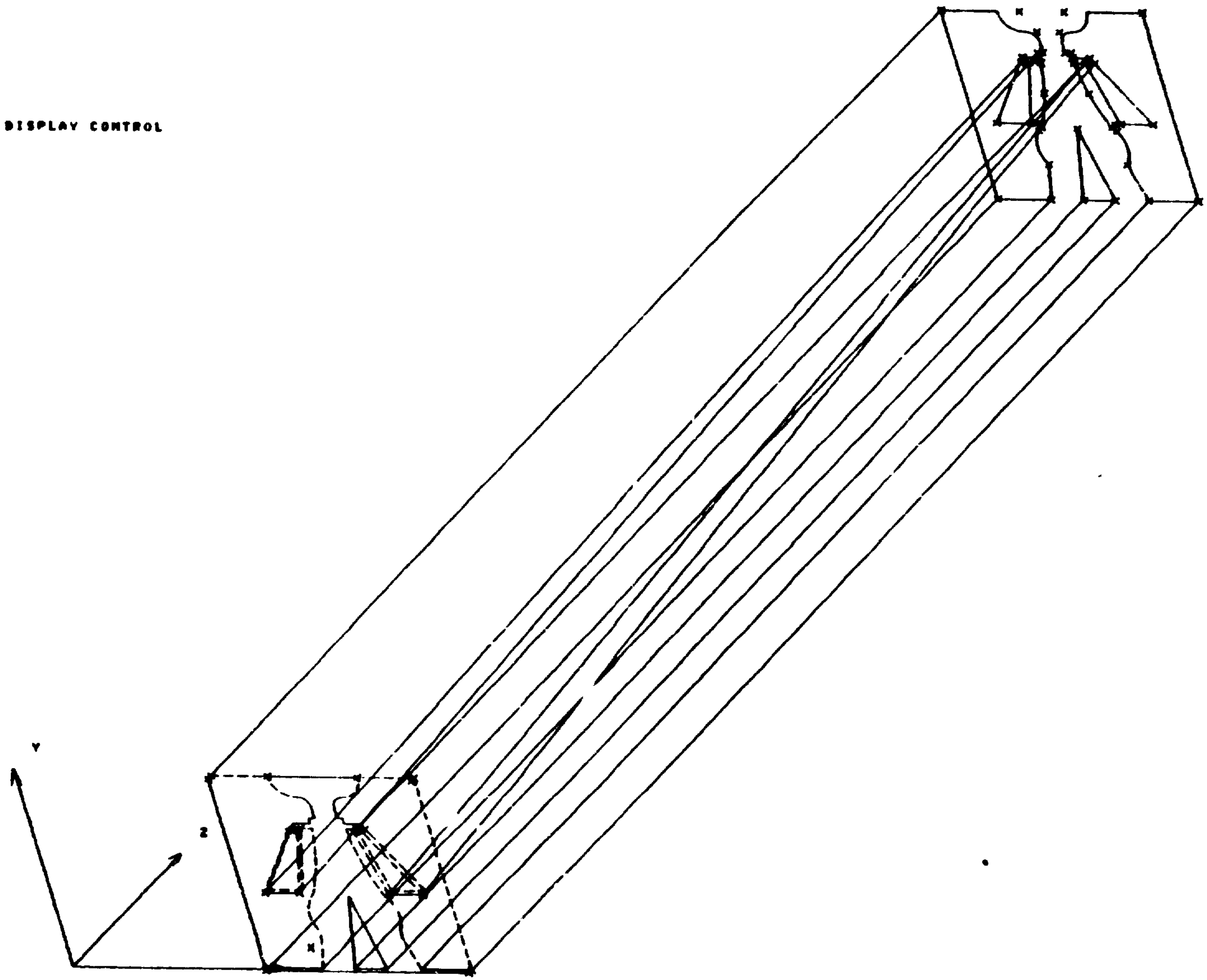

Figure 6(b). Isometric view of 32" amplifier.

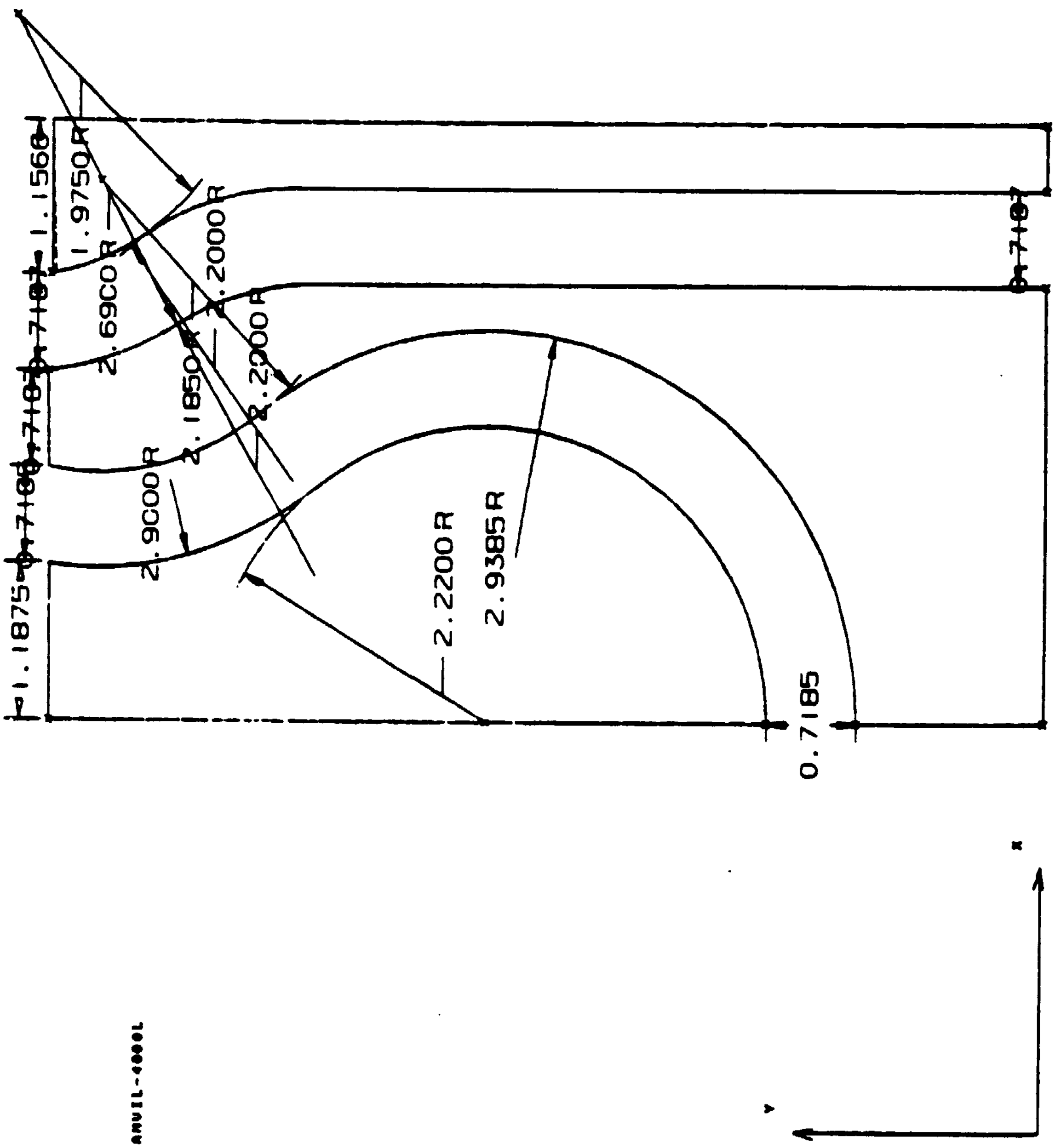

Figure 7. Loading stage for 32" amplifier.

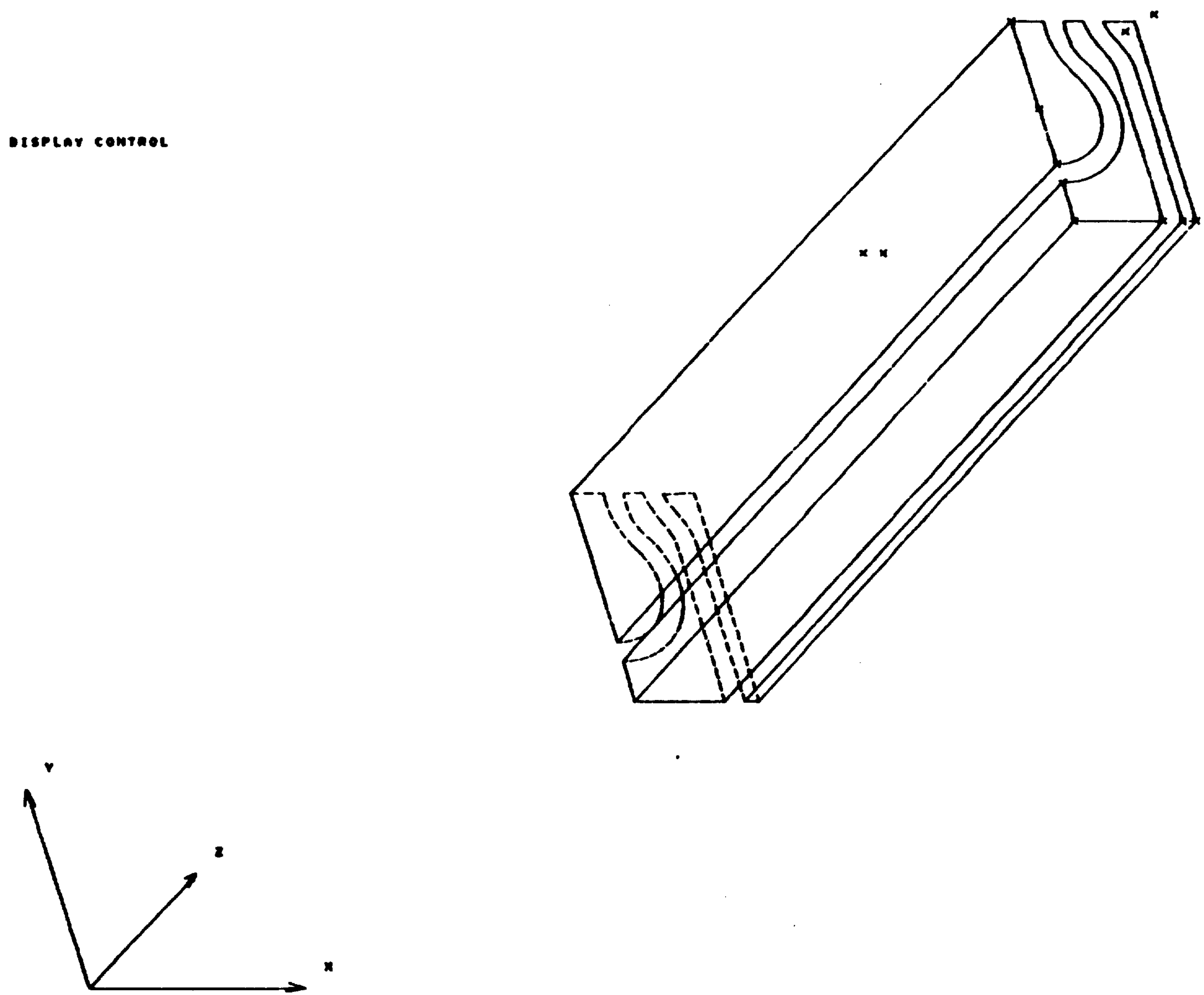

Figure 7 (a). Isometric view.

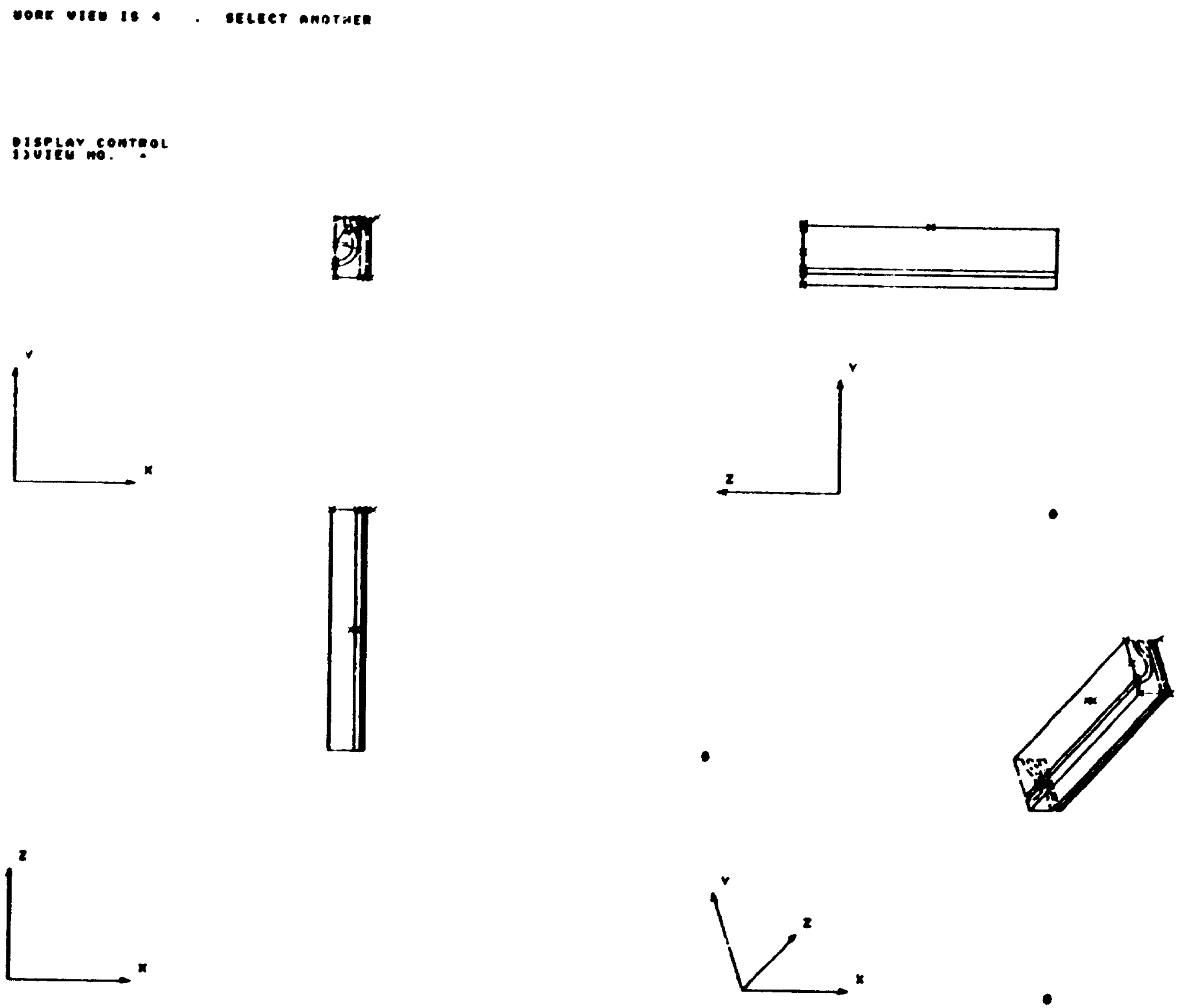

Figure 7(b). Loading stage.

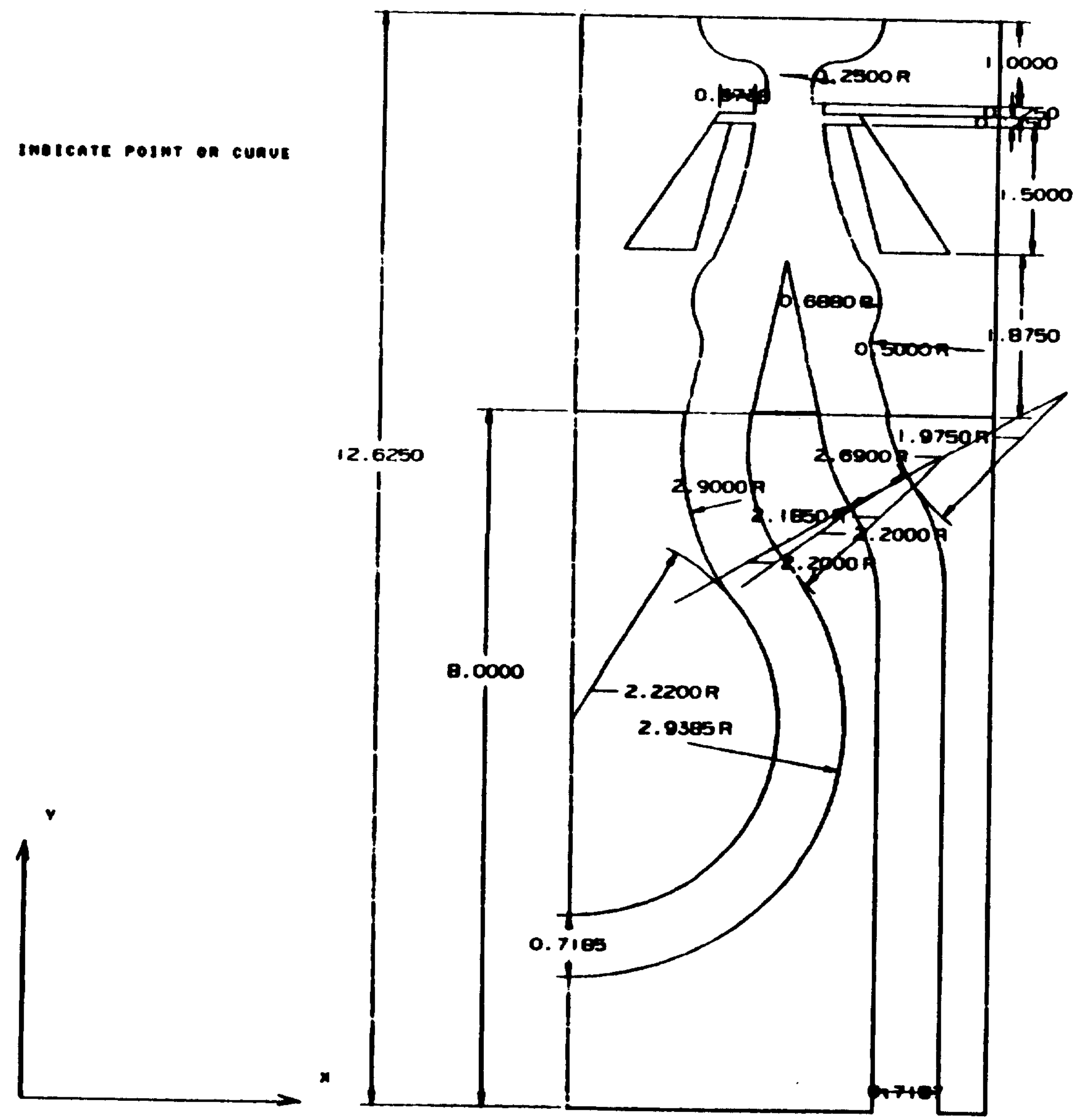

Figure 8. Output amplifier loaded.

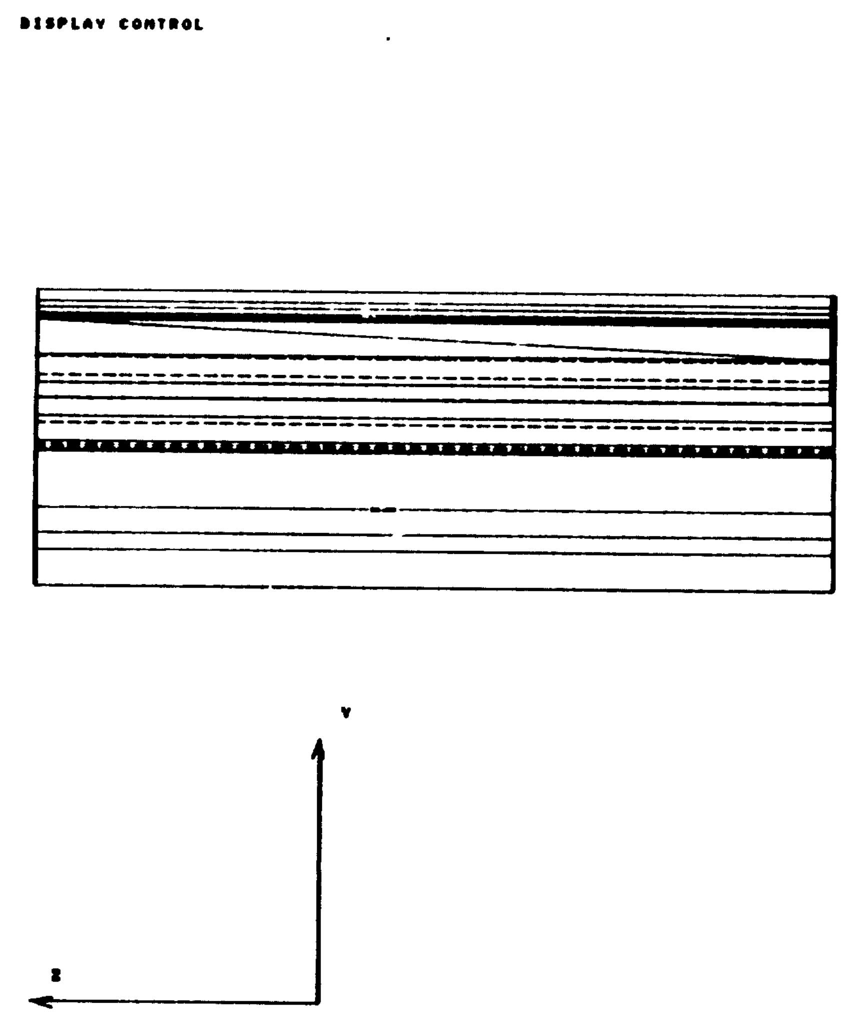

Figure 8(a). Bottom view.

Figure 8(b). Right view.

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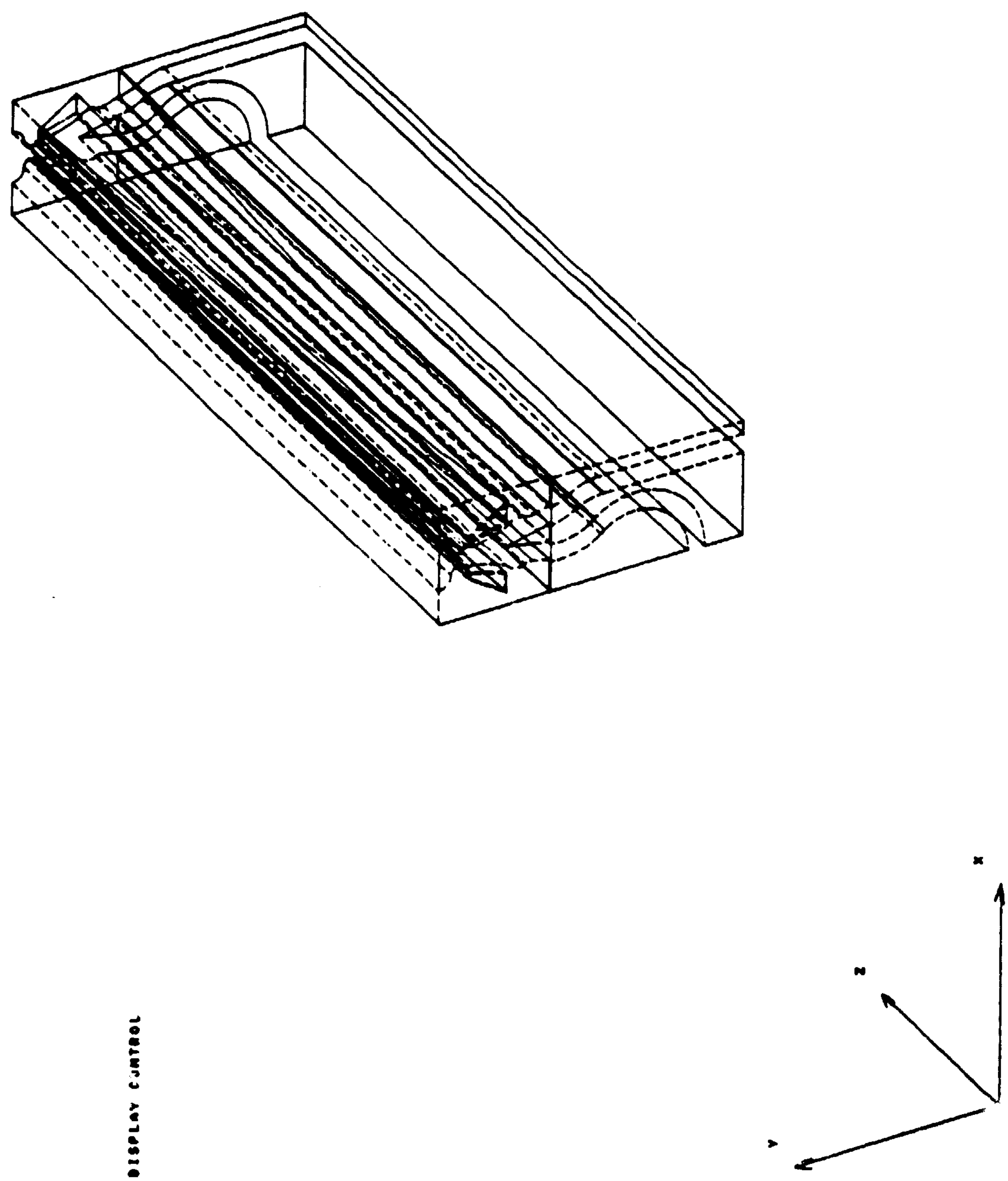

Figure 8(c). Isometric view.

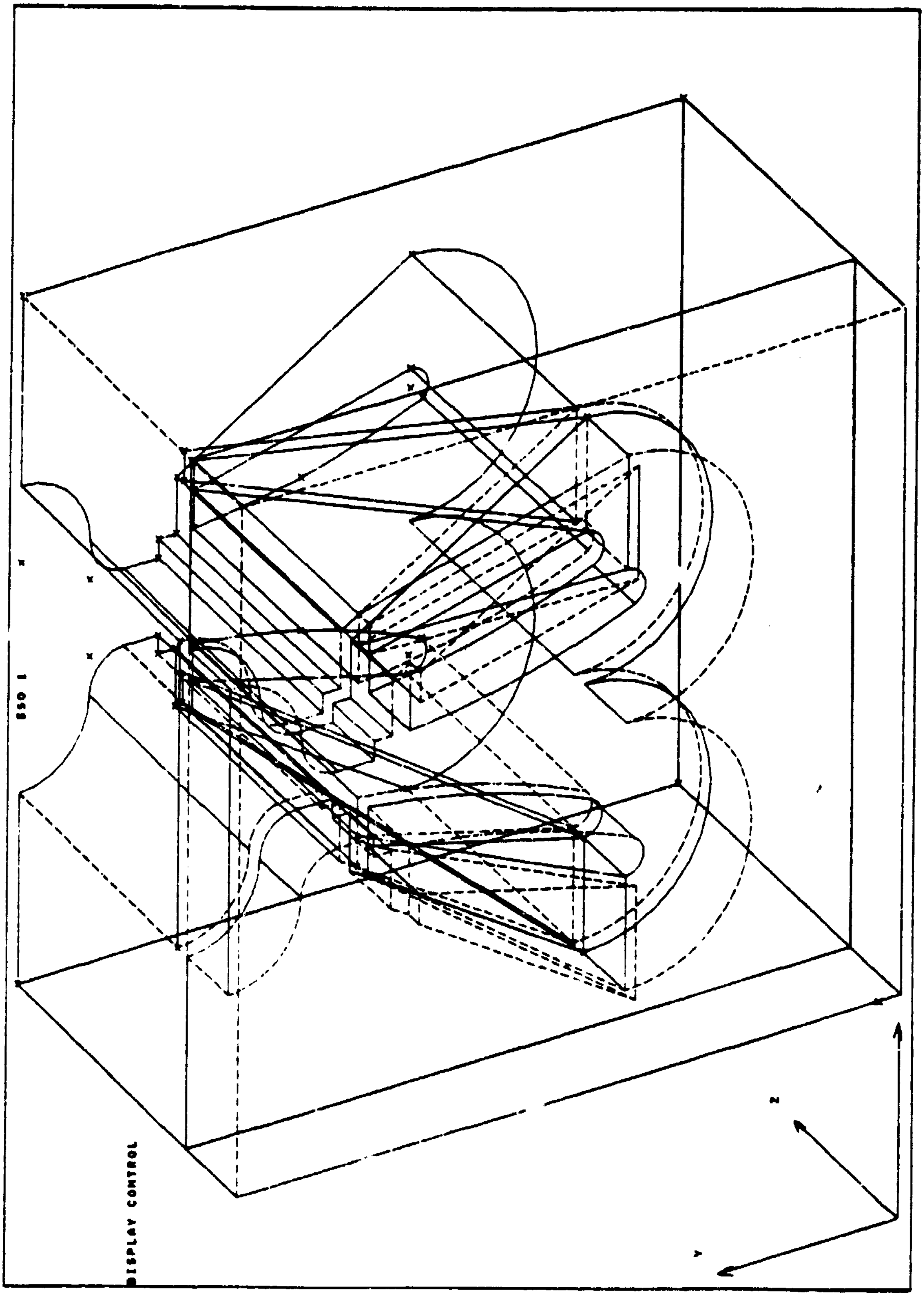

Figure 9. Staging of 0.5" amplifier with 2" amplifier.

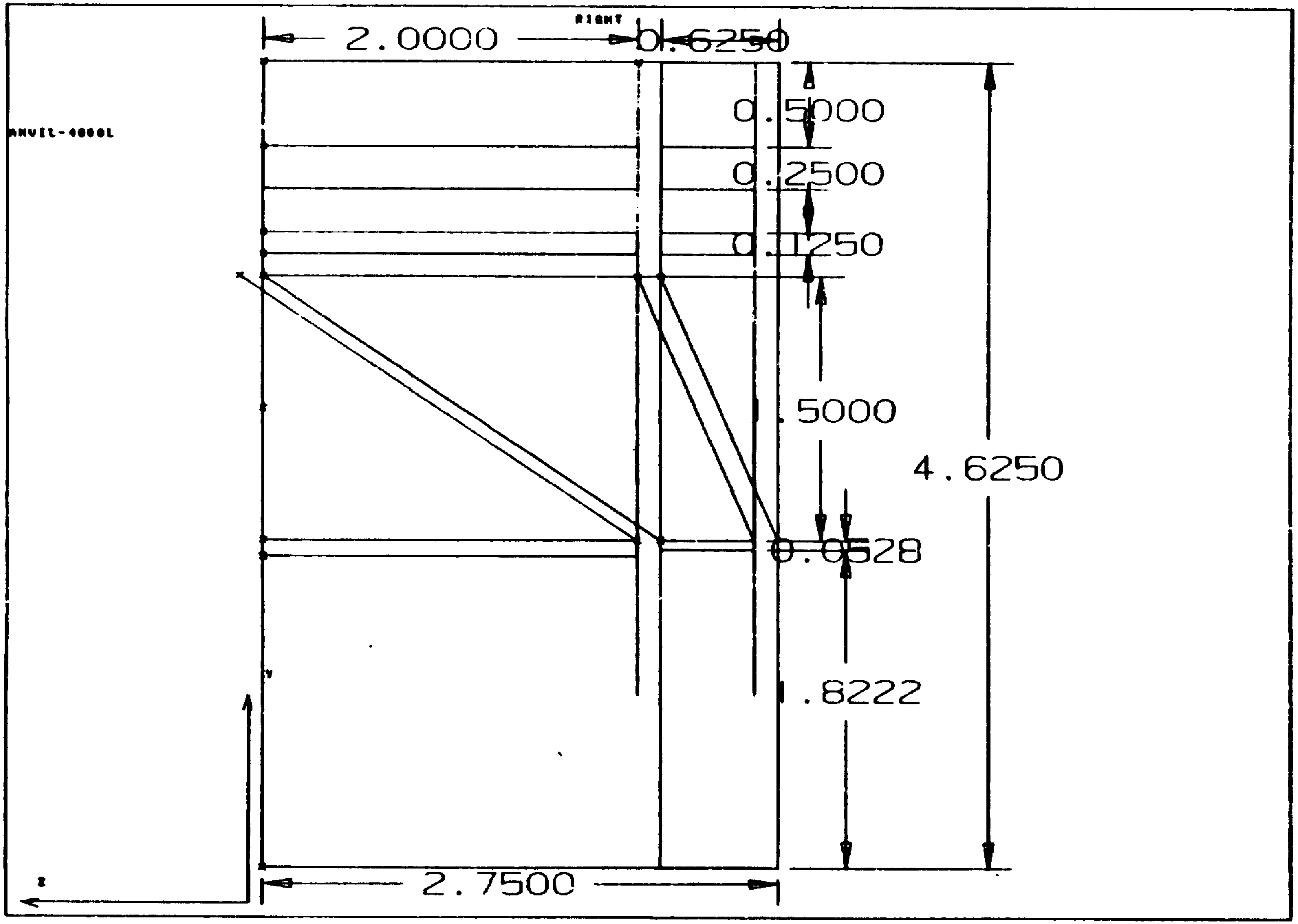

Figure 9(a). Right view.

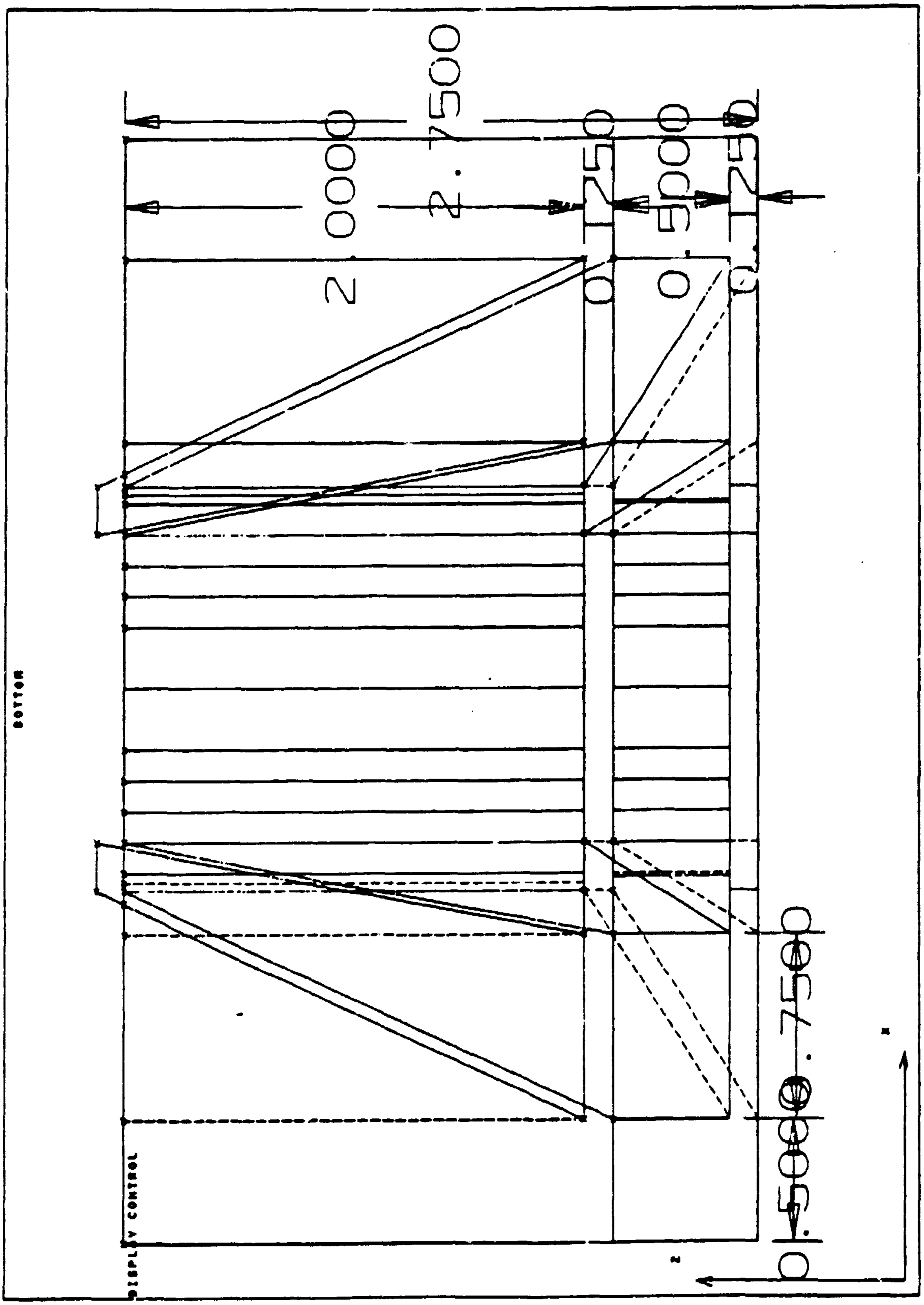

Figure 9(b). Bottom view.

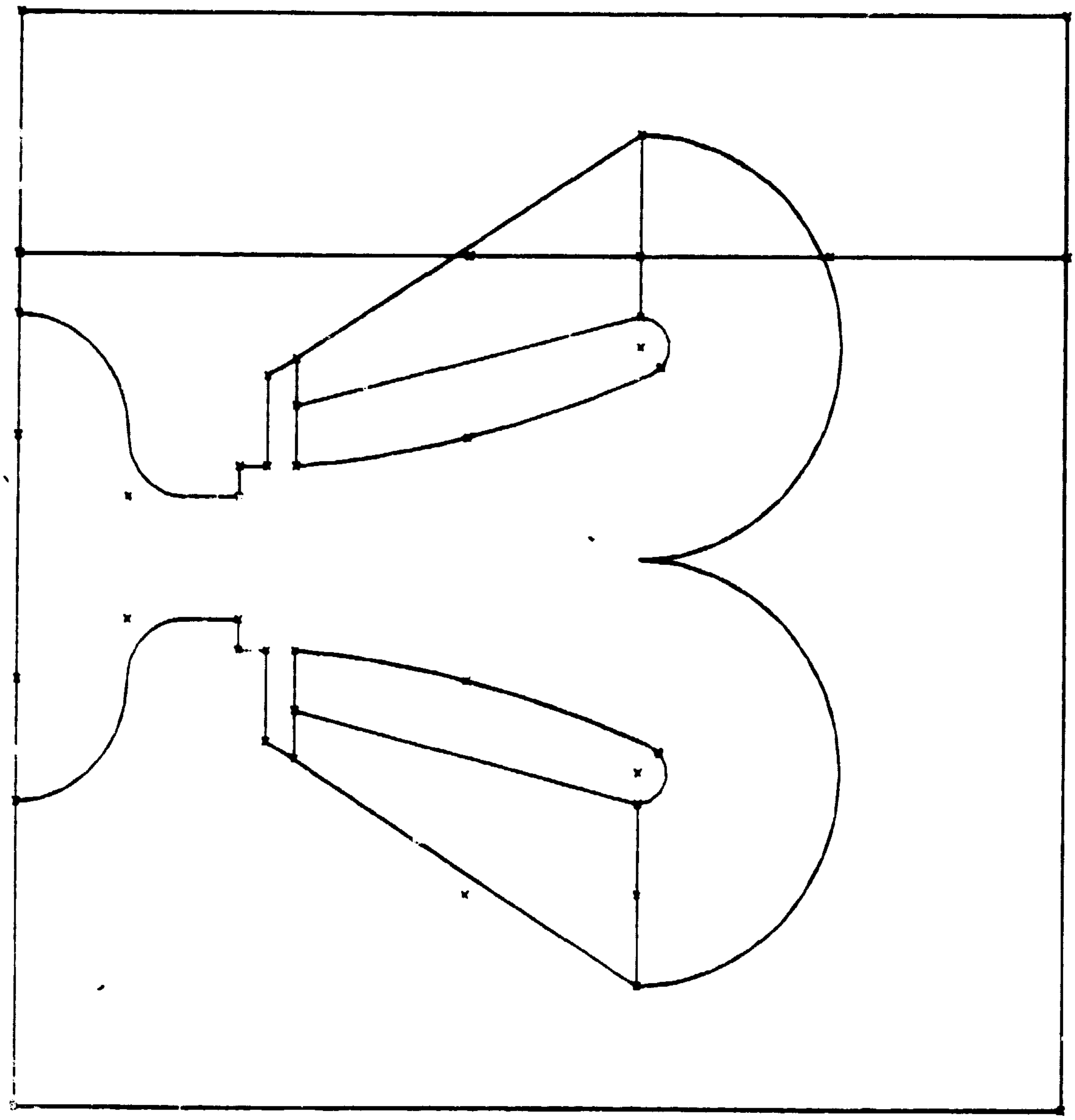

Figure 10. Sectional view of 0.5" amplifier.

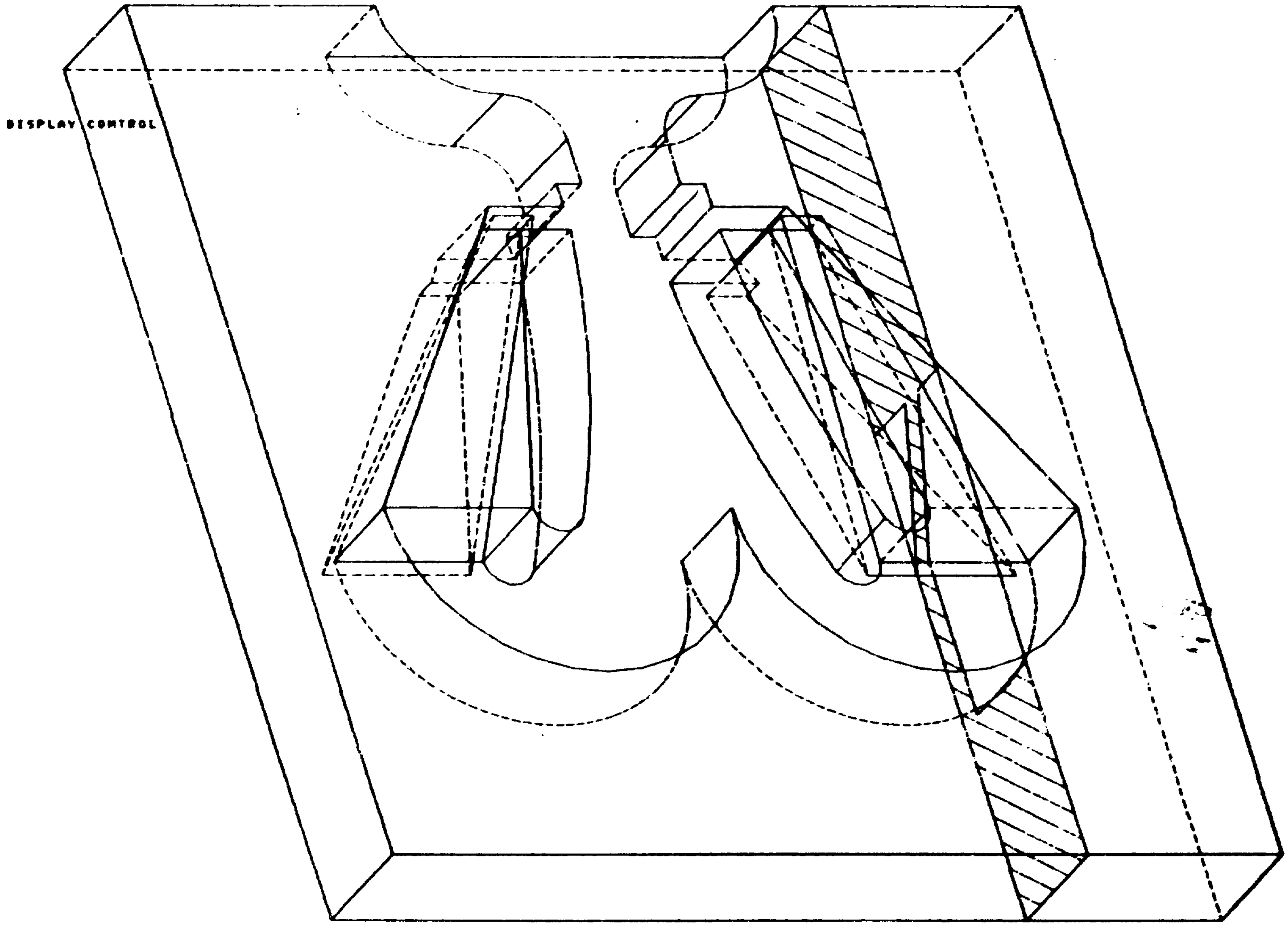

Figure 10(a). Isometric sectional view.

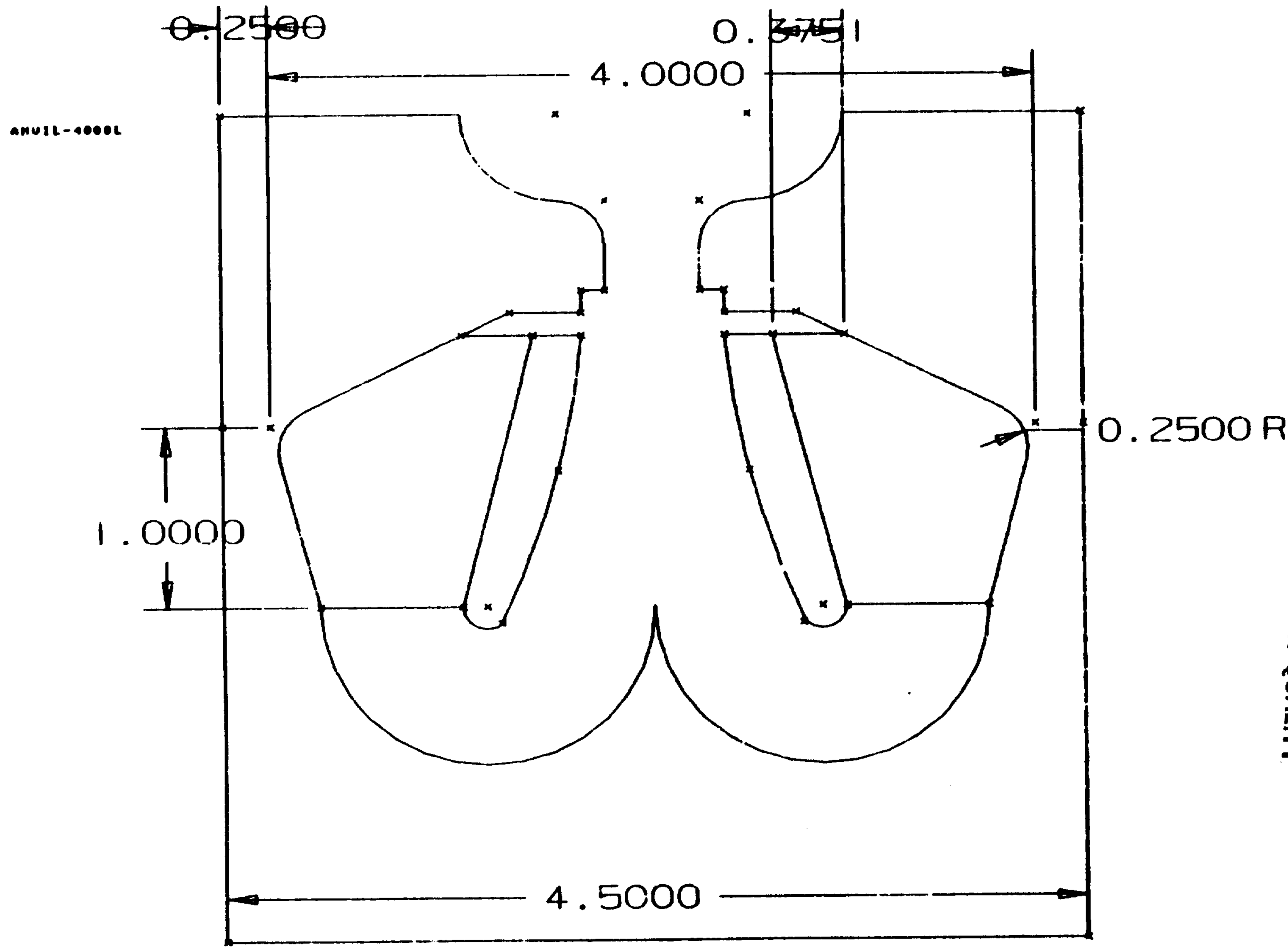

Figure 11. Amplifier with increased ramp area.

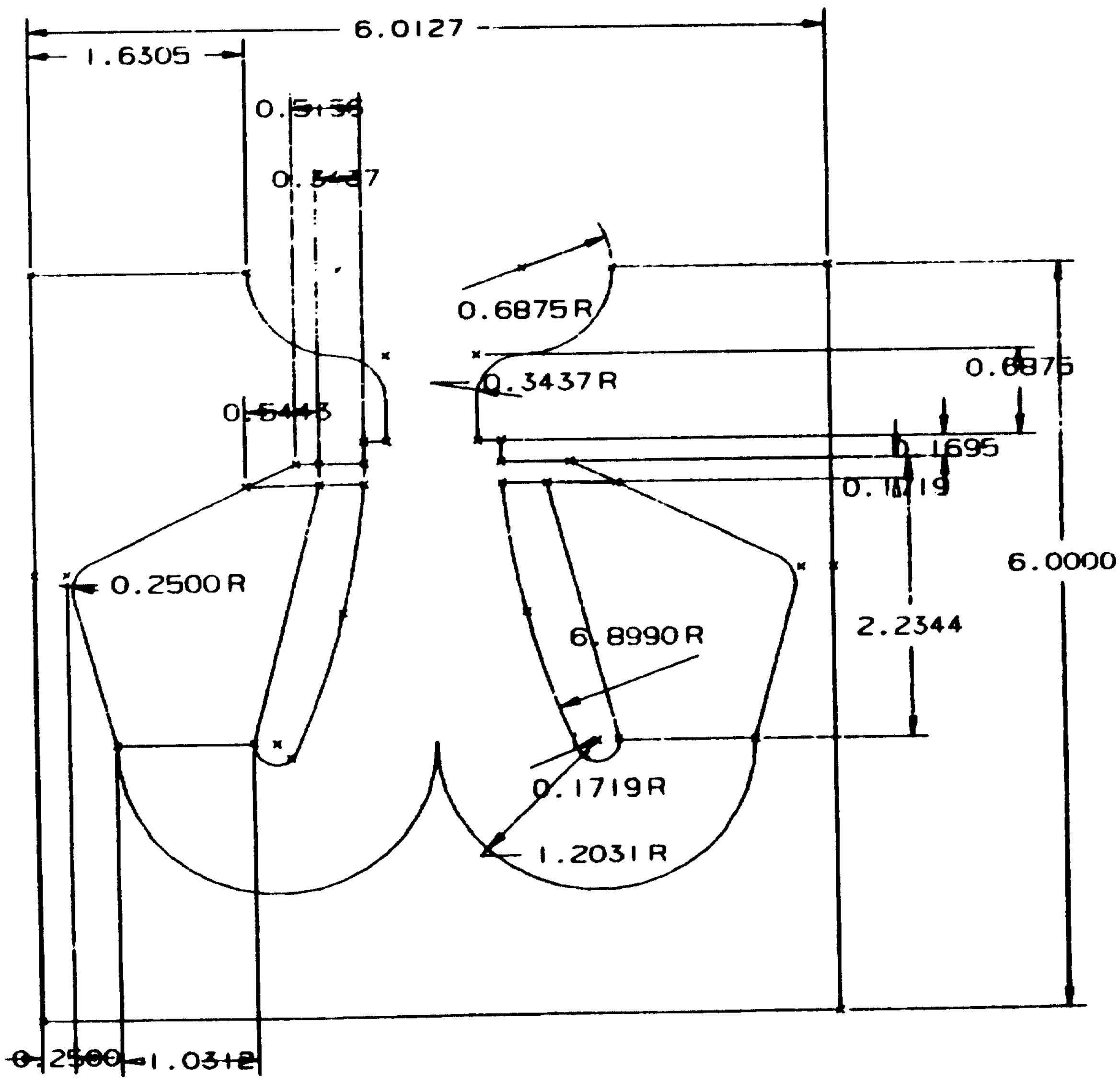

Figure 12. Expanded amplifier with increased ramp area.

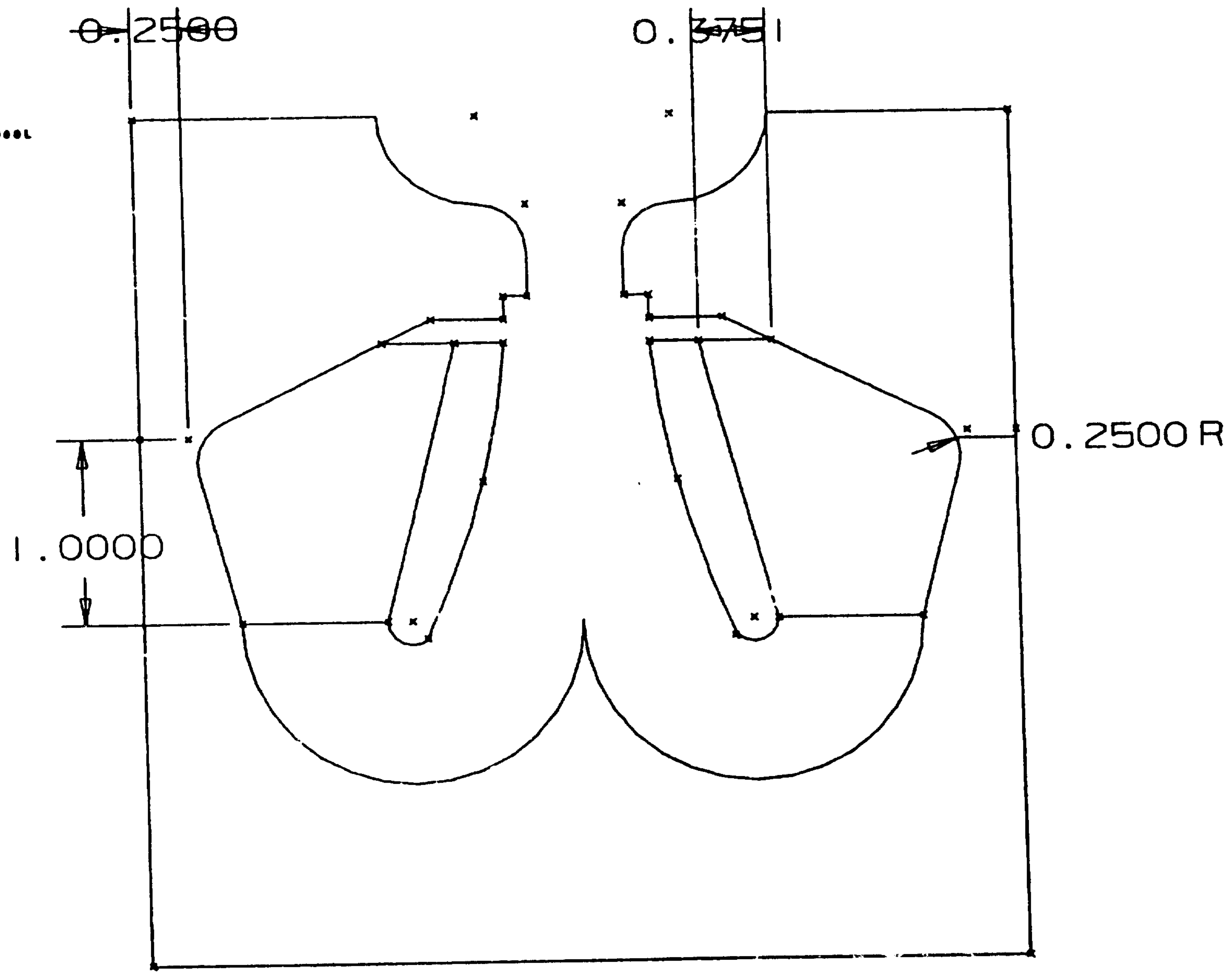

Figure 13. Regular amplifier with increased ramp area.

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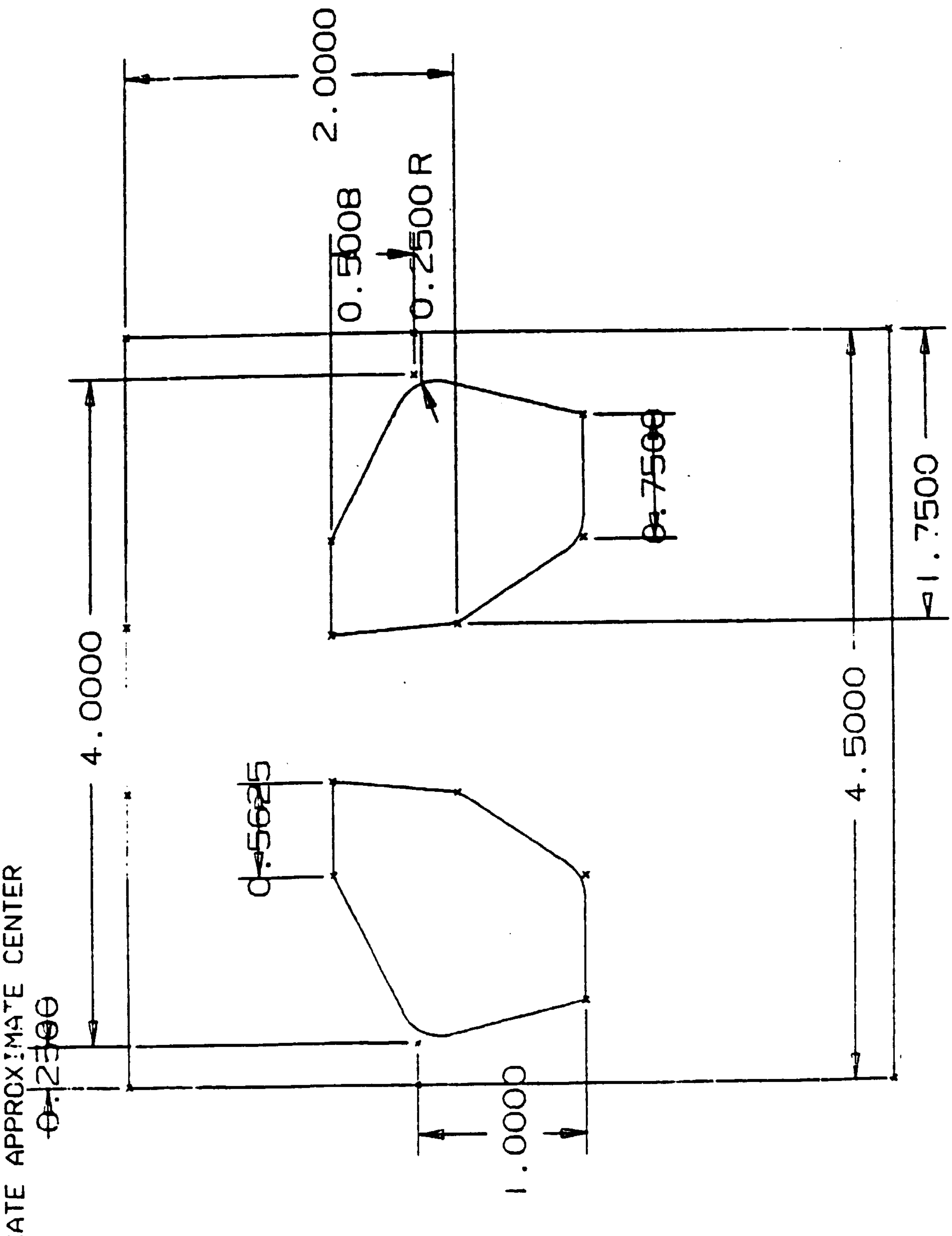

Figure 14. Transition from 0.125" to 0.5" closed.
Depth = 1"

VERTICAL DIMENSION
INDICATE POINT OR CURVE

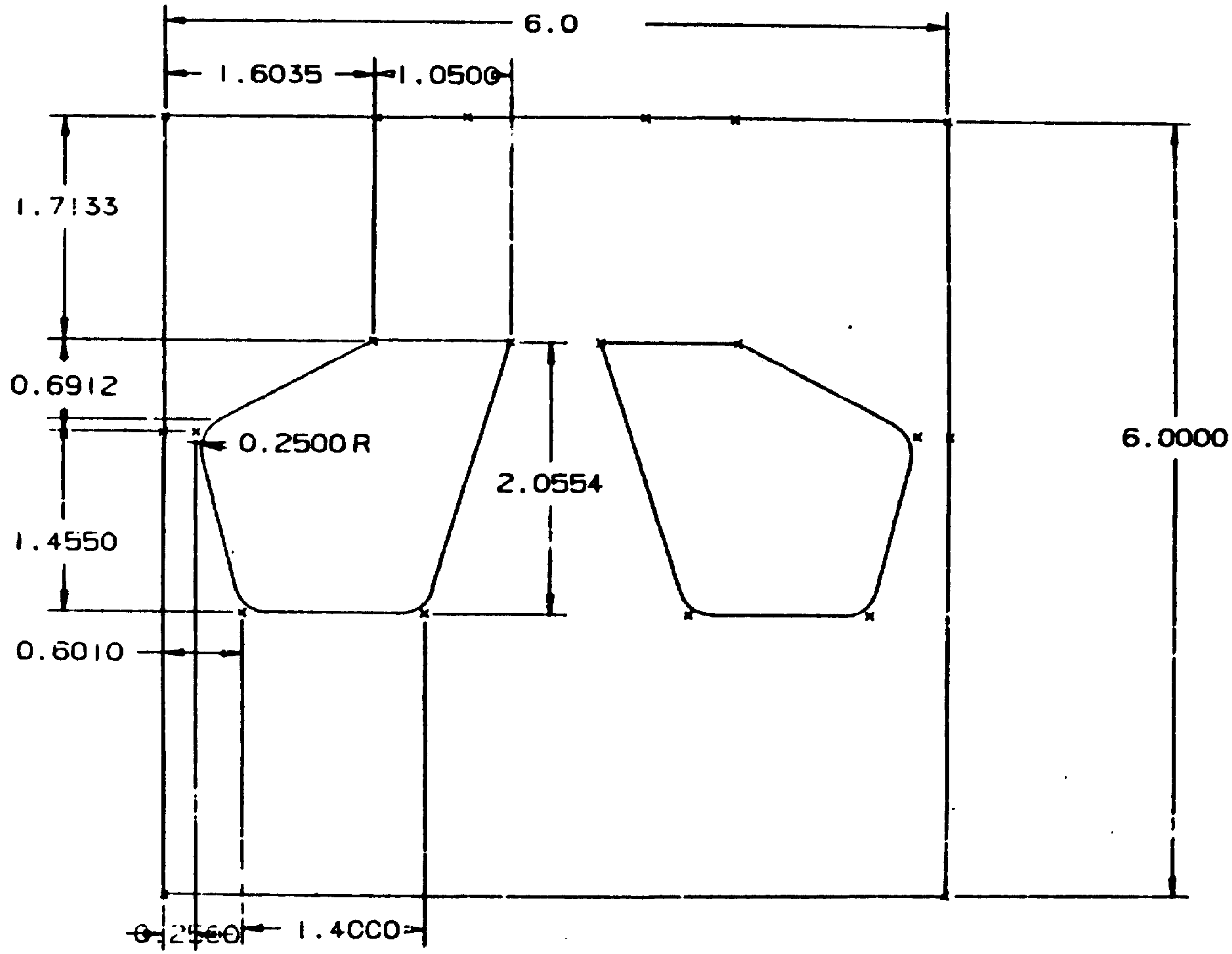

Figure 15. Transition stage from 0.5" closed to 0.6875" opened.
Depth = 1.25"