Does the Resistive Tearing Instability Nonlinearly Evolve to a Fast Reconnection Mode?*

R.S. Steinolfson (U. Texas, Austin)

A fundamental problem in applying linear tearing instability theory to the rapid processes (particle acceleration, heating) in flares has been the characteristically slow rate of reconnection. This problem can be at least partially overcome if the tearing mode nonlinearly evolves to a regime in which the reconnection rate is substantially enhanced, such as that for the Petschek configuration. This possibility has often been suggested, and some numerical simulations appear to provide support for such a view. We use numerical simulations to study the nonlinear evolution of the tearing instability and show that a fast Petschek-like regime may not be achieved. This conclusion follows when there are sufficient grid points within the diffusion region to completely resolve the nonlinear dynamical interactions in the diffusion layer. When the numerical resolution is not adequate, the solution does appear to approach a Petschek configuration. The resolved solution contains reverse flow vortices and current sheets, terminated with a current reversal, similar to those obtained by Syrovatsky (JETP, 33, 933, 1971).

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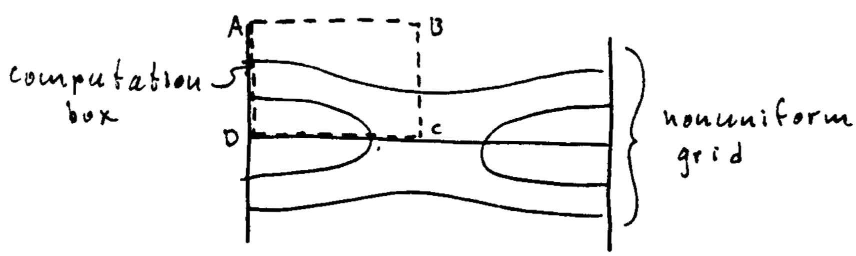
Results from two studies concerning the rate of reconnection of magnetic field lines are reported on. Both illustrate the need to numerically resolve the physical processes <u>inside</u> the diffusion layer in order to simulate the correct evolution.

The model assumes incompressible MHD with constant resistivity in a slab geometry. The time-dependent equations are solved numerically using a fully implicit method. A linearly growing mode provides the initial disturbance. Only one quadrant of the complete mode is simulated as shown in the sketch below:



The boundary conditions are -

B-C, C-D; symmetry

D-A; symmetry for the first study, outflow for the second

A-B; linear extrapolation although it is so far removed from the tearing layer by the nonuniform grid that it has virtually no influence.

The results from the individual studies are as follows:

A. Nonlinear evolution of a linearly growing mode

The first set of plots below (indicated by 1) are for an unresolved diffusion layer while for the second 2 sufficient resolution was used to correctly simulate the nonlinear effects of the resistive terms. The two solutions were started with the same linear mode and are compared after evolving for the same time period. The solution in set 1 is simply an amplified linear mode, while that in set 2 shows the development of reverse flow vortices.

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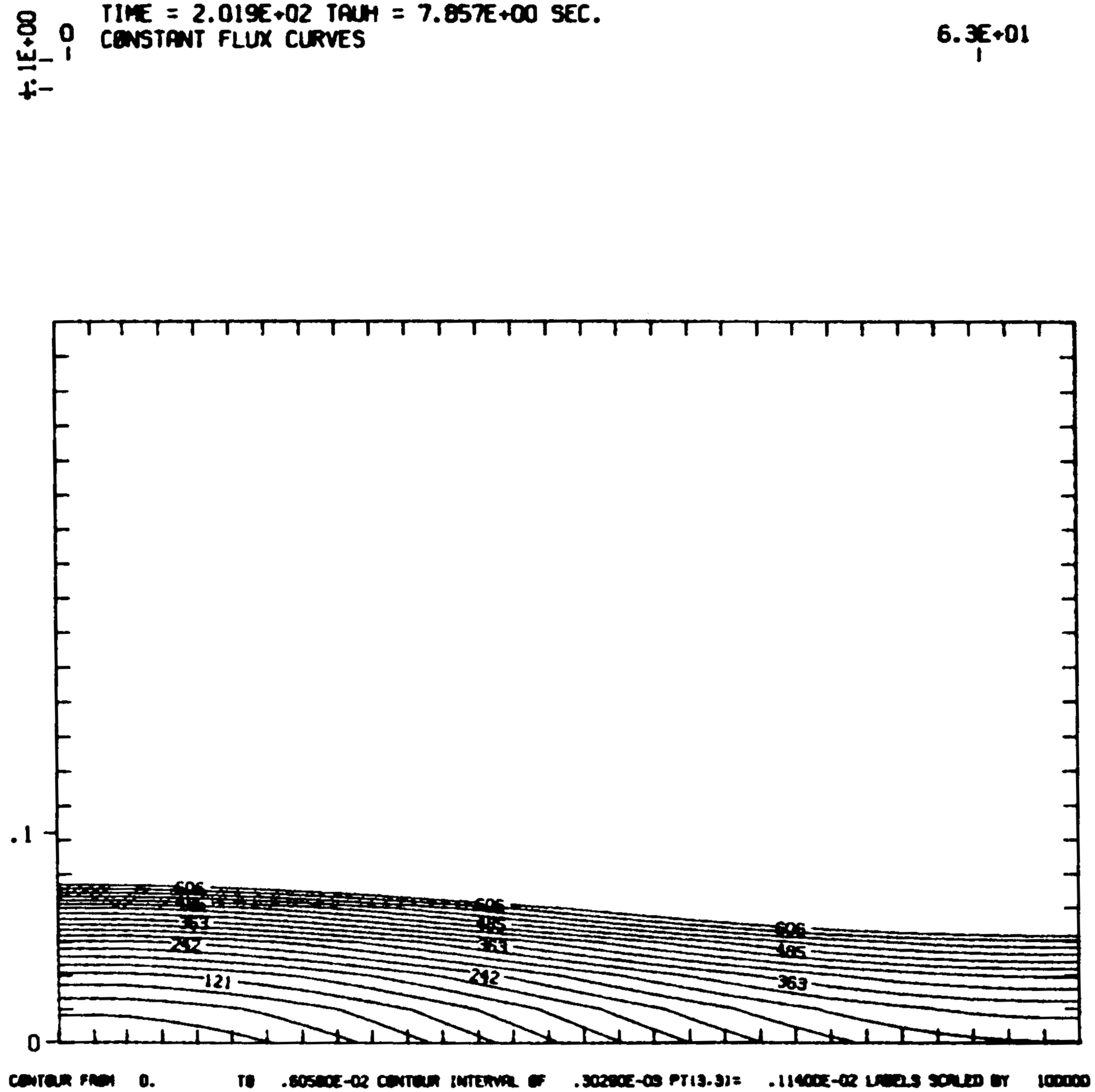
① Unresolved diffusion layer

TIME = 2.019E+02 TAUH = 7.857E+00 SEC.
CONSTANT FLUX CURVES



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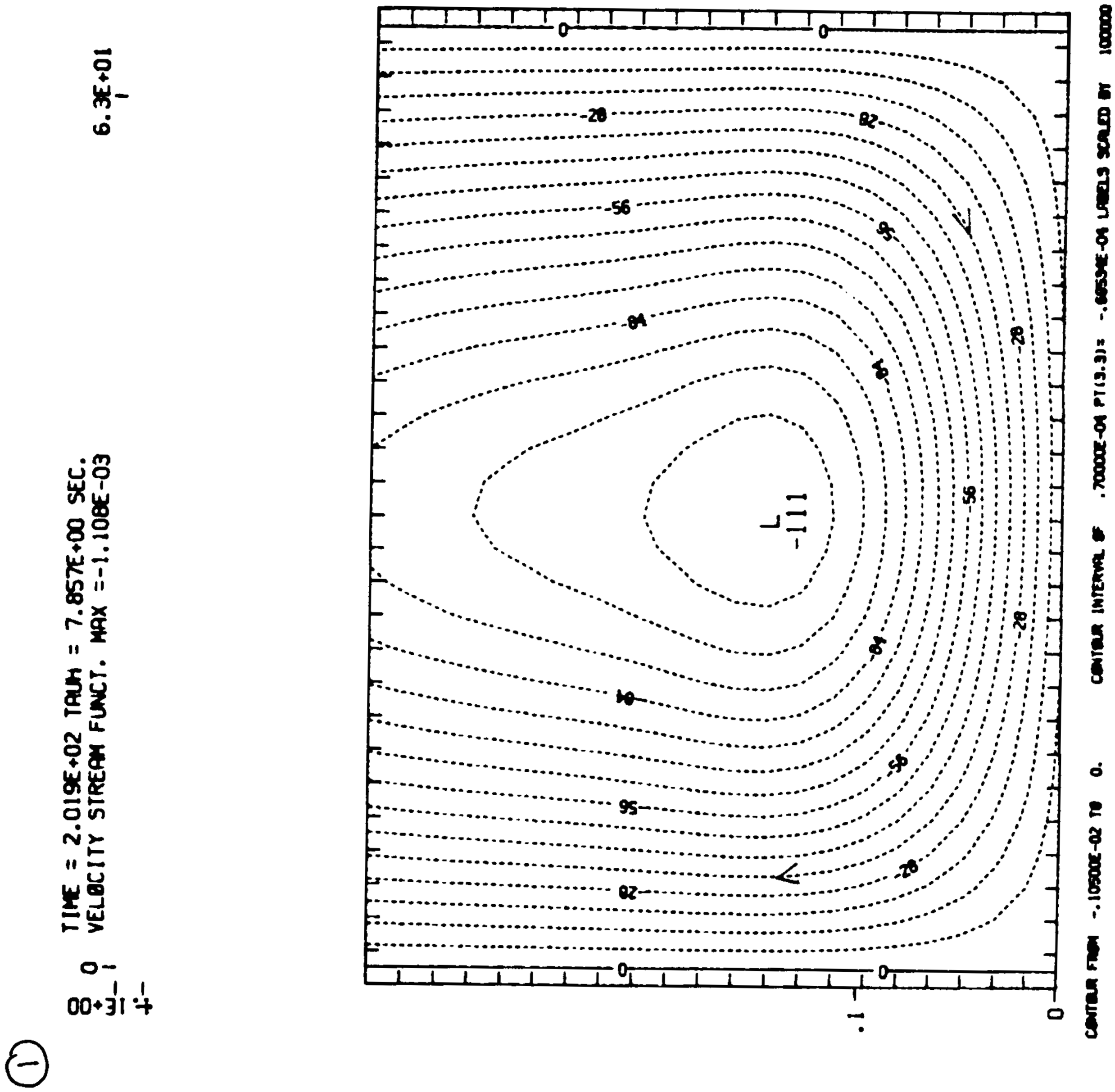
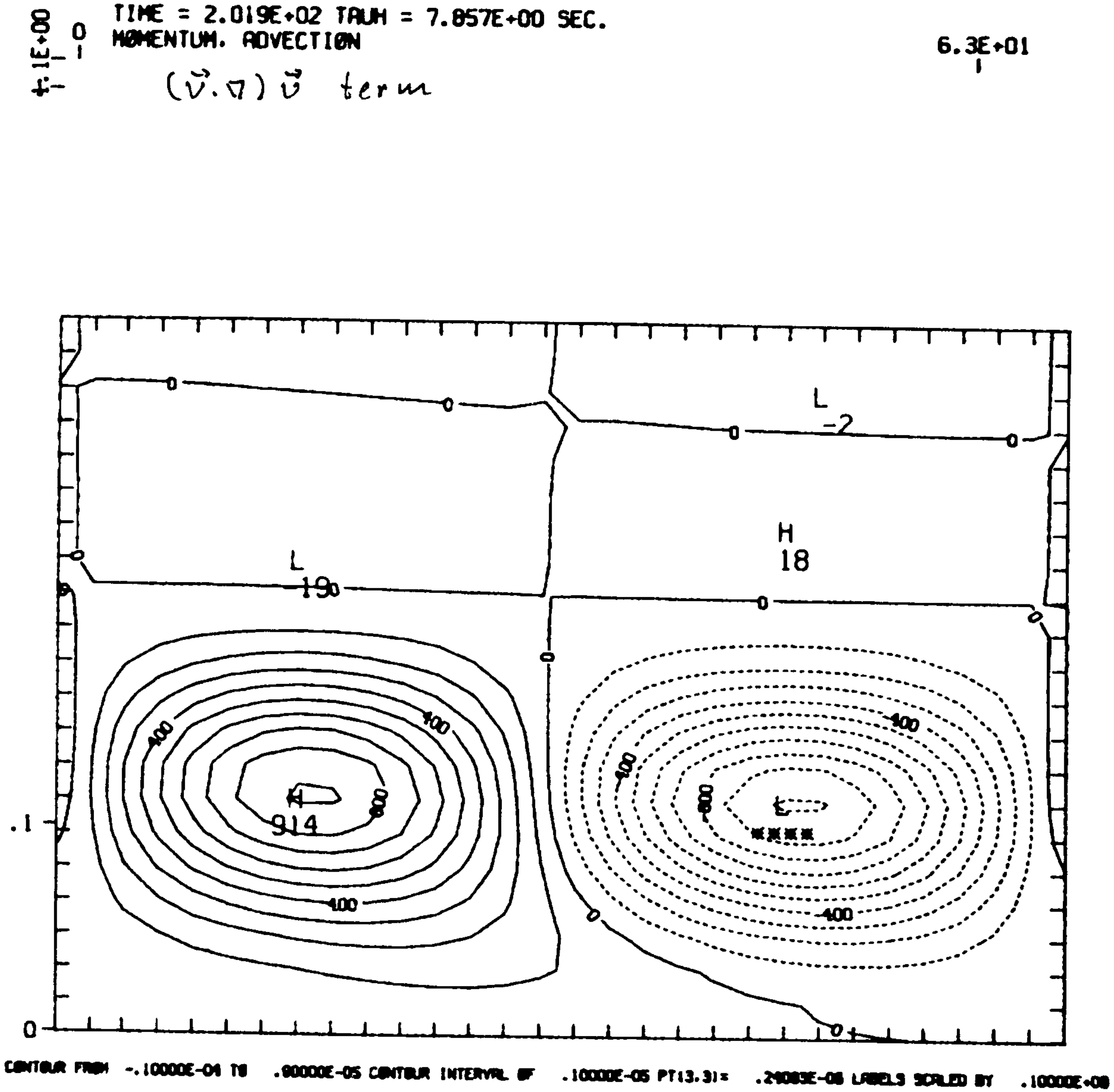


①



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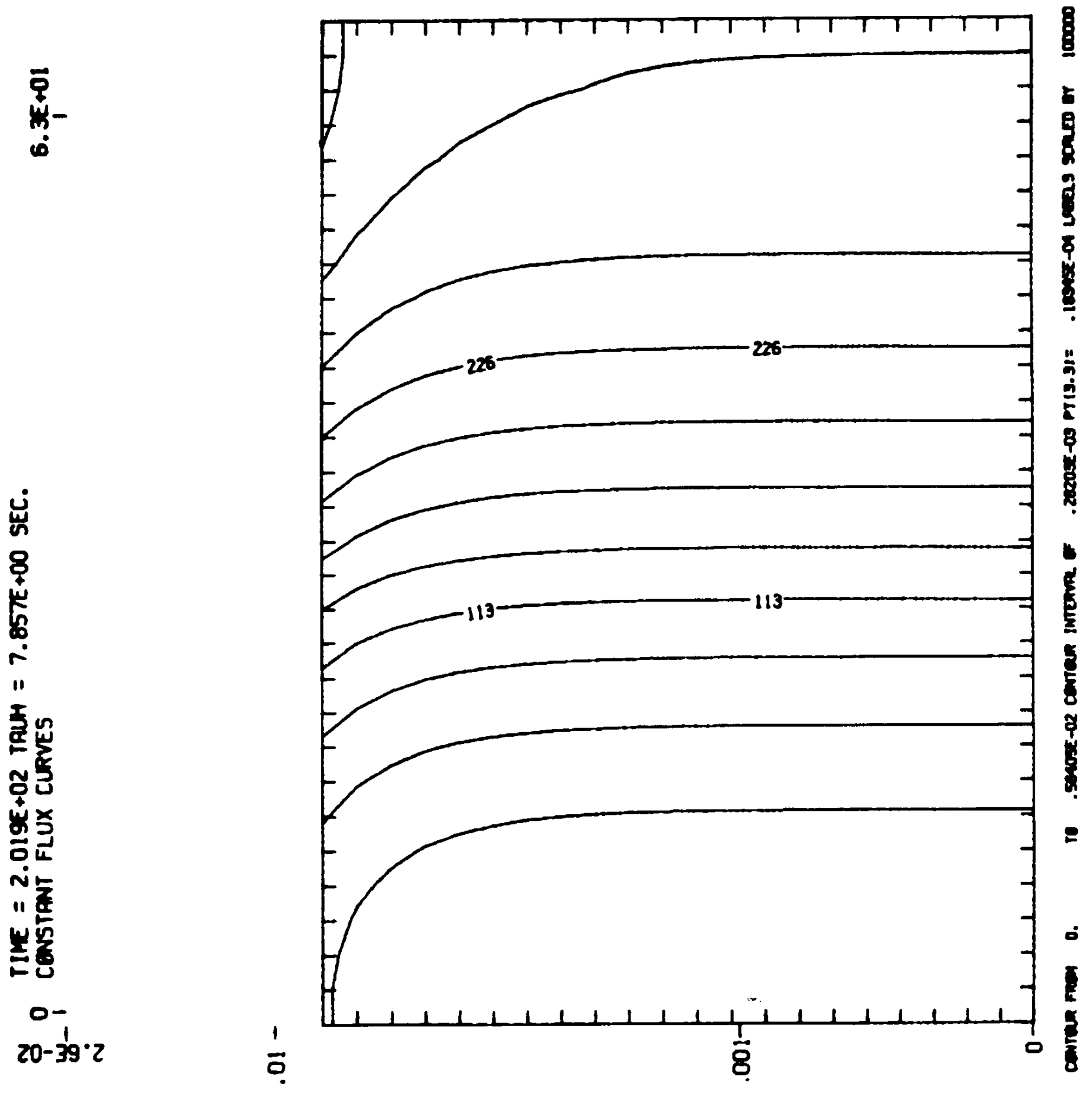
② Resolved



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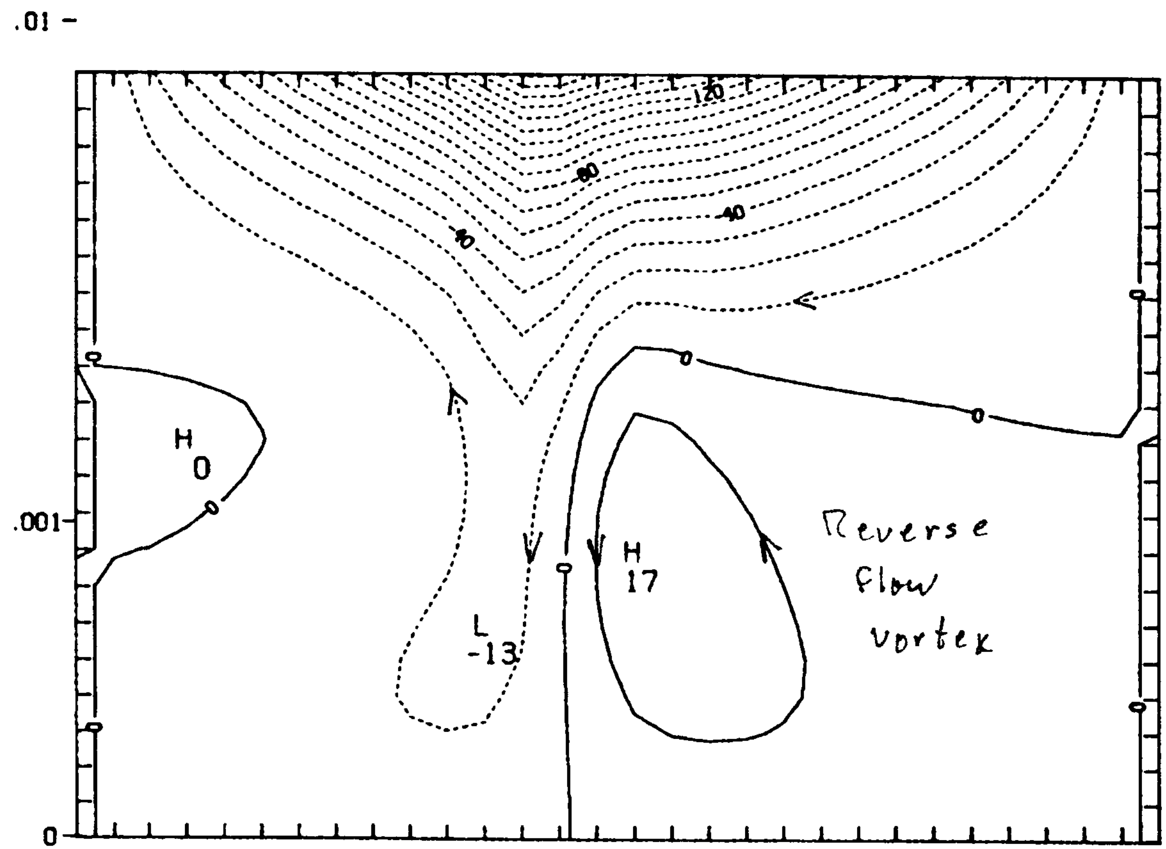
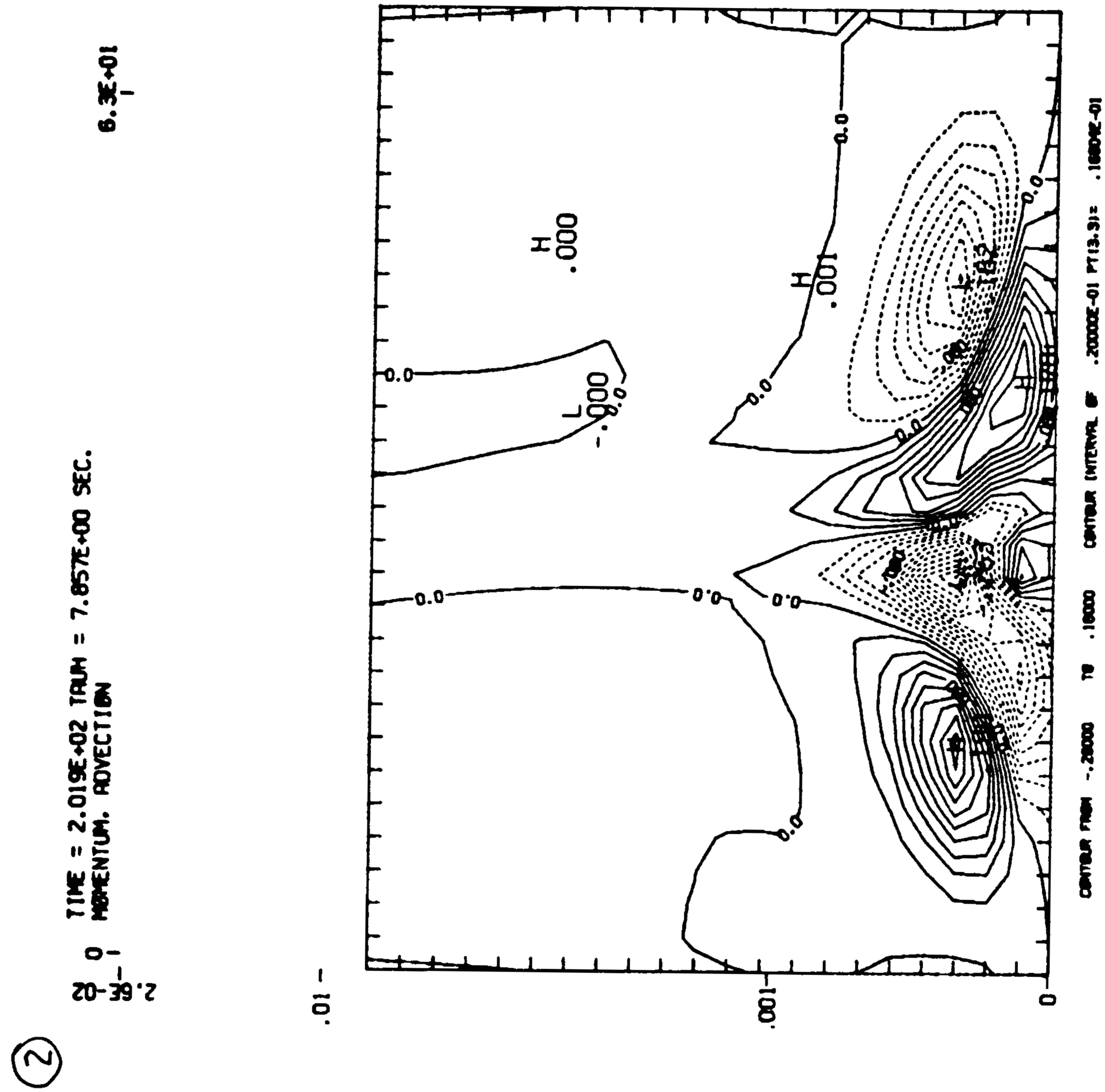
2

TIME = 2.019E+02 TAUM = 7.857E+00 SEC.
VELOCITY STREAM FUNCT. MAX =-1.715E-04

2.6E-02 0 6.3E+01



CONTOUR FROM -.17000E-03 TO .10000E-04 CONTOUR INTERVAL OF .10000E-04 PT(3,3)= -.77724E-06 LABELS SCALED BY .10000E+07



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B. Development of the Petschek regime

The solutions are again initiated with the same linear mode, but the boundary conditions along boundary D-A in the above figure are modified to permit an outflow. As shown in set 3, a continuous outflow develops when the resistive layer is not resolved. However, when sufficient grid points are located within the layer, as shown in set 4, ~~the~~ an outflow initially develops but eventually the nonlinear terms prevent the formation of a regime with outflow along D-A

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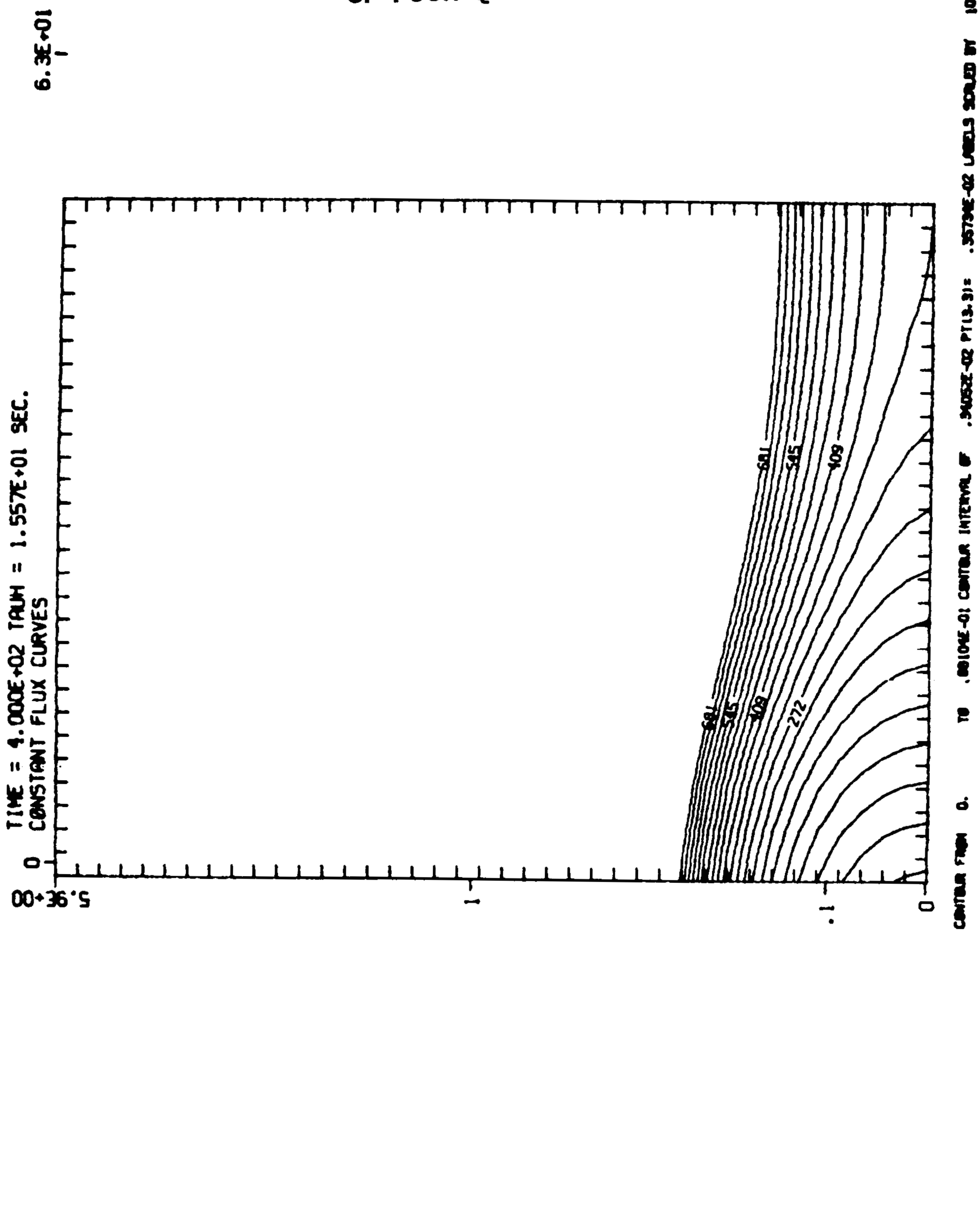
③ Insufficient resolution



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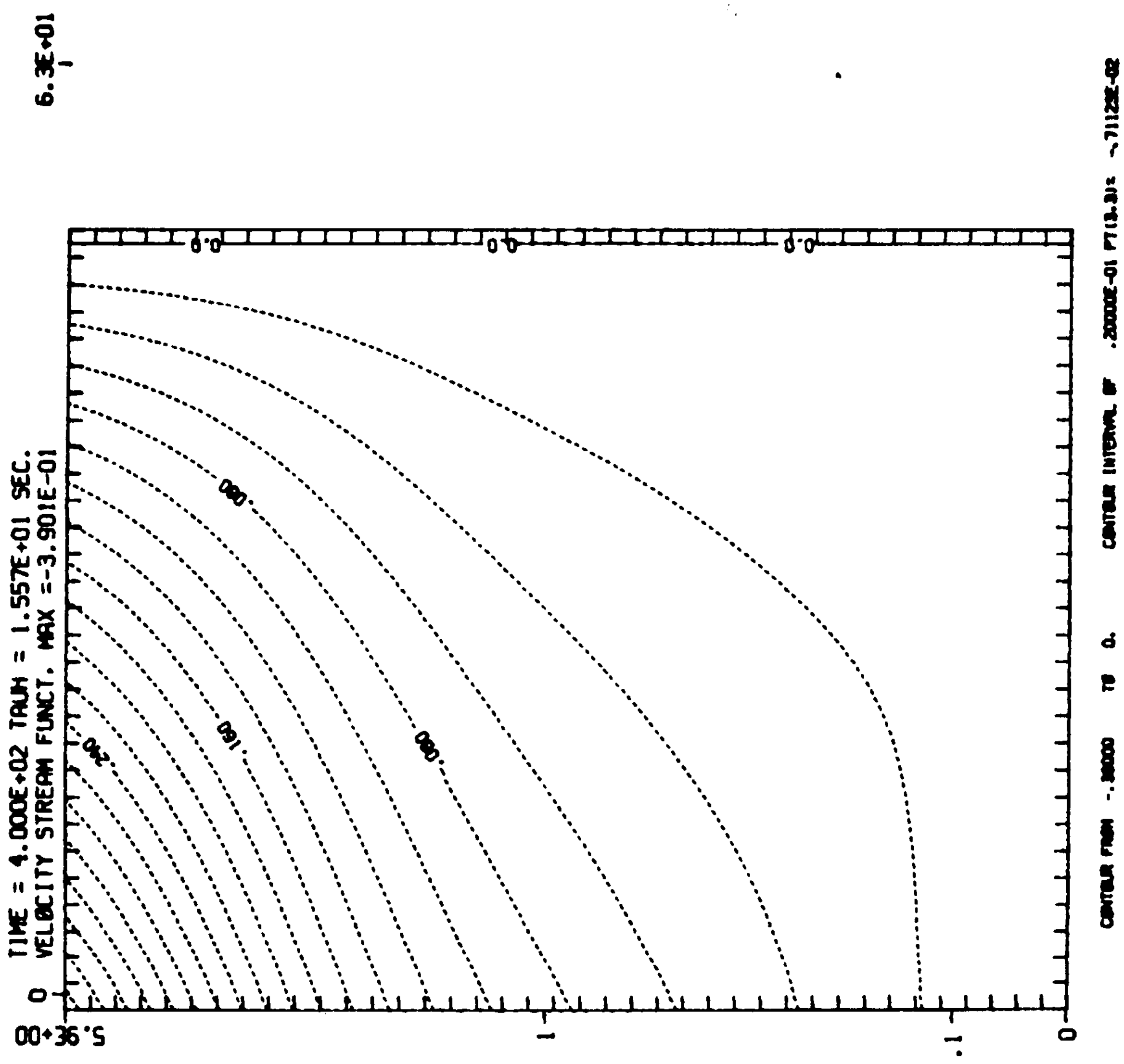
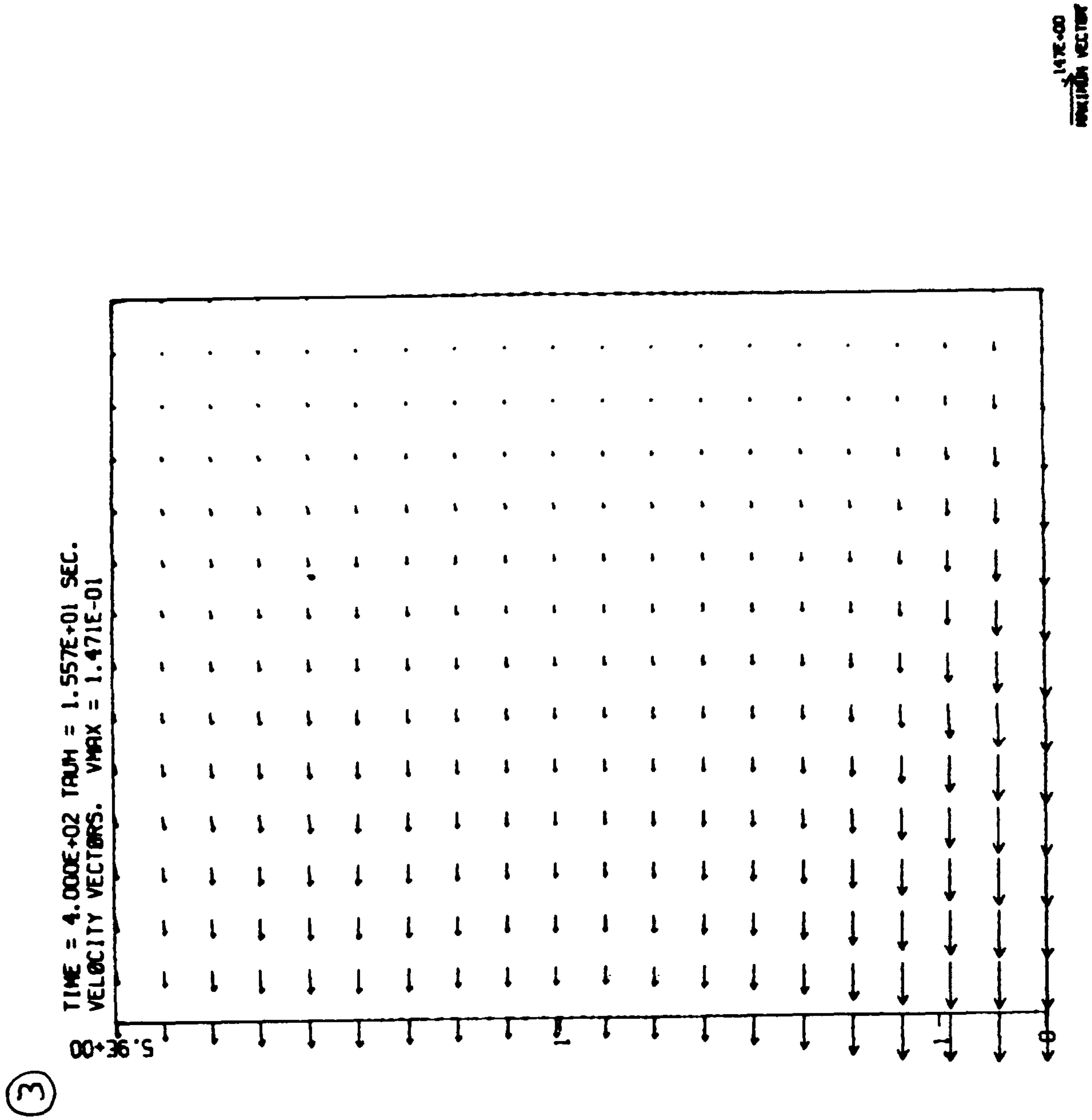


(3)



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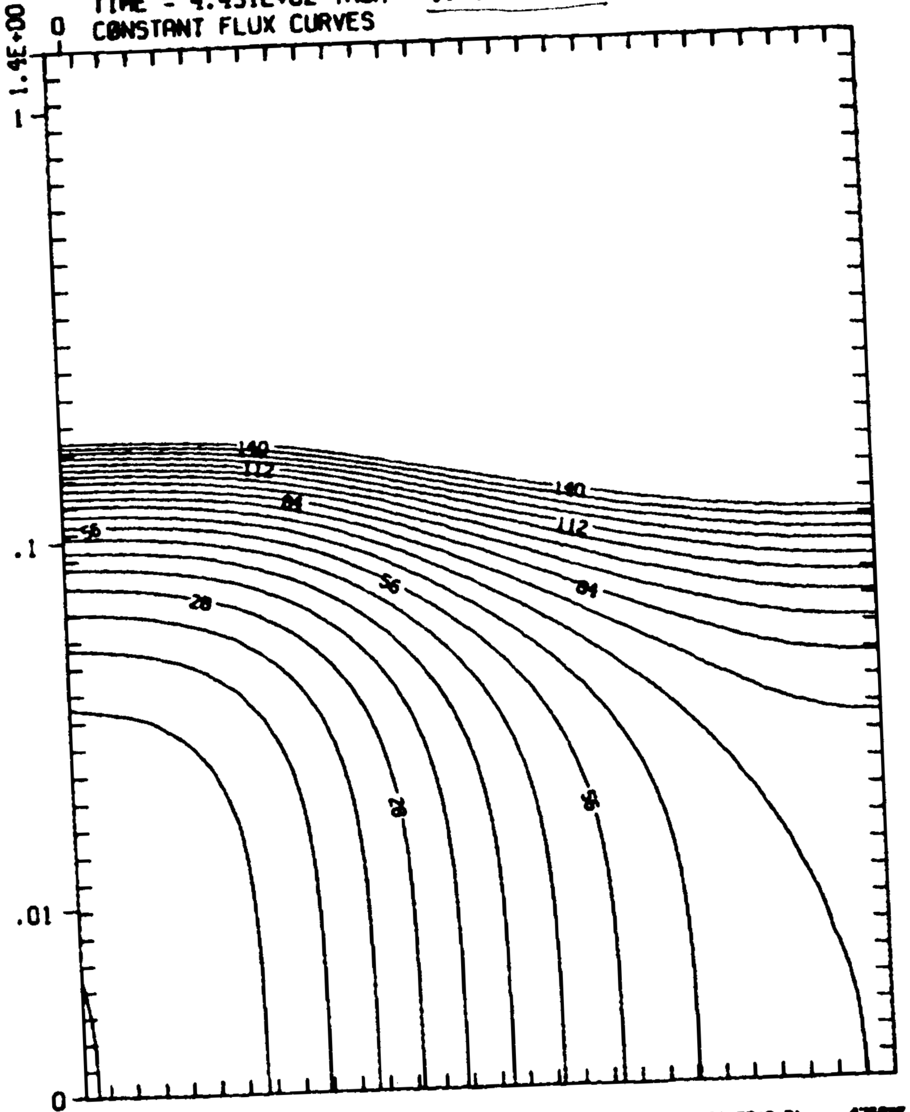
④ Sufficient numerical resolution

TIME = 4.451E+02 TAUM = 1.732E+01 SEC.
CONSTANT FLUX CURVES



17.3 sec.

CONTOUR FROM 0. TO .14018E-01 CONTOUR INTERVAL OF .70080E-03 PT(3.3)= .47883E-04 LABELS SCALED BY 10000.

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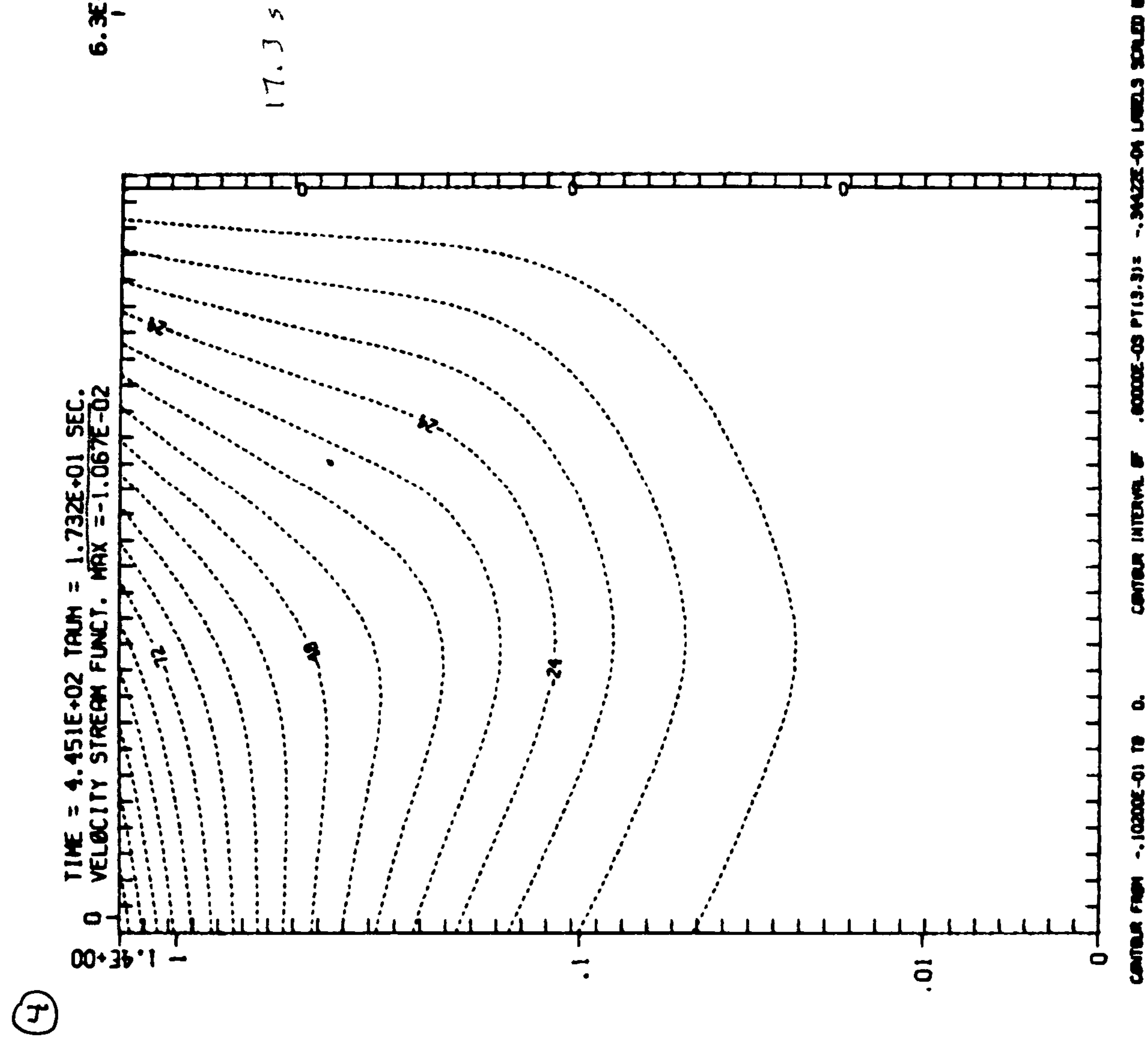

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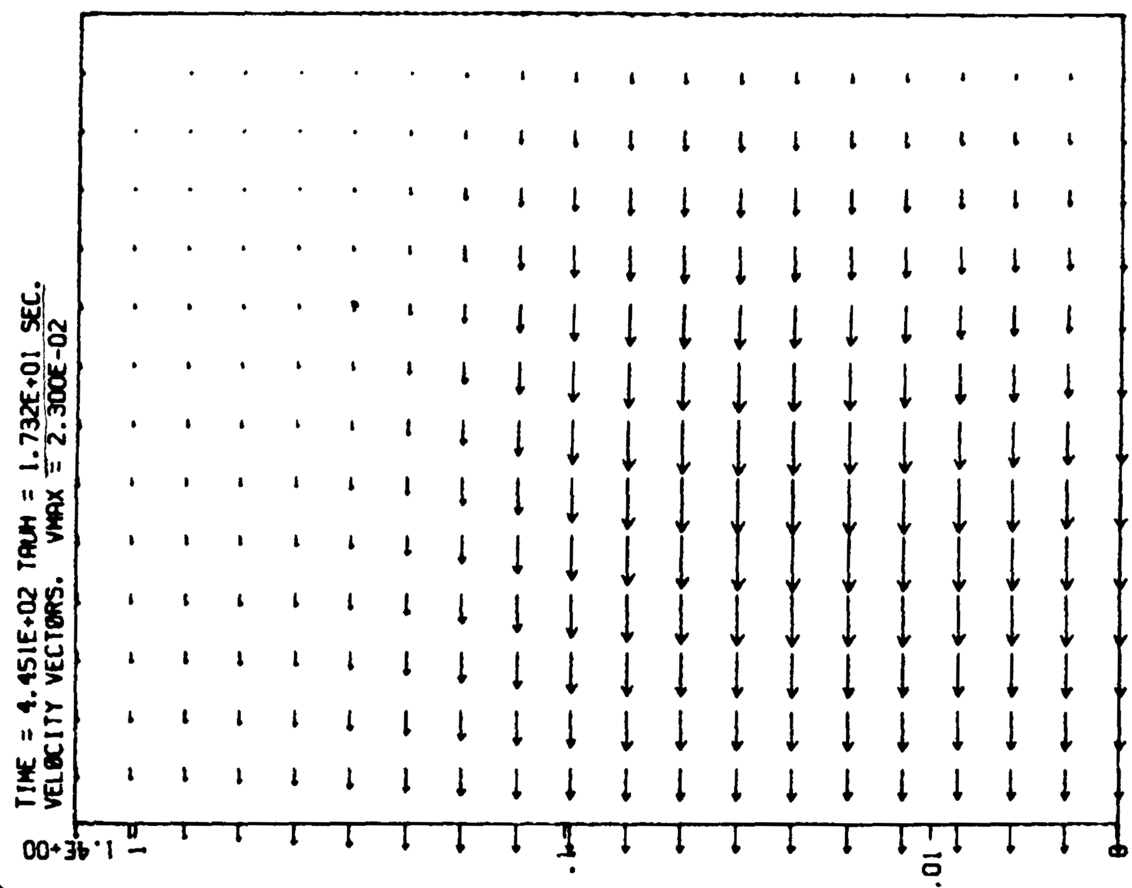
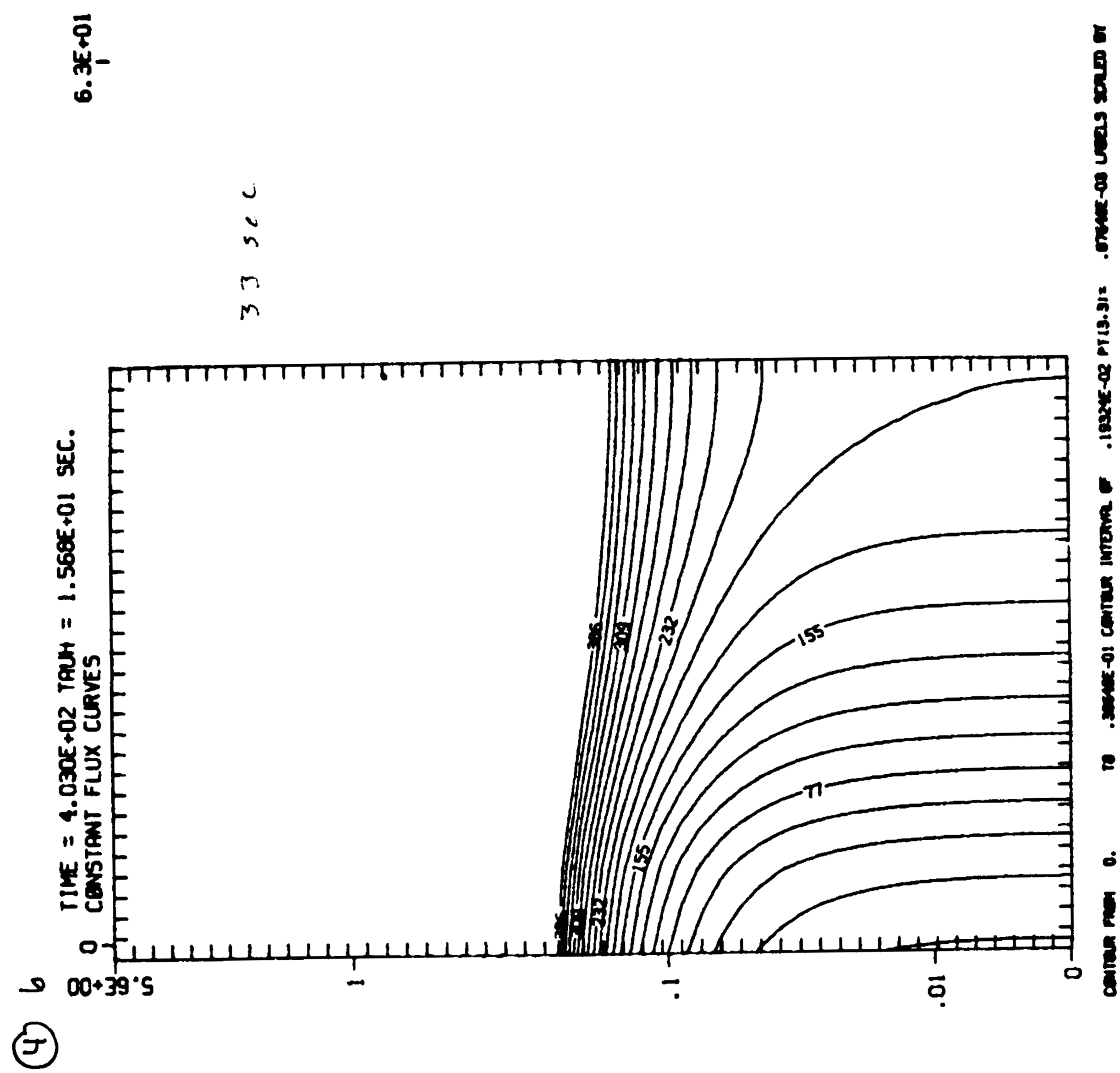
17.3 sec



(4)



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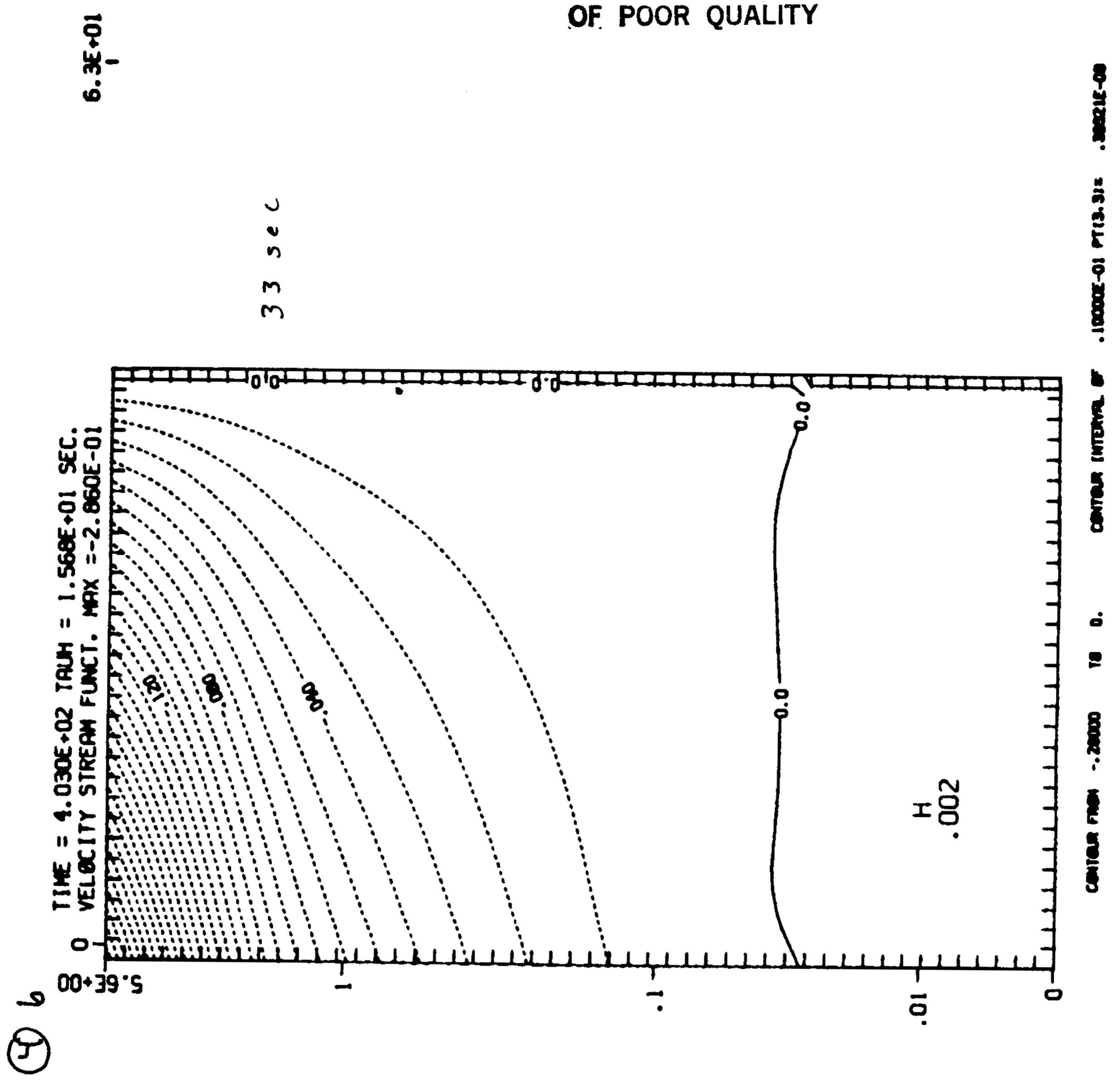

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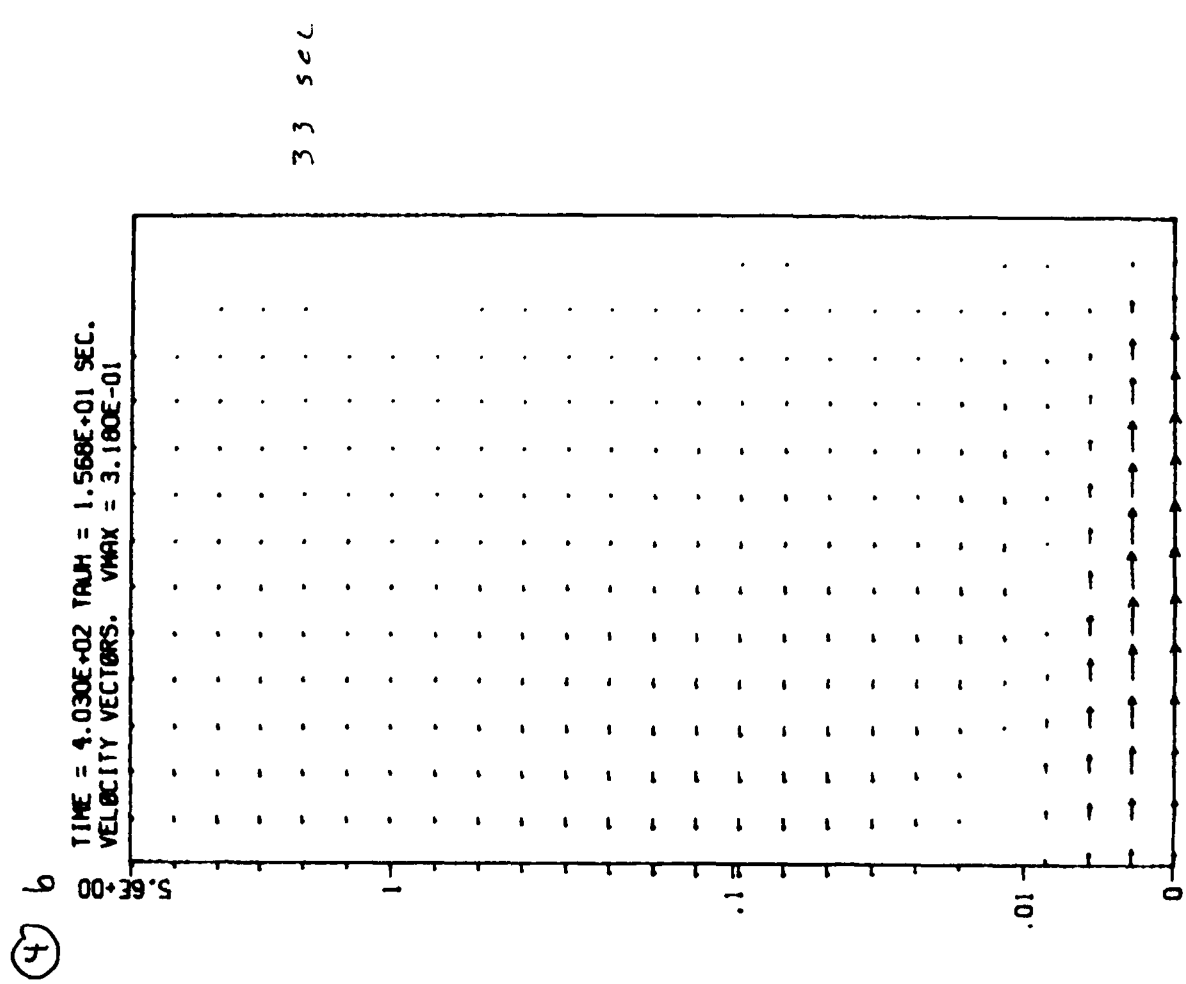

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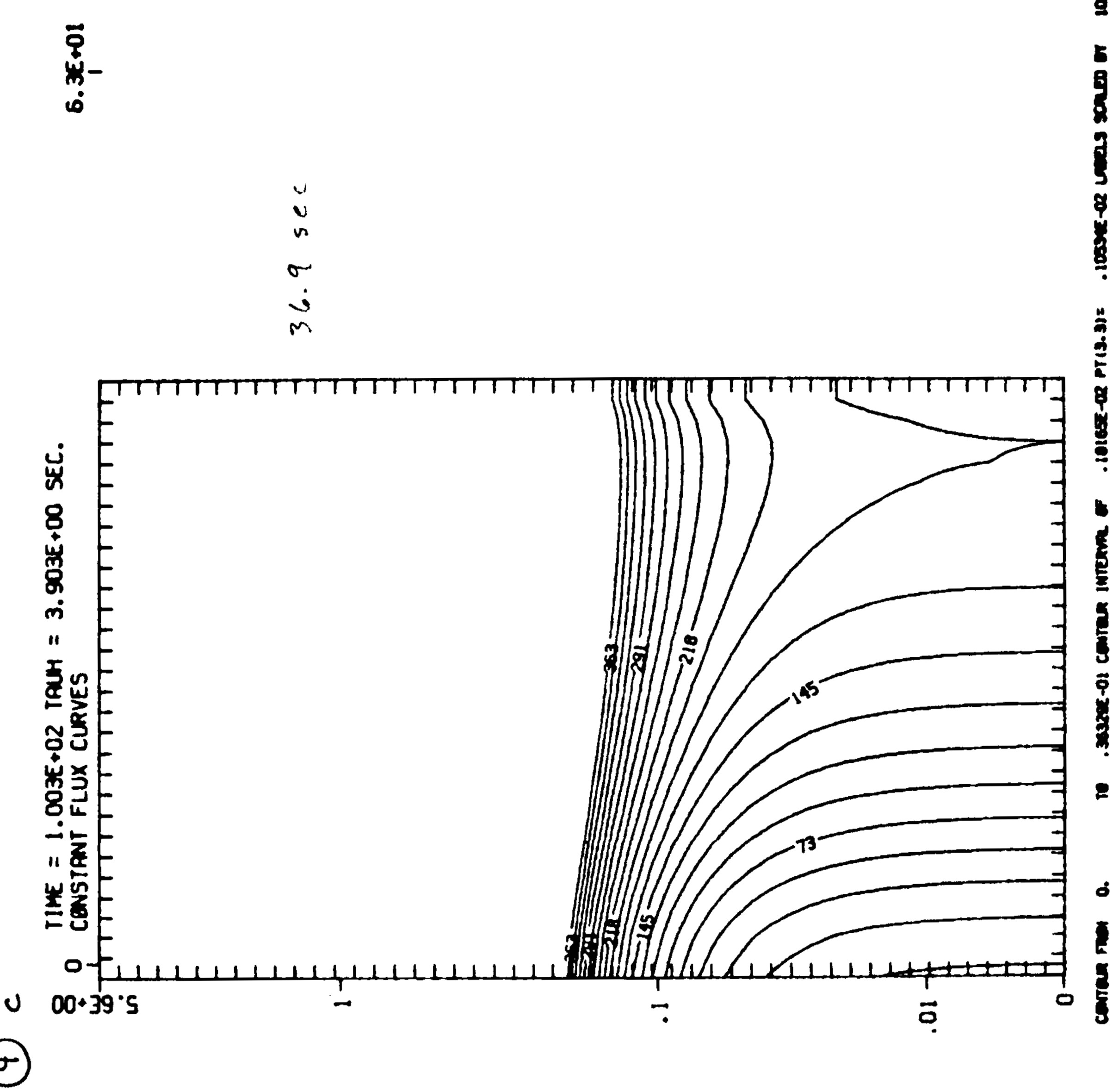

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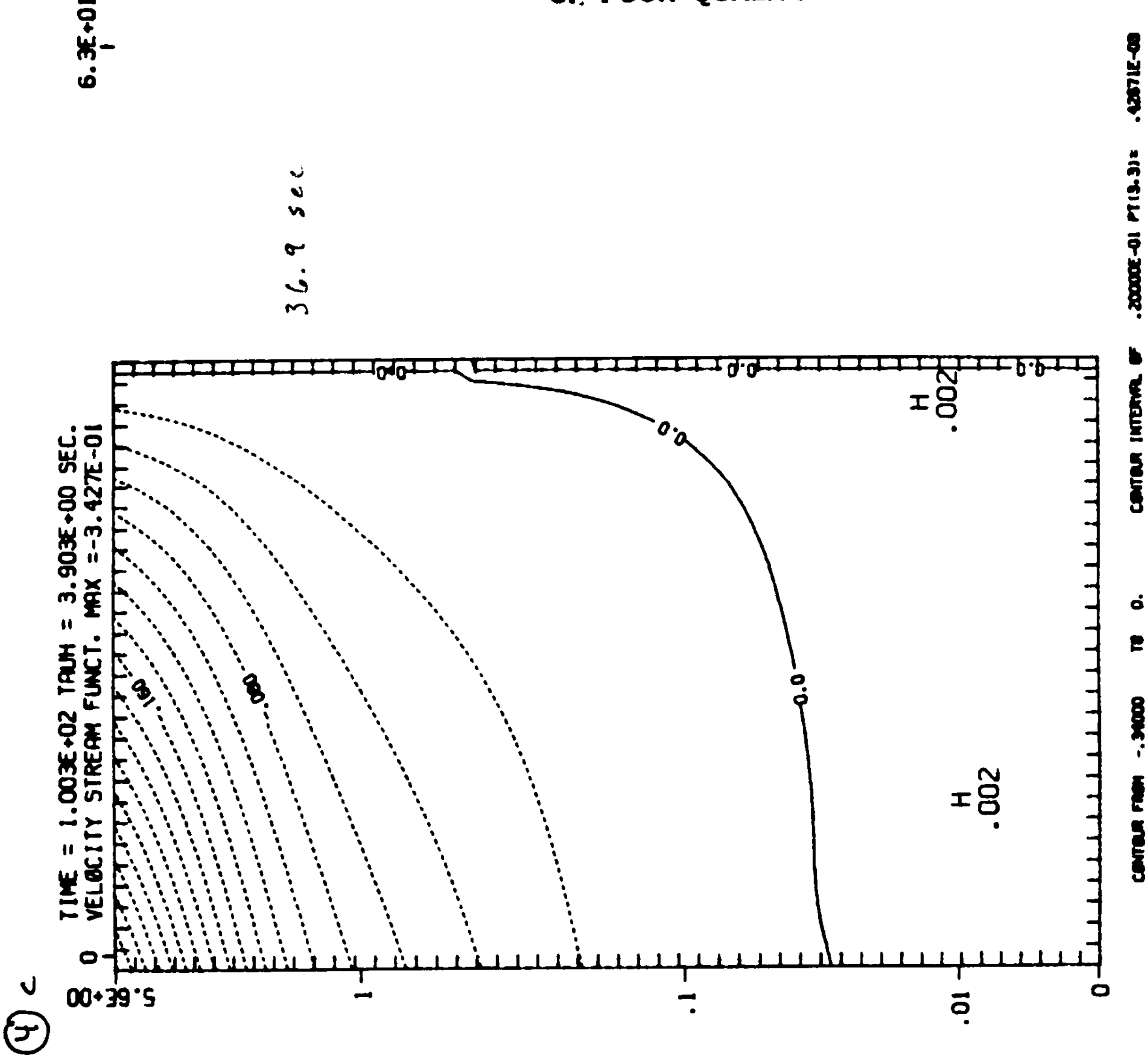

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