APPENDIX B: ELEMENT SIZE

B-1. Parametric Study

a. General. The integration procedures used in the program for transient heat transfer analysis requires a relationship between the minimum time step and the element size. The equation to establish this relationship is given as:

$$\Delta t > (\rho c/6k)\Delta l^2 \; or < l \; \sqrt{(6k\Delta t/\rho c)} \qquad \text{(B-1)}$$

where:

Δt = time step

ρ = density

c = specific heat

k = thermal conductivity

Δl = element dimension

b. Adiabatic heat gain. Adiabatic heat gain in concrete begins within the first 12 hr after placement and can continue rapidly until a maximum is attained. Therefore, when performing incremental time dependent stress analysis for concrete, it is important to keep the time steps sufficiently small during the early stages of the analysis. Input of the appropriate properties for Zintel Canyon Dam into Equation B-1 yields a maximum length of element, using a 6-hr time interval, of 27 in. Analysis for a 12-hr time interval yields a 38-in. element. A 12-hr time interval is not a good choice for calculating early heat gain in the concrete, while placing a 27-in. restriction for a 6-hr time interval doubled the size of the model. A 48-in. step height nearly matched production rates for daily concrete placements, however, did not fit the criteria established in ABAQUS. Therefore, this study focused on a 48-in. element size to determine its reliability in reporting temperature data.

c. One-dimensional heat flow. This study is a simple one-dimensional heat flow problem, using material properties for Zintel Canyon Dam. Two models were generated, one with a 24-in. element size in either direction and the other with a 48-in. element size in either direction. Depicted in Figure B-1 are the two finite element meshes, and boundary conditions used for the study. One exterior row of boundary nodes were held at a constant 50 deg while the ambient surface conditions along the opposite face was a fixed 90 deg. The thermal models calculated nodal temperatures in 0.25 day increments for a period of 10 days. Corresponding nodal temperatures were compared from both models to determine accuracy, and if stable heat gain was being generated. Figure B-2 contains plots of nodal temperatures for both the 24- and 48-in. meshes for various times. The only inconsistency was at time t = 0.5 days, for the 48-in. mesh, where a slight inconsistency in the heat gain exists. This can be seen in Figure B-2.1. Figures B-2a through B-2d, indicate nearly identical heat gain, when comparing nodal temperatures at the same time steps of the two models. Because this amount of inconsistency was at small, and only occurred at one time step, it was considered negligible and would not effect the outcome of the study. Therefore, we decided to use a time step of 6 hr (0.25 days) and a maximum element size in any direction of 48 in.

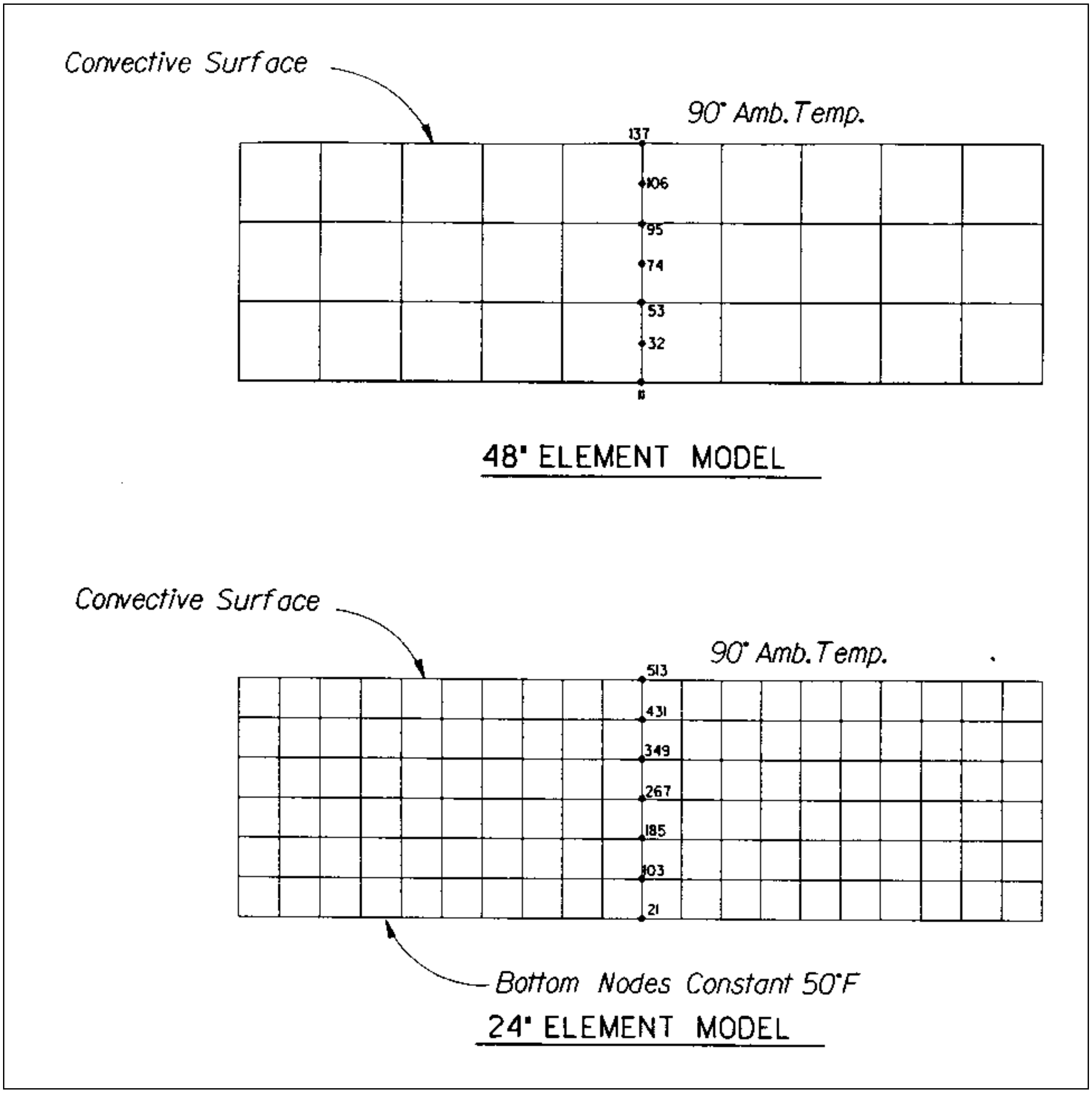

Figure B-1. Finite element mesh and input data

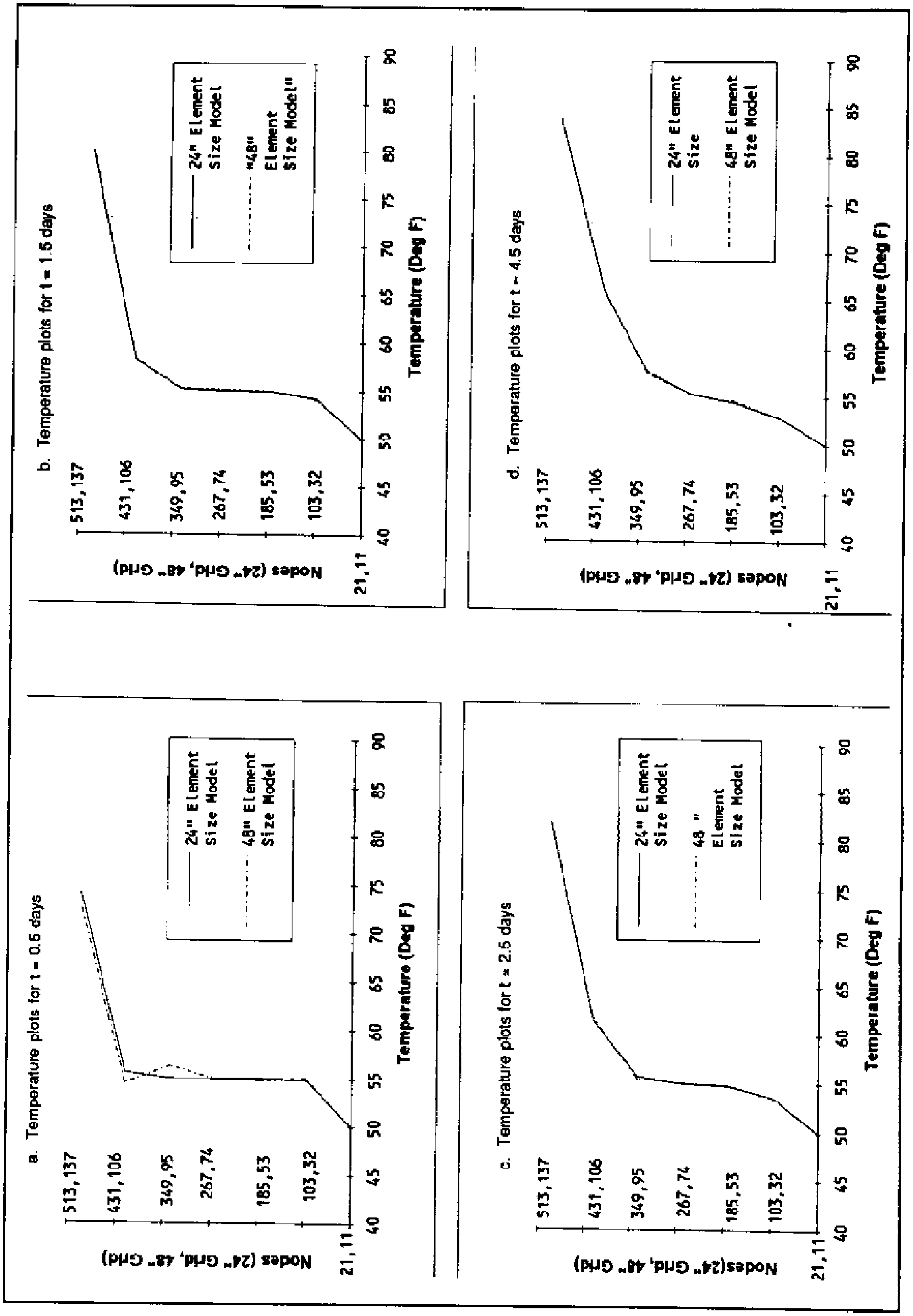

Figure B-2. Temperature comparisons