Since α_i should be tested against variation within α_i, i.e., $\beta_{j(i)}$, the following MANOVA specfications can be used:

```
MANOVA       Y BY COUNTY(1,5),TOWN(1,3)/
             DESIGN=COUNTY VS 1, TOWN WITHIN COUNTY=1 VS WITHIN/
```

Note that the first keyword WITHIN (or just W) indicates nesting. The DESIGN specification requests that COUNTY be tested against the error 1 term, which is the effect of TOWN (nested within COUNTY), and that the within-cells error term (second WITHIN) be used for testing the TOWN effect.

When crossing and nesting are both used in the design, attention must be paid to the choice of appropriate error terms for testing the various effects. Consider a three-factor example, with factors A, B, and C. If

1 C is nested within B, and B is nested within A, the model is

$$Y_{ijk} = \mu + \alpha_i + \beta_{j(i)} + \gamma_{k(ij)} + \epsilon_{ijk}$$

The DESIGN specification should be

```
DESIGN=A VS 1, B W A=1 VS 2, C W B W A=2 VS WITHIN/
```

2 C is nested within B, and B is crossed with A, the model is

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_{k(j)} + (\alpha\gamma)_{ik(j)} + \epsilon_{ijk}$$

The rule for writing down the model is that no interaction in which the subscript j appears twice is in the model. For example, interactions $(\beta\gamma)_{jk(j)}$ and $(\alpha\beta\gamma)_{ijk(j)}$ do not exist.

Since C is nested within B, β_j is tested against $\gamma_{k(j)}$. The appropriate error term for α_i and $(\alpha\beta)_{ij}$ is the residual of the A-B two-way table, $(\alpha\gamma)_{ik(j)}$, which is the interaction effect of α_i and $\gamma_{k(j)}$. If the number of observations per cell is greater than one, then $(\alpha\gamma)_{ik(j)}$ and $\gamma_{k(j)}$ can be tested against the within-cells error term. The DESIGN specification for this model is

```
DESIGN=A VS 2, B VS 1, C W B=1 VS WITHIN,
    A BY B VS 2, A BY C W B=2 VS WITHIN/
```

3 C is crossed with B, and B is nested within A. The model and the DESIGN specification are the same as those in (2) except for the names of the effects.

An experiment (Hicks, 1973, p. 195) was conducted to compare a new gun-loading method with the existing one (factor METHOD). Three teams were chosen randomly from each of three groups. Each team used the two methods of gun loading in random order. The data and SPSS commands for the analysis are as given in Figure 1.25a, and the ANOVA table is presented in Figure 1.25b.

Figure 1.25a

```
RUN NAME       NESTED DESIGN.
COMMENT        DATA ARE TAKEN FROM HICKS(1973) P. 194.
COMMENT        METHOD : 2 LEVELS CROSSED WITH GROUP.
COMMENT        GROUP  : 3 LEVELS.
COMMENT        TEAM   : 3 LEVELS NESTED WITHIN GROUP.
COMMENT        NUMBER OF OBSERVATIONS PER CELL = 2.
VARIABLE LIST  GROUP,TEAM,METHOD,RESP
N OF CASES     UNKNOWN
INPUT FORMAT   FREEFIELD
INPUT MEDIUM   CARD
MANOVA         RESP BY METHOD(1,2),GROUP,TEAM(1,3)/
               DESIGN=METHOD VS 1,GROUP VS 2,
               METHOD BY GROUP VS 1,TEAM W GROUP=2,
               METHOD BY TEAM W GROUP=1/
READ INPUT DATA
1 1 1 20.2
1 1 1 24.1
1 1 2 14.2
1 1 2 16.2
1 2 1 26.2
1 2 1 26.9
 .  .  .
 .  .  .
3 3 1 21.8
3 3 1 23.5
3 3 2 12.7
3 3 2 15.1
END INPUT DATA
FINISH
```