Marshall Long Acoustics

1629 Stanford Street
Santa Monica, CA 90404
Telephone (213) 829-4311

DESIGN OF HOUSING FOR AIRCRAFT NOISE

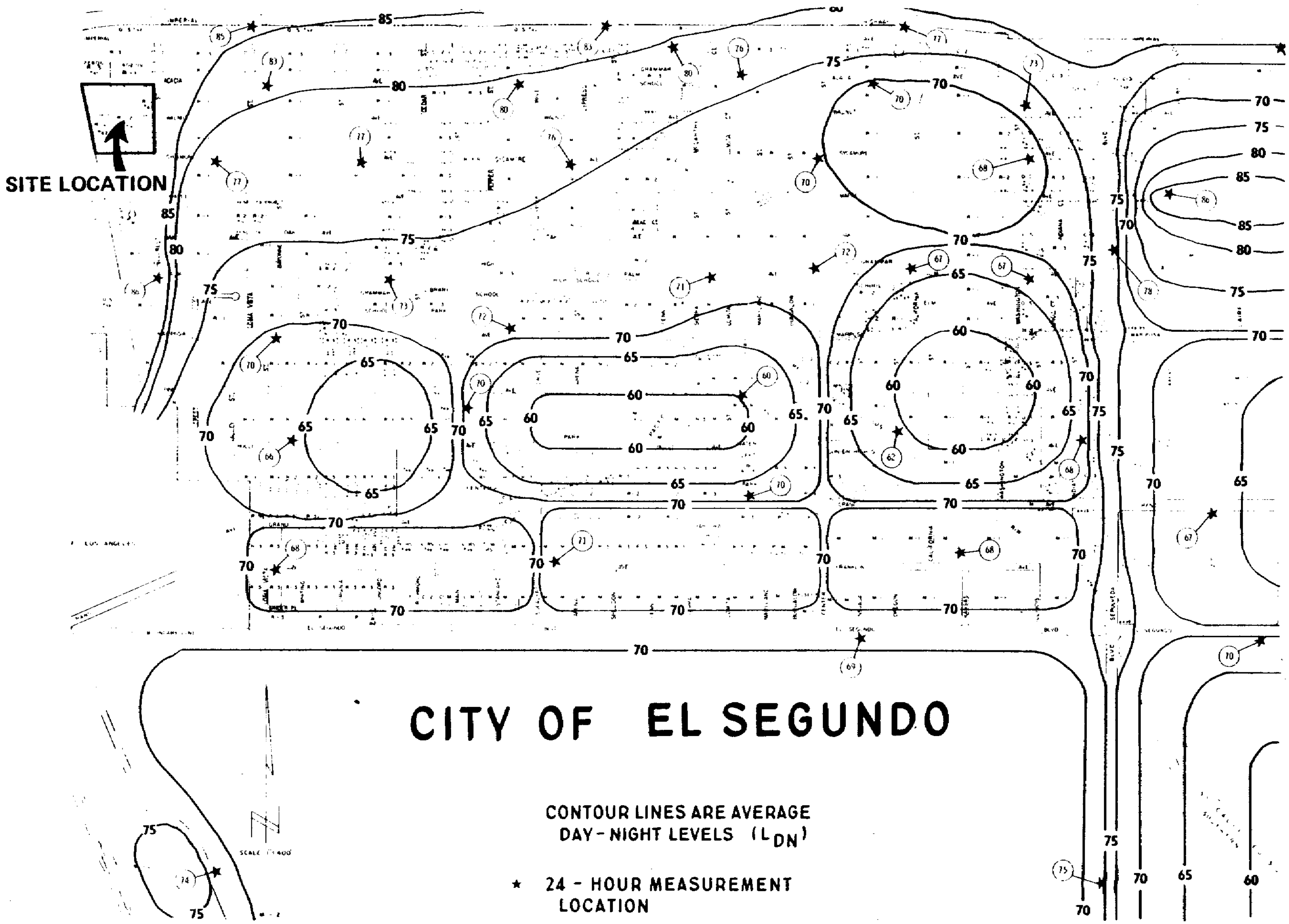
Marshall Long

Presented to the 100th Meeting of the Acoustical Society of America, Los Angeles, California 17-21 November, 1980.

As land becomes more valuable it is inevitable that homes will be built close to airports. Local government agencies have quite different attitudes toward land use planning as a solution to the problem of aircraft noise. Near Los Angeles International Airport (LAX), for example, homes on the north and west sides of the airport in the City of Los Angeles have been torn down in L_{dn} 75-80 noise zones, while on the south side of the airport, in El Segundo, homes are being built with a vengence at levels of L_{dn} 80 and above. The position of the City of El Segundo on permitting construction of multifamily dwellings has been to enforce the California Noise Insulation Standards requiring L_{dn} 45 in habitable rooms. Recently, when a project was proposed for 61 single family dwellings, not regulated under California Standards, near the end of the runway, El Segundo imposed an L_{dn} 45 limit in all bedrooms and L_{dn} 55 in other rooms of the development. Compliance with the El Segundo requirements was to be demonstrated by monitoring on the inside of the units after construction in order to confirm the results. This measurement requirement did not stimulate an inordinate rush of firms bidding on the project. We were the successful and as far as is known, the only bidder.

The first task was to establish the ambient level at the site. The City of El Segundo has a Noise Element of General Plan prepared in 1975 by McDonnell Douglas Corp. The contour map developed as part of the Noise Element is shown in Figure 1. Also shown in the figure is the site location.

The principal noise source at the site are aircraft using the southern most LAX runway just to the north. Aircraft take off and land principally in a westerly direction, generally parallel to Imperial Boulevard at the top of Figure 1. An unusual feature of the McDonnell Douglas contours is the sharp turn to the south which they make and the unusually high noise levels they



SITE LOCATION
CITY OF EL SEGUNDO
CONTOUR LINES ARE AVERAGE DAY-NIGHT LEVELS (L_{DN})
★ 24 - HOUR MEASUREMENT LOCATION

Figure 1.

show. This sharp turn feature at the end of the runway at right angles to the flight path is unique among airport contours of the world so far as I know. Other contour studies of LAX such as that prepared by BBN and Olson Laboratories and shown in Figure 2 do not exhibit this phenomenon. The BBN/Olson Labs data are also considerably lower in level than the McDonnell Douglas data.

Due to this inconsistency, on-site measurements were made at two locations, for six days at each location. The two locations are shown in Figure 3 along with contours established from the measurements. The center post measurement was an L_{dn} of 79.7 dB $\pm$ 1.0 and the south post measurement was 76.2 dB $\pm$ 1.2. There is a downward slope on the site to the south which affords a slight bit of shielding to the southern portion and accounts for the closer spacing of the southernmost contours. The results were in close agreement with the BBN and Olson Laboratories data.

Having established the exterior levels, calculations were carried out on the required construction elements. Since there was a standard deviation of about 1 dB at the measurement location a safety factor of 2 sigma or 2 dB was allowed for the external variation. The general design goal was an L_{dn} 43 in bedrooms and L_{dn} 50 elsewhere. Although the City of El Segundo allowed an L_{dn} 55 it was felt by the consultant that this was excessive. The opinion of the client was that an L_{dn} 45 was an unduly expensive design goal for all rooms. Calculations were carried out for each individual house type, orientation, exterior level and where required for individual rooms. By using this detailed approach at a higher initial engineering cost, a considerable savings in construction was achieved for the client over simply using one specification based on the worst case condition. All calculations were done in six octave bands using laboratory transmission loss data for all surfaces

Figure 2.

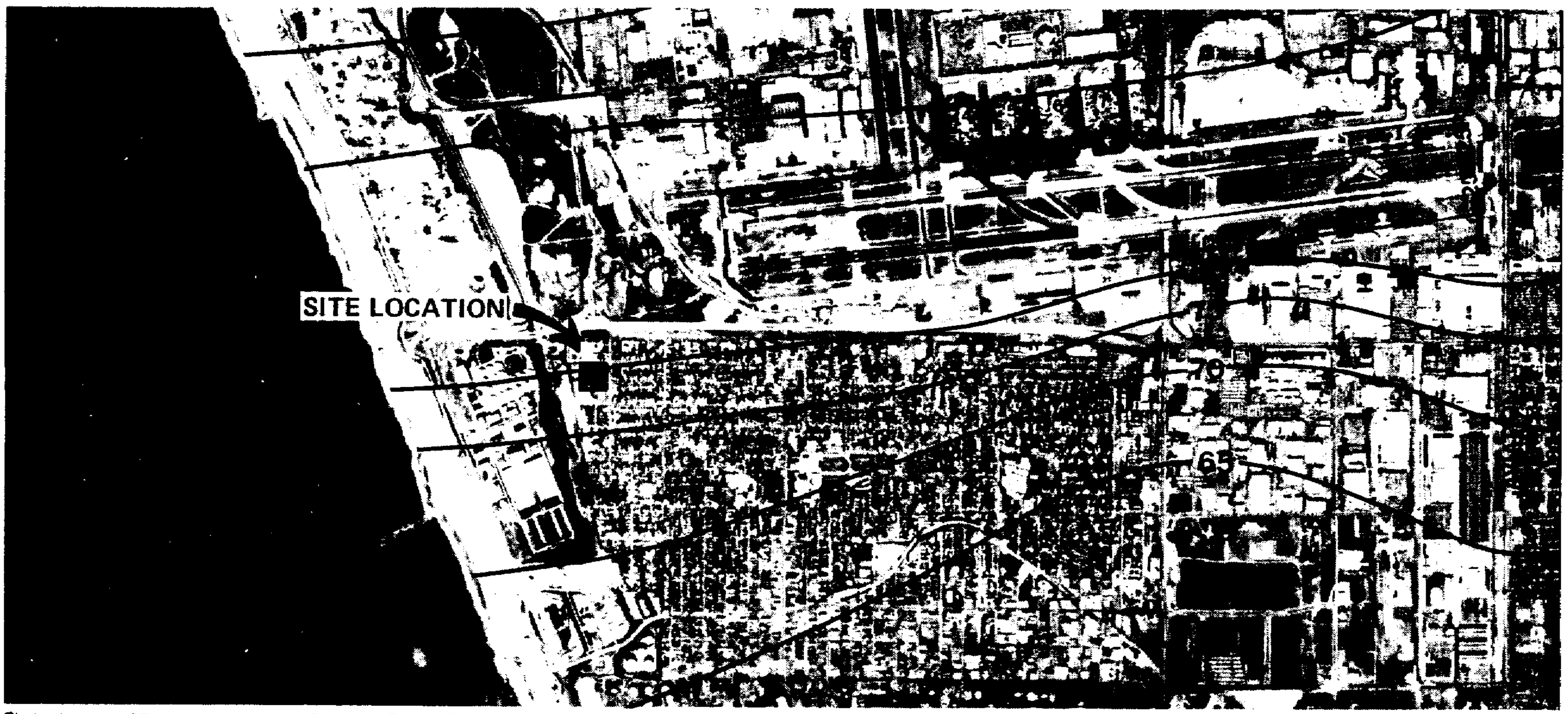
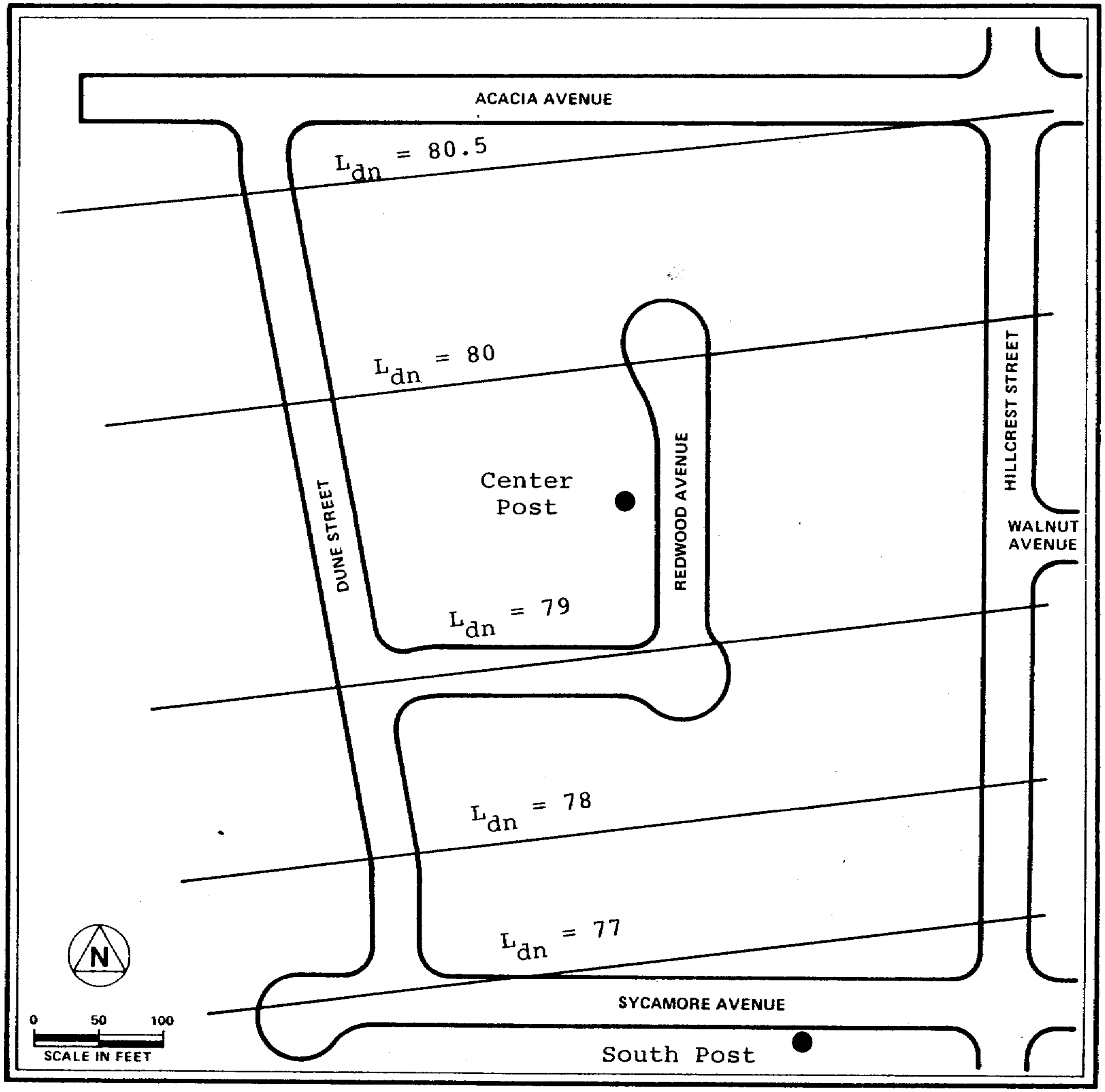


Photo Nov 11 1974 American Aerial Surveys Covina CA

—65— Contours of equal noise levels, decibels CNEL or L_{dn}
Computer estimates by Bolt, Beranek and Newman and Olson Laboratories modified by field monitor data

CITY OF INGLEWOOD
DEPARTMENT OF PLANNING AND DEVELOPMENT

1976 Aircraft Noise Levels



PROJECT SITE SHOWING MEASUREMENT LOCATIONS AND RESULTING CONTOURS

Figure 3.

except for the roofs. With the roofs a theoretical calculation of the transmission loss was utilized. Calculations of interior noise must account for the location, directivity, shielding and spectral content of the source. The passage of a jet as seen from the project is shown in Figures 4 and 5. The jets lift off northeast of the site and continue rising to the northwest. Figures 6 and 7 continue the chronicle of this passage. The sound from the northeast is predominantly high frequency compressor whine while the northwest sound is dominated by lower frequency exhaust noise.

In the design, the most critical parameter was the ceiling roof. Ceiling roofs were the largest exposed area, the most complicated structure and the least well known acoustically. The roofs were especially difficult when lightweight wood shingles were used. The treatment recommended is shown in Figures 8 and 9. Roofs were solid sheeted using 1/2" plywood. To gain additional mass 90 lb roofing paper was added before the cap sheet and shingling. The total minimum roof weight used was about 4.5 lbs/ft^2. When gravel or mission tile roofs were used the 90 lb paper was not required.

Blocking where roofs meet the exterior walls is particularly difficult to control. Figures 10 and 13 show the solution to this problem. Since most of the exterior walls were plaster, the plaster was carried out under the eaves to avoid having to caulk the blocking.

Figure 11 shows a typical home at the framing and wrapping stage. Exterior walls were 7/8" stucco with R-11 batt and 1/2" gypboard. Some units with mansard roofs had wood shingle walls. These had exterior plywood under the shingles and double 1/2" gypsum board on the interior walls in the high noise level areas.

The choice of windows depended on their orientation, area and the exterior noise level. The critical areas STC 38 double glazed

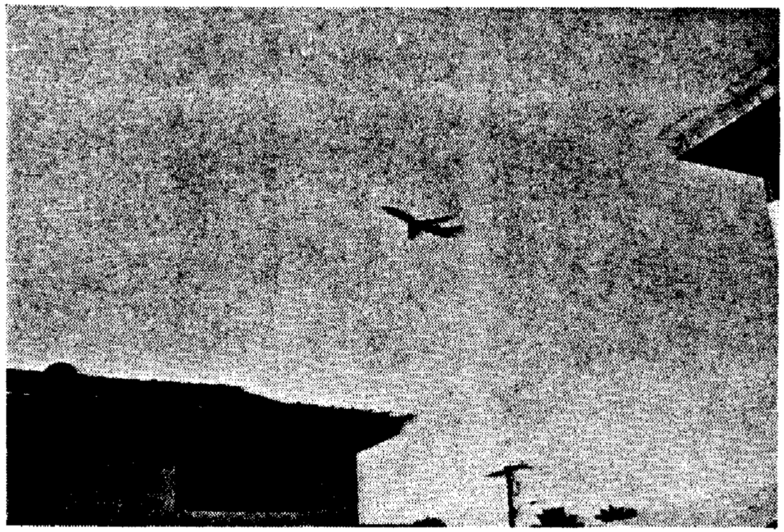


Figure 5. A Typical Jet Passage-
Climb

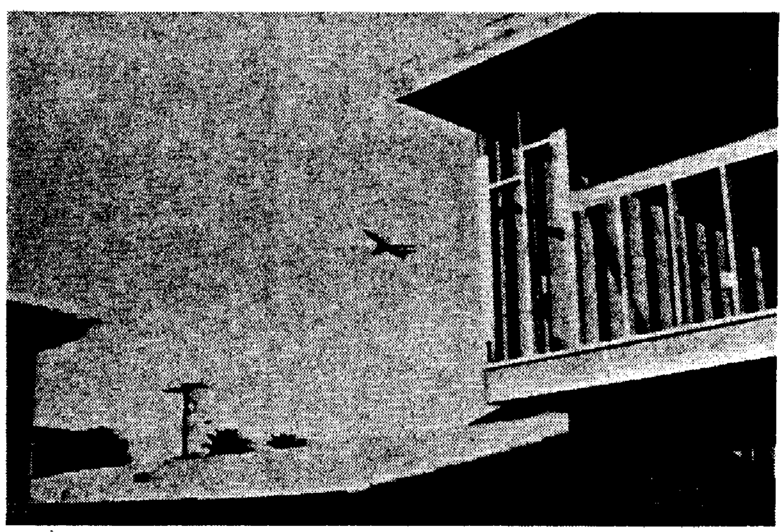


Figure 4. A Typical Jet Passage
Lift-Off

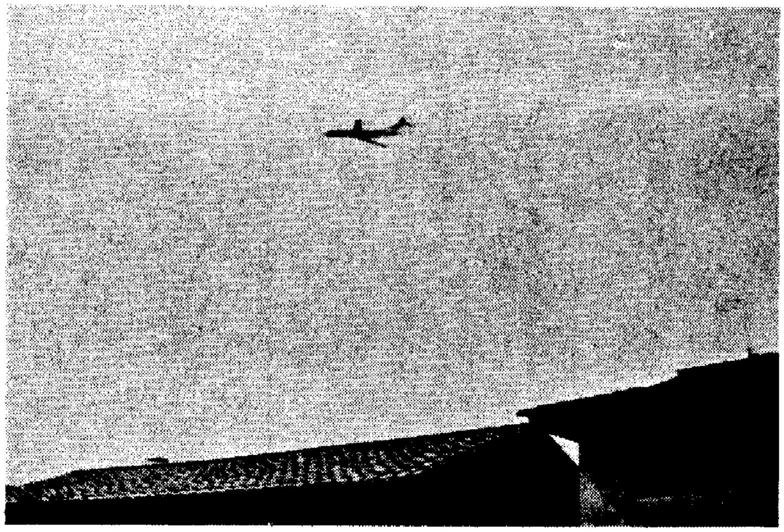


Figure 7. A Typical Jet Passage-
Thrust Cutback

Figure 6. A Typical Jet Passage-
Passby

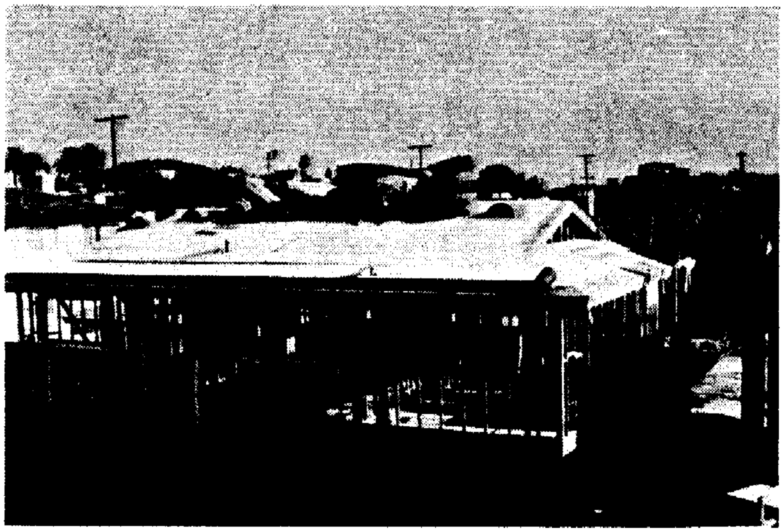


Figure 9. Treatment with 90 lb Roofing Paper.

Figure 8. Plywood Sheeted Roofs

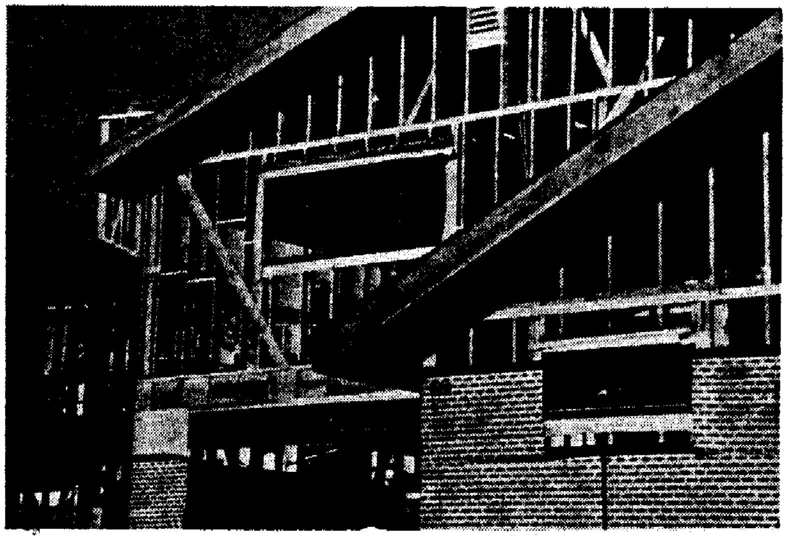


Figure 11. A Typical House During Framing and Wrapping

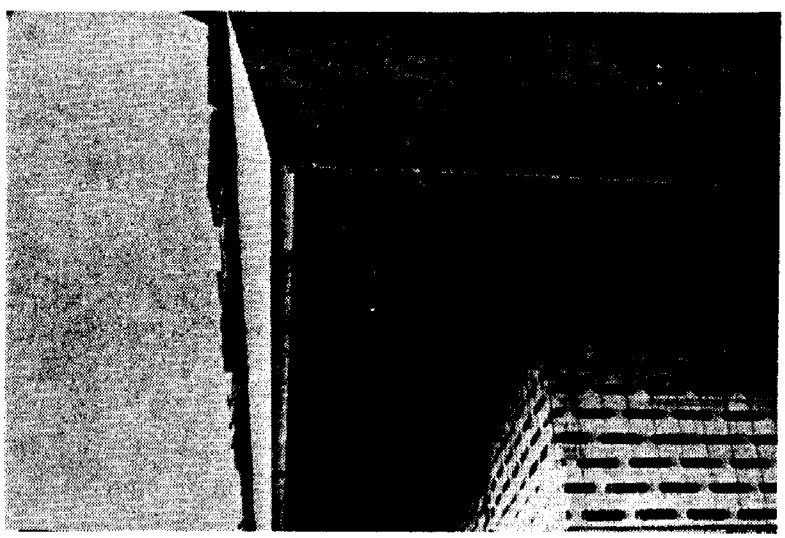


Figure 10. Wire Mesh Supports for Exterior Plaster is Carried under Eaves

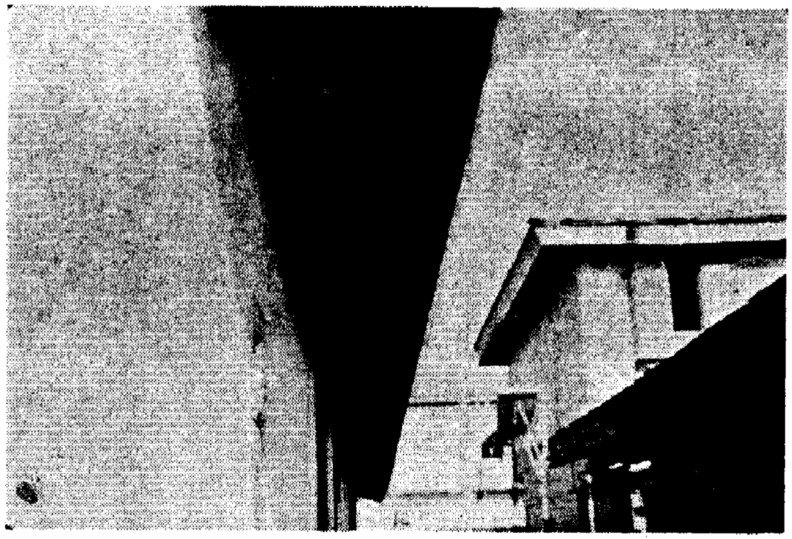


Figure 13. Exterior Plastering on Walls and under Eaves

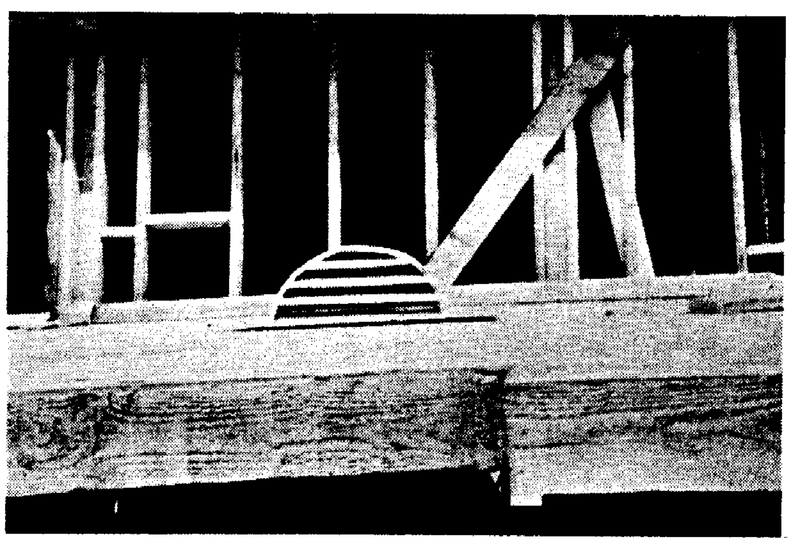


Figure 12. Attic Vents in the Roof

Figure 15. Roof Vent Silencer
Shown Installed

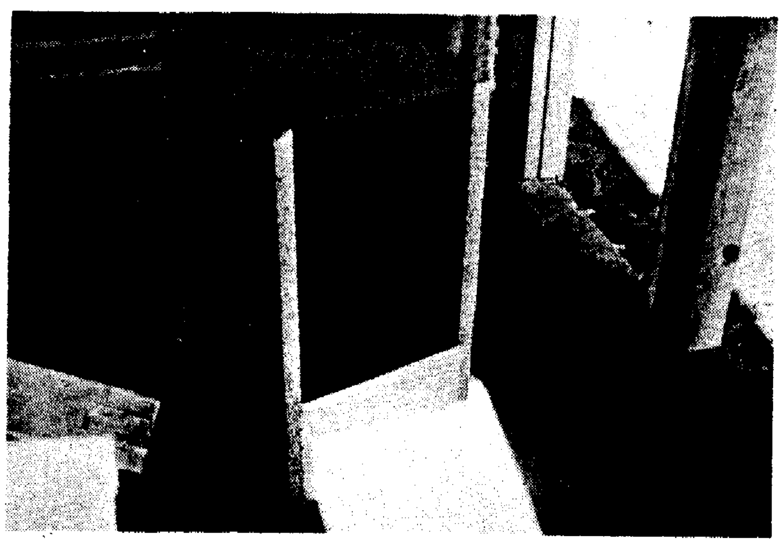


Figure 14. Side Vent Silencer
Design

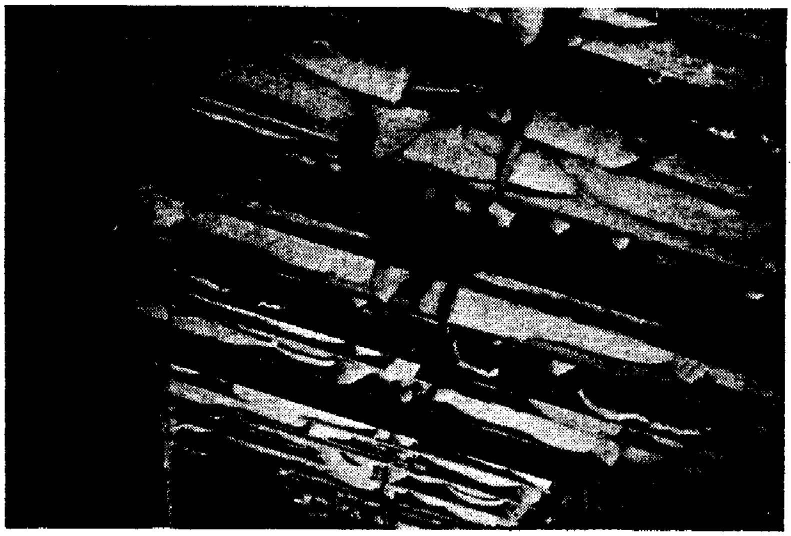


Figure 17. A Beam Ceiling before Resilient Channel and Drywall were Applied

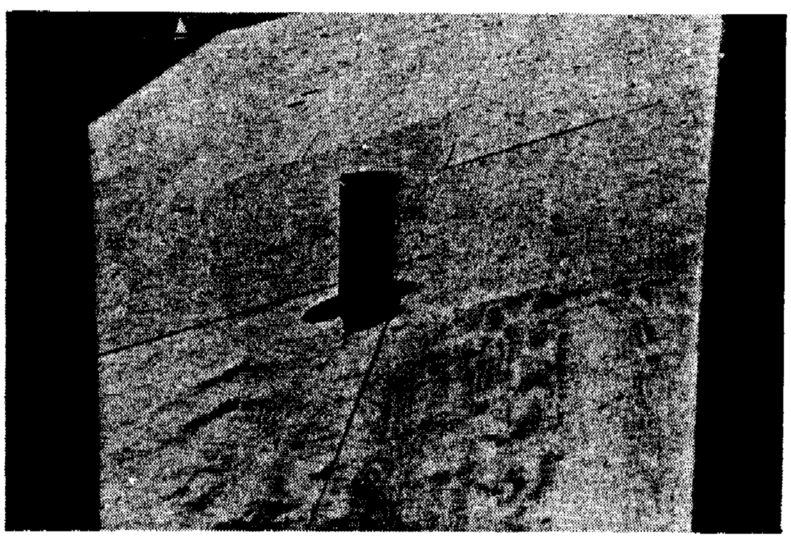


Figure 16. A Potential Sound Path through the Roof

windows were specified. These contained 1/4" and 3/16" glass with a 2" airspace. In less critical areas STC 34 windows having single glazed 1/4" sandwich glass were called out. All sliding glass doors were STC-34 as well. No sliding glass doors were specified in bedrooms. Only window manufacturers with laboratory test data on their products were allowed to bid. The successful window and sliding glass door supplier was Premiere Aluminum Products.

Figure 11 shows the wall vents for the attic space. Roof vent details are shown in Figure 12. The vent openings in the roof were treated using a duct silencers shown in Figures 14 and 15. The silencers has one 180° bend and total length of 5' of duct, lined with 1" duct liner. Slightly different designs were used for a wall and roof mounting. The silencers were fitted tightly against the roof sheeting and caulked.

Detailing for noise control is particularly important. Cutouts for the vent stacks shown in Figure 16 were covered with roofing paper and the usual sheet metal covers. Where possible, standard construction practices were utilized with only minor modifications. Exotic construction requirements are as a rule simply ignored in the field.

Occasionally unusual techniques were used. Some resilient channel was used in the ceilings especially when there was no attic. Figure 17 shows such a case. Here a beam ceiling effect was desired. Resilient channel was used between the beams with a drywall ceiling sealed at the beams. In highly critical areas a double 1/2" drywall ceiling was used on resilient channel, even where there was an attic. Standard R-19 and R-11 batt were used in the ceiling-roofs and walls respectively. A typical finished ceiling is shown in Figure 18. All joints and cracks were caulked or mudded in exterior walls and ceilings. Details are shown in Figures 19, 20 and 21 for light wall plugs,

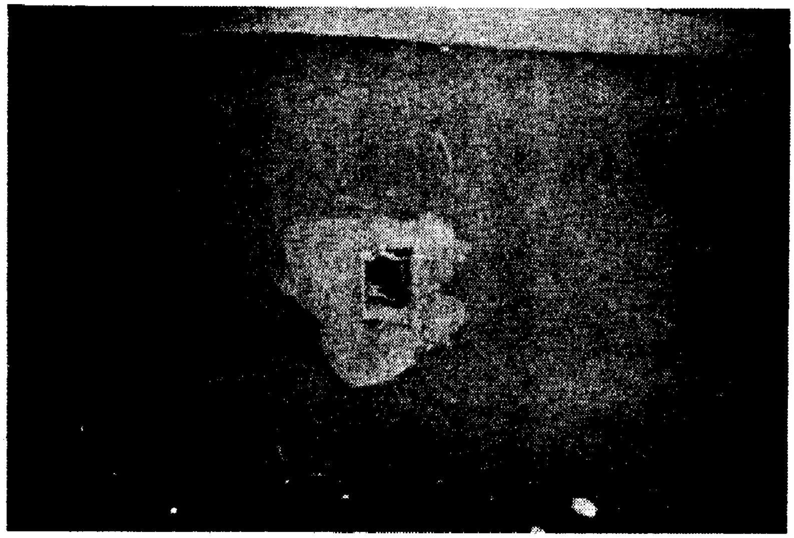


Figure 19. A Typical Wall Mounted Electrical Outlet

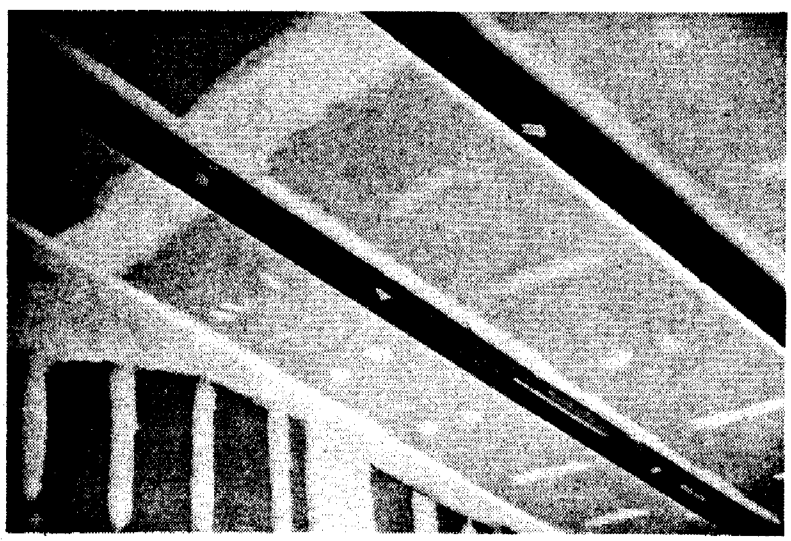


Figure 18. Resiliently Mounted Ceiling after Taping and Mudding

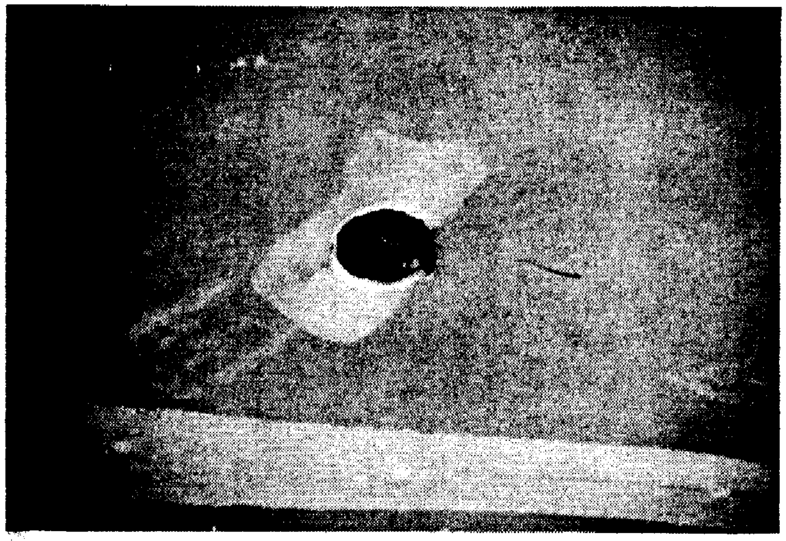


Figure 21. A Ceiling Mounted Light Fixture

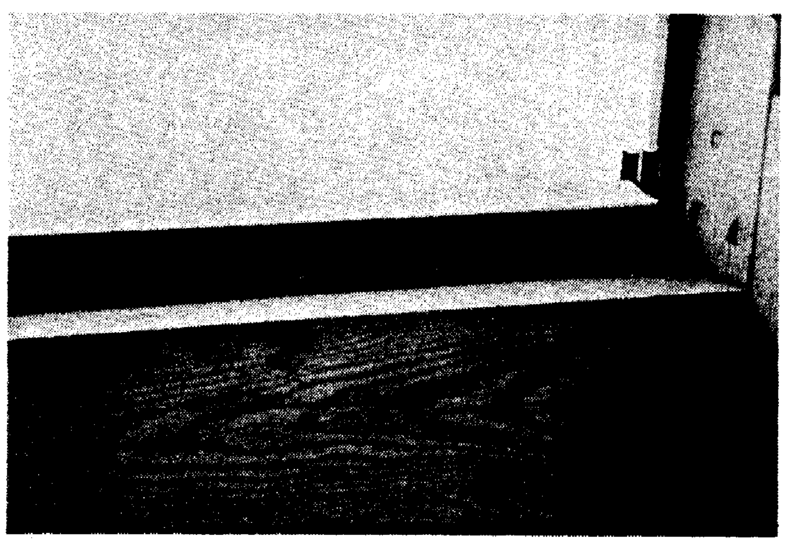


Figure 20. A Window Sill Showing Caulking

window sills and ceiling mounted lights.

Typical finished houses are shown in Figures 22 and 23. A mansard roof mode and wood shingled model are shown. Other than the double glazing there is no visible alteration to these homes. The selling price of the houses ranged from $140,000 to $180,000. The additional cost for noise control was about $5,000 per house.

Upon completion of construction the worst case bedrooms in a number of houses were tested. Only bedrooms were tested due to the difference in noise criteria. Every model along the northern edge of the site was included in the tests. All bedrooms had a standard queen size bed, curtains on the windows and a closet full of clothes simulated by fiberglass batt. The microphone was placed in the center of the room usually about 5 feet above the floor. In all seventeen 24 hour measurements were carried out. Measurements were made with either a Gen Rad 1945 or a Digital Acoustics 605 recording sound level meter. The average difference between predicted and measured levels was .08 dB. The standard deviation of the difference was .94 dB. This is quite close to the standard deviation of the exterior levels.

Given economic pressures on real estate especially in Southern California, the construction of housing in high noise level areas is likely to continue. The design of homes in these areas to precise standards allows government to retain some control over the acoustical environment while allowing the developer to spend only what is required to meet the standard. Studies of people living in these homes should provide an excellent opportunity to examine the psychoacoustic impact of current standards under controlled conditions.

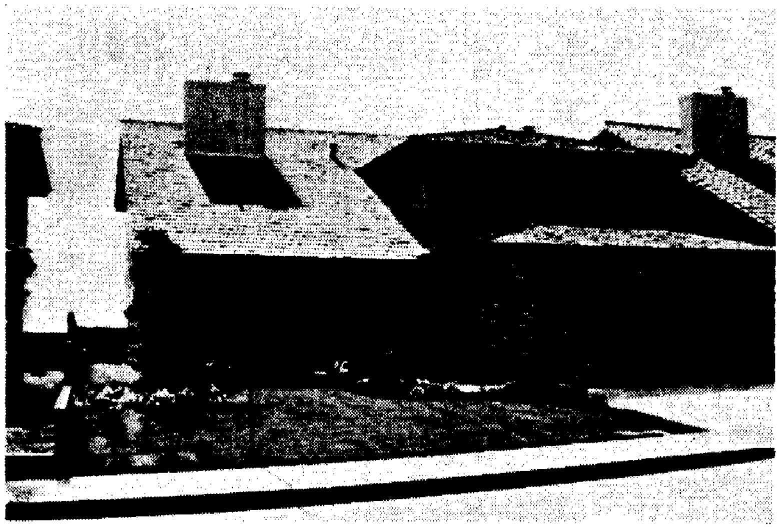


Figure 23. A Finished Shingle Roof Model

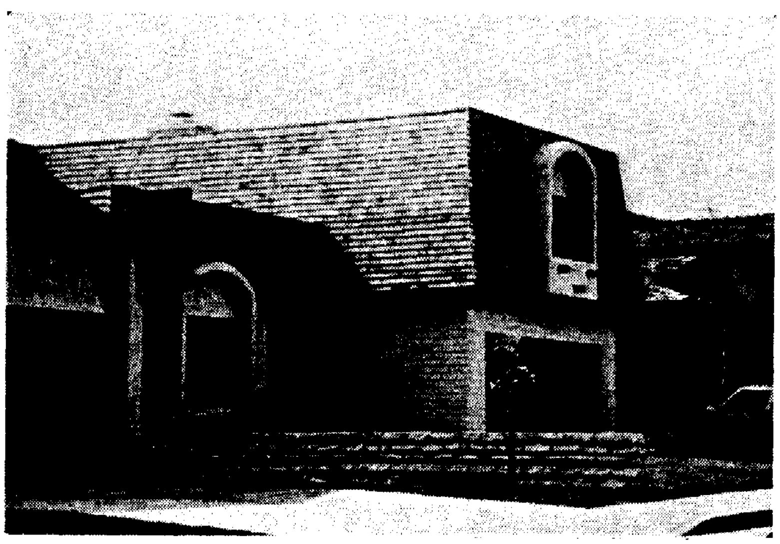


Figure 22. A Finished Mansard Roof Model