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Standard Oil Development Company

DESIGN AND CONSTRUCTION OF TYPICAL GERMAN AND JAPANESE TEST STRUCTURES AT DUGWAY PROVING GROUNDS, UTAH

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SOD Project 30601

Request Chemical Warfare Service-Technical Division SPCWT 161 March 12, 1943

Letter Contract Corps of Engineers, March 18, 1943

PDN 1340 - May 27, 1943

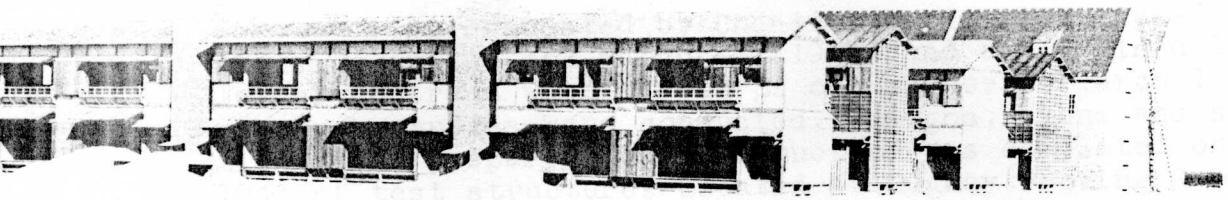
C O N F I D E N T I A L

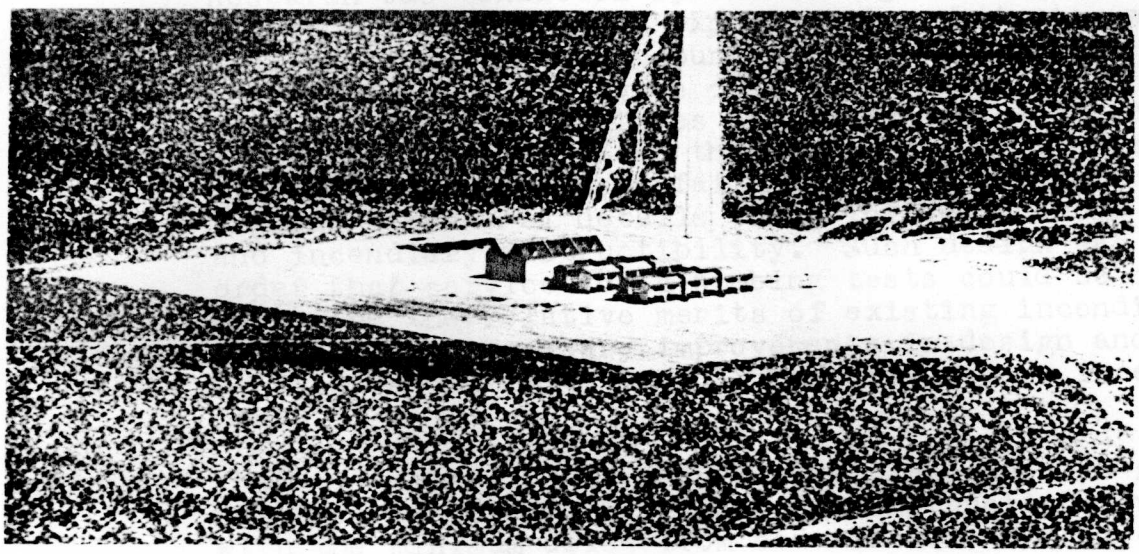
STANDARD OIL DEVELOPMENT COMPANY

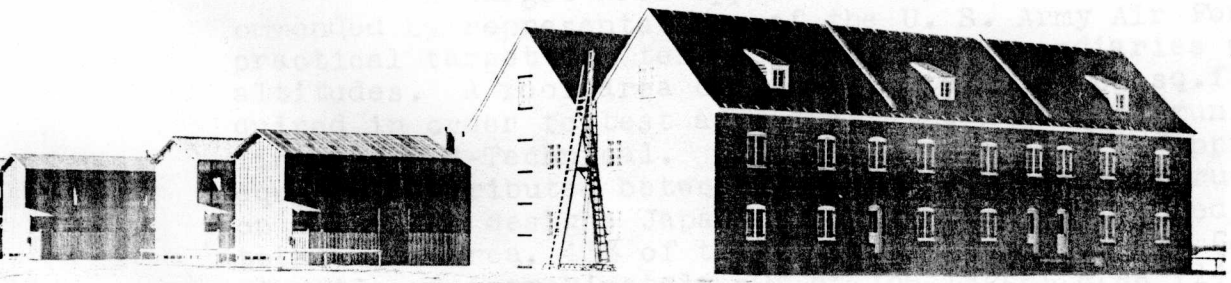
INDEX

FIGURE 1

AERIAL VIEWS OF DUMMY STRUCTURES







DESIGN AND CONSTRUCTION OF TYPICAL GERMAN AND JAPANESE TEST STRUCTURES AT DUGWAY PROVING GROUNDS, UTAH

I. INTRODUCTION

As requested by Chemical Warfare Service-Technical Division (SPCWT 161-March 12, 1943) and as outlined in the letter contract with the Corps of Engineers (March 18, 1943), research studies were conducted, designs, plans and specifications were prepared and construction was completed on May 11, 1943 of test structures located at Dugway Proving Grounds, Utah.

These test structures consisting of approximately 400,000 cu.ft. of construction on a plot approximately 140 ft. x 252 ft. represent the majority of the roof area in the industrial sections of the leading cities of Germany and Japan. Research was conducted by contacting several authorities on such construction; generally experienced architects, who had lived and practiced in these countries for many years. Studies were made of the various types of construction in the industrial sections of leading cities and designs were completed representing approximately 70% of the roof area. In these designs the typical structures were faithfully reproduced in full scale as regards structural details which influenced bomb penetration and incendiary destructibility. Such design was necessary in order that service scale bombing tests could be conducted to determine the relative merits of existing incendiary munitions, to determine necessary improvements in design and functioning of existing munitions, and to program future incendiary development.

The site of this target structure was selected by Chemical Warfare Service because construction could be expedited with the minimum delay from bad weather, lumber could be dried and maintained in a dry condition similar to aged structures, and high altitude bombing tests could be conducted without interference.

A target area approximately 150 ft. x 250 ft. was recommended by representatives of the U. S. Army Air Force as a practical target for test bombing with incendiaries at high altitudes. A roof area of approximately 15,000 sq.ft. was required in order to test adequately the number of munitions outlined by CWS-Technical. The roof area was to be approximately equally distributed between German and Japanese structures and on the final designs Japanese structures constituted 57% of the total roof area, 43% of the roof area representing German construction. Approximately 50% of the target area (140 ft. x 252 ft.) is represented by roof area.

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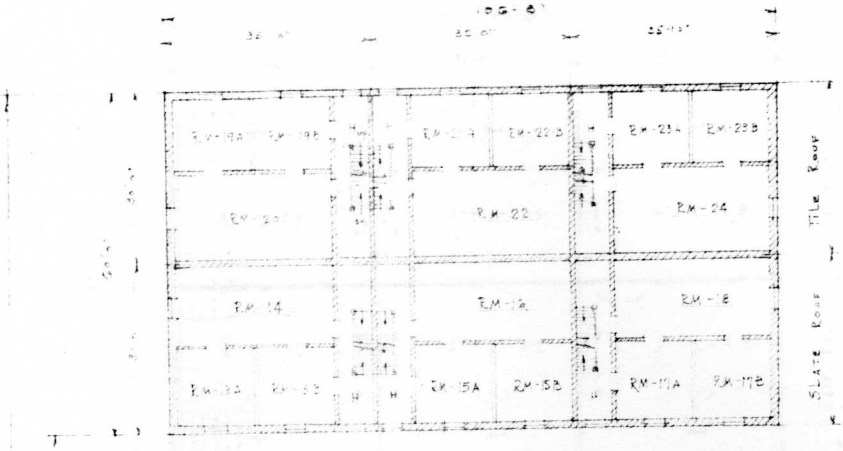
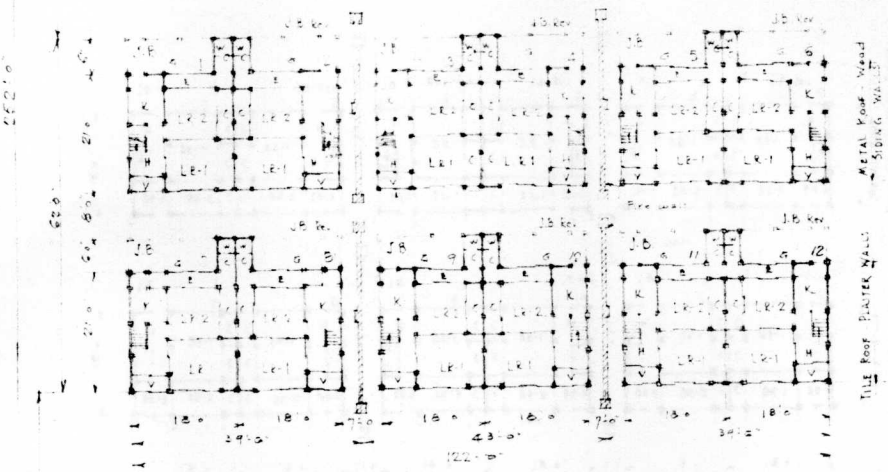
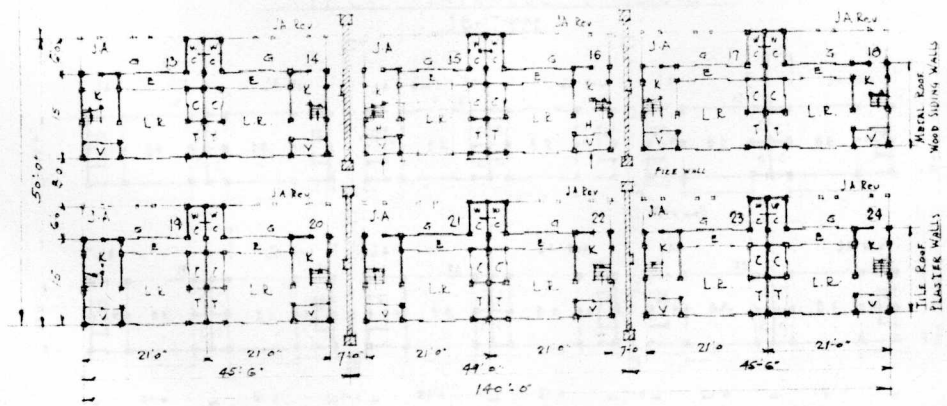


SECOND FLOOR PLAN
TYPICAL GERMAN STRUCTURE
FIRST FLOOR SIMILAR
Scale - 1/32" = 1'-0"



GROUND FLOOR PLAN
TYPICAL JAPANESE STRUCTURE
JB-TYPE



GROUND FLOOR PLAN
TYPICAL JAPANESE STRUCTURE
JA-TYPE

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LAYOUT & PLANS OF ~~JAPANESE~~ TEST STRUCTURES
SHOWING ~~GERMAN~~ FLOOR PLANS
DUGWAY PROVING GROUND - DUGWAY - CLOVER - UTAH.

Date 6-26-43
By J.F.B.

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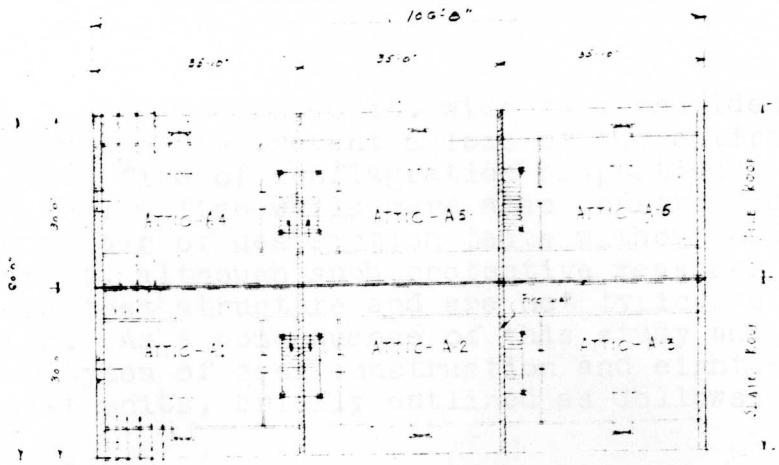
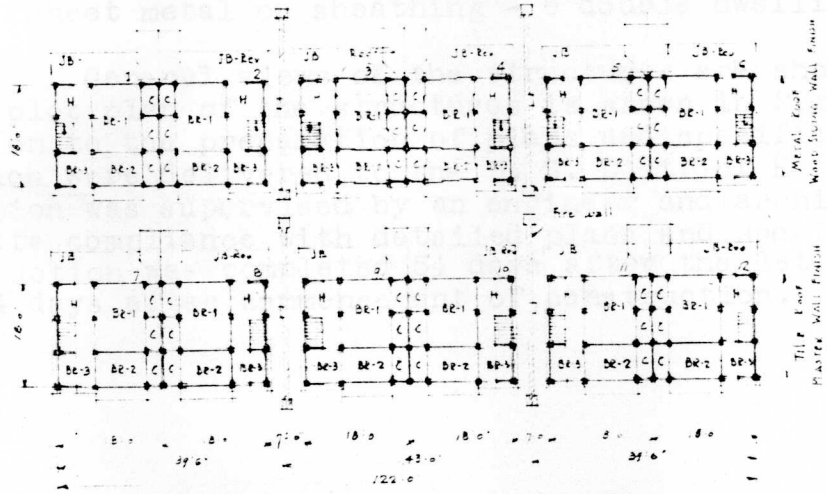
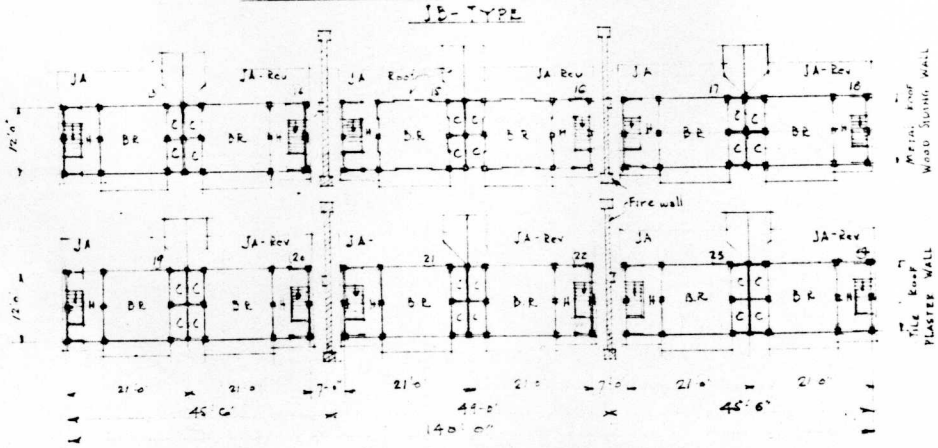


ATTIC FLOOR PLAN
TYPICAL GERMAN STRUCTURE
Scale - 1/16" = 1'-0"



TOP FLOOR PLAN
TYPICAL JAPANESE STRUCTURE
JB-TYPE



TOP FLOOR PLAN
TYPICAL JAPANESE STRUCTURE
JA-TYPE

LAYOUT & PLANS OF DUGWAY TEST STRUCTURES

SHOWING ATTIC & TOP FLOOR PLANS

DUGWAY PROVING GROUNDS - DUGWAY - CLOVER - UTAH.

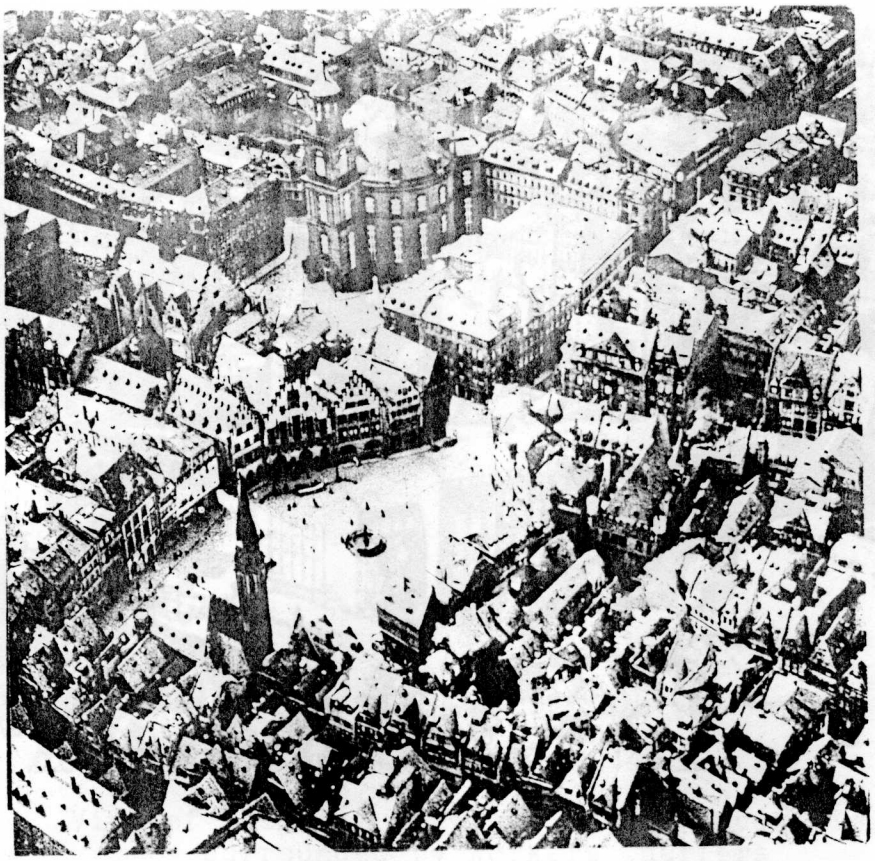
Sheet G-TOP-43

Fire breaks 40 ft. wide were provided between types of construction to prevent a loss of the entire target by a destructive fire of conflagration proportions. Within each section, brick fire walls were also constructed to permit the maximum number of destruction tests without endangering the entire target, although such protective measures were made to conserve the test structure and are not typical of foreign construction. As a consequence of this study and design, there are four types of roof construction and eighteen separate two story test units, briefly outlined as follows:

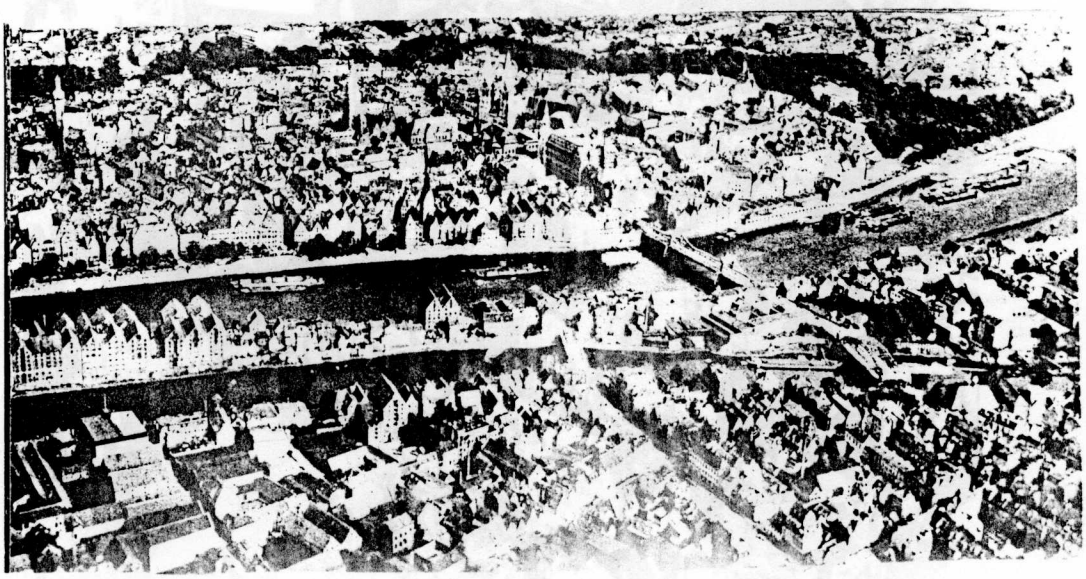
German
- Tile on batten roof - 3 apartments including attics
- Slate on sheathing roof - 3 apartments including attics

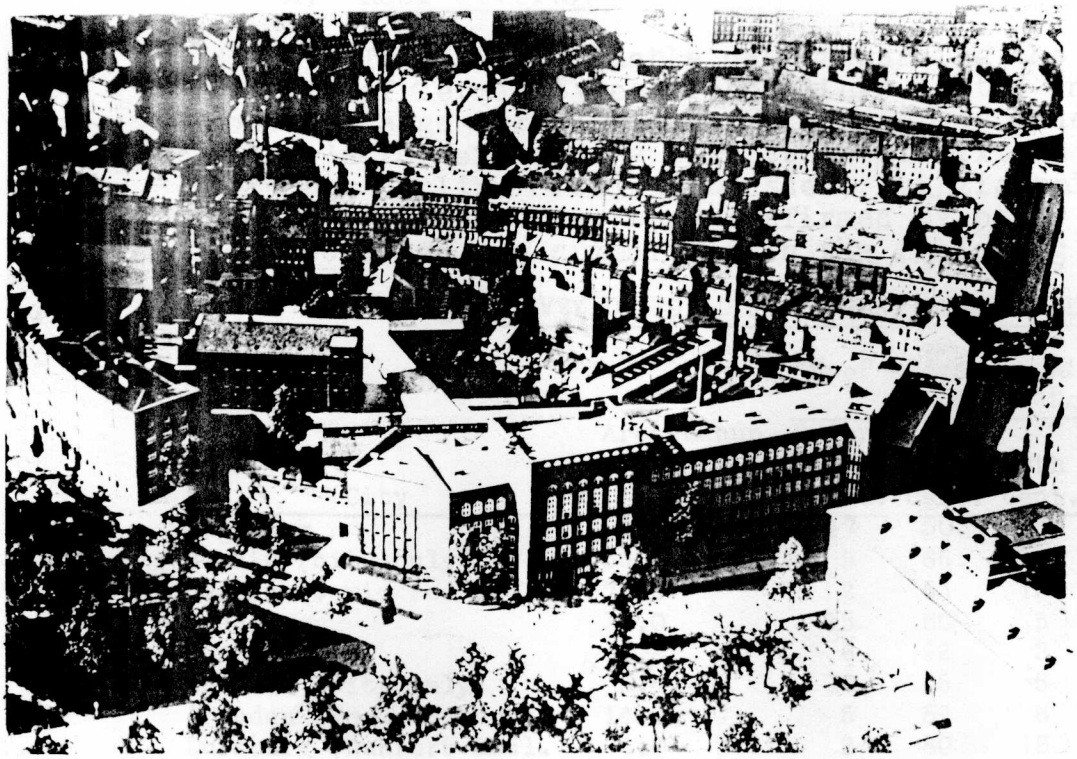
Japanese
- Tile on sheathing - 6 double dwellings
- Sheet metal on sheathing - 6 double dwellings

General views of the structures are shown in Figure 1 and a plot plan of the structures is shown in Figure 2. In addition to the preparation of plans and specifications, copies of which were delivered to the U. S. District Engineer, construction was supervised by an engineer and architects to insure complete compliance with detailed plans and specifications. Construction was completed 54 days after the letter contract and 44 days after commencement of construction.

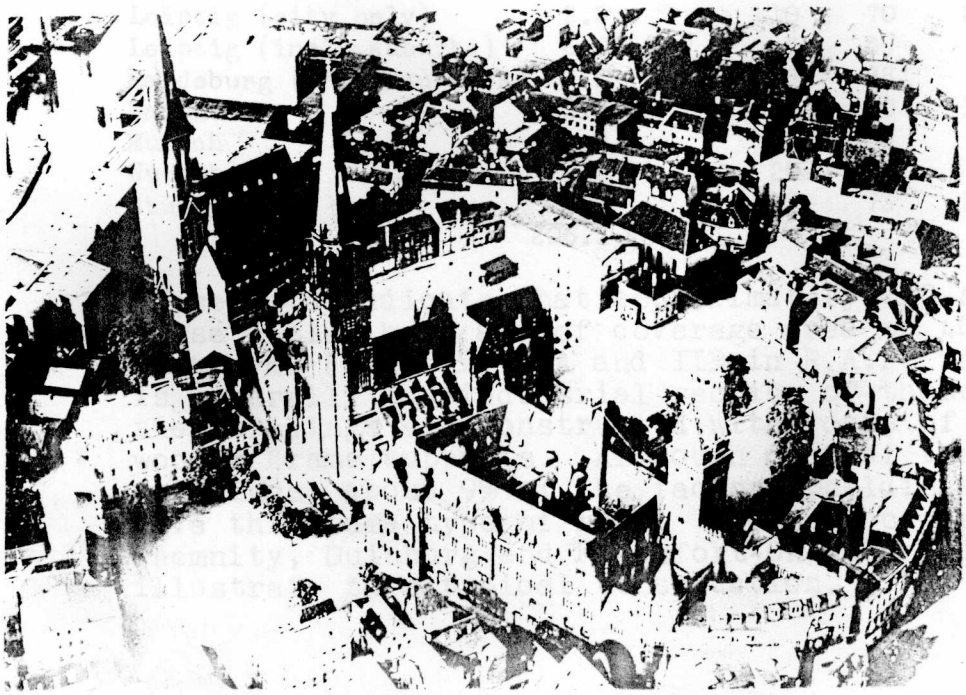


View of Frankfort-on-Main





View of Chemnitz showing Typical Industries surrounded by Workers Quarters



II. GERMAN STRUCTURES

A. Roof Coverage

To obtain reliable data regarding the roof area coverage of German types of buildings in the industrial sections of large German cities, a survey was made by one of Germany's former leading architects of sixteen large cities, including Berlin, Breslau, Dresden, Leipzig and Munich. The results of this survey were confirmed by other ex-German architects and are summarized in the following table:

SURVEY OF BUILDING CONSTRUCTION IN GERMANY

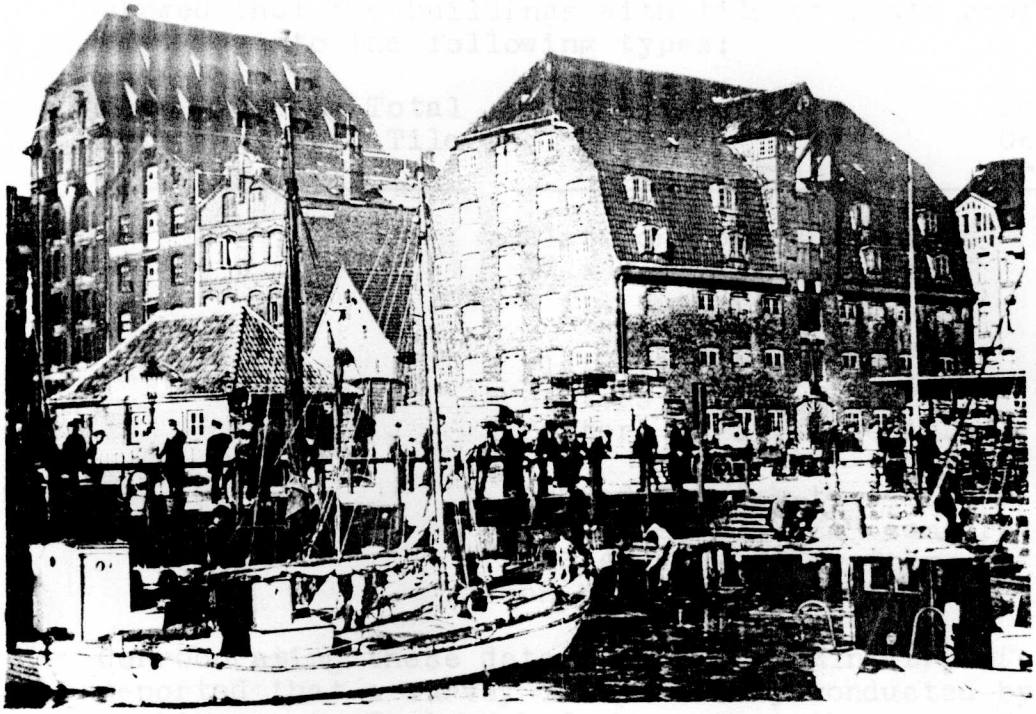
City	Area Occup. by Zones I & II	% of Bldgs. within Zones I and II (40% + Roof Area) Before 19th Cent.	19th Cent.	20th Cent.	Tile or Slate on Wood Frame
Augsburg	1.5 sq.mi.	47	50	3	90
Berlin (city only)	38.0	5	65	30	60
Berlin (9 mi. radius)	70.0	2	83	15	75
Breslau	15.0	15	80	5	90
Danzig	1.2	6	92	2	86
Dresden (city only)	3.4	10	85	5	90
Dresden (incl. suburbs)	14.0	5	89	6	88
Duisburg (Ruhrort incl.	4.0	2	80	18	64
Frankfort-On-Main	3.0	5	80	15	75
Halle	2.5	15	70	15	78
Hannover (city only)	2.5	22	73	5	90
Hannover (incl. suburbs)	8.0	8	80	12	78
Koenigsberg	8.0	5	94	1	89
Leipzig (city only)	2.5	10	70	20	74
Leipzig (incl. suburbs)	6.0	6	89	5	90
Magdeburg (incl. suburbs)	3.5	8	88	4	81
Mannheim	3.5	2	80	18	62
Munich	10.0	12	83	5	85
Nuremberg	6.0	20	75	5	85
Stuttgart	5.5	12	73	15	78
	208.1 sq.mi.				

These data indicate that approximately 210 square miles in these cities have a roof coverage area of 40% or higher. In that area (Zones I, IIA and IIB in R.A.F. terminology) which is generally the industrial section of these cities, 80% of the buildings are constructed with roofs of tile or slate on wooden frame supports. Although most of these buildings are dwellings, about 9% of the factory buildings in Germany also have this same type of roof. Pictures of sections of Bremen, Chemnity, Duisburg and Frankfort-On-Main (Figures 3 and 4) illustrate this typical construction.

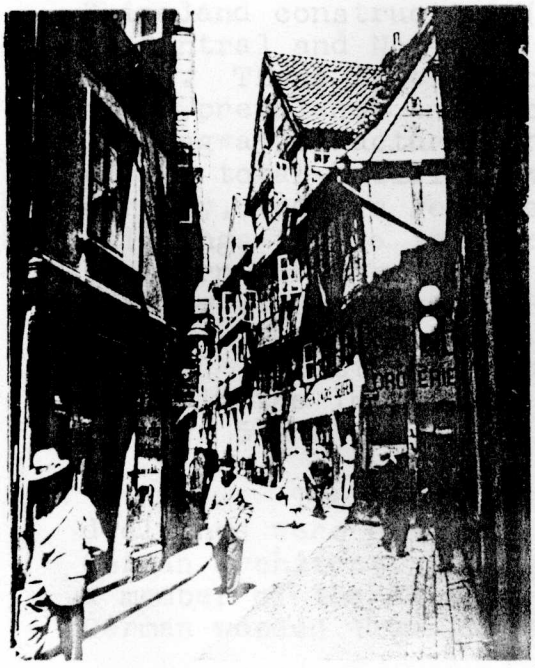
FIGURE 5

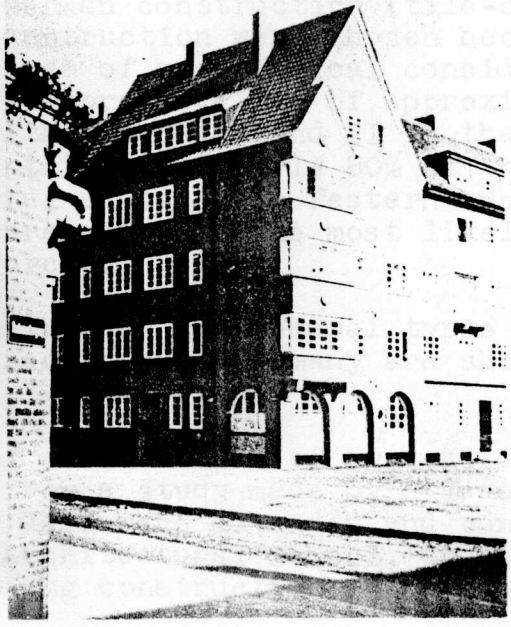
TYPICAL TYPES OF BELLIED ROOF CONSTRUCTION

Buildings in Mainz-on-Rhine



Warehouses in Kiel





B. Typical Construction

Further analysis of German dwelling construction showed that the buildings with tile or slate roof were subdivided into the following types:

Percentage of Total Buildings with Tile or Slate Roof	Roof Construction	Section of Germany where Predominant
25	Slate on wood sheathing, 4" x 4-3/4" rafters on 2 ft. centers	Rhineland
45	Flat tile on batten (6" centers), 4" x 4-3/4" rafters on 3 ft. centers	Central and Northern
30	Curved Spanish-type tile on batten (10-1/4" centers) 4-3/4" x 5-1/2" rafters on 3 ft. centers	Eastern

Corroborating these data the British Ministry of Home Security reported that a survey independently conducted by ex-German architects in England had shown that the majority of workers' homes, particularly in industrial sections, were constructed with flat tile on batten supported by wooden frame construction.

The target structure built at Dugway Proving Grounds was constructed in two sections, one representative of the Rhineland construction (slate-on-sheathing roof) and the other of Central and Northern German construction (tile-on-batten roof). These types of construction were chosen because of their prevalence and because of geographical considerations. The Dugway structures are representative of approximately 58% of the total buildings within Zones I and II in the whole of Germany, and are representative of nearly 80% of the total buildings in the industrial sections in Western, Central and Northern Germany, which are probably the most likely targets for the U. S. Army Air Forces.

Pictures illustrating the general types of roofs found in the industrial sections of Germany are shown in Figures 5 and 6.

The details of construction of typical German dwellings were obtained from a study made by a leading ex-German architect. These data were extended and confirmed by a member of the Harvard Architectural School, an expert on German wooden frame building construction. An independent

FIGURE - 7

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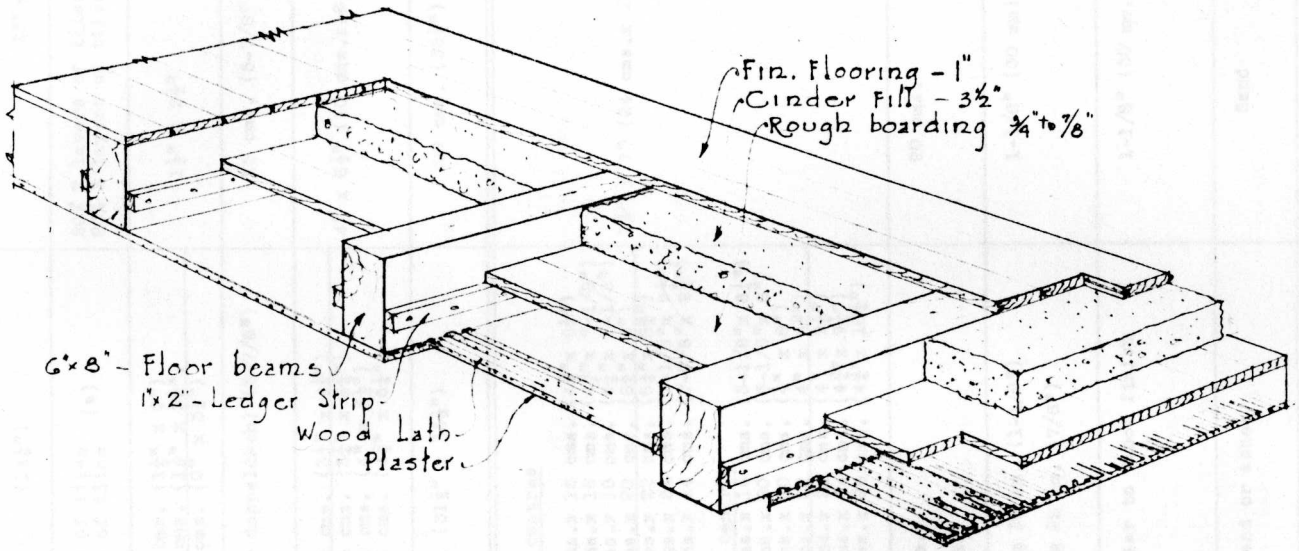

TYPICAL GERMAN FLOOR CONSTRUCTION

Date - 1-16-43 —— J.F.B.

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Material		R.E.8. Studies in German Domestic Architecture (British)	Target erected at Harmondsworth (British)	Structure #1	Str
Tile Slate	(1) Thickness	12 mm. ($\frac{1}{2}$" +)	Actual German made tiles used. $\frac{1}{2}$"	Bangor Slate 3/8"	Luc mar Til
	(2) Length	36 mm. ($14\frac{1}{4}$")	15" max.	14"	
	(3) Overlap	20% 2 layers of tiles 80% 3 layers of tiles (a)	20% 2 layers of tiles 80% 3 layers of tiles	21% 2 layers 79% 3 layers	19 81
Battens (laths)	(4) Sizes	3 cms. x 5 cms. ($1\frac{1}{4}$" x 2") 4 cms. x 6 cms. ($1\frac{5}{8}$" x $2\frac{1}{4}$") 5 cms. x 8 cms. (2" x $3\frac{1}{4}$")	$1\frac{1}{2}$" x $2\frac{1}{2}$"	Boarding or Sheathing 15/16"	
	(5) Spacing centre to centre	15 cms. (for doppeldach) (5-7/8")	15 cms. (5-7/8")	$5\frac{1}{8}$"	
Spars (Rafters)	(6) Sizes	8 cms. x 12 cms. ($3\frac{1}{4}$" x $4\frac{3}{4}$") 8 cms. x 15 cms. ($3\frac{1}{4}$" x $5\frac{3}{4}$") 10 cms. x 14 cms. (4" x $5\frac{1}{2}$") 12 cms. x 16 cms. ($4\frac{3}{4}$" x $6\frac{1}{4}$")	4" x $6\frac{1}{2}$" (10 cms.x16.5cms.)	4" x $4\frac{3}{4}$"	
	(7) Spacing centre to centre	80 - 90 cms. ($31\frac{1}{2}$" x $35\frac{1}{2}$")	90 cms. ($35\frac{1}{2}$")	24"	
Joists	(8) Sizes	(a) 90 cms. centres Span Size 3.0 m. 12 cms.x 16 cms. ($4\frac{3}{4}$"x $6\frac{1}{4}$") 3.5 m. 12 cms.x 18 cms. ($4\frac{3}{4}$"x 7-1/8") 4.0 m. 16 cms.x 18 cms. ($6\frac{1}{2}$"x 7-1/8") 4.5 m. 16 cms.x 20 cms. ($6\frac{1}{2}$"x 8") 5.0 m. 16 cms.x 22 cms. ($6\frac{1}{2}$"x $8\frac{3}{4}$") 5.5 m. 18 cms.x 24 cms. (7-1/8"x $9\frac{1}{2}$") 6.0 m. 20 cms.x 24 cms. (7-7/8"x $9\frac{1}{2}$") (b) 65 cms. centres 3.0 m. 8 cms.x 16 cms. (3-1/8"x $6\frac{1}{4}$") 3.5 m. 8 cms.x 20 cms. (3-1/8"x 8") 4.0 m. 10 cms.x 20 cms. (4" x 8") 4.5 m. 10 cms.x 22 cms. (4" x $8\frac{3}{4}$") 5.0 m. 10 cms.x 24 cms. (4" x $9\frac{1}{2}$") 5.5 m. 12 cms.x 24 cms. ($4\frac{3}{4}$"x $9\frac{1}{2}$") 6.0 m. 12 cms.x 26 cms. ($4\frac{3}{4}$"x $10\frac{1}{4}$")	$9\frac{1}{2}$" x 7" (24 cms.x 17.5 cms.)	4" x 10" nom. size	
	(9) Centres	(a) 90 cms. (b) 65 cms.	90 cms.	24"	
Finish	(10) Floor	(a) boarding 30 mm. (1-1/8") (b) boarding 22 mm. (7/8")	1-1/8" (30 mm)	15/16"	
	(11) Ceiling under	Can be similar to floor finish	1-1/8" (30 mm.)	3/8" wood lath 3/8" plaster	Pl 2" 3/ pl
Pugging (joist infilling)	(12) Material	Clay with sand or ashes	Sand	Cinders	
	(13) Thickness	$3\frac{1}{4}$" min. (8 cms.)	$4\frac{1}{2}$"	$3\frac{1}{2}$"	

(a) Scale layouts indicate 29% (2 layers) and 71% (3 layers) instead of values reported.

TYPICAL GERMAN TARGET STRUCTURES

Targets erected in America

	Targets at Bayway -			Dugway Structure	
Structure #1	Structure #2	Structure #2A	Structure #3	Structure A Slate Portion	Structure A Tile Portion
Bangor Slate 3/8"	Ludowici Norman Shingle Tile 1/2" +	Reroofed Ludowici Provincial Shingle Tile 1/2" +	Ludowici Spanish Tile 1/2"	Bangor Slate $\frac{1}{4}$"	Ludowici Provincial Shingle Tile 1/2" +
14"	12"	15"	14$\frac{1}{4}$"	14"	15"
21% 2 layers 79% 3 layers	19% 2 layers 81% 3 layers	24% 2 layers 76% 3 layers	34% Single 66% Double	25% 2 layers 75% 3 layers	24% 2 layers 76% 3 layers
Boarding or Sheathing 15/16"	1$\frac{1}{2}$ x 2$\frac{1}{2}$"	1$\frac{1}{2}$ x 2$\frac{1}{2}$"	1$\frac{1}{2}$ x 2$\frac{1}{2}$"	Boarding or Sheathing 15/16"	1$\frac{1}{2}$ x 2$\frac{1}{2}$"
5$\frac{1}{2}$"	4$\frac{3}{4}$"	6"	11$\frac{1}{4}$"	5$\frac{1}{2}$"	6"
4" x 4$\frac{3}{4}$"	4" x 4$\frac{3}{4}$"	4" x 4$\frac{3}{4}$"	4$\frac{3}{4}$" x 5$\frac{1}{2}$"	4" x 4$\frac{3}{4}$"	4$\frac{3}{4}$" x 5$\frac{1}{2}$"
24"	36"	36"	36"	24"	36"
s.) 4" x 10" nom. size	6" x 8" nom. size	6" x 8" nom. size	6" x 8" nom. size	4" x 10" nom. size	6" x 8" (nom.size)
24"	36"	36"	36"	24"	36"
15/16"	15/16"	15/16"	15/16"	15/16"	15/16"
3/8" wood lath 3/8" plaster	Furring-1" x 2"; wood lath 3/8" - 3/8" plaster	Furring-1" x 2"; wood lath 3/8" - 3/8" plaster	Furring-1" x 2"; wood lath 3/8" - 3/8" plaster	3/8" wood lath; 3/8" plaster	1" x 2" (nom.size) furring; 3/8" wood lath; 3/8" plaster
Cinders	Cinders	Cinders	Cinders	Cinders	Cinders
3$\frac{1}{2}$"	3$\frac{1}{2}$"	3$\frac{1}{2}$"	3$\frac{1}{2}$"	3$\frac{1}{2}$"	3$\frac{1}{2}$"

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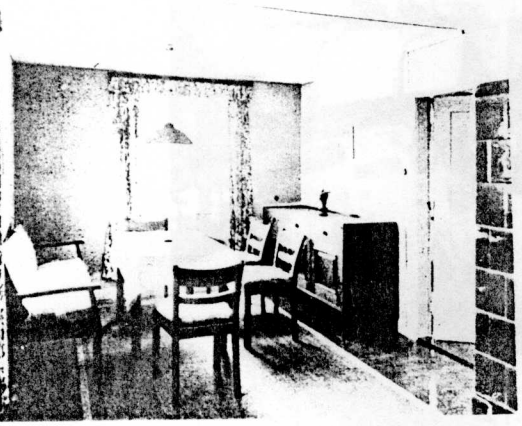
PDW 1340-A

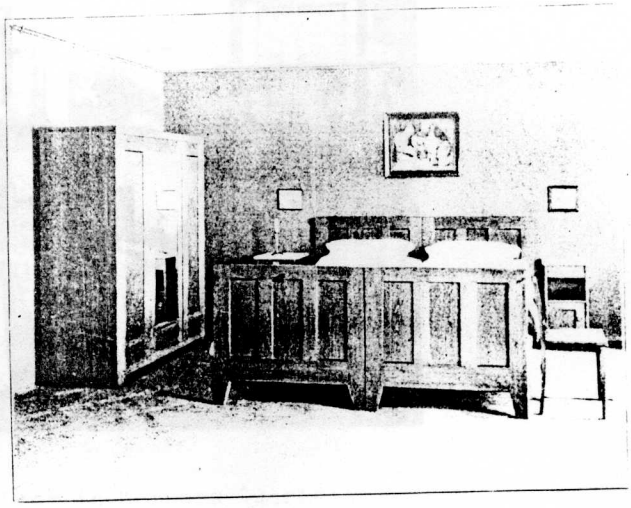
study of German domestic architecture made by the British Ministry of Home Security (R.E. 8) previously mentioned in this report was critically examined and found to be in excellent agreement with these data. A table summarizing these data, together with data regarding test structures built in England and by N.D.R.C. at Elizabeth, New Jersey is shown opposite.

German dwelling construction follows the same general wooden truss construction but is appreciably heavier and more massive than either English or American building practices. The outstanding features of the German wooden frame construction are the large rafters (4" x 4-3/4" to 4-3/4" x 5-1/2"), heavy roofing tile and slate (1/2" and 3/8" thick respectively) laid with a 60% overlap, large batten (1-1/2" x 2-1/2"), and in particular the massive floor shown in Figure 7. Instead of wooden stud walls typical German practice employs heavy masonry walls both on the inside and outside of the building. A plaster coat is applied to the masonry walls as an interior finish.

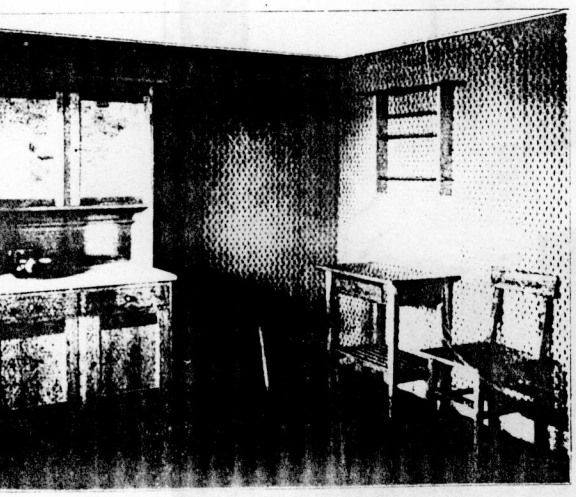
Investigation of German lumber types disclosed that "kiefer" or Scotch pine and to a lesser extent "fichte" or European spruce were the predominant woods used in German construction. Advise received from ex-German consultants indicated that Southern Loblolly Pine and Coastal Douglas Fir were satisfactory substitutes for "kiefer." According to the U. S. Department of Agriculture, specific gravity is the most reliable index of the strength properties of a wood. The specific gravities (12% moisture) for "kiefer" and "fichte" are approximately 0.53 and 0.41, respectively. Coastal Douglas Fir has a specific gravity of approximately 0.48 (12% moisture) and, while not duplicating "kiefer" as closely as Southern Loblolly Pine (0.54 sp.gr.), was considered to be a satisfactory substitute for typical German lumber and was used in the Dugway German structures.

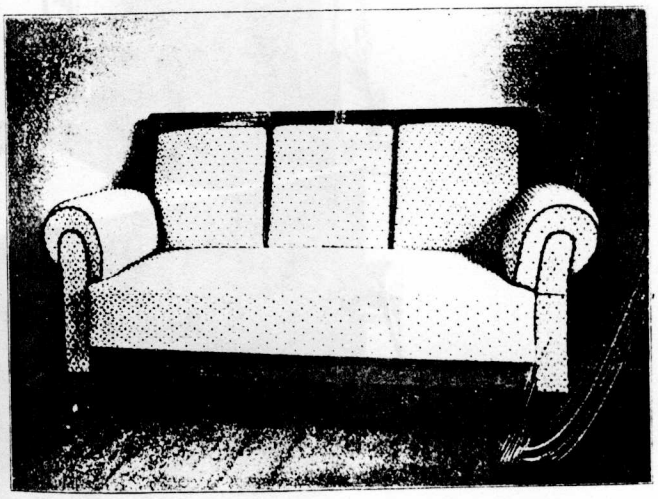


edenza, Chairs, Table and Settee in
a typical Dining Room arrangement



Beds and Clothes Closet





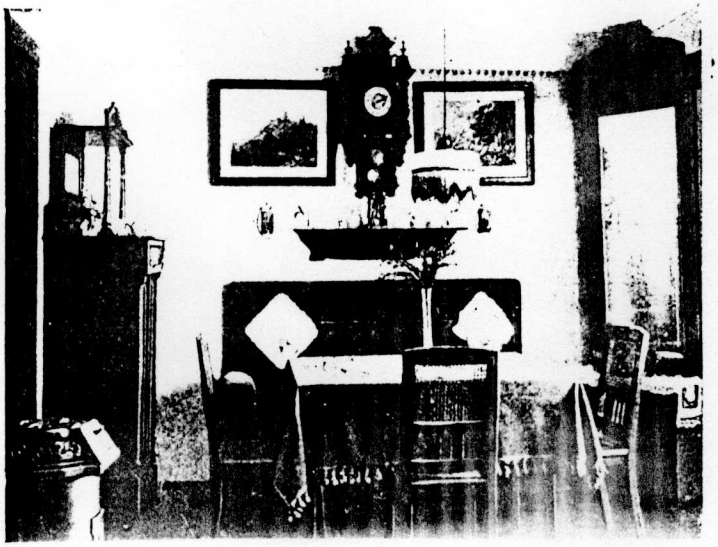
Overstuffed Sofa

ypical Crowded Living Room in Workers Quarters

FIGURE 10

ROOM ARRANGEMENTS IN GERMANY

Typical Dining Alcove Arrangement
at end of Living Room



Dining Room

C. Furnishings

Fire severity (the measure of intensity and duration of fire) in German structures below the attic is mainly a function of the combustible furnishings. Unlike American or Japanese construction, the typical German structure utilizes little wood as framework or trim below the attic. For this reason a thorough study of typical furnishings was made so that proper fire severity would be reproduced in floors beneath the attic.

Studies were conducted by the Authenticity Division of RKO Studios, by two furniture makers who learned their trade in Germany, and by an experienced ex-German architect and sociologist. Results of these studies indicated:

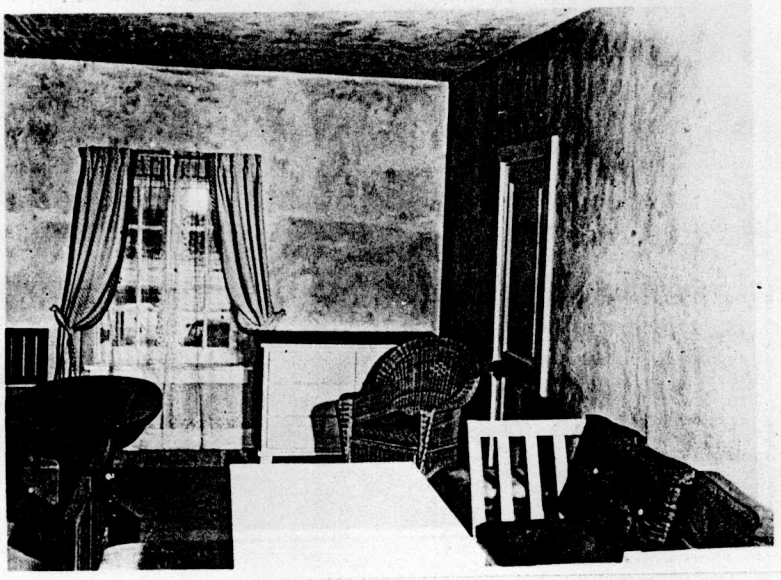
1. Articles of furnishing found in typical German dwellings are heavier in construction than American furnishings as shown in Figure 8.

2. More furnishings are crowded into available floor space in the German home than in the American home. Arrangement is such that the density of furnishings is more than twice that found in American homes. Pictures illustrating this crowded condition are shown in Figures 9 and 10.

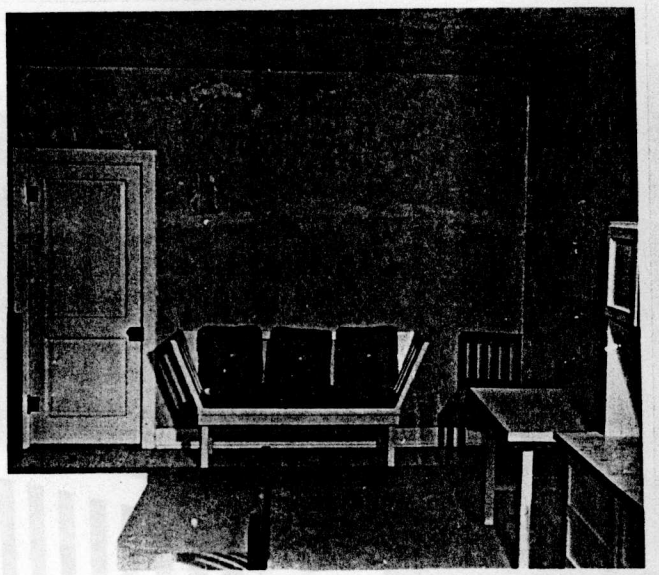
To reproduce faithfully these conditions special furniture was designed and manufactured since it was not available in stock pieces.

FIGURE 11

TEST FURNISHINGS USED IN DUGWAY GERMAN STRUCTURES



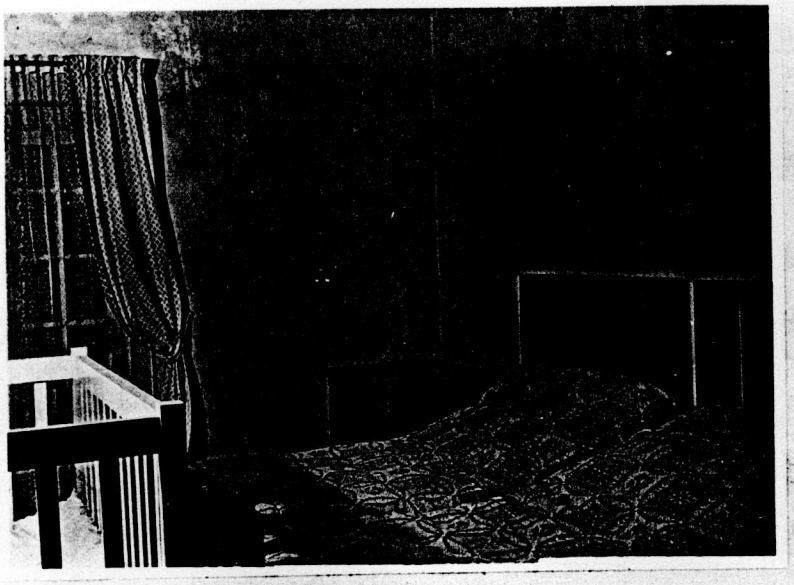
Living Room-Dining Room Combination



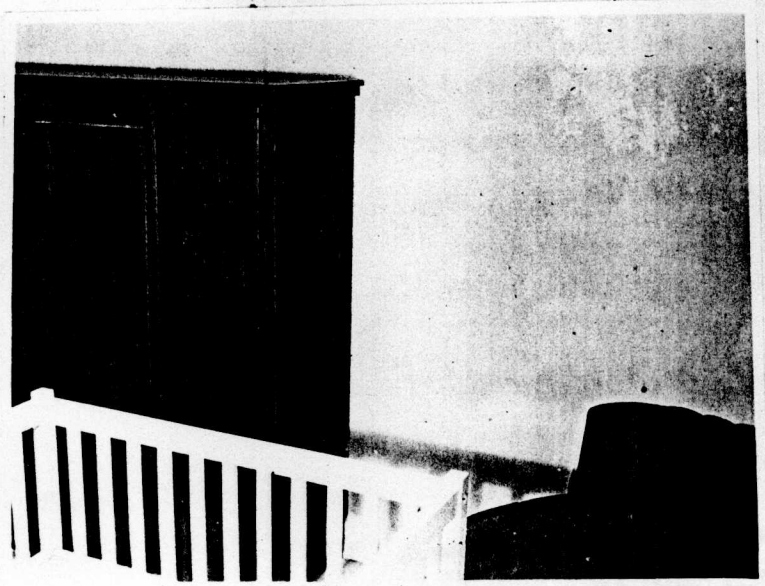
Living Room-Dining Room Combination

FIGURE 12

TEST FURNISHINGS USED IN DUGWAY GERMAN STRUCTURES



Beds,Crib and Bedside Table in Bedroom



Crib,Clothes Closet and Easy Chair in Bedroom

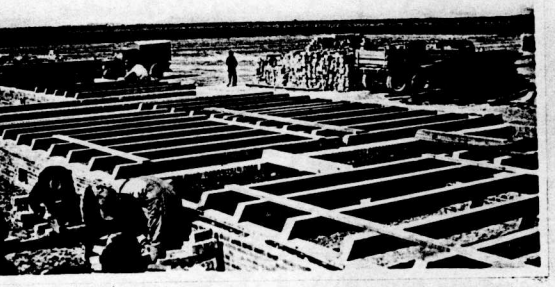
The furniture in the Dugway structures is typical as regards arrangement and density; the articles are authentic as regards size and materials of construction. The density of these test furnishings are: bedroom - 9.7 lb./sq.ft.; living room-dining room - 4.9 lb./sq.ft. A comparison with average Japanese and American furnishings is tabulated below:

Type of Home	Movable Furnishings	
	lb./sq.ft. floor area	lb./cu.ft. structure vol.
German	7	0.5
Japanese (a)	2.5	0.1
American	3.5	--

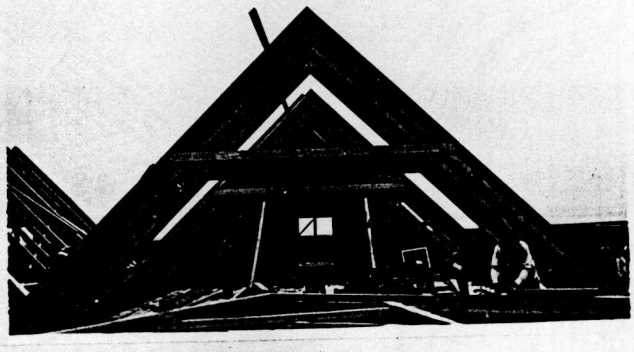
(a) Includes 2.0 lb./sq.ft. of Tatami (floor mats)

FIGURE 13

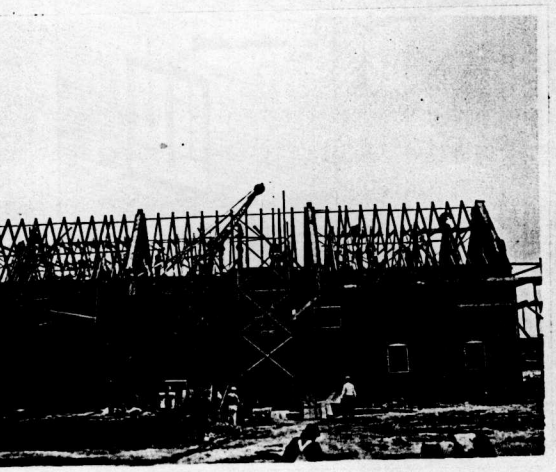
CONSTRUCTION OF DUGWAY GERMAN STRUCTURES



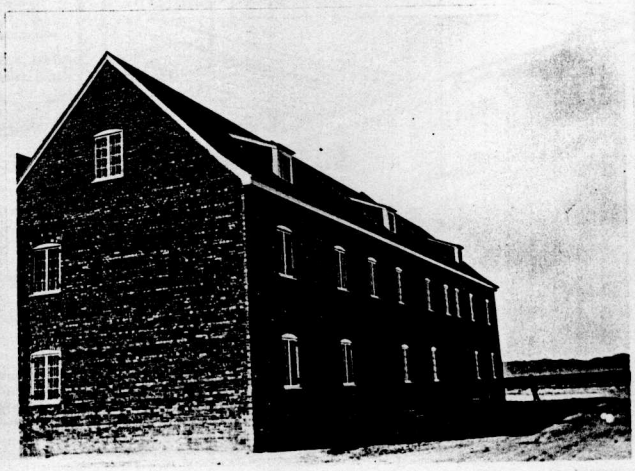
Laying Foundations



Details of Roof Construction



nstruction of Heavy Masonry Wall



Tile-Roofed Structure

FIGURE - 14

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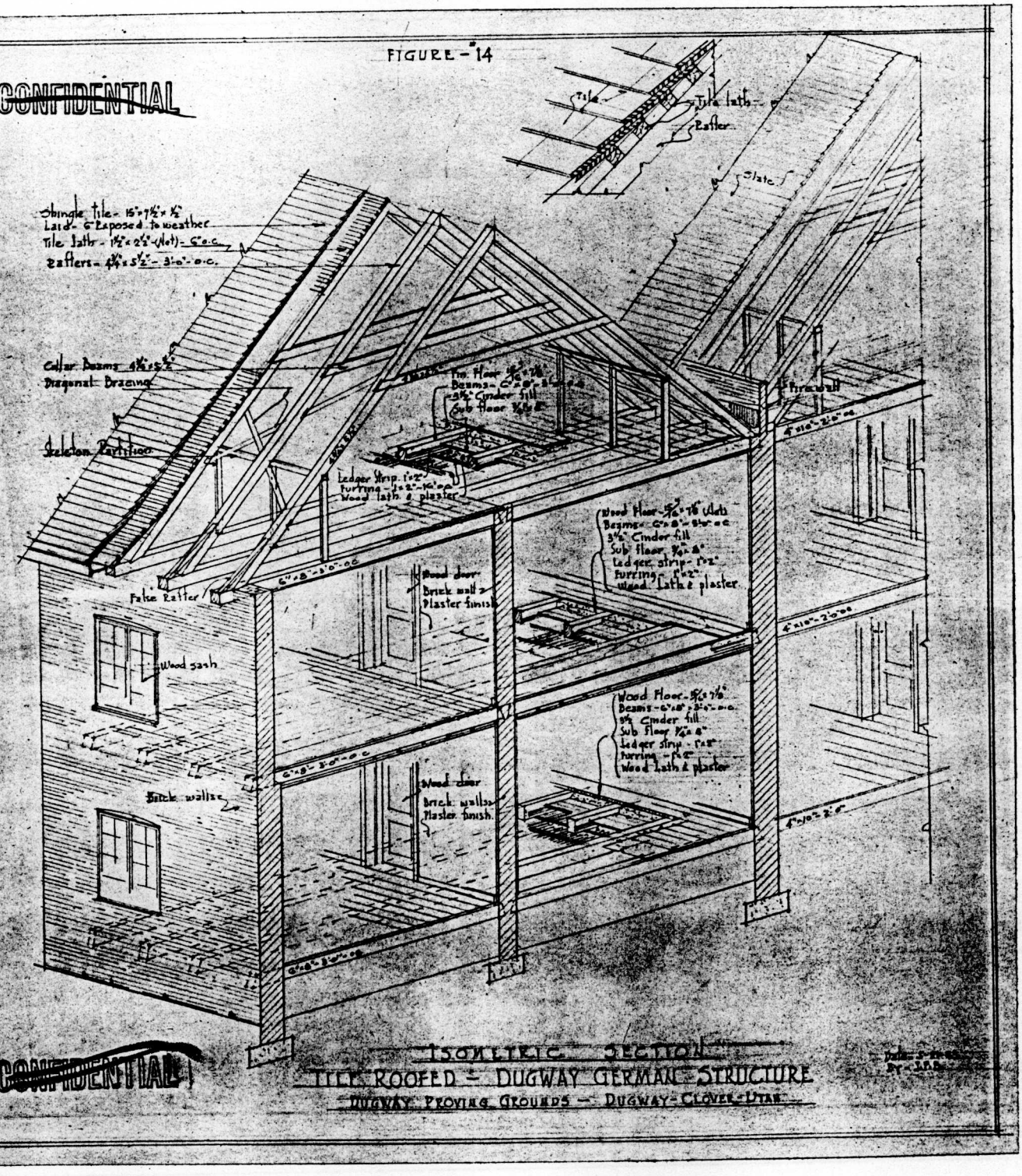

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ISOMETRIC SECTION

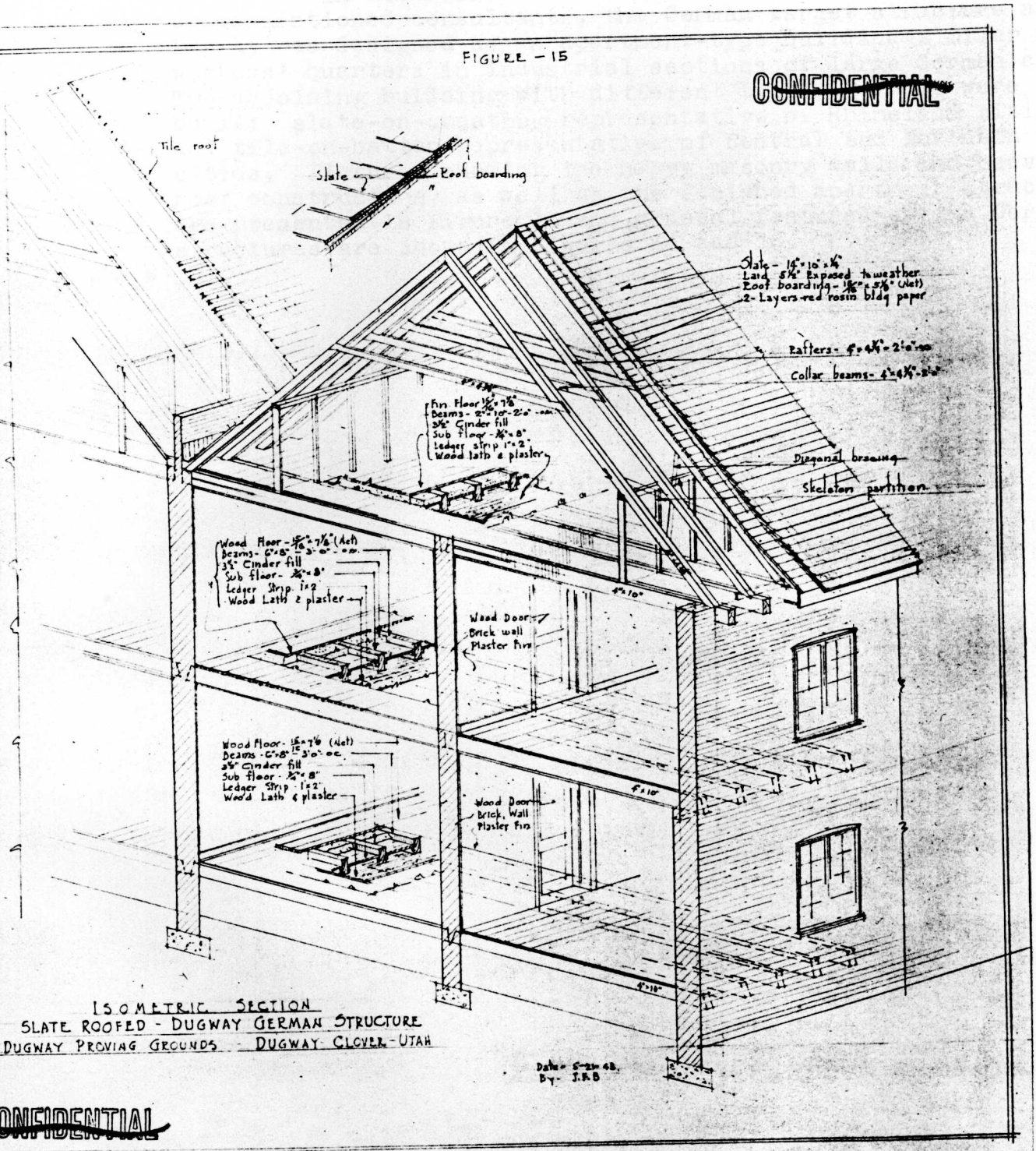
TILE ROOFED - DUGWAY GERMAN STRUCTURE

DUGWAY PROVING GROUNDS - DUGWAY - CLOVER - UTAH

Date: 5-11-43
By: J.P.S.

FIGURE – 15

~~CONFIDENTIAL~~



ISOMETRIC SECTION
SLATE ROOFED - DUGWAY GERMAN STRUCTURE
DUGWAY PROVING GROUNDS DUGWAY CLOVER - UTAH

Date – 5-25-42
By – J.F.B

~~CONFIDENTIAL~~

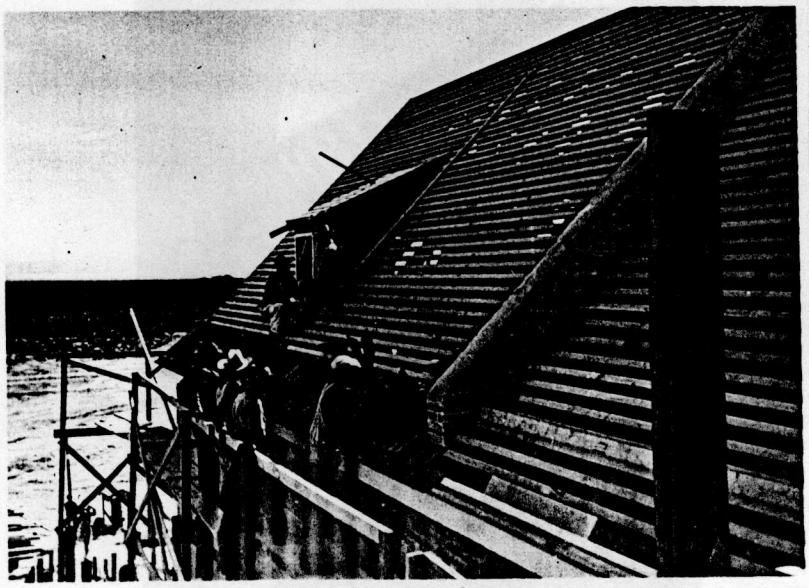
D. Design and Construction of Dugway Structures

In accordance with information obtained from the above-mentioned consultants, the German target structure at Dugway was designed as an apartment-type building similar to workers' quarters in industrial sections of large German cities. Two adjoining buildings with different types of roofs were built: slate-on-sheathing representative of Rhineland cities and tile-on-batten representative of Central and Northern cities. Pictures showing the heavy masonry walls and heavy roof construction, as well as the finished apartment structure are presented in Figure 13 and general features of the German structures are shown in Figures 14 and 15.

FIGURE 16

DETAILS OF CONSTRUCTION OF DUGWAY GERMAN STRUCTURE

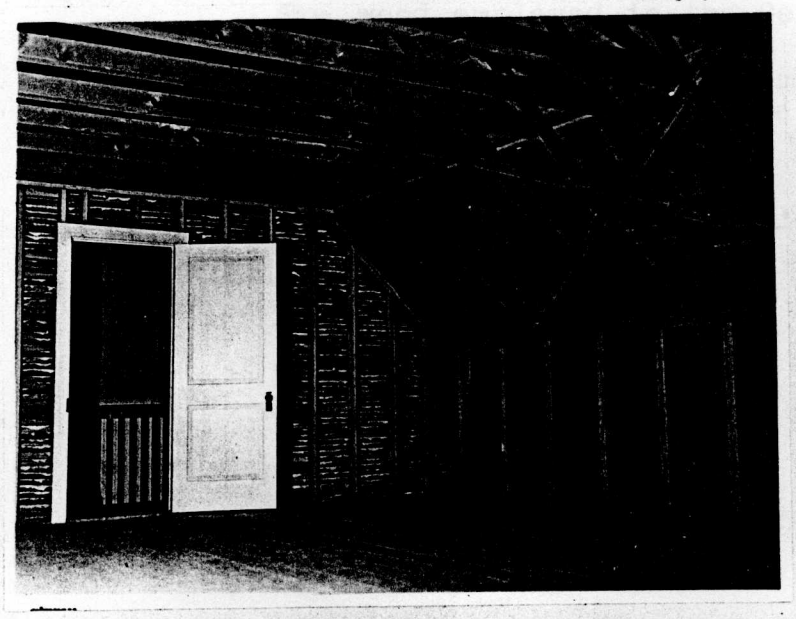
Inside of Tile-Roofed Attic Showing
Dormer Window and Masonry End Wall



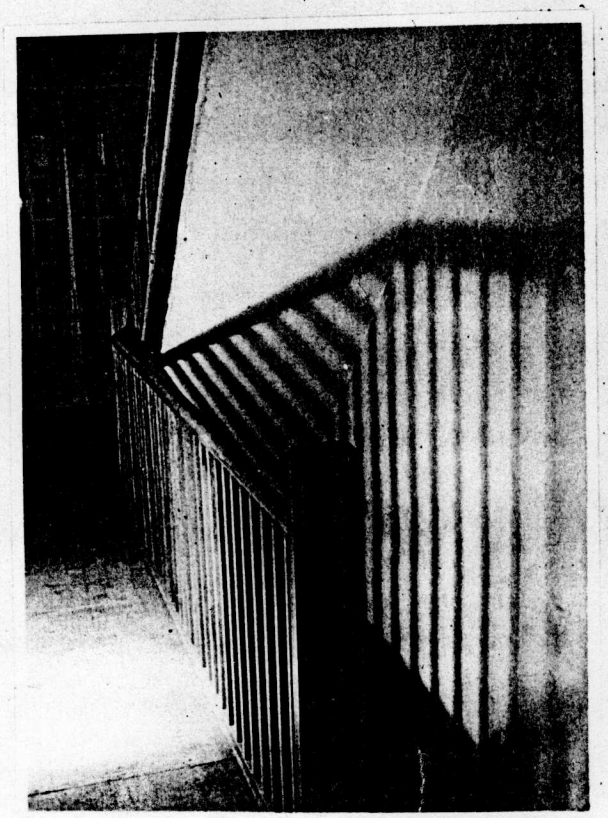
View Showing Laying of Tile over Batten

FIGURE 17

VIEWS INSIDE DUGWAY GERMAN STRUCTURE



Inside of Slate-roofed Attic
Showing Head of Stair-Well



View of Stair-Well

Pictures showing construction of the tile-roofed and slate-roofed attics are presented in Figures 16 and 17.

The wood employed in the German structures was yard dried Coastal Douglas Fir, which was further dried by means of steam radiators to about 10% to 15% moisture content. Average moisture contents of some of the more pertinent structural members are given below:

Structure Member	Av. Moisture Content - %
1-1/2"x2-1/2" Batten under Tile	11.0
15/16" Sheathing under Slate	10.5
4"x4-3/4" Rafters under Slate	14.4
4-3/4"x5-1/2 Rafters under Tile	15.1
15/16" Top Flooring (attic)	13.1
" " " (2nd floor)	13.6
" " " (1st floor)	13.2

The data indicate that the moisture content of the wooden structural members of the German target will approximate 10% to 15% at the time of the destruction tests which corresponds to but is slightly higher than the known moisture content of wood in structures from 10 to 100 years old located on the Northeastern U. S. coast.

For further details of construction, reference should be made to the specifications and detailed drawings submitted to the U. S. District Engineer, Salt Lake City, Utah.

FIGURE 18

AERIAL VIEWS OF TYPICAL JAPANESE CITIES

View of Osaka showing Workers Quarters
in Industrial Section

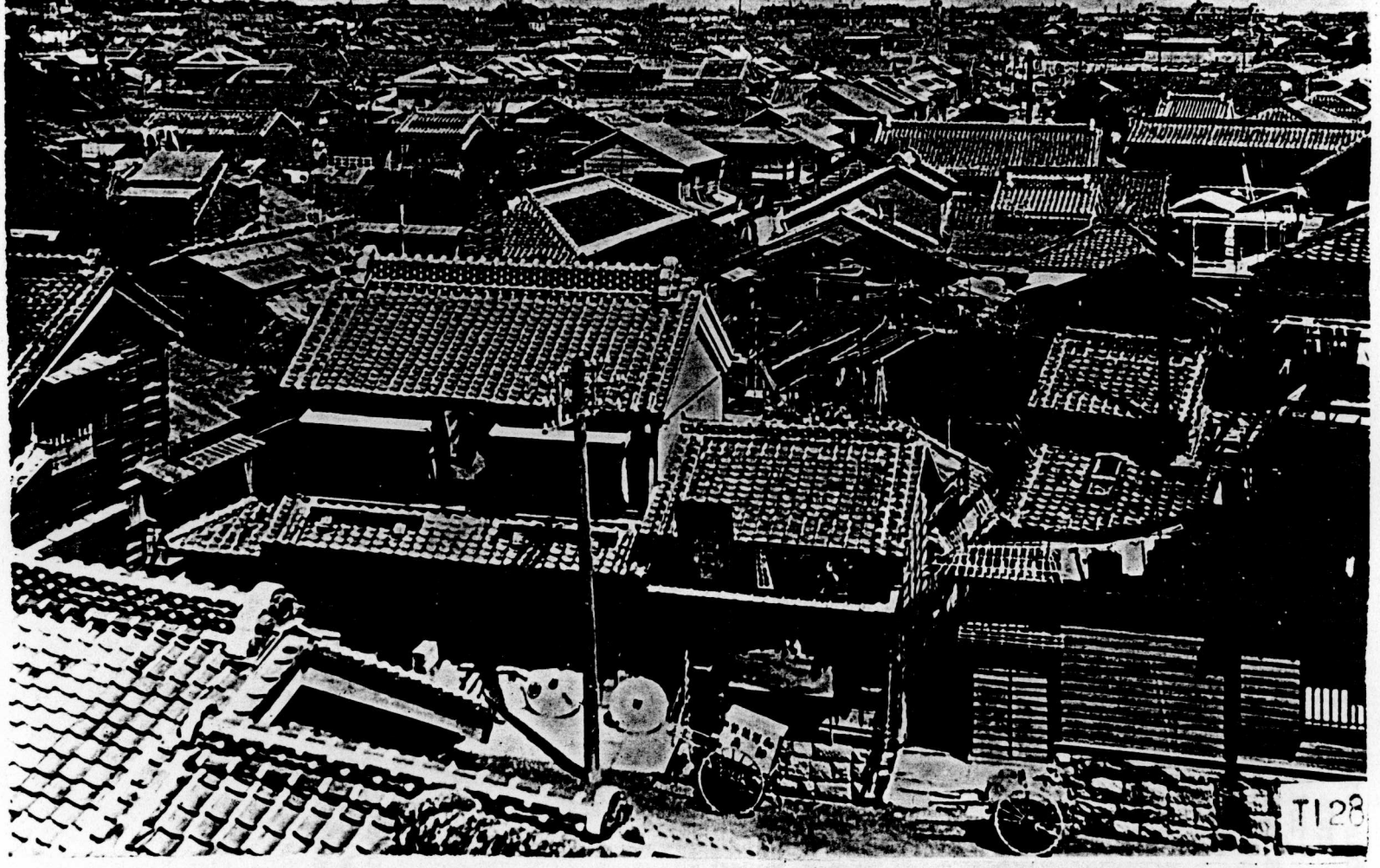
View of Nagoya showing Tenement Buildings
in Main Business District

FIGURE 19

AERIAL VIEWS OF TYPICAL JAPANESE CITIES

Workers Dwellings along Main Railroad, Kobe

Yawata Steel Mills, Workers Hpuses in Foreground



TILE ROOF CONSTRUCTION IN TOKYO

FIGURE 20

III. JAPANESE STRUCTURES

A. Roof Coverage

Analysis of roof coverage and roof types in the larger industrial cities of Japan was made by former residents of Japan now in the Military Intelligence Branch of the U. S. Army and by a practicing architect with eighteen years experience in Japan. Results of these studies closely checked each other and showed:

1) Approximately 60% of the industrial area of the larger cities of Japan is built-up, i.e., covered by roofs.

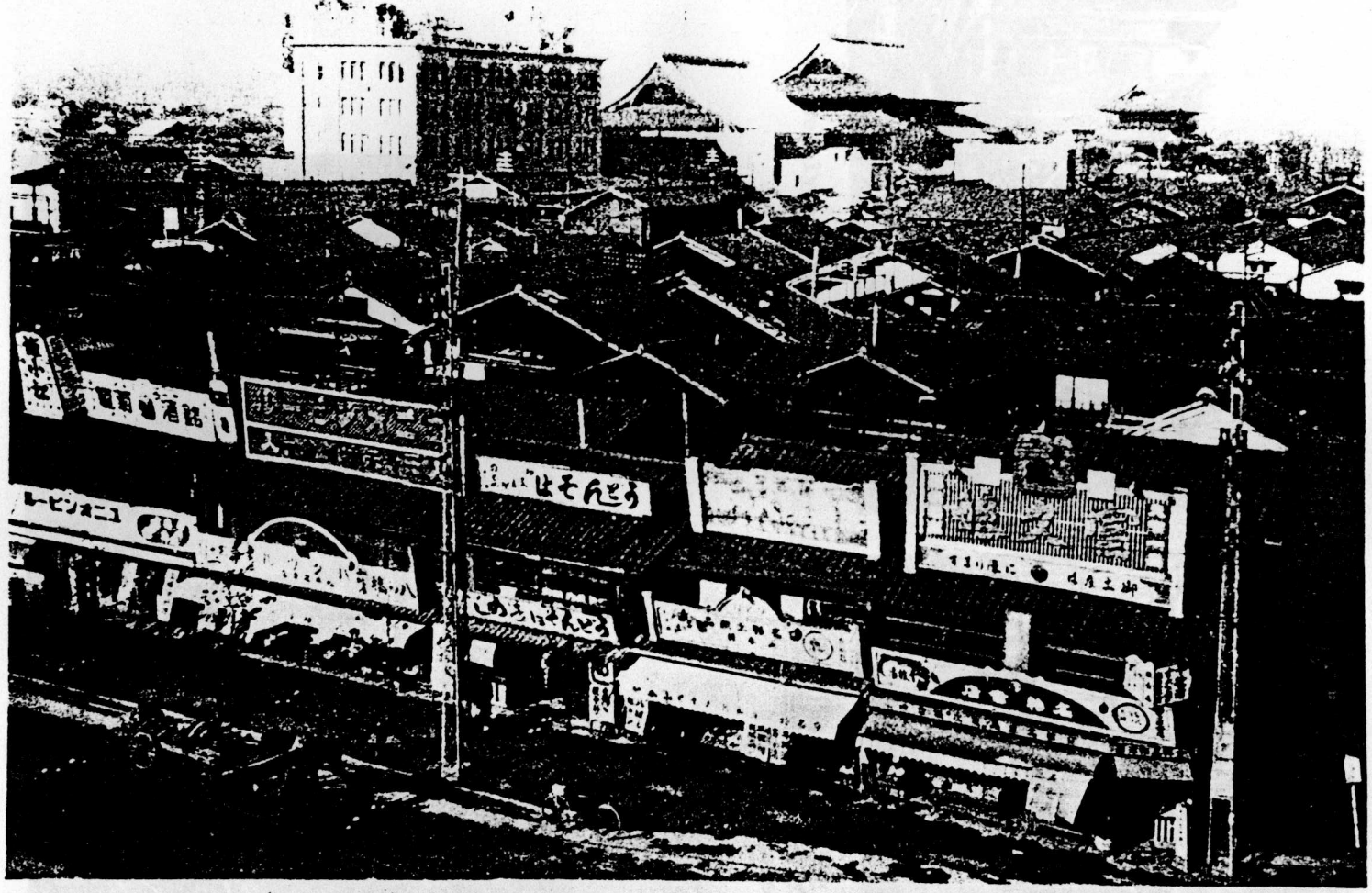
2) The predominant roof area in industrial sections of the larger Japanese cities is occupied by workers' dwellings. At least 80% of these dwellings are of tile or sheet metal roof construction.

3) Tile and sheet metal roof construction is also typical of at least 65% of the roof construction of the entire area of most Japanese cities as shown in the following tabulation:

% Roof Area of Entire City Occupied by Type Roof

	Consultant A			Consultant B		
	Tile	Metal	Other	Tile	Metal	Other
Tokio	60-65	5-15	20-30	45	40	15
Yokohomo	50	30	20	40-50	40-50	10
Kyoto	85	5	10	80	-	-
Kobe	75	15	10	65	25	10
Nagoya	70-85	10-15	10	80	-	-
Osaka	-	-	-	80	-	-

Figs. 18 and 19 are views of large industrial centers in Japan, showing the high percentage of total roof area and the large proportion of workers dwellings in the factory districts. Fig. 20 shows typical roof construction as found in Tokio.



Congested Section of Kyoto Showing
Typical Roof Construction

FIGURE 21

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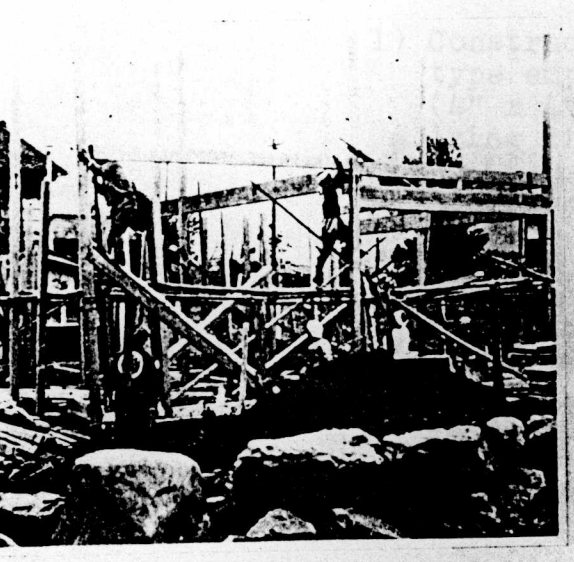
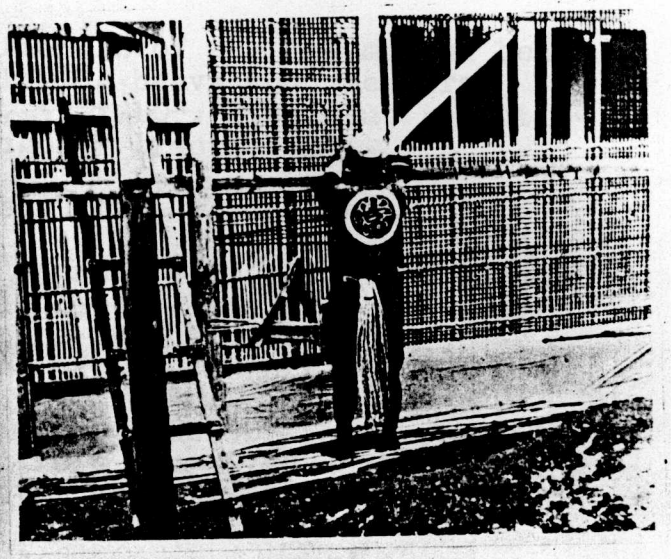
FIGURE 22

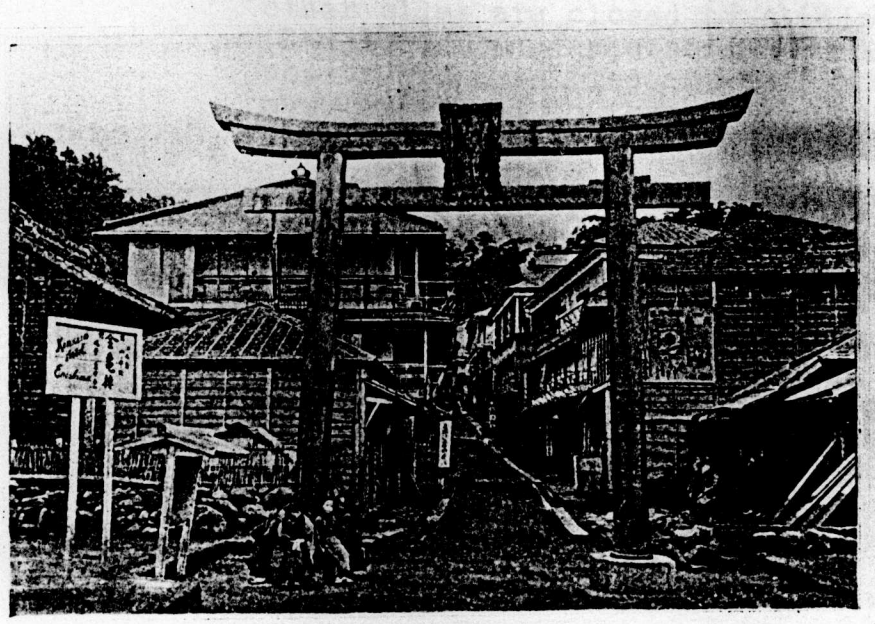
DETAILS OF CONSTRUCTION OF TYPICAL JAPANESE DWELLINGS



Assembly of Framework



Fabrication of Wall Construction
Placing Bamboo Framework
before Plastering



Typical Wood Siding over Plaster Walls

B. Typical Construction

Research on Japanese construction was concentrated on small dwellings and tenement type construction which represent the largest portion of roof area in industrial Japan. Several authorities on Japanese construction were consulted and a survey of existing literature was made. Results indicated the following construction details to be typical:

1) Construction is of the column and beam type employing heavy wood members (4" x 4", 5" x 10", etc.) but not utilizing diagonal bracing.

2) Roof construction is either:

   a) tile (approx. 3/4" thick) embedded in mud plaster laid over 1/2" wood sheathing supported by 2" x 3" rafters on 18" centers, or

   b) sheet metal (approx. 26 gage) laid on tar felt over 1/2" wood sheathing supported by 2" x 3" rafters on 18" centers.

   The roof rafters are generally supported by heavy purlins running parallel to the ridge pole. The roof slope is generally 20° or less as illustrated in Fig. 21.

3) Wall construction is permanent on only two or occasionally three sides--the other sides are closed by sliding screens (Shoji) and wood shutters. Permanent wall construction is predominantly mud plaster over split bamboo framework as shown by Fig. 22.

4) Concrete foundations are not used; dwellings are raised approximately 18" off ground on pillar supports.

5) Major portions of the floor are covered by hard packed rice straw Tatami mats. The size of the Tatami is the Japanese unit of measure and construction is dimensioned to fit the Tatami. Subflooring is generally 1/2" thick under the Tatami.

6) Ceiling construction is a light wooden section built on ribs and suspended from the structural beams in the floor or roof above.

7) The interior of the dwelling is divided into rooms by sliding paper partitions (Fusuma). There are no permanent partitions. Closets for storage of household goods are closed by the Fusuma.

8) Wood construction is seldom painted or stained--the natural finish is used. Typical Japanese wood construction employs:

Use	Wood	Approx. Equivalent
Structural members	Hinoki	Rocky Mt. Douglas fir
Frame work & trim	Sugi	Russian spruce
Roof and floor sheathing	Pine	Ponderosa pine
Ceiling and wall siding	Cedar	Red Cedar

The Board of Economic Warfare reported that one or two story buildings of wooden frame construction as described account for 95% of all the structures in Tokio. In the most congested district this construction totals 68% of the entire target area. Approximately 50% of the buildings in this district (Asakusa) are one story. Typical one and two story buildings of this construction are shown in Fig. 22.

One consultant reported that this typical dwelling is frequently an integral part of the J apanese industrial system where manufacture and sub-assembly is carried on in the home.

The woods employed in the Japanese structures were mainly Mountain Douglas Fir, Russian Spruce, White Ponderosa Pine, and Western Red Cedar. These woods were generally air-dried before being used, and the structures themselves were then further dried by means of temporary steam radiators to simulate aged wood. Moisture contents of the various beams and boarding in these structures varied from about 8% to 15% (excepting the ceilings), as shown by the following table:

Structural Member	Wood	Av. Moisture Content
5"x5" Sills	Mt. Douglas Fir	12.6
5"x5" Interior Columns	" " "	14.0
5"x5" Exterior Columns	" " "	15.7
1-1/8" T.&G. Flooring	Russian Spruce	10.5
1/2" Flooring	Ponderosa White Pine	11.2
1/2" Shelving	Western Red Cedar	8.0
5/16" Ceiling	" " "	3.0

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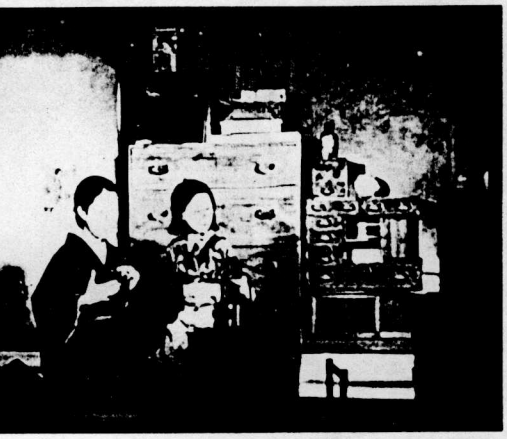
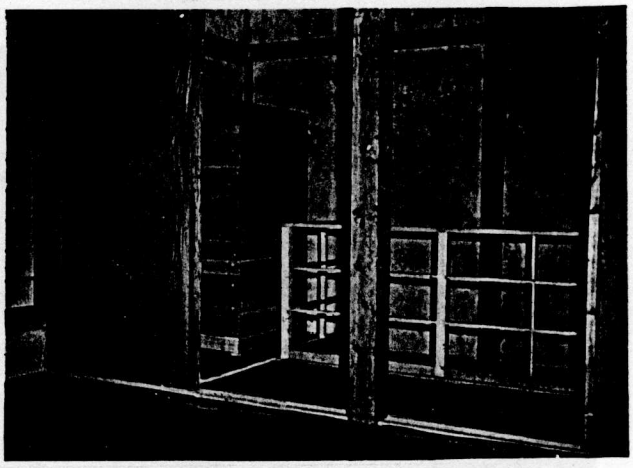
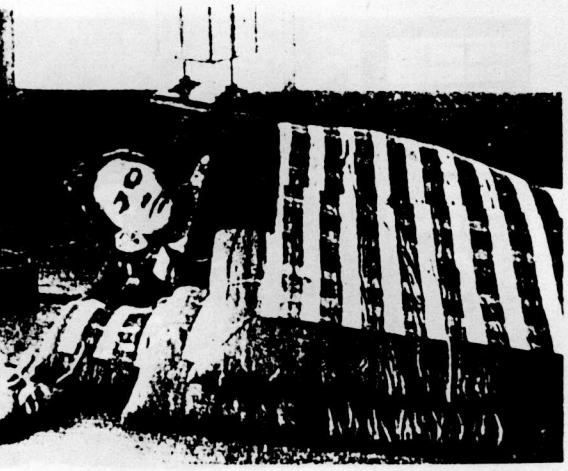
FIGURE 23
TYPICAL JAPANESE FURNISHINGS AND EQUIVALENT TEST
FURNISHINGS USED IN DUGWAY STRUCTURE



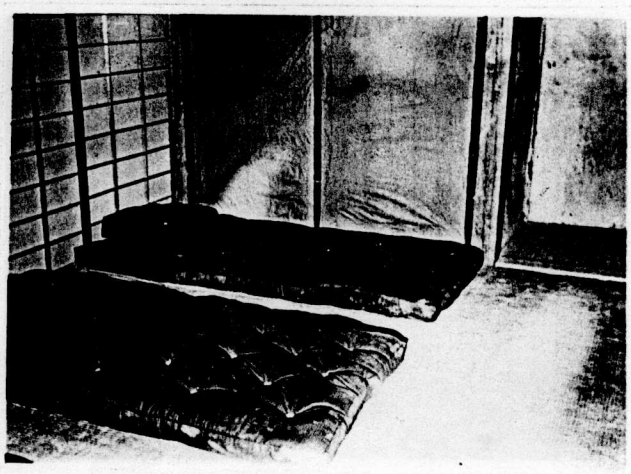
Tansu (Chest of Drawers)



Tansu (Chest of Drawers)



Futon (Bedding)



Futon (Bedding)

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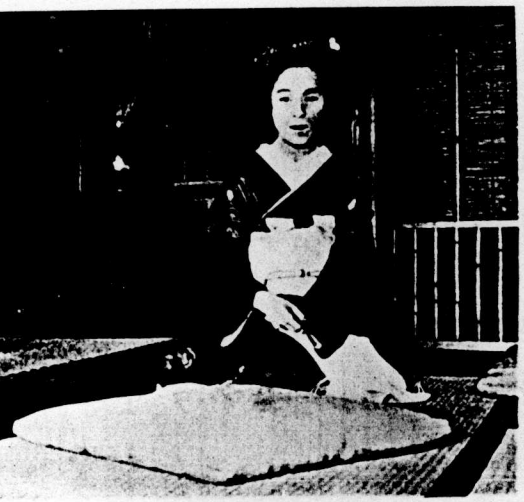
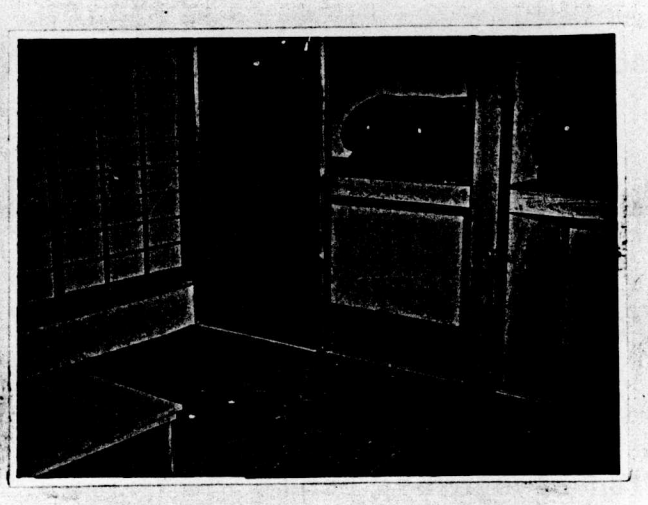
FIGURE 24

TYPICAL JAPANESE FURNISHINGS AND EQUIVALENT TEST FURNISHINGS USED IN DUGWAY STRUCTURE

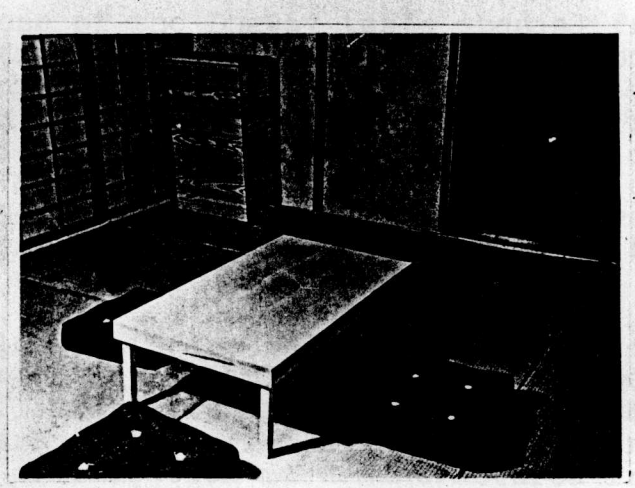


Zabuton (Sitting Pillow)



Finished Room showing Tatami and Futons stored in Closet

Low Table in Typical Dwelling



Low Table and Zabuton in Dugway Structure

C. Furnishings

Japanese furnishings were studied and found to differ from typical American furnishings both in the nature of the articles and in arrangement. The main item of furnishing is the Tatami mat which covers the major portion of the floor area. Other items found to be typical are:

Article	Illustrated	Equivalent	Use
Tansu	Fig.23	Chest of Drawers	Storage of clothing, etc.
Futon	"	Mattress	Bed (stored in closet during day time).
Zabuton	Fig.24	Pillow	Chair.
Hibachi	-	Stove or Brazier	Cooking & heating (burns charcoal).
Low Table	Fig.24	Stool-table	Dining table, writing desk, etc.
Radio			
Shoe Cabinet			Shoe storage in hallway - no shoes worn in house.

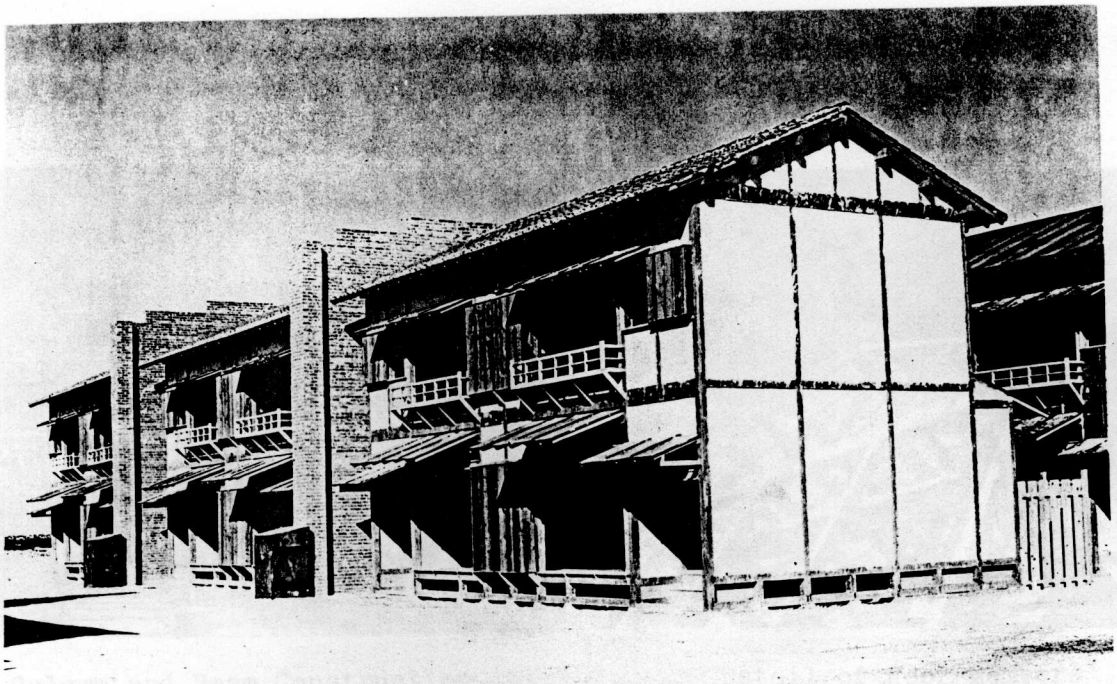
All of the furnishings are of inflammable construction. The woods used are generally oak, pine or poplar and are seldom painted. The Futons and Zabutons are stuffed with cotton batting.

For the purpose of the Dugway tests special furnishings were constructed from authentic materials to reproduce size and density. Figures 23 and 24 show views of typical Japanese furnishings in the ordinary dwelling and the reproductions in the test structures. These represent a density (not including Tatami) of 1.1 lb./sq.ft. of floor area or 0.05 lb./cu.ft. of structure volume. Comparative figures of American and German furnishing density are included in the German section of this report.

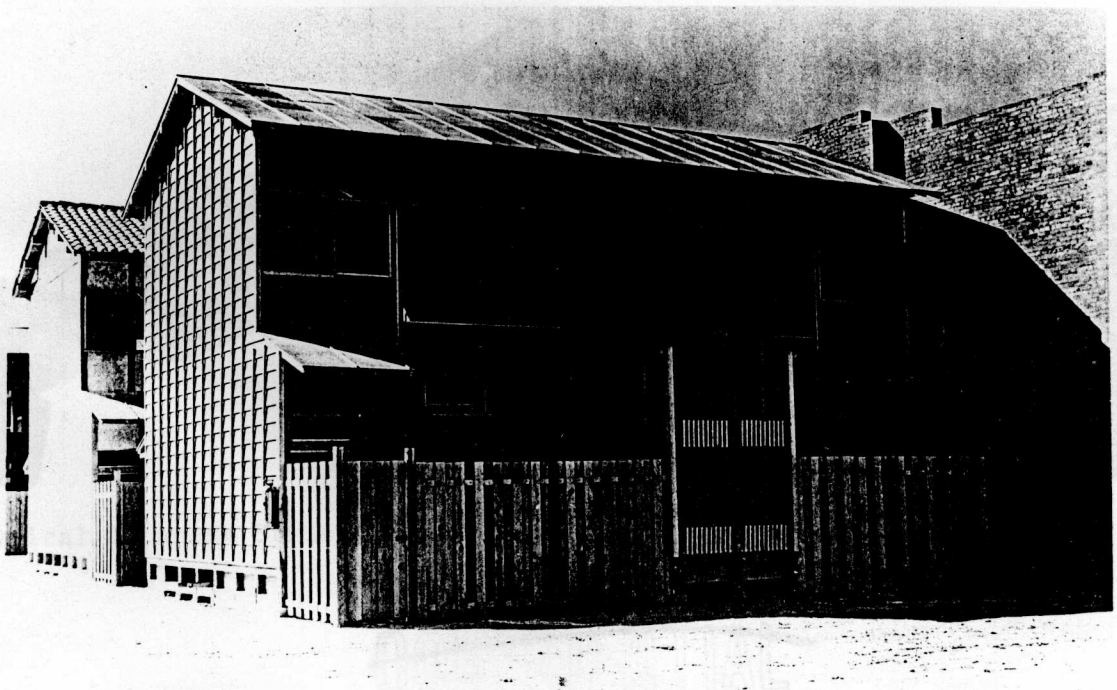
The Tatami floor mats are the most important item of Japanese furnishing since they greatly influence bomb penetration as well as the inflammability of the test structure. The Tatami used at Dugway are either originals made in Japan from hard packed rice straw or imitation mats manufactured from istle which have been shown by test to approach the original mats in both bomb penetration characteristics and inflammability.

FIGURE 25

JAPANESE TEST STRUCTURES AT DUGWAY



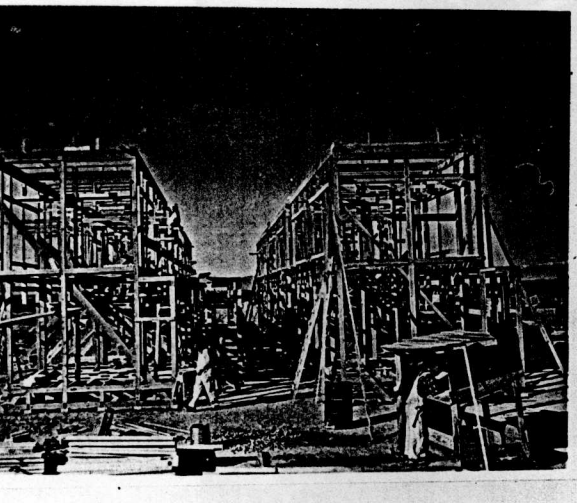
Tile Roof with Plaster Siding



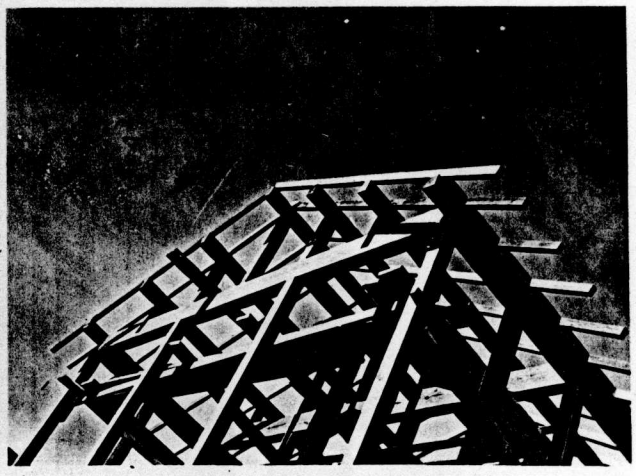
Sheet Metal Roof with Wood Siding

FIGURE 27

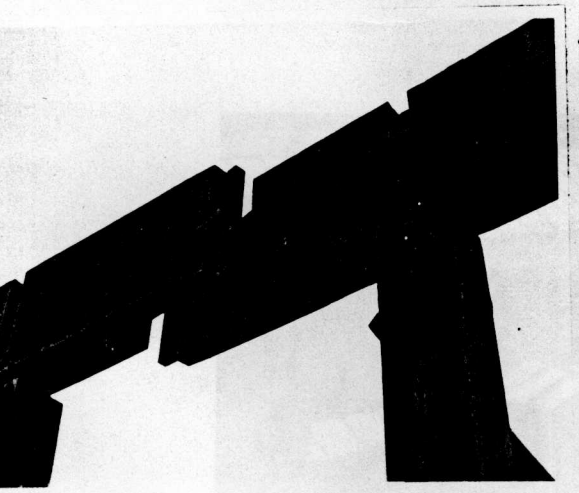
DETAILS OF CONSTRUCTION OF DUGWAY JAPANESE STRUCTURES



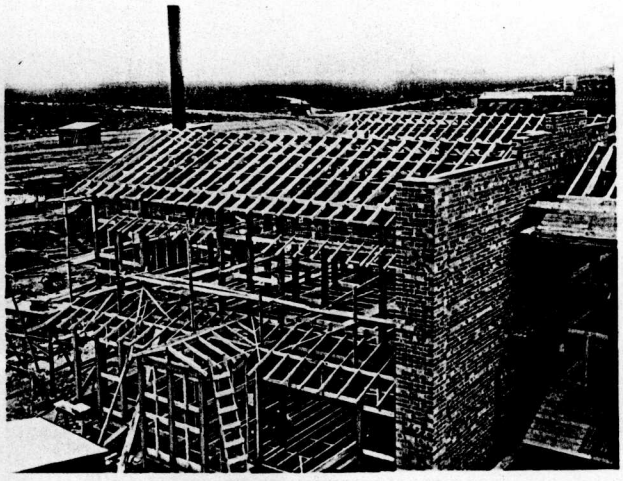
Columm and Beam Construction



Detail of Roof Members



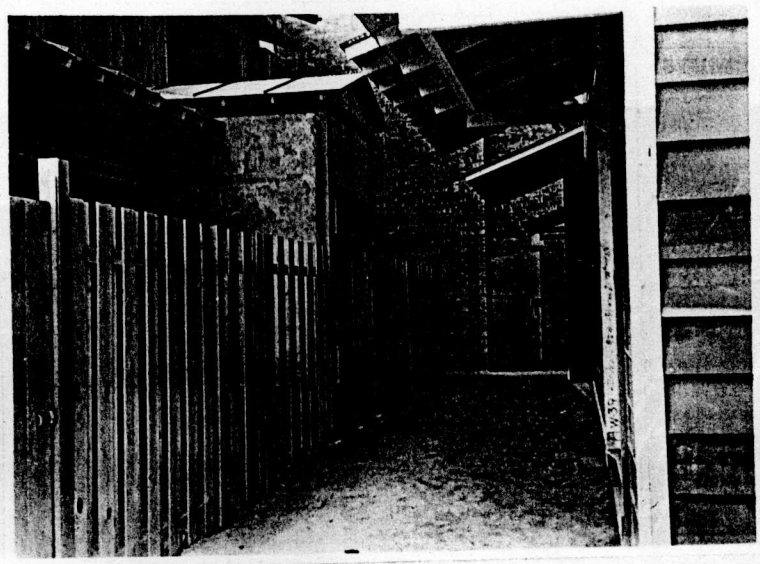
Typical Japanese Structure Joint



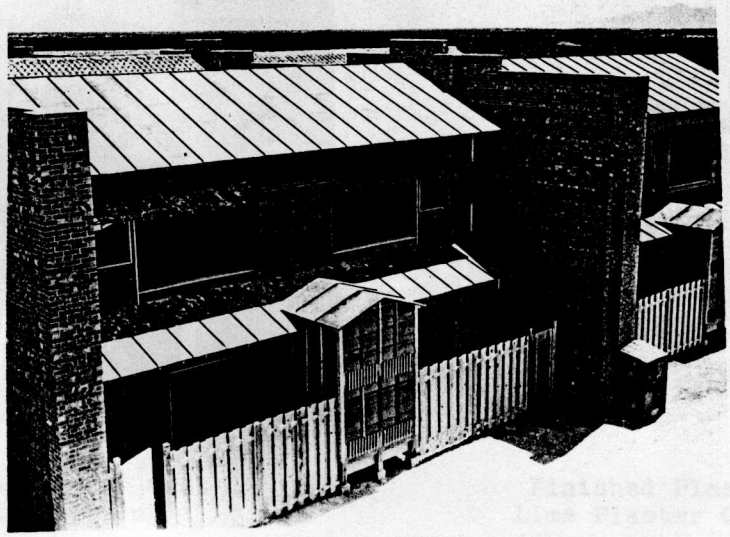
Wood Framework

FIGURE 26

JAPANESE TEST STRUCTURES AT DUGWAY



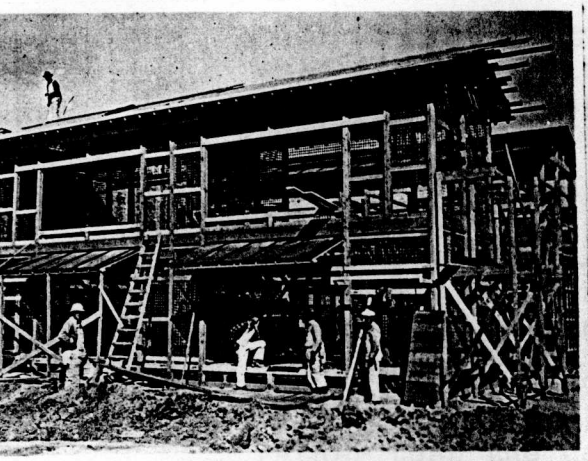
Narrow Street Between Test Structures



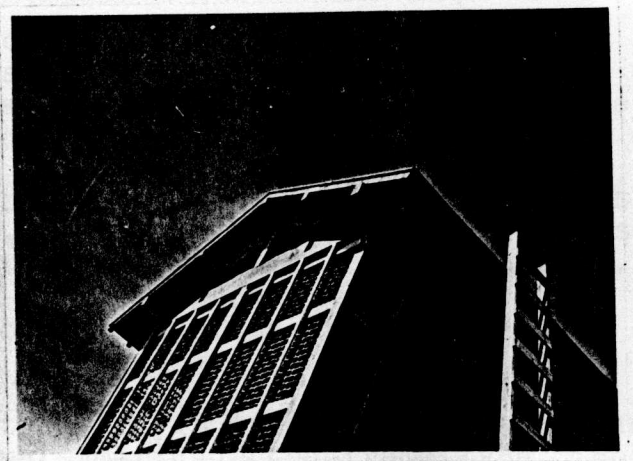
Typical Unit Between Fire Walls

FIGURE 28

CONSTRUCTION OF PLASTER WALLS



General View of Rattan Matting
Before Plaster Application



Close Up of Rattan Matting

First Adobe Plaster Coat
Over Rattan Matting

Finished Plaster Wall-
Lime Plaster Over Adobe

D. Design and Construction of Dugway Structures

In accordance with the information obtained from the aforementioned sources, Japanese structures were designed for construction at Dugway and are shown in Fig. 25. Structures JA and JB are fundamentally the same in design details, differing only in size. Both represent typical workers' dwellings in the industrial districts of the larger Japanese cities and are representative of the major portion of the roof area in these districts.

One set of both the JA and JB structures is built with a tile-in-plaster on sheathing type roof (the most typical of all Japanese construction); the other set employs typical sheet metal over sheathing.

The narrow 8 ft. street between sets of structures can be seen in Fig. 26. This is typical of Japanese city plan and accounts for the congestion noted in Figs. 18 and 19. The roof area of the Japanese test structures is approximately 60% of that portion of the plot covered by Japanese structures.

The construction is of the column and beam type rather than the usual American stud-frame type. Heavy structural members are used as shown in Fig. 27 and employ complicated keyed or mortised joints, a typical joint being shown in Fig. 27. The columns are spaced on 6 foot centers or multiples thereof; floor joists are either 2" x 3" or 2" x 5" depending on span length. Fig. 28 shows the construction detail of the permanent walls. Here 2-1/2" of adobe plaster is laid over a rattan screen held between the columns. The rattan was used as a substitute for bamboo which is typical of Japan. Fig. 28 also shows the outside wall of the finished construction; 1/4" of lime plaster is laid over the adobe as a finish coat.

The sliding Shoji and Fusuma screens are shown in Fig. 24. These add to the density of inflammable construction material which is higher than in the German construction as tabulated below.

Inflam.Materials in Construction	Japanese Test Structure	German Test Structure
Based on Lb./Sq.Ft. Floor Area	67.8	34.4
Based on Lb./Cu.Ft.of Struct.Vol.	3.0	1.1