

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

HEADQUARTERS XXI BOMBER COMMAND
Operations Analysis Section
APO 234, c/o Postmaster
San Francisco, California



30 June 1945.

WEAPON ANALYSIS REPORT NO. WA-1

This is the first of a series of weapons analyses by the Operations Analysis Section, Headquarters, XXI Bomber Command. Each report discusses the weapon effectiveness achieved in a single mission of the XXI Bomber Command or one or more of its bombardment units.

The purpose of each analysis is to determine the effectiveness of the particular bomb and fuze combination or combination of bombs used on the type of target attacked. From a series of such analyses it is anticipated that sufficient data will be accumulated to furnish firm planning factors upon which to base the selection of the best weapons for future attacks. The procedures used in the analysis are discussed in Appendix "A" of the report.

Leroy A. Brothers
LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

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

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

30 June 1945.

WEAPON ANALYSIS REPORT NO. WA-1.

SUBJECT: Effectiveness of the 4,000# L.C. Bomb.

Mission No. 193

Targets: 90:20 - 198, Aichi A/C Works, Atsuta Plant.
90:20 - 2010, Aichi A/C Engine Works, Nagoya Plant.

Date of Attack: 9 June 1945.

Summary

The purpose of the study was to obtain a measure of the effectiveness of the 4,000# L.C. bomb against aircraft factories. The analysis was complicated somewhat by the fact that a few 2,000# G.P.'s and 1,000# G.P.'s were also dropped in the attack but the effect of the G.P. bombs was considered to be relatively small and for the purposes of this paper the G.P. bombs were converted into equivalent 4,000# L.C.'s on the basis of relative charge weights.

The mean area of effectiveness (MAE) of the 4,000# L.C. against this type of target in this attack was found to be 0.71 acres/ton, or 31,000 sq. ft./ton. These figures include the fire damage resulting from H.E. and therefore may be slightly too high.

1. Mission Plan. The original plan called for 66 aircraft of the 313th Wing to be airborne carrying three 4,000# L.C. bombs each (fuzed Inst. nose, N.D. tail). It was assumed that at least 54 aircraft would reach the primary target and that 40% of their bombs would fall within 1,000 ft. of the assigned M.P.I. (See attached damage plot). This would result in 65 bombs hitting within the 1,000 ft. circle. With these assumptions it was expected that the target would suffer 60% structural damage. Planned altitude was 18,000 ft.

2. The Attack. Forty-four (44) aircraft were airborne and twenty-five (25) of them carried one 2,000# G.P. each (fuzed Inst. nose, N.D. tail) in addition to the three 4,000# L.C.'s. Examination of the strike photos and the bombing data indicates that the squadrons carrying only 4,000# bombs did not hit the target. The squadrons hitting the target were those carrying the mixed loads; in addition hitting the target were those carrying the mixed loads; in addition one airplane from the 58th Wing carrying 12 x 1,000# G.P. bombs (fuzed O.01 nose, N.D. tail) attached itself to one of these squadrons and also bombed the target. Table 1 compares actual execution with the plan.

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Table 1.

	PLAN	EXECUTION
No. A/C Airborne	66	44
No. A/C Bombing P.T.	54	41
No. Bombs within 1,000 ft. of Assigned M.P.I.	65	47
Fraction of Damage (structural) to Portion of Target within 1,000 ft. Circle about M.P.I.	60%	57%

From careful examination of the strike photos and the bombing data it is estimated that twenty-five (25) aircraft actually succeeded in hitting the primary target as shown in Table 2.

Table 2.

No. A/C Bombing P.T.	No. Bombs Dropped		
	4,000# L.C.	2,000# G.P.	1,000# G.P.
23	69	23	
1	1*		
1			12
Totals 25	70	23	12
Total No. Bombs = 105			
* 2 x 4,000# L.C. and 1 x 2,000# G.P. jettisoned.			

3. The Damage. Thirty-nine of the 48 buildings in the two targets, 198 and 2010, suffered damage, either structural or superficial. Buildings with less than 3,500 sq. ft. were omitted except in cases such as buildings of at least this size reduced below this by previous damage unrepaired. Table 3 summarizes the damage.

Table 3.

	Targets 198 & 2010	Within Targets & Enclosed by 1,000 ft. Circle
Total Floor Area (Sq. Ft.)	1,577,600	1,113,400
Total Structural Damage (Sq.Ft.)	894,500	626,900
Percent Structural Damage	57	57
Total Superficial Damage (Sq. Ft.)	317,700	174,000
Percent Superficial Damage	20	16

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Full itemization of the damage, building by building, is shown on the accompanying damage schedule.

4. The Analysis. Since the attack consisted of a mixed load of L.C. and G.P. bombs it was necessary to convert the G.P. bombs into equivalent L.C. bombs. The conversion was made on the basis of the relative charge weights of the bombs. It was assumed that one 2,000# G.P. was equivalent to $1117/3362$ or $1/3 \times 4,000\#$ L.C. And one 1,000# G.P. was equivalent to $558/3362$ or $1/6 \times 4,000\#$ L.C. Table 4 gives the actual computations. It should be noted that the 57 actual bombs hitting within the areas of targets 198 and 2010 finally reduced to 38 actual 4,000# L.C.'s and 5.3 equivalent 4,000# L.C.'s, thus the G.P. bombs made up slightly more than 1/9 of the attack (on a charge weight basis).

The effectiveness of the 4,000# L.C. bombs (including the equivalent bombs) was then calculated. The unit of measure used was the mean area of effectiveness (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of a specified kind (visible structural damage is used for this purpose). The MAE is expressed in acres per ton (or thousands of square feet per ton) and is obtained by solving the following equation for M:

$$F = 1 - e^{-MD}$$

Where F = fraction of damage, in this analysis the total visible structural damage divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (acres/ton)

D = density of bombs achieved (tons/acre)

e = base of Napierian logarithms (= 2.72 approx.)

For further discussion of the equation and the procedures of weapon analysis see Appendix "A".

5. The Results. The computation of the MAE of the 4,000# L.C. bomb against target 198 is shown in Table 5. The area of damage and bomb density were taken from the attached damage assessment. The bomb hits shown were located visually with the aid of relatively good post-attack and strike-attack photographs, and accordingly may be considered to have a high degree of reliability.

The formula used in computing the MAE (see section 4) is derived on the assumption of uniform density of bomb fall in the target area. Under conditions approximating this assumption it gives quite reliable results. An inspection of the damage plot reveals that target 198 received almost perfectly uniform distribution of bomb hits but that in 2010 the bombs fell in a heavily concentrated pattern in the N.E. corner. Since the MAE for 2010 would have been highly unreliable it was not computed.

Table 4.

Target Area	No. of Bombs in Target Area	Proportion of Various Size Bombs on Target Areas*			Equivalent No. of 4,000# L.C. Bombs from 1,000# and 2,000# G.P. Bombs		Total Equivalent No. Of 4,000# L.C. Bombs Dropped on Target Areas
		1,000# G.P.	2,000# G.P.	4,000# L.C.	1,000# G.P.	2,000# G.P.	
Target Area Enclosed by 1,000 ft. Circle	47	5.4	10.3	31.3	0.9	3.4	35.6
2010	12	1.4	2.6	8.0	0.2	0.9	9.1
198	45	5.1	9.9	30.0	0.9	3.3	34.2
198 & 2010	57	6.5	12.5	38.0	1.1	4.2	43.3

*These bombs were assumed to have fallen on the target in the same proportions as the numbers of the various size bombs dropped. As an example, in target 198 of 105 bombs dropped (70 - 4,000# L.C., 23 - 2,000# G.P., 12 - 1,000# G.P.), 45 fell on the target; thus $12 \times 45/105 = 5.1$ 1,000# G.P., $23 \times 45/105 = 9.9$ 2,000# G.P., and $70 \times 45/105 = 30$ 4,000# L.C.

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Table 5.

Area of Target	Density of Bombs in Target	Total Area Of Buildings	Area of Struct. Damage	Fraction Of Structural Damage	MAE	
					Acres ton	1,000 sq.ft. ton
48.6	1.48	26.7	17.5	0.65	0.71	31.0

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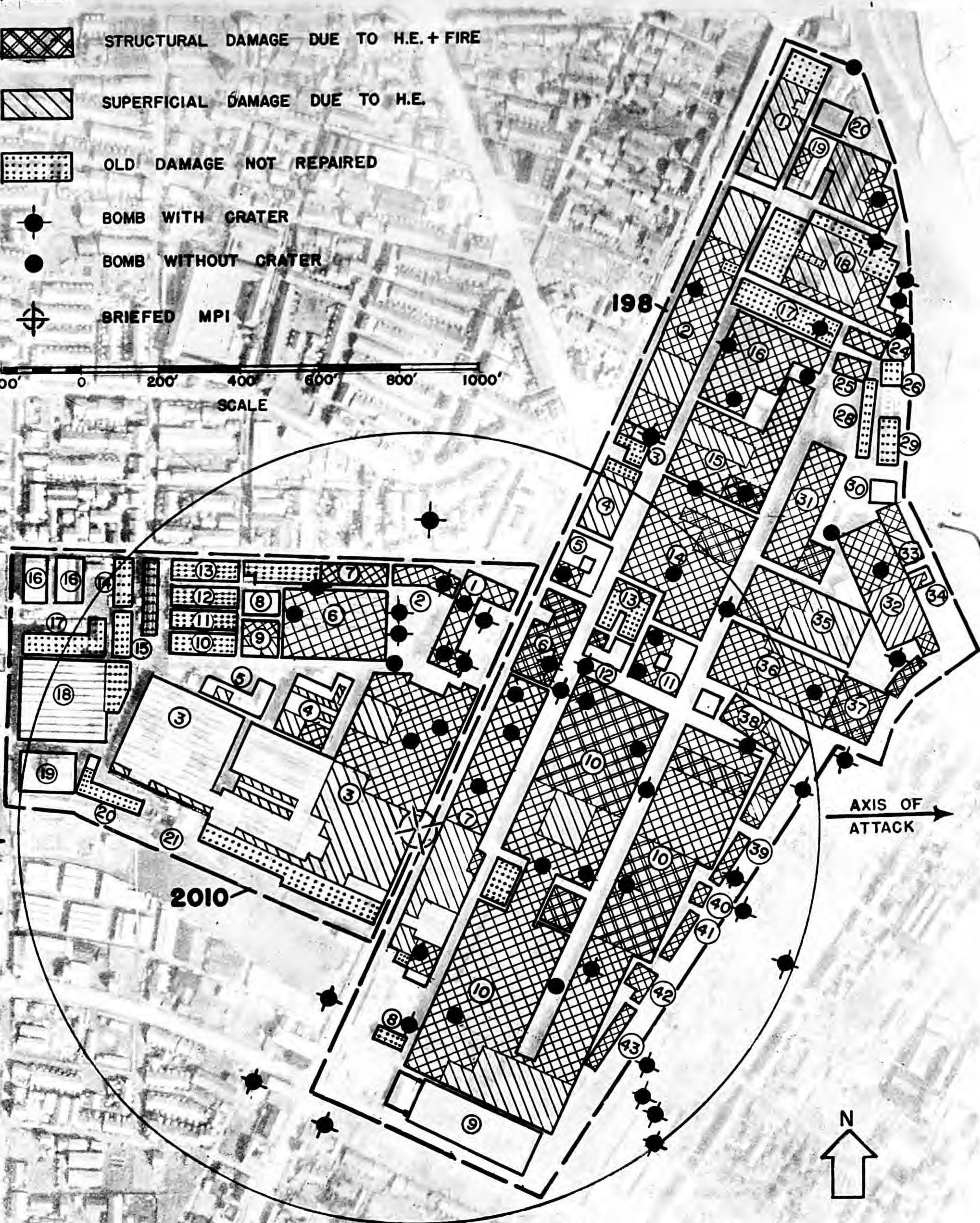
APPROVED:

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LEROY A. BROTHERS,
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Operations Analysis Section.

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LEGEND:

-  STRUCTURAL DAMAGE DUE TO H.E.
-  STRUCTURAL DAMAGE DUE TO H.E. + FIRE
-  SUPERFICIAL DAMAGE DUE TO H.E.
-  OLD DAMAGE NOT REPAIRED
-  BOMB WITH CRATER
-  BOMB WITHOUT CRATER
-  BRIEFED MPI



DAMAGE ASSESSMENT FOR WEAPON ANALYSIS

- MISSION 193 -

TARGETS 90.20 - 198 & 2010

HEADQUARTERS XXI BOMBER COMMAND
OPERATIONS ANALYSIS SECTION

30 JUNE, 1945

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62-10000-100-10000

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HEADQUARTERS XXI BOMBER COMMAND
OPERATIONS ANALYSIS SECTION

INDUSTRIAL DAMAGE SCHEDULE
FOR
WEAPON ANALYSIS

NAME OF TARGET: AICHI A/C WORKS, ATSUTA PLANT (90.20-198)
AICHI A/C ENGINE WORKS, NAGOYA PLANT (90.20 2010)
LOCATION: NAGOYA, HONSHU

PHOTO COVER USED					MISSION NO: 193	TARGET NO
MISSION	PRINTS		DATE	QUALITY	SCALE	ATTACK DATE: 9 June 45
	PRE-STRIKE	POST-STRIKE				REPORT DATE: 30 June 45
3PR5M222	2: 37-39		18 May 45	Fair	1/9150	90.20-198/2010
3PR5M27B	3L: 78-100		12 June 45	Fair		
ENLARGEMENT NO:					SHADOW SCALE:	INTER.: R.D. Burson
					LAT.: 35°07'24" N	LONG.: 136° 54'00" E
					SHEET NO 1 OF 3 SHEETS	

BUILDINGS				AREAS OF VISIBLE DAMAGE									DESCRIPTION OF DAMAGE	
NUMBER	SUB-DIV.	OCCUPANCY	AREA* 1000 SQ. FT.	STRUCTURAL				SUPERFICIAL				OLD DAMG NOT REPD		
				H.E.	FIRE	HE. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	HE. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	
<u>TARGET N^o 198</u>														
1		Probable Instru- ment Assembly	24.2					196						Sections of roofing stripped, contents probably not damaged to any extent.
2		Unidentified	57.4	35.4				22.0						Center and south portions greatly damaged. Damage to contents probably great.
3		"	2.3	2.3										
4		Offices	12.0					12.0						Damage to contents probably extensive.
5		"	37.5	3.4										Damage confined to corner of upper part.
6		Unidentified	15.0			15.0								Demolished
7		"	78.2	35.8				30.4						Internal damage severe except south portion.
9		"	35.4											No visible damage
10		Probable Fuselage Assembly	371.3	202.3		114.5		45.5						Building severely damaged by combination of blast and fire. Internal damage extensive.
11		Unidentified	60.0	7.8										Top floor on west side damaged.
12		"	7.5			1.1								One section demolished
13		"	3.0	3.0										Demolished
SUB-TOTALS			704.3	244.0		135.6		129.5						
GRAND TOTALS														

* Floor Area (Unrepaired old damage omitted)

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**HEADQUARTERS XXI BOMBER COMMAND
OPERATIONS ANALYSIS SECTION**

TARGET No 90.20-148/2010

MISSION No 143

SHEET 2 OF 3 SHEETS

BUILDINGS				AREAS OF VISIBLE DAMAGE								OLD DAMAGE NOT REPAIRED	DESCRIPTION OF DAMAGE	
NUMBER	SUB-DIV.	OCCUPANCY	AREA* 1000 SQ.FT.	STRUCTURAL				SUPERFICIAL						
				H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	
SUB-TOTALS BROUGHT FORD			704.3	294.0		135.6		124.5						
14		Machine Shop	68.6	58.2		10.4								Framing badly distorted. Evidence of some fire.
15		"	57.0	10.4		5.3		8.3						So. section demolished. Trusses distorted, except for area in center, in re- mainder of building. Internal damage severe.
16		Unidentified	36.5	36.5										Framing demolished or badly distorted.
18		Probable Machine Shop	34.9	12.7				22.2						Center part of framing intact. Internal damage severe.
19		Probable Machine & Heat Treatment Shop.	34.0	9.7				15.6						Except for east side damage repairable.
20		Unidentified	4.0											No visible damage
24		"	3.3	3.9										Demolished
25		"	3.6	3.6										"
30		"	2.8											Minor roof damage
31		Torpedo Testing	34.8	27.9		6.9								East wing demolished. Framing of remainder distorted.
32		Iron Foundry	40.4	21.8				18.6						North section badly distorted. Probable severe internal damage.
33		Unidentified	7.4	3.1				4.3						Framing of north end distorted
34		"	1.8					0.3						
35		"	37.8	15.2				22.6						Internal damage severe
36		"	42.0	32.0				10.0						Damage to building & contents almost complete
37		"	13.7			13.7								Gutted by fire
38		"	22.3	13.5				8.8						Internal damage probably extensive.
39 thru 43		"	19.0	19.0										No repair of remaining portions possible.
SUB-TOTALS			1165.7	593.4		171.4		240.7						
GRAND TOTALS														

Old Damage Omitted

* Floor Area (Unrepaired old damage omitted) (CONFIDENTIAL)

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HEADQUARTERS XXI BOMBER COMMAND
OPERATIONS ANALYSIS SECTION

TARGET No 90.20-198/2010

MISSION No 193

SHEET 3 OF 3 SHEETS

BUILDINGS				AREAS OF VISIBLE DAMAGE								OLD DAMAGE NOT REPAIRED	DESCRIPTION OF DAMAGE	
NUMBER	SUB-DIV.	OCCUPANCY	AREA* 1000 SQ.FT.	STRUCTURAL				SUPERFICIAL						
				H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	
SUB-TOTALS BROUGHT FORWARD			1165.7	603.4		171.9		240.7						
				591.4	TARGET No 2010									
1		Offices and Cafeterias	16.1	16.1										Demolished
2		Offices	6.3	6.3										"
3		Engine Parts Factory & Assembly	236.4	56.6				66.6						Damage severe in north-east section. Damage to remainder, including interior, light.
4		Probable Foundry or Parts Factory	13.2	3.0				6.3						Building easily repairable. Internal damage minor
5		Probable Parts Factory	8.2					1.1						Easily repairable
6		Probable Foundry & Storage	39.4	39.4										Framing demolished or badly distorted. Internal damage complete.
7		Storage	7.0	7.0										Demolished
8		Unidentified	4.1											Minor damage in one corner.
9		"	6.9	2.8				3.0						North section partly demolished. Internal damage probably severe.
16		Possible 13mm. Ammunition Fact.	15.4											Scattered minor roof disturbance.
18		Engine Parts Factory	46.5											No visible new damage
19		Unidentified	12.4											No visible damage
SUB-TOTALS				722.6										
GRAND TOTALS				1577.6	734.6	171.9		317.7						

CID Damage Omitted

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35PTU 25-6-45-2A

* Floor Area (Unrepaired old damage omitted)

By AK-A NARA, Date 2/2/11

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

Appendix "A"

PROCEDURES USED IN WEAPON ANALYSIS

1. Definition of Weapon Analysis. A weapon analysis is a study relating the damage achieved in a bombing attack to the weapon or weapon combination to which it may be attributed.

2. Limitations of Weapon Analysis. 2. Due to the inherent nature of bombing and the varied character of targets, resulting in relatively wide variations in results achieved from attack to attack, the results of the analysis of a single attack cannot be accepted unqualifiedly. However, data accumulated from analyses of several attacks under relatively similar conditions will have sufficient stability to furnish adequate planning factors.

b. Where the combination of bombs or bombs and fuzings is not rather carefully controlled it becomes practically impossible to sort out the damage and attribute it to the weapon causing it. Accordingly weapon analyses are attempted only for the "controlled attacks" or for those attacks in which sufficient control was in fact accomplished to promise a measure of success in obtaining reliable results.

3. Procedure. The following procedure is followed in weapon analysis:

a. Damage Assessment. A special damage assessment is made using the following categories of damage, defined as stated:

(1) Visible Structural Damage. Destruction, callapse, or serious distortion (over 12 inches, vertical or horizontal) of roof trusses, beams, girders, columns or load-bearing walls.

(2) Visible Superficial Damage. Damage to roofing, roof lights and secondary members such as purlins which are easily replaced and are not essential to the stability of the building; minor disturbance of roofing is not included. Each of these categories is further subdivided as to cause, as follows:

- (3) H.E.
- (4) Fire
- (5) H.E. and Fire
- (6) Cause not known.

b. Determination of Density of Bombs. On the damage plot are also shown the bombs falling within the target area and within a circle (radius 1,000) about the assigned M.P.I. All available photography is used, pre-attack and post-attack reconnaissance and all strike-attack. When it is necessary to resort to computed bomb fall, as in the cases where clustered I.B. are used or the target is heavily obscured by smoke, a distinction is made between bombs located visually and those calculated. The estimated reliability of the plot is clearly stated in each case.

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c. Effectiveness Calculations. Only the structural damage is used in calculating the effectiveness of weapon, for two reasons:

(1) From careful studies of the damage suffered by British factories due to German bombing it was determined that the most usable measurable quantity relating bombing to loss of production (the ultimate goal) is visible structural damage; it must be visible on photo cover to be measurable.

(2) Almost all previously obtained data has been related to visible structural damage. Thus, in order to relate the results of these analyses to existing data this unit must be used.

The unit of measure of effectiveness is the mean area of effectiveness in acres per ton (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of a specified kind (visible structural damage in these analyses). If a target were attacked with a single bomb-fuze combination and consisted of a very large area containing a great many identical buildings with identical contents, and both buildings and bombs (all making direct hits) were widely and uniformly spaced throughout the area the MAE would be a constant and would equal the average damage per ton. Since these conditions never occur in practice it is necessary to solve the following equation for M,

$$M = 1 - e^{-MD} \quad (\text{For the case in which a single bomb-fuze combination is used})$$

Where

F = fraction of damage, in this analysis the total visible structural damage divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (Acres/Ton)

D = density of bombs achieved (Tons/Acre)

e = base of Napierian logarithms (= 2.72 approx.)

This formula attempts to account for near-misses as well as direct hits and also for overlap where two bombs hit close together. It was derived by the British-American Target Analysis Unit at Princes-Risborough, England* and has more recently been in use by the Joint Target Group in Washington and by this Section in its bomb selection calculations.

Where more than one bomb-fuze combination are used the following equation may be used:

$$F = 1 - e^{-MD - M'D'}$$

*For derivation see REN 284 and REN 331, Research and Experiments Department, Ministry of Home Security.

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where the M' and D' have the same meaning as M and D but apply to the additional weapon. An additional term occurs in the exponent for each additional weapon. There is little practical value in attempting an analysis where more than two weapons are used.

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HEADQUARTERS TWENTIETH AIR FORCE
Operations Analysis Section
APO 234, c/o Postmaster
San Francisco, California

19 August 1945.

WEAPON ANALYSIS REPORT NO. WA-2

This is one of a series of weapons analyses by the Operations Analysis Section, Headquarters, Twentieth Air Force. Each report discusses the weapon effectiveness achieved in a single mission of the Twentieth Air Force or one or more of its bombardment units.

The purpose of each analysis is to determine the effectiveness of the particular bomb and fuze combination or combination of bombs used on the type of target attacked. From a series of such analyses it is anticipated that sufficient data will be accumulated to furnish firm planning factors upon which to base the selection of the best weapons for future attacks. The procedures used in the analysis are discussed in Appendix "A" of the report.

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



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

19 August 1945.

WEAPON ANALYSIS REPORT NO. WA-2.

SUBJECT: Effectiveness of the 2,000# G.P. Bomb.

Mission No. 197

Target: 90:14 - 1476, Hitachi Engineering Works,
Kaigan Plant.

Date of Attack: 10 June 1945.

Summary

The purpose of the study was to obtain a measure of the effectiveness of the 2,000# G.P. bomb against a medium manufacturing plant. The analysis was complicated slightly by the fact that a small percentage (2.5%) of the bombs dropped on the target were 500# G.P.'s, but the effect of these bombs was almost negligible and for the purpose of this paper the 500# G.P.'s were converted into equivalent 2,000# G.P.'s on the basis of relative charge weights.

The mean area of effectiveness (MAE) of the 2,000# G.P. against this type of target in this attack was found to be 0.69 acres/ton, or 30,000 sq. ft./ton. Because of the excellence of the photographic coverage and the uniform distribution of hits throughout the target area this is considered to be a reliable figure.

1. Mission Plan. This target was designated as a primary radar target, to be included in a mission plan in which the primary visual target required the same type of bomb and fuzing and in which the force required for the primary visual target was adequate to ensure a sufficient number of hits on target 1476 when bombing by radar methods. The 2,000# G.P. bomb (fuzed 0.025 or 0.1 nose, 0.025 tail) was selected as the most efficient bomb for the target.

2. The Attack. One hundred twenty-four (124) aircraft of the 73rd Wing were airborne, each carrying 2,000# G.P. bombs (25% fuzed 0.1 nose, 0.025 tail, and 75% fuzed 0.025 nose, 0.025 tail). The primary visual target was 90:17 - 357 in the Tokyo area. Target 357 was socked-in, however, and the aircraft proceeded to the primary radar target, 1476. CAVU conditions existed at target 1476 and one hundred eighteen (118) aircraft dropped eight hundred six (806) 2,000# G.P. bombs using visual sighting methods. In addition, one (1) aircraft of the 314th Wing bombed with the 73rd Wing, dropping twenty (20) 500# G.P. bombs (fuzed 0.01 nose, N.D. tail). The assigned aiming point was the center of the target area.

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3. The Damage. Target 1476 was very completely damaged by this attack. The fact that the force was planned for radar bombing while visual sighting was able to be employed accounted for a greater degree of damage than normally would be planned for. Only five (5) of the eighty-one (81) buildings in the target area of over 4,000 sq. ft. in plan area escaped being damaged. In addition, numerous small buildings of less than 4,000 sq. ft. in plan area were demolished. Table 1 summarizes the damage. (Buildings smaller than 4,000 sq. ft. not included.)

Table 1.

Total Floor Area (Sq. Ft.)	2,077,200
Total Structural Damage (Sq. Ft.)	1,638,900
Percent Structural Damage	79
Total Superficial Damage (Sq. Ft.)	196,000
Percent Superficial Damage	9

Full itemization of the damage, building by building, is shown on the accompanying damage schedule. Serious internal damage to building or contents without structural is included as structural in this schedule. Such damage is equally as effective as structural damage in stopping production.

4. The Analysis. A total of three hundred forty-six (346) bombs were identified as striking within the target area. Since of the eight hundred twenty-six (826) bombs aimed at the target eight hundred six (806) were 2,000# G.P.'s and twenty (20) were 500# G.P.'s, it was assumed that the bombs hitting in the target area were in the same proportion, namely, three hundred thirty-eight (338) were 2,000# G.P.'s and eight (8) were 500# G.P.'s. The assumed 500# G.P.'s were converted to equivalent 2,000# G.P.'s on the basis of relative charge weights of the bombs. Thus, the eight (8) 500# G.P.'s were equivalent to two (2) 2,000# G.P.'s, making a total of three hundred forty (340) 2,000# G.P.'s on the target area.

The effectiveness of the 2,000# G.P. bombs (including the equivalent bombs) was then calculated. The unit of measure used was the mean area of effectiveness (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of a specified kind (visible structural plus visible serious internal damage to buildings or contents without structural damage). The MAE is expressed in acres per ton (or thousands of square feet per ton) and is obtained by solving the following equation for M:

$$F = 1 - e^{-MD}$$

Where F = fraction of damage, in this analysis the total visible structural damage (including visible serious internal damage to building or contents without structural damage) divided by the total undamaged floor area of the target before the attack.

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

M = mean area of effectiveness (acres/ton)

D = density of bombs achieved (tons/acre)

e = base of Napierian logarithms (= 2.72 approx.)

For further discussion of the equation and the procedures of weapon analysis see Appendix "A".

5. The Results. The computation of the MAE of the 2,000# G.P. bomb against target 1476 is shown in Table 2. The areas of damage and the bomb density were taken from the attached damage assessment. The damage and the bomb hits were located with the aid of fair strike-attack and excellent post-attack photographs and accordingly may be considered to have a high degree of reliability.

The formula used in computing the MAE (see Section 4) is derived on the assumption of uniform density of bomb fall in the target area. Under conditions approximating this assumption it gives quite reliable results. An inspection of the damage plot reveals that the distribution of bomb hits is very uniform, thus giving further reliance to the computed value of the MAE.

Table 2.

Area of Target	Density of Bombs in Target	Total Floor Area of Buildings	Area of Structural Damage	Fraction of Structural Damage	MAE	
					Acres ton	1,000 sq.ft. ton
Acres	Tons/Acre	Acres	Acres			
150.	2.27	47.7	37.6	0.79	0.69	30.

Richard D. Burson

RICHARD D. BURSON,
Operations Analyst.

Norman Dahl

NORMAN DAHL,
Operations Analyst.

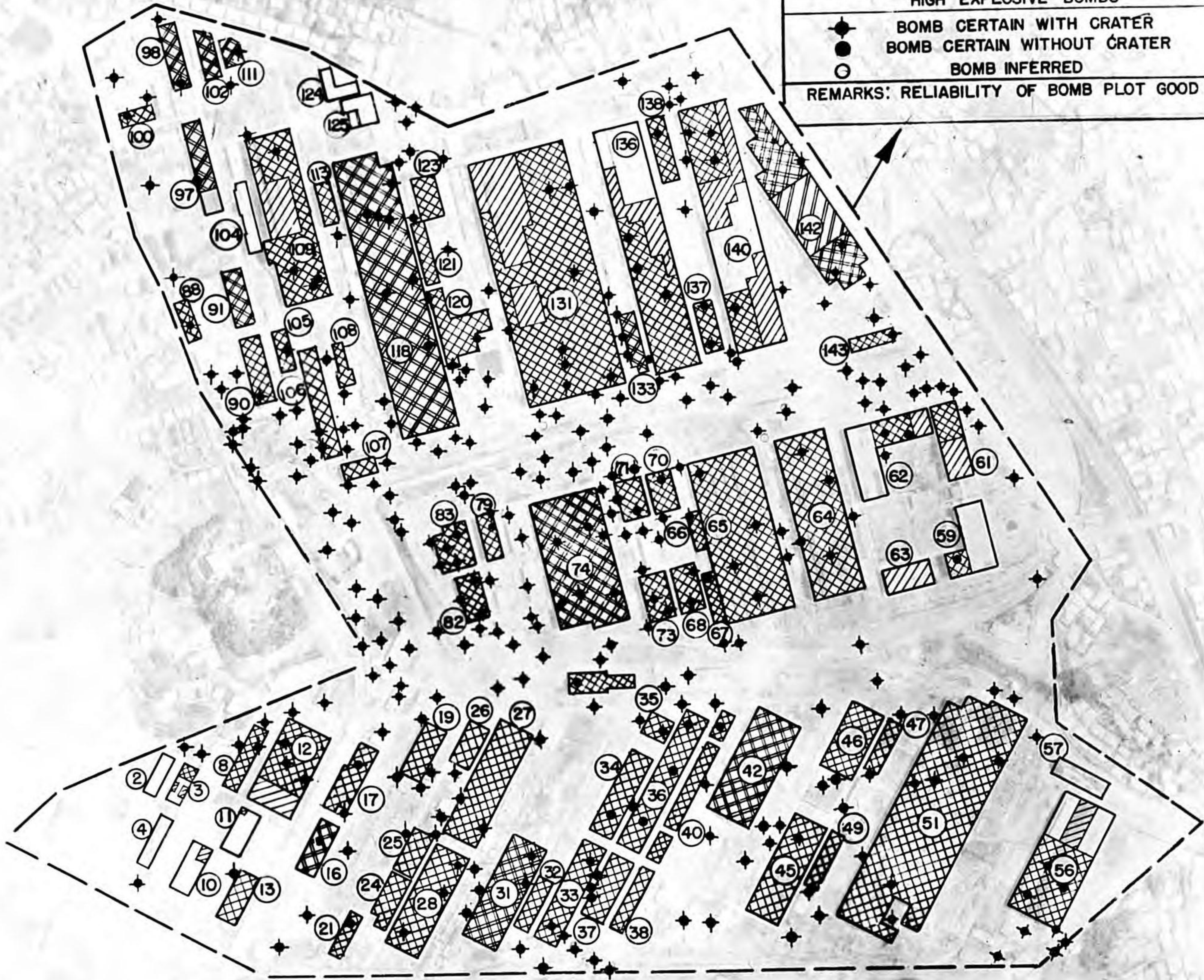
APPROVED:

Leroy A. Brothers

LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

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DAMAGE LEGEND		
AREAS OF VISIBLE DAMAGE		
STRUCTURAL	CAUSE	SUPERFICIAL
	H.E.	
	FIRE	
	H.E.+FIRE	
	CAUSE NOT ASSIGNED	
	PRIOR DAMAGE NOT REPAIRED	
HIGH EXPLOSIVE BOMBS		
	BOMB CERTAIN WITH CRATER	
	BOMB CERTAIN WITHOUT CRATER	
	BOMB INFERRED	
REMARKS: RELIABILITY OF BOMB PLOT GOOD		



DAMAGE ASSESSMENT FOR WEAPON ANALYSIS
 MISSION 197
 TARGET 90.14 1476
 HEADQUARTERS TWENTIETH AIR FORCE
 OPERATIONS ANALYSIS SECTION
 AUGUST 17, 1945



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HEADQUARTERS TWENTIETH AIR FORCE OPERATIONS ANALYSIS SECTION INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS	PHOTO COVER USED					MISSION NO 197	TARGET NO 90.14 - 1476
	MISSION	PRINTS		DATE	QUALITY		
		PRE-STRIKE	POST STRIKE			PLAN	SHADOW
	3PR5M118	3L: 45-47		6 April 45	Excellent	1/9500	1/13,600
21BC5M197	2V: 8		10 June 45	Fair	1/9500		ATTACK DATE 10 June 1945
"	8V: 13		" " "	"	1/9600		REPORT DATE 17 August 1945
"		1V: 19-21	" " "	"	1/9700		INTERPRETER NORMAN C. DAHL
"		16V: 5 - 6	" " "	"	1/9800		LATITUDE 36/35N
"		19V: 2 - 9	" " "	"	1/10000		LONGITUDE 140/39E
"		20V: 5 - 7	" " "	"	1/19600		SHEET NO 1 OF 4 SHEETS
3PR5M323		4L: 148-150	5 July 45	Excellent	1/8680		
NAME OF TARGET: HITACHI ENGINEERING WORKS, KAIGAN PLANT					ENLARGEMENT NO: 3PR5M118 3L: 16		

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE	
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL *				SUPERFICIAL					OLD DAMAGE NOT REPAIRED
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
																					Undamaged
2		Storage	124	35	4.3	1	4.3	16	D		V4						0.7				Contents probably 30% destroyed
3		Storage	116	35	4.1	1	4.1	10	D		V4	1.3									Roof slightly disturbed
4		Storage	152	31	4.7	1	4.7	13	D		V4										Building unusable, Content damage 100%
8		Possible Pattern Store	200	38	7.6	1	7.6	13	D		V4	7.6									Some roofing blown off. Content damage negligible
10		Possible Heat Treatment Shop	147	52	7.6	1	7.6	15	D		V4					1.0					Some roofing blown off. Content damage negligible
11		Storage	133	52	6.9	1	6.9	20	D		V4					0.3					Some roofing blown off. Content damage negligible
12		Possible Light Metal Casting Foundry	260	133	34.6	1	34.6	23	A2.3		V4	25.3				9.3					Entire building probably unusable. Content damage 75%
13		Work Shop	175	52	9.1	1	9.1	20	D		V4	9.1									Building pulled in towards east end. Content damage 50%
16		Storage	170	52	8.8	1	8.8	20	D		V4			8.8							Destroyed
17		Storage	Irreg.		12.3	1	12.3	14	A2.3		V4	12.3									Demolished
19		Covered Stock Yard	165	57	9.4	1	9.4	25	D		V4	9.4									Building unusable
21		Storage	138	35	4.6	1	4.6	10	D		V4	4.6									Demolished
24		Storage	Irreg.		8.9	1	8.9	13	D		V4	8.9									Contents damage 50%
25		Storage	135	52	7.0	1	7.0	15	D		V4	7.0									Contents damage 100%
26		Storage	135	52	7.0	1	7.0	16	D		V4	7.0									Contents damage 30%
27		Machine Shop	390	100	39.0	1	39.0	25	A2.3		V4	39.0									Building unusable
28		Machine Shop	340	100	34.0	1	34.0	25	A2.3		V4	34.0									Building unusable
31		Assembly	340	100	34.0	1	34.0	25	A2.3		V4			34.0							Destroyed
SUB-TOTALS												163.5	7	42.8		11.3					
GRAND TOTALS							213.9														

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R = FIRE RESISTANT N = NON-COMBUSTIBLE G = COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JT6/M/3/REV

* Includes visible serious internal damage to building or contents without structural damage

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HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTIONMISSION NO
197TARGET NO
90.14 - 1476

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 2 OF SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE			
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL *				SUPERFICIAL					OLD DAMAGE NOT REPAIRED		
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Sub-Totals Brought Forward							213.9					155.5		42.8		11.3							
32		Storage	170	38	6.5	1	6.5	8	D	V4		6.5										Demolished	
33		Machine Shop	340	68	23.1	1	23.1	25	A2.3	V4		23.1										West end repairable	
34		Machine Shop	275	61	16.8	1	16.8	14	A2.3	V4		16.8										Repairable	
35		Probable Test Shop	70	65	4.6	1	4.6	13	D	V4		4.6										Demolished	
36		Machine Shop	450	68	30.6	1	30.6	15	A2.3	V4		30.6										Unusable	
37		Machine Shop	200	70	14.0	1	14.0	18	A2.3	V4		14.0										Unusable	
38		Machine Shop	200	38	7.6	1	7.6	10	D	V4		7.6										Unusable	
40		Machine Shop	285	38	10.8	1	10.8	10	A2.3	V4		10.8										Demolished	
42		Assembly	340	135	45.9	1	45.9	27	B1	V2				45.9								Repairable	
43		Probable Test Shop	65	65	4.2	1	4.2	13	D	V4		4.2										Repairable	
45		Machine Shop	330	100	33.0	1	33.0	13	A2.3	V4		33.0										Repairable	
46		Machine Shop	210	100	21.0	1	21.0	13	A2.3	V4		21.0										Repairable	
47		Storage	165	38	6.3	1	6.3	11	D	V4		6.3										Unusable	
49		Storage	185	38	7.0	1	7.0	11	D	V4		7.0										Contents damage 50%	
51		Heavy Castings Fdry	Irreg.		163.0	1	163.0	32	B1	V2		163.0										Unusable	
56		Probable Foundry	375	160	60.0	1	60.0	30	B1	V2		36.0				8.4						East end unusable	
57		Probable Pattern Shop	160	52	8.3	1	8.3	20	D	V4												Undamaged	
59		Probable Admin. Office	Irreg.		18.3	3	54.7	40	B2	V3		12.9										Damaged portion completely collapsed	
61		Probable Offices	205	70	14.4	3	43.2	40	B2	V3		13.4				7.7						Roof and top floor of east end collapsed	
62		Probable Drawing & Technical Offices	Irreg.		27.7	3	83.1	40	B2	V3		25.5				1.2						Structurally damaged. Portion completely collapsed	
63		Unidentified	133	70	9.3	1	9.3	27	D	V4						9.3						Roofing damaged	
64		Heavy Casting Foundry	500	147	73.5	1	73.5	35	B1	V2		73.5										Repairable	
SUB-TOTALS																							
GRAND TOTALS							970.6					675.3		88.7		40.9							

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE

C= COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV

*Includes visible serious internal damage to building or contents without structural damage

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HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO
197TARGET NO
90.14 - 1476

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 3 OF 4 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE			
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL *				SUPERFICIAL					OLD DAMAGE NOT REPAIRED		
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Sub-Totals Brought Forward							970.6					675.3		88.7		40.9							
																					Repairable		
65		Machine Shop & Probable Forge Shop	500	200	100.0	1	100.0	27	B2		V2	100.0										Demolished	
66		Storage	135	38	5.1	1	5.1	13	D		V4	5.1										Demolished	
67		Storage	147	38	5.6	1	5.6	11	D		V4	5.6										Demolished	
68		Unidentified	130	65	8.4	1	8.4	35	D		V4	8.4										Unusable	
70		Unidentified	115	65	7.5	1	7.5	35	D		V4	7.5										Demolished	
71		Unidentified	115	65	7.5	1	7.5	27	D		V4	7.5										Demolished	
73		Unidentified	130	65	8.4	1	8.4	27	D		V4	8.4										Unusable	
74		Assembly	395	195	77.0	1	77.0	27	A2.3		V4			77.0								Demolished	
75		Unidentified	Irreg.		8.2	1	8.2	16	D		V4	8.2										Unusable	
79		Unidentified	127	41	5.2	1	5.2	27	D		V4	5.2										Demolished	
82		Unidentified	130	65	8.4	1	8.4	20	D		V4	8.4										Demolished	
83		Unidentified	Irreg.		11.5	1	11.5	20	A2.3		V4	11.5										Demolished	
88		Storage	123	33	4.1	1	4.1	7	D		V4	4.1										Content damaged 50%	
90		Storage	200	48	9.6	1	9.6	15	D		V4	9.6										Destroyed	
91		Storage	175	48	8.4	1	8.4	15	D		V4			8.4								Complete destruction stopped by fire wall	
97		Storage	285	47	13.4	1	13.4	17	A2.3		V4			10.5								Destroyed	
98		Storage	200	48	9.6	1	9.6	17	D		V4			9.6								Demolished	
100		Shop	100	40	4.0	1	4.0	15	D		V4	4.0										Destroyed	
102		Storage	150	48	7.2	1	7.2	17	D		V4			7.2								Undamaged	
104		Unidentified	210	33	6.9	1	6.9	30	D		V4											Demolished	
105		Unidentified	150	38	5.7	1	5.7	8	D		V4	5.7										Demolished	
106		Storage	320	48	15.4	1	15.4	15	A2.3		V4	15.4										Demolished	
107		Storage	105	52	5.5	1	5.5	20	D		V4	5.5										Demolished	
108		Storage	Irreg.		4.2	1	4.2	10	D		V4	4.2											
SUB-TOTALS																							
GRAND TOTALS							1317.4						899.6		201.4		40.9						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N= NON-COMBUSTIBLE G= COMBUSTIBLE
*Includes visible internal damage to building or contents without structural damage

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

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HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

197

TARGET NO

90.14 - 1476

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 4 OF 4 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE						DESCRIPTION OF DAMAGE				
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL *				SUPERFICIAL			OLD DAMAGE NOT REPAIRED			
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE			H.E. + FIRE	CAUSE NOT KNOWN	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							1317.4					899.6		201.4		40.9						
109		Reported Small Transformer Assembly Shop	505	130	65.6	1	65.6	30	B2		V2	45.5				20.1					Partly usable. All repairable	
111		Unidentified	83	50	4.2	1	4.2	17	D		V4			4.2							Destroyed	
113		Storage	123	33	4.1	1	4.1	27	D		V4	4.1									Demolished	
118		Large Transformer	840	160	134.4	1	134.4	30	B2		V2			134.4							Unusable	
120		Storage	Irreg.		15.7	1	15.7	15	A2.3		V4	15.7									Demolished	
121		Storage	185	29	5.4	1	5.4	17	D		V4	5.4									Demolished	
123		Shop	125	69	8.6	1	8.6	17	D		V4	8.6									Demolished	
124		Offices	Irreg.		4.1	2	8.2	25	B2		V3										Undamaged	
125		Offices	Irreg.		4.5	1	4.5	15	D		V4										Undamaged	
131		Reported Turbine Shop	740	290	214.6	1	214.6	30	B2		V2	162.9				45.7					Repairable	
133		Storage	155	38	5.9	1	5.9	30	D		V4			5.9							Demolished	
136		Probable Motor & Switch Gear Assembly	740	130	96.2	1	96.2	28	A2.3		V4	5.7				18.3					Repairable	
137		Pattern Shop	155	48	7.4	1	7.4	17	D		V4	7.4									Demolished	
138		Pattern Shop	195	48	9.4	1	9.4	17	D		V4	5.4									Demolished	
140		Large Casting Foundry	740	135	99.9	1	99.9	30	B2		V2	34.7				38.3					Partly usable	
142		Probable Material Stores	Irreg.		70.6	1	70.6	38	B1		V2			37.9			32.7				Repairable	
143		Storage	133	38	5.1	1	5.1	13	D		V4	5.1									Demolished	
SUB-TOTALS																						
GRAND TOTALS							2077.2					1255.1		383.8		163.3		32.7				

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE G= COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

*Includes visible serious internal damage to building or contents without structural damage

7-18-59

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

Appendix "A"

PROCEDURES USED IN WEAPON ANALYSIS

1. Definition of Weapon Analysis. A weapon analysis is a study relating the damage achieved in a bombing attack to the weapon or weapon combination to which it may be attributed.

2. Limitations of Weapon Analysis. Due to the inherent nature of bombing and the varied character of targets, resulting in relatively wide variations in results achieved from attack to attack, the results of the analysis of a single attack cannot be accepted unqualifiedly. However, data accumulated from analyses of several attacks under relatively similar conditions will have sufficient stability to furnish adequate planning factors.

b. Where the combination of bombs or bombs and fuzings is not rather carefully controlled it becomes practically impossible to sort out the damage and attribute it to the weapon causing it. Accordingly weapon analyses are attempted only for the "controlled attacks" or for those attacks in which sufficient control was in fact accomplished to promise a measure of success in obtaining reliable results.

3. Procedure. The following procedure is followed in weapon analysis:

a. Damage Assessment. A special damage assessment is made using the following categories of damage, defined as stated:

(1) Visible Structural Damage. Destruction, callapse, or serious distortion (over 12 inches, vertical or horizontal) of roof trusses, beams, girders, columns or load-bearing walls.

(2) Visible serious internal damage to buildings or contents.

(3) Visible Superficial Damage. Damage to roofing, roof lights and secondary members such as purlins which are easily replaced and are not essential to the stability of the building; minor disturbance of roofing is not included.

Each of these categories is further subdivided as to cause, as follows:

(4) H.E.

(5) Fire

(6) H.E. and Fire

(7) Cause not known.

b. Determination of Density of Bombs. On the damage plot are also shown the bombs falling within the target area. All available photography is used, pre-attack and post-attack reconnaissance and all strike-attack. When it is necessary to resort to computed bomb fall, as in the cases where clustered I.B. are used or the target is heavily obscured by smoke, a distinction is made between bombs located visually and those calculated. The estimated reliability of the plot is clearly stated in each case.

- a -

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

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

c. Effectiveness Calculations. The structural damage plus the serious internal damage to building or contents without structural is used in calculating the effectiveness of weapon, for the following reasons:

(1) From careful studies of the damage suffered by British factories due to German bombing it was determined that the most usable measurable quantity relating bombing to loss of production (the ultimate goal) is visible structural damage; it must be visible on photo cover to be measurable.

(2) Our attacks on Japanese targets have yielded a considerable amount of visible serious internal damage without structural damage. This damage is as important in stopping production as is structural damage.

The unit of measure of effectiveness is the mean area of effectiveness in acres per ton (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of specified kind (defined above). If a target were attacked with a single bomb-fuze combination and consisted of a very large area containing a great many identical buildings with identical contents, and both buildings and bombs (all making direct hits) were widely and uniformly spaced throughout the area the MAE would be a constant and would equal the average damage per ton. Since these conditions never occur in practice it is necessary to solve the following equation for M,

$$M = 1 - e^{-MD} \quad (\text{For the case in which a single bomb-fuze combination is used})$$

Where

F = fraction of damage, in this analysis the total damage as defined above divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (Acres/Ton)

D = density of bombs achieved (Tons/Acre)

e = base of Napierian logarithms (= 2.72 approx.)

This formula attempts to account for near-misses as well as direct hits and also for overlap where two bombs hit close together. It was derived by the British-American Target Analysis Unit at Princes Risborough, England* and has more recently been in use by the Joint Target Group in Washington and by this Section in its bomb selection calculations.

Where more than one bomb-fuze combination are used the following equation may be used:

$$F = 1 - e^{-MD} - M'D'$$

*For derivation see REN 284 and REN 331, Research and Experiments Department, Ministry of Home Security.

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

Where the M' and D' have the same meaning as M and D but apply to the additional weapon. An additional term occurs in the exponent for each additional weapon. There is little practical value in attempting an analysis where more than two weapons are used.

- c -

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

C O N F I D E N T I A L
HEADQUARTERS TWENTIETH AIR FORCE
Operations Analysis Section
APO 234, c/o Postmaster
San Francisco, California

28 August 1945.

WEAPON ANALYSIS REPORT NO. WA-3

This is one of a series of weapons analyses by the Operations Analysis Section, Headquarters, Twentieth Air Force. Each report discusses the weapon effectiveness achieved in a single mission of the Twentieth Air Force or one or more of its bombardment units.

The purpose of each analysis is to determine the effectiveness of the particular bomb and fuze combination or combination of bombs used on the type of target attacked. From a series of such analyses it is anticipated that sufficient data will be accumulated to furnish firm planning factors upon which to base the selection of the best weapons for future attacks. The procedures used in the analysis are discussed in Appendix "A" of the report.

Leroy A. Brothers
LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

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

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

28 August 1945.

WEAPON ANALYSIS REPORT NO. WA-3.

SUBJECT: Effectiveness of the 4,000# L.C. Bomb.

Mission No. 220 and No. 225

Target: 90.25 - 1547, Kawasaki A/C Co., Akashi Plant.

Dates of Attack: 22 June 1945 and 26 June 1945.

Summary

The purpose of this study was to obtain a measure of the effectiveness of the 4,000# L.C. bomb against aircraft factories. As Missions 220 and 225 were against the same target using the same type bomb and fuzing it was decided to incorporate the results of the two missions in one report.

The mean area of effectiveness (MAE) of the 4,000# L.C. bomb against this type of target in the two attacks was found to be 0.68 acres/ton for Mission 220 and 1.17 acres/ton for Mission 225. These figures include the fire damage resulting from H.E. as it is thought on the average the fire bonus due to H.E. will be fairly consistent for any one type of industry. Thus, it is only proper that it should be included in the computations to determine a value for an MAE to be used in planning for future missions.

1. Mission Plan. Due to the fact that Mission 220 was not completely successful it was decided to send another mission against the same target. As a result Mission 225 was assigned the same target as Mission 220. The planning and results of both missions are consolidated in this report. Planning was as follows:

a. Mission No. 220. The plan called for one bombardment group of 33 aircraft to be airborne carrying three (3) 4,000# L.C. bombs each (fuzed Inst. nose, N.D. tail). It was estimated that at least 28 aircraft would reach the primary target and that 60% of their bombs would fall within 1,500 feet of the assigned M.P.I. (See attached damage plot). This would result in 50 bombs hitting within the 1,500 foot circle. With these assumptions it was expected that the target within that area would suffer 30% structural damage. Planned altitude of attack was 18,000 feet.

b. Mission No. 225. The plan was identical to that of Mission 220 with the exception that the planned altitude of attack was 15,000 ft.

2. The Attack. The two attacks were carried out as follows:

a. Mission No. 220. Thirty (30) aircraft were airborne and twenty-five (25) of them bombed the primary target. Seventy-four (74) 4,000# L.C. bombs were aimed at the target.

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

b. Mission No. 225. Thirty-eight (38) aircraft were airborne with thirty-one (31) aircraft bombing the primary target. Ninety-three (93) 4,000# L.C. bombs were aimed at the target.

Table 1 compares the actual execution with the plans of the missions.

Table 1.

	Mission No. 220		Mission No. 225	
	Plan	Execution	Plan	Execution
No. A/C Airborne	33	30	33	38
No. A/C Bombing P.T.	28	25	28	31
No. Bombs within 1,500 ft. of Assigned M.P.I.	50	24	50	13
Fraction of Damage* (structural) in portion of Target within 1,500 ft. Circle about M.P.I.	30%	22%	30%	27%

3. The Damage. As a result of Mission 220 thirty-one (31) of the eighty-nine (89) buildings (not destroyed in previous attacks) in the target suffered new or further damage, either structural or superficial. Mission 225 added new or additional damage, structural or superficial, to thirteen (13) buildings in the target area. Buildings with less than 4,000 sq. ft. were omitted in both analyses. Table 2 summarizes the damage.

Table 2.

	Mission No. 220	Mission No. 225
	For Entire Area of Target	
Total Undamaged Floor Area (Sq. Ft.)	3,183,800	2,580,600
Total Structural Damage (Sq. Ft.)	575,900	479,800
Percent Structural Damage	18.1	18.5
Total Superficial Damage (Sq. Ft.)	99,800	156,200
Percent Superficial Damage	3.1	6.0

Full itemization of the damage, building by building, is shown on the accompanying schedule.

4. The Analysis. The effectiveness of the 4,000# L.C. bombs was calculated for each mission. The unit of measure was the mean area of effectiveness (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of a specified kind (visible structural damage plus serious internal damage to building or contents without structural used for this purpose). The MAE is expressed in acres per ton (or thousands of square feet per ton) and is obtained by solving the following equation for M:

$$F = 1 - e^{-MD}$$

*See definition in Section 4.

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

Where F = fraction of damage, in this analysis the total damage (defined above) divided by the total undamaged floor area before the attack of the target or fraction of target used for analysis.

M = mean area of effectiveness (acres/ton)

D = density of bombs achieved in area under consideration (tons/acre)

e = base of Napierian logarithms (= 2.72 approx.)

For further discussion of the equation and the procedures of weapon analysis see Appendix "A".

5. The Results. The computation of the MAE's of the 4,000# L.C. bomb as a result of Missions 220 and 225 is shown in Table 3. The area of damage and bomb densities were taken from the attached damage assessments. The bomb hits were located visually with the aid of relatively good post-attack cover, and accordingly may be considered to have a good degree of reliability.

The formula used in computing the MAE (see Section 4) is derived on the assumption of uniform density of bomb fall in the target area. Under conditions approximating this assumption it can be expected that reliable results will be obtained. An inspection of the damage plots reveals that as a result of Mission 220 target 1547 received a fairly uniform distribution of bomb hits in one section of the target. Mission 225 reveals a similar characteristic also. Therefore, a line was drawn on each target isolating that portion of the target within which the bomb fall was approximately uniformly distributed (See attached damage plots). The MAE's were computed using the fractions of damage and bomb densities within those areas.

Table 3.

	Area of Target	Bomb Density In Target	Total Area Of Bldgs. In Target	Area of Struct. Damage	Fraction Of Structural Damage	MAE	
	Acres	Tons/Acre	Acres	Acres		Acres ton	1000 sq.ft. ton
Mission 220	87.3	0.82	30.4	13.2	43%	0.68	29.5
Mission 225	83.6	0.33	34.0	10.8	32%	1.17	51.0

References: Building Construction Analysis, Target 90.25 - 1547, dated 10 February 1945 by Joint P.I. Group, AC/AS Intelligence - Photographic Division.

Richard D. Burson
RICHARD D. BURSON,
Operations Analyst.

Norman C. Dahl
NORMAN DAHL,
Operations Analyst.

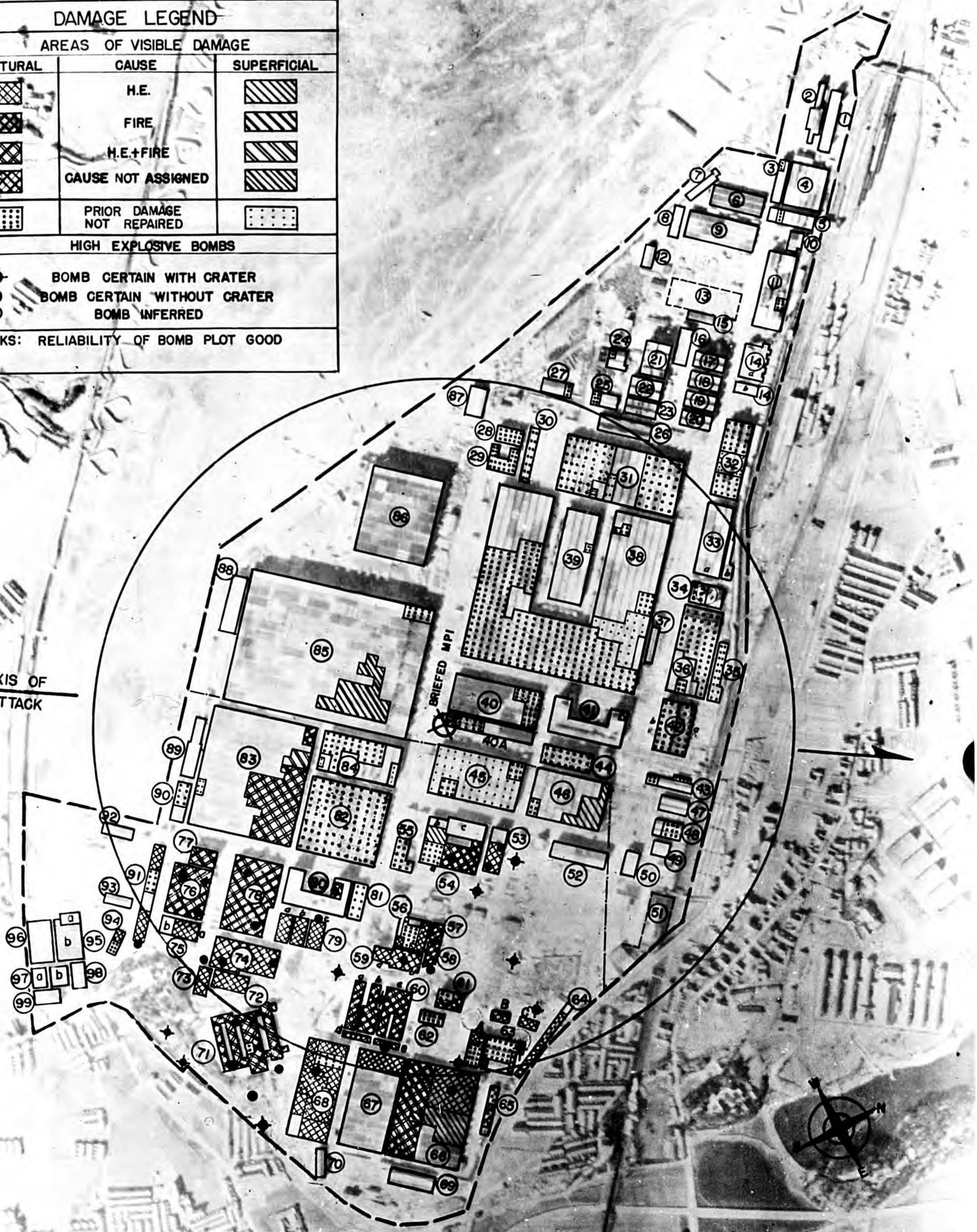
APPROVED:

Leroy A. Brothers
LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

(CONFIDENTIAL)

DAMAGE LEGEND		
AREAS OF VISIBLE DAMAGE		
STRUCTURAL	CAUSE	SUPERFICIAL
	H.E.	
	FIRE	
	H.E.+FIRE	
	CAUSE NOT ASSIGNED	
	PRIOR DAMAGE NOT REPAIRED	
HIGH EXPLOSIVE BOMBS		
	BOMB CERTAIN WITH CRATER	
	BOMB CERTAIN WITHOUT CRATER	
	BOMB INFERRED	
REMARKS: RELIABILITY OF BOMB PLOT GOOD		

AXIS OF ATTACK



DAMAGE ASSESSMENT FOR WEAPON ANALYSIS
MISSION 220
TARGET 90.25 1547
HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION
AUGUST 18, 1945



SCALE

(CONFIDENTIAL)

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE OPERATIONS ANALYSIS SECTION INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS	PHOTO COVER USED				MISSION NO 220	TARGET NO 90.25 - 1547	
	MISSION	PRINTS		DATE	QUALITY	SCALE	
		PRE-STRIKE	POST STRIKE			PLAN	SHADOW
	3PR5M279	3L: 5, 6		10 June 45	Good		
	3PR5M279	2: 3-5		10 June 45	Fair		
3PR5M290		3R: 83-85	22 June 45	Fair			
3PR5M290		2: 53-55	22 June 45	Fair			
NAME OF TARGET: KAWASAKI AIRCRAFT CO., AKASHI PLANT				ENLARGEMENT NO: 3PR5M235-2:26		ATTACK DATE 22 June 1945	
				DATE: 24 May 45		REPORT DATE 18 August 1945	
				QUALITY: Good		INTERPRETER R. D. BURSON	
				SCALE: 1/4000		LATITUDE 34/39 N	
						LONGITUDE 134/58 E	
						SHEET NO 1 OF 6 SHEETS	

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL**				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		Offices	260	40	10.4	2	20.8	25	E2	C	V3										Undamaged	
2		Offices	115	55	6.3																Undamaged	
			155	40	6.2	2	25.0	25	E2	C	V3											
3		Experiment	190	35	6.6	2	13.2	25	E2	C	V3										0.9 superficial unrepaired old damage. Building usable.	
4		Experiment	180	155	27.8	1	27.8	30 ^a	A1.1	N	V4										Undamaged.	
5		Experiment	190	55	10.4	1	10.4	-	A1.1	C	V4									1.2	Building Usable.	
6		Shop	225	85	19.1	1	19.1	18	A1.1	C	V4										Undamaged.	
7		Storage	160	35	5.6																Undamaged.	
			40	20	0.8	1	6.4	-	D	C	V4											
8		Storage	115	35	4.0	1	4.0	-	D	C	V4										Undamaged.	
9		Shop	300	115	34.5	1	34.5	18	A1.1	C	V4										Undamaged.	
10		Boiler House	65	70	4.5	1	4.5	-	D	N	V4										Undamaged.	
11		Experiment	330	115	38.0	1	38.0	25	B2	C	V2									2.7	Building Usable.	
12		Unidentified	100	40	4.0	1	4.0	12	D	C	V4										Undamaged.	
13		Under Construction																			Foundations only.	
14	a	Engine Development	155	90	14.0	1	14.0	-	A2.4	R	V4										Undamaged.	
	b	Possible Thru Type Test Cell	90	35	3.2	1	3.2	-	D	N	V4											
15		Contractors Hut	110	35	4.0	1	4.0	12	D	C	V4										Undamaged.	
16		Test Unit	140	50	7.1	1	7.1	-	D	R	V4										Undamaged.	
17		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3										Undamaged.	
18		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3										Undamaged.	
SUB-TOTALS							255.0													3.9		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R= FIRE RESISTANT

N= NON-COMBUSTIBLE

C= COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/REV

7-18-54 a Ridge Height *Structural

(CONFIDENTIAL)**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

MISSION	PRINTS		DATE	QUALITY	SCALE				
	PRE-STRIKE	POST STRIKE			PLAN	SHADOW			
	3PR5M279	3L: 5, 6		10 June 45	Good				
3PR5M279	2: 3-5		10 June 45	Fair					
3PR5M290		3R: 83-85	22 June 45	Fair					
3PR5M290		2: 53-55	22 June 45	Fair					
ENLARGEMENT NO. 3PR5M235-2:26							24 May 45	Good	1/4000

MISSION NO	220	TARGET NO	90.25 - 1547
ATTACK DATE	22 June 1945		
REPORT DATE	18 August 1945		
INTERPRETER	R. D. BURSON		
LATITUDE	34/39 N		
LONGITUDE	134/58 E		
SHEET NO	1 OF 6 SHEETS		

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

INDUSTRIAL DAMAGE SCHEDULE
FOR
WEAPON ANALYSIS

NAME OF TARGET: KAWASAKI AIRCRAFT CO., AKASHI PLANT

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL**				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1		Offices	260	40	10.4	2	20.8	25	E2	C	V3										Undamaged	
2		Offices	115	55	6.3																Undamaged	
			155	40	6.2	2	25.0	25	E2	C	V3											
3		Experiment	190	35	6.6	2	13.2	25	E2	C	V3										0.9 superficial unrepaired old damage. Building usable.	
4		Experiment	180	155	27.8	1	27.8	30 ^a	A1.1	N	V4										Undamaged.	
5		Experiment	190	55	10.4	1	10.4	-	A1.1	C	V4									1.2	Building Usable.	
6		Shop	225	85	19.1	1	19.1	18	A1.1	C	V4										Undamaged.	
7		Storage	160	35	5.6																Undamaged.	
			40	20	0.8	1	6.4	-	D	C	V4											
8		Storage	115	35	4.0	1	4.0	-	D	C	V4										Undamaged.	
9		Shop	300	115	34.5	1	34.5	18	A1.1	C	V4										Undamaged.	
10		Boiler House	65	70	4.5	1	4.5	-	D	N	V4										Undamaged.	
11		Experiment	330	115	38.0	1	38.0	25	B2	C	V2									2.7	Building Usable.	
12		Unidentified	100	40	4.0	1	4.0	12	D	C	V4										Undamaged.	
13		Under Construction																			Foundations only.	
14	a	Engine Development	155	90	14.0	1	14.0	-	A2.4	R	V4										Undamaged.	
	b	Possible Thru Type Test Cell	90	35	3.2	1	3.2	-	D	N	V4											Undamaged.
15		Contractors Hut	110	35	4.0	1	4.0	12	D	C	V4										Undamaged.	
16		Test Unit	140	50	7.1	1	7.1	-	D	R	V4										Undamaged.	
17		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3										Undamaged.	
18		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3										Undamaged.	
SUB-TOTALS							255.0													3.9		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R= FIRE RESISTANT

N= NON-COMBUSTIBLE

C= COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JT6/M/3/1945

(CONFIDENTIAL)**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

220

TARGET NO

90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 2 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE			
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED		
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Sub-Totals Brought Forward							255.0														3.9		
19		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3											Undamaged	
20		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3											Undamaged	
21		Test Cells 4	145	110	15.9	1	15.9	-	S	R	V3											Undamaged	
22		Test Cells 4	145	80	11.6	1	11.6	-	S	R	V3											Undamaged	
23		Test Cells 4	145	65	9.5	1	9.5	-	S	R	V3											Undamaged	
24		Unidentified	65	75	4.9	1	4.9	-	D	C	V4											0.7 Building Usable	
25		Unidentified	135	55	7.5	1	7.5	-	D	C	V4											2.6 Undamaged - end of building usable.	
26		Shop	240	75	18.0	1	18.0	15	A2.3	C	V4											Undamaged	
27		Unidentified	125	55	6.9	1	6.9	12	D	C	V4											1.4 Undamaged end of building usable.	
28		Shop	105	65	6.8	1	6.8	20	D	C	V4											6.8 Unusable	
29		Shop	110	55	5.8	1	9.1	-	D	C	V4											9.1 Demolished	
30		Stores	250	30	7.5	1	7.5	-	D	C	V4											7.5 Demolished	
31		Final Engine Assembly	515	240	123.9	1	123.9	24	A1.1	N	V4											89.2 5.4 superficial unrepaired old damage also. Undamaged portion probably in use.	
32		Disassembly - Assembly & Dispatch	330	110	36.3	1	36.3	24	B2	N	V2											26.1 10.2 unrepaired superficial old damage. Not usable.	
33	a	Disassembly - Assembly & Dispatch	330	110	36.3	1	36.3	24	B2	N	V2												Undamaged
	b	Unidentified	Irreg.		5.8	1	5.8	-	D	C	V4												
34		Receiving & Storage	140	80	11.2	1	11.2	-	A2.3	C	V4												5.7 Undamaged end of building usable.
35		Receiving & Storage	180	40	7.2	1	11.2	-	A2.3	C	V4												11.2 Practically demolished
36		Receiving & Storage	325	160	52.8	1	52.8	-	A2.3	C	V4												37.7 Building probably not in use.
37		Storage	160	25	4.0	1	4.0	12	D	C	V4												Undamaged
SUB-TOTALS							653.2															201.9	
GRAND TOTALS																							

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE C=COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTGM/3/1 REV.

*Structural

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

220

TARGET NO

90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 3 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE					
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED				
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22				
Sub-Totals Brought Forward							553.2													201.9					
38		Machining	240 770	270 470	65.0 362.0	1	427.0	24	C1.2	N	V4A									229.9	29.8 unrepaired superficial old damage also. Undamaged part of building probably in use.				
39		Heat Treating & Anodizing	415	135	56.0	1	56.0	24	C1.2	N	V4A										0.8 unrepaired superficial old damage. Use of building not affected.				
40		Foundry, Castings, etc.	375	160	60.0	1	60.0	24	B2	N	V2										14.8	Undamaged part of building usable.			
40A		Foundry, Castings, etc.	375	60	22.5	1	22.5	24	B2	N	V2											9.7	Undamaged part of building usable.		
41		Administration	470	65	30.6	4	122.4	44	E2	R	V3											2.3	Use of building unaffected.		
42	a	Receiving & Storage	220	70	15.4	2	30.8	28	E2	C	V3											30.8	Demolished		
	b	Receiving & Storage	220	70	15.4	1	15.4	18	A2.3	C	V4											15.4	Demolished		
43		Receiving & Storage	210 65	35 30	7.4 2.0	1	9.4	12	D	C	V4											3.2	Undamaged part of building intact		
44		Tool Shop	200	70	14.0	1	14.0	28	A1.1	C	V4											14.0	Demolished		
45		Machining	370	215	79.5	1	79.5	40	C1.2	N	V4A											10.1	Remainder of roofing stripped after previous attack. Building not in use.		
46		Machining	305	215	65.5	1	65.5	40	C1.2	N	V4A					19.1						3.6	Except for portion of old damage, production capabilities of building not affected.		
47		Receiving & Storage	110	55	6.1	1	6.1	12	D	C	V4													Undamaged.	
48		Receiving & Storage	110	55	6.1	1	6.1	12	D	C	V4											4.4	Undamaged part usable.		
49		Unidentified	70	60	4.2	1	4.2	12	D	R	V4													Undamaged	
50		Unidentified	110	60	6.6	2	13.2	24	E2	C	V3													Undamaged	
51		Bicycle Shed																							Not considered
52		Storage	240	65	15.6	2	31.2	28	E2	C	V3														Undamaged
53		Press Forge	190	65	12.5	1	12.5	30	A2.4	R	V4	7.9													Internal damage severe in whole building
SUB-TOTALS							1629.0					7.9				19.1					570.1				
GRAND TOTALS																									

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE C=COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV

7-78-59 *Structural a Ridge Height

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

220

TARGET NO

90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 4 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							1629.0					7.9				19.1				540.1		
54	a	Maintenance Shop	Irreg.		29.6	1	29.6	27	A1.1	N	V4			17.2		6.0				7.5	Completely unusable	
	b	"	70	35	2.5	1	2.5	27	D	R	V4										Undamaged	
	c	"	160	65	10.4	2	20.8	30	A2	R	V3										Undamaged	
55		Unidentified	110	60	6.6	1	6.6	-	D	C	V4									6.6	Demolished	
56		Unidentified	140	110	15.4	1	15.4	-	A2.3	C	V4	6.8								6.4	Undamaged part of building probably of little use.	
57		Unidentified	75	55	4.1	1	4.1	12	D	C	V4			4.1							Demolished	
58		Unidentified	100	50	5.0	1	5.0	12	D	C	V4			5.0							Demolished	
59	a	Transformer Station	70	30	2.1	1	2.1	-	D	N	V4	2.1									Demolished	
	b	"	135	70	9.5	1	9.5	-	S	N	V5	9.5									Demolished	
60	a	Possible Cafeteria	205	40	8.2	1	8.2	12	D	C	V4			8.2							Demolished	
	b	"	Irreg.		10.7	1	10.7	12	D	C	V4			10.7							"	
	c	"	"	"	18.9	1	18.9	12	A2.3	C	V4			18.9							Demolished	
	d	"	110	20	2.2	1	2.2	12	D	C	V4			2.2							Demolished	
	e	"	110	20	2.2	1	2.2	12	D	C	V4			2.2							Demolished	
61		Boiler House	105	65	6.8	1	6.8	37	D	N	V4			4.2						2.6	Demolished	
62		Unidentified	100	60	6.0	1	6.0	-	D	C	V4									6.0	Demolished	
63		Shop	Irreg.		19.7	1	19.7	17	A2.3	C	V4	1.1									15.1	Undamaged part usable
63A		Shop	135	75	10.0	1	10.0	17	A2.3	C	V4	2.0									8.0	Demolished
63B		Unidentified	90	45	4.0	1	4.0	-	D	C	V4	4.0										Demolished
63C		Unidentified	100	40	4.0	1	4.0	-	D	C	V4	4.0										Demolished
64		Storage	390	25	9.8	1	9.8	-	D	C	V4	4.5									3.7	Remainder of structure usable
65		Storage	185	30	5.5	1	5.5	-	D	C	V4	0.7									4.0	Remainder of structure too small to be of much value
66		Shop Type Building	420	315	132.3	1	132.3	25	G1.2	N	V4A	36.0		46.3		21.6		1.6				Superficial damage not severe and can be repaired easily. Approximately 60% of floor area suffered severe internal damage
67		Shop Type Building	420	200	84.0	1	84.0	20	A1.1	N	V4	14.9										Damage repairable. Internal damage probably severe over 20% of floor area
SUB-TOTALS							2048.9					92.5		119.0		46.7		1.6		600.0		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R = FIRE RESISTANT

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C = COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

7-18-59

*Structural

(CONFIDENTIAL)

**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO 220
TARGET NO 90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 5 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							2018.9					93.5		119.0		46.7		1.3		300.0		
68		Gantry Type Shop	420	180	75.6	1	75.6	24	B1	N	V2	64.1								7.1	Building unreairable and is of no value as a shop in future	
69		Small Shop	190	80	15.2	1	15.2	14	A2.3	C	V4										Undamaged	
70		Storage	130	45	5.8	1	5.8	-	D	C	V4										Undamaged	
71		Cafeteria	Irreg.		30.3	1	30.3	-	A2.3	C	V4			28.8						1.5	Demolished	
72		Storage	135	65	8.8	1	8.8	-	D	C	V4	8.8									Demolished	
73		Storage	110	45	5.0	1	5.0	-	D	C	V4	5.0									Demolished	
74		Shop	260	110	28.6																Demolished	
			130	15	2.0	1	30.6	-	A2.3	C	V4	30.6									Demolished	
75	a	Foundry	110	70	7.7	1	7.7	-	D	C	V4	7.7									Demolished	
	b	"	50	70	3.5	1	3.5	-	D	R	V4										Apparantly undamaged	
76		Wood Working & Pattern Shop	190	160	30.4	1	30.4	-	A1.1	N	V4			30.4							Demolished	
77		Forge	100	70	7.0	1	7.0	-	D	C	V4			7.0							Demolished	
78		Sheet Metal & Fabrication Shop	Irreg.		58.9	1	58.9	22	A1.1	N	V4			58.9							Demolished	
79	a	Storage	115	45	5.2	2	10.4	20	E2	C	V3	10.4									Demolished	
	b	"	115	50	5.7	2	11.4	20	E2	C	V3	11.4									Demolished	
	c	"	115	50	5.7	2	11.4	20	E2	C	V3	11.4									Demolished	
80		Engineering & Administration	430	60	25.8	4	103.2	48	E2	R	V3	1.5									Not much visible damage, but internal damage in wing where bomb hit probably severe on upper floor	
81		Unidentified	153	55	8.5	1	8.5	14	D	C	V4									8.5	Demolished	
82		Machining	350	320	112.0	1	112.0	30	C1.2	N	V4A									112.0	Building completely gutted, but appears to be repairable	
83		Sub Assembly	530	450	238.5	1	238.5	30	C1.2	N	V4A			73.0			6.5				1.8 old superficial damage. Building repairable. Internal damage severe over 35% of floor area	
84		Foundry & Heat Treating	330	165	54.4	1	54.4	50	B2	N	V2									26.4	3.1 old superficial damage. Bldg not being used, but is repairable.	
SUB-TOTALS							2877.5					244.4		317.1		46.7		38.1		735.5		
GRAND TOTALS																						

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7-18-59 *Structural a Ridge Height

(CONFIDENTIAL)

**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

220

TARGET NO

90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 6 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE							DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL				OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE			CAUSE NOT KNOWN
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Sub-Totals Brought Forward							2877.5					214.4		317.1		46.7		8.1		755.5	
85		Sub & Final Assembly	800	555	444.0	1	444.0	35	B2	N	V2								45.0	6.4	Damage not severe and production in building probably not greatly affected
86		Post Assembly	375	330	123.5	1	123.5	34	C1.2	N	V4A										Undamaged
87		Small Shop	140	70	9.8	1	9.8	17	D	C	V4										Undamaged
88		Paint Shop	240	65	15.6	1	15.6	20	A2.3	C	V4										Undamaged
89		Receiving & Storage	110	45	5.0																
			145	50	7.3	1	12.3	14	A2.3	C	V4										Undamaged
90		Receiving & Storage	175	50	8.8	1	8.8	14	D	C	V4									5.3	Undamaged part usable.
91		Receiving & Storage	425	50	21.2	1	21.2	14	A2.3	C	V4	11.8								5.0	Undamaged part usable.
92		Receiving & Storage	135	35	4.7	1	4.7	12	D	C	V4										Undamaged
93		Receiving & Storage	120	35	4.2	1	4.2	12	D	C	V4										Undamaged
94		Receiving & Storage	115	45	5.2	1	5.2	12	D	C	V4	2.6								2.6	Demolished
95	a	Shop Type Building	65	35	2.3	1	2.3	-	D	R	V4										Undamaged
	b	or possible lab.	100	145	14.5	1	14.5	-	A1.1	N	V4										Undamaged
96		Shop Type Building or possible lab.	173	100	17.3	1	17.3	-	A1.1	N	V4										Undamaged
97	a	Shop Type Building	70	55	3.8	1	3.8	-	D	R	V4										Undamaged
	b	or possible lab.	90	70	6.3	1	6.3	-	D	N	V4										Undamaged
98		Classrooms	110	65	7.2	2	14.4	-	E2	C	V3										Undamaged
99		Classrooms	120	55	6.6	2	13.2	-	E2	C	V3										Undamaged
SUB-TOTALS																					
GRAND TOTALS							3598.6					258.8		317.1		46.7		8.1	45.0	771.8	

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FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

7-78-59 Structural

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO
225TARGET NO
90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 2 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE NOTE: For description of old damage see Mission 220		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							255.0														3.9	
19		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3											
20		Test Cells 4	145	65	9.5	1	9.5	22	S	R	V3											
21		Test Cells 4	145	110	15.9	1	15.9	-	S	R	V3											
22		Test Cells 4	145	80	11.6	1	11.6	-	S	R	V3											
23		Test Cells 4	145	65	9.5	1	9.5	-	S	R	V3											
24		Unidentified	65	75	4.9	1	4.9	-	D	C	V4										0.7	
25		Unidentified	135	55	7.5	1	7.5	-	D	C	V4										2.6	
26		Shop	240	75	18.0	1	18.0	15	A2.3	C	V4											
27		Unidentified	125	55	6.9	1	6.9	12	D	C	V4			5.5							1.4	
28		Shop	105	65	6.8	1	6.8	20	D	C	V4										6.8	
29		Shop	110	55	5.8	1	5.8	-	D	C	V4										9.1	
			110	30	3.3	1	3.3	-	D	C	V4										7.5	
30		Stores	250	30	7.5	1	7.5	-	D	C	V4										89.2	
31		Final Engine Assembly	515	240	123.9	1	123.9	24	A1.1	N	V4										5.4 unrepaired superficial old damage	
32		Disassembly - Assembly & Dispatch	330	110	36.3	1	36.3	24	B2	N	V2										26.1	
33	a	Disassembly - Assembly & Dispatch	330	110	36.3	1	36.3	24	B2	N	V2											
	b	Unidentified	Irreg.		5.8	1	5.8	-	D	C	V4										5.7	
34		Receiving & Storage	140	80	11.2	1	11.2	-	A2.3	C	V4											
35		Receiving & Storage	180	40	7.2	1	7.2	-	A2.3	C	V4											
			60	65	4.0	1	4.0	-	A2.3	C	V4										11.2	
36		Receiving & Storage	325	163	52.8	1	52.8	-	A2.3	C	V4										27.7	
37		Storage	160	25	4.0	1	4.0	12	D	C	V4											
38		Machining	770	470	362.0	1	362.0	24	C1.2	N	V4A			59.5		1.1					229.9	
			240	270	65.0	1	65.0	-														
SUB-TOTALS							1080.2							65.0		1.1					431.8	
GRAND TOTALS																						

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FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

7-18-59

* Structural

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO 225 TARGET NO 90.25 - 1547
SHEET NO 3 OF 6 SHEETS

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE NOTE: For description of old damage see Mission 220		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **			SUPERFICIAL				OLD DAMAGE NOT REPAIRED			
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE			CAUSE NOT KNOWN	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							1030.4						65.0			1.1					431.8	
39		Heat Treating & Anodizing	415	135	56.0	1	56.0	24	C1.2	N	V4A					55.2					0.8 unrepaired superficial old damage. Internal damage probably not great. Building easily repairable	
40		Foundry, Casting etc	375	160	60.0	1	60.0	24	B2	N	V2			45.2							14.8 Demolished	
40A		Foundry, Casting etc	375	60	22.5	1	22.5	24	B2	N	V2	13.2									9.7 Demolished	
41		Administration	470	65	30.6	4	122.4	44	E2	R	V3										2.3	
42	a	Receiving & Storage	220	70	15.4	2	30.8	28	E2	C	V3										30.8	
	b	" "	220	70	15.4	1	15.4	18	A2.3	C	V4										15.4	
43		Receiving & Storage	210	35	7.4																3.2	
			65	30	2.0	1	9.4	12	D	C	V4											
44		Tool Shop	200	70	14.5	1	14.5	28	A1.1	C	V4										14.0	
45		Machining	370	215	79.5	1	79.5	40	C1.2	N	V4A	3.9									10.1 Previously stripped section of building, now structurally damaged	
46		Machining	305	215	65.5	1	65.5	40a	C1.2	N	V4A										3.6 19.1 unrepaired superficial old damage	
47		Receiving & Storage	110	55	6.1	1	6.1	12	D	C	V4											
48		Receiving & Storage	110	55	6.1	1	6.1	12	D	C	V4										4.4	
49		Unidentified	70	60	4.2	1	4.2	12	D	R	V4											
50		Unidentified	110	60	6.6	2	13.2	24	E2	C	V3											
51		Bicycle Shed	-	-																	Not considered	
52		Storage	240	65	15.6	2	31.2	28	E2	C	V3											
53		Press Forge	190	65	12.5	1	12.5	30	A2.1	R	V4										7.9	
54	a	Maintenance Shops	Irreg.		29.6	1	29.6	27	A1.1	N	V4	6.0									24.7 Old superficial damage now is structural damage. Section b and c appear undamaged	
	b	" "	70	35	2.5	1	2.5	27	D	R	V4											
	c	" "	160	65	10.4	2	20.8	30	E2	R	V3											
55		Unidentified	110	60	6.6	1	6.6	-	D	C	V4										6.6	
56		Unidentified	140	110	15.4	1	15.4	-	A2.3	C	V4										13.2	
57		Unidentified	75	55	4.1	1	4.1	12	D	C	V4										4.1	
SUB-TOTALS							1708.0					23.1		170.2		6.3					576.3	
GRAND TOTALS																						

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7-18-59 *Structural a Ridge Height

(CONFIDENTIAL)

**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO 225 TARGET NO 90.25 - 1547
SHEET NO 4 OF 6 SHEETS

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE NOTE: For description of old damage see Mission 220		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL**				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Total Brought Forward							1708.0					23.1		110.2		56.3					596.6	
58		Unidentified	100	50	5.0	1	5.0	12	D	C	V4										5.0	
59	a	Transformer Station	70	30	2.1	1	2.1	-	D	N	V4										2.1	
	b	"	135	70	9.5	1	9.5	-	S	N	V5										9.5	
60	a	Possible Cafeteria	205	40	8.2	1	8.2	12	D	C	V4										8.2	
	b	"	Irreg.		10.7	1	10.7	12	D	C	V4										10.7	
	c	"	Irreg.		18.9	1	18.9	12	A2.3	C	V4										18.9	
	d	"	110	20	2.2	1	2.2	12	D	C	V4										2.2	
	e	"	110	20	2.2	1	2.2	12	D	C	V4										2.2	
61		Boiler House	105	65	6.8	1	6.8	37	D	C	V4										6.8	
62		Unidentified	100	60	6.0	1	6.0	-	D	C	V4										6.0	
63		Shop	Irreg.		19.7	1	19.7	17	A2.3	C	V4										16.2	
63A		Shop	135	75	10.0	1	10.0	17	A2.3	C	V4										10.0	
63B		Unidentified	90	45	4.0	1	4.0	-	D	C	V4										4.0	
63C		Unidentified	100	40	4.0	1	4.0	-	D	C	V4										4.0	
64		Storage	390	25	9.8	1	9.8	-	D	C	V4										8.2	
65		Storage	185	30	5.5	1	5.5	-	D	C	V4										4.7	
66		Shop Type Building	420	315	132.3	1	132.3	25	C1.2	N	V4A										82.3	
67		Shop Type Building	420	200	84.0	1	84.0	20	A1.1	N	V4										42.2	
																					27.3 of old damage appears to be demolition carried out by enemy between missions 220 and 225	
68		Gantry Type Bldg	420	180	75.6	1	75.6	24	B1	N	V2										71.2	
69		Small Shop	190	80	15.2	1	15.2	14	A2.3	C	V4											
70		Storage	130	45	5.8	1	5.8	-	D	C	V4											
71		Cafeteria	Irreg.		30.3	1	30.3	-	A2.3	C	V4										30.3	
72		Storage	135	65	8.8	1	8.8	-	D	C	V4										8.8	
73		Storage	110	45	5.0	1	5.0	-	D	C	V4										5.0	
74		Shop	260	110	28.6	1															30.6	
			130	15	2.0		30.6	-	A2.3	C	V4	23.1		110.2		56.3					985.7	
SUB-TOTALS							2220.2					23.1		110.2		56.3						
GRAND TOTALS																						

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(CONFIDENTIAL)**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO
225TARGET NO
90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 5 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE NOTE: For description of old damage see Mission 220		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL**				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							2220.2					23.1		210.2		35.3				235.7		
75	a	Foundry	110	70	7.7	1	7.7	-	D	C	V4										7.7	
	b	"	50	70	3.5	1	3.5	-	D	R	V4											
76		Wood Working & Pattern Shop	190	160	30.4	1	30.4	-	A1.1	N	V4										30.4	
77		Forge	100	70	7.0	1	7.0	-	D	C	V4										7.0	
78		Sheet Metal & Fabrication Shop	Irreg.		58.9	1	58.9	22	A1.1	N	V4										58.9	
79	a	Storage	115	45	5.2	2	10.4	20	E2	C	V3											
	b	"	115	50	5.7	2	11.4	20	E2	C	V3											
	c	"	115	50	5.7	2	11.4	20	E2	C	V3										33.2	
80		Engineering & Administration	430	60	25.8	4	103.2	48	E2	R	V3										1.5	
81		Unidentified	153	55	8.5	1	8.5	14	D	C	V4										1.5	
82		Machining	350	320	112.0	1	112.0	30	C1.2	N	V4A										112.0	
83		Sub-Assembly	530	450	238.5	1	238.5	30	C1.2	N	V4A			14.2					51.0	73.0	8.3 old unrepaired superficial damage. Internal damage probably severe over 50% of floor area. Bldg repairable	
84		Foundry & Heat Treating	330	165	54.4	1	54.4	50a	B2	N	V2										26.4	
85		Sub & Final Assembly	800	555	444.0	1	444.0	35	B2	N	V2	71.6		127.1		48.2					6.4	
86		Post Assembly	375	330	123.5	1	123.5	34	C1.2	N	V4A	123.5										
87		Small Shop	140	70	9.8	1	9.8	17	D	C	V4											
88		Paint Shop	240	65	15.6	1	15.6	20	A2.3	C	V4											
89		Receiving & Storage	110	45	5.0																	
			145	50	7.3	1	12.3	14	D	C	V4											
90		Receiving & Storage	175	50	8.8	1	8.8	14	D	C	V4										5.3	
91		Receiving & Storage	125	50	21.2	1	21.2	14	A2.3	C	V4										16.3	
SUB-TOTALS							2512.7					212.2		251.5		104.5			51.0	1372.8		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE C= COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV

7-18-59

a Ridge Height * Structural

(CONFIDENTIAL)**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

225

TARGET NO

90.25 - 1547

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 6 OF 6 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE NOTE: For description of old damage see Mission 220		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL**				SUPERFICIAL					OLD DAMAGE	NOT REPAIRED
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							302.7						218.2		251.5		107.5			51.0	1378.8	
92		Receiving & Storage	135	35	4.7	1	4.7	12	D	C	V4											
93		Receiving & Storage	120	35	4.2	1	4.2	12	D	C	V4											
94		Receiving & Storage	115	45	5.2	1	5.2	12	D	C	V4										5.2	
95	a	Shop Type Building	65	35	2.3	1	2.3	-	D	R	V4											Building repairable. Damage probably severe internally over 50% of floor area
	b	or possible lab.	100	14.5	14.5	1	14.5	-	A1.1	N	V4	6.6										
96		Shop Type Building or possible Lab.	173	100	17.3	1	17.3	-	A1.1	N	V4	3.5				0.7						Building repairable. Internal damage probably severe over 30% of floor area
97	a	Shop Type Building	70	55	3.8	1	3.8	-	D	R	V4											Easily repairable. Probably no internal damage (serious)
	b	or possible lab.	90	70	6.3	1	6.3	-	D	N	V4					2.0						
98		Classrooms	110	65	7.2	2	14.4	-	E2	C	V3											
99		Classrooms	120	55	6.6	2	13.2	-	E2	C	V3											
SUB-TOTALS																						
GRAND TOTALS							3598.6						228.3		251.5		107.2			51.0	1378.0	

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R= FIRE RESISTANT

N= NON-COMBUSTIBLE

G= COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

By HR-1 NARA, Date 2/27/11

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

Appendix "A"

PROCEDURES USED IN WEAPON ANALYSIS

1. Definition of Weapon Analysis. A weapon analysis is a study relating the damage achieved in a bombing attack to the weapon or weapon combination to which it may be attributed.

2. Limitations of Weapon Analysis. Due to the inherent nature of bombing and the varied character of targets, resulting in relatively wide variations in results achieved from attack to attack, the results of the analysis of a single attack cannot be accepted unqualifiedly. However, data accumulated from analyses of several attacks under relatively similar conditions will have sufficient stability to furnish adequate planning factors.

b. Where the combination of bombs or bombs and fuzings is not rather carefully controlled it becomes practically impossible to sort out the damage and attribute it to the weapon causing it. Accordingly weapon analyses are attempted only for the "controlled attacks" or for those attacks in which sufficient control was in fact accomplished to promise a measure of success in obtaining reliable results.

3. Procedure. The following procedure is followed in weapon analysis:

a. Damage Assessment. A special damage assessment is made using the following categories of damage, defined as stated:

(1) Visible Structural Damage. Destruction, callapse, or serious distortion (over 12 inches, vertical or horizontal) of roof trusses, beams, girders, columns or load-bearing walls.

(2) Visible serious internal damage to buildings or contents.

(3) Visible Superficial Damage. Damage to roofing, roof lights and secondary members such as purlins which are easily replaced and are not essential to the stability of the building; minor disturbance of roofing is not included.

Each of these categories is further subdivided as to cause, as follows:

(4) H.E.

(5) Fire

(6) H.E. and Fire

(7) Cause not known.

b. Determination of Density of Bombs. On the damage plot are also shown the bombs falling within the target area. All available photography is used, pre-attack and post-attack reconnaissance and all strike-attack. When it is necessary to resort to computed bomb fall, as in the cases where clustered I.B. are used or the target is heavily obscured by smoke, a distinction is made between bombs located visually and those calculated. The estimated reliability of the plot is clearly stated in each case.

- a -

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

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

c. Effectiveness Calculations. The structural damage plus the serious internal damage to building or contents without structural is used in calculating the effectiveness of weapon, for the following reasons:

(1) From careful studies of the damage suffered by British factories due to German bombing it was determined that the most usable measurable quantity relating bombing to loss of production (the ultimate goal) is visible structural damage; it must be visible on photo cover to be measurable.

(2) Our attacks on Japanese targets have yielded a considerable amount of visible serious internal damage without structural damage. This damage is as important in stopping production as is structural damage.

The unit of measure of effectiveness is the mean area of effectiveness in acres per ton (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of specified kind (defined above). If a target were attacked with a single bomb-fuze combination and consisted of a very large area containing a great many identical buildings with identical contents, and both buildings and bombs (all making direct hits) were widely and uniformly spaced throughout the area the MAE would be a constant and would equal the average damage per ton. Since these conditions never occur in practice it is necessary to solve the following equation for M,

$$M = 1 - e^{-MD} \quad (\text{For the case in which a single bomb-fuze combination is used})$$

Where

F = fraction of damage, in this analysis the total damage as defined above divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (Acres/Ton)

D = density of bombs achieved (Tons/Acre)

e = base of Napierian logarithms (= 2.72 approx.)

This formula attempts to account for near-misses as well as direct hits and also for overlap where two bombs hit close together. It was derived by the British-American Target Analysis Unit at Princes Risborough, England* and has more recently been in use by the Joint Target Group in Washington and by this Section in its bomb selection calculations.

Where more than one bomb-fuze combination are used the following equation may be used:

$$F = 1 - e^{-MD} - M'D'$$

*For derivation see REN 284 and REN 331, Research and Experiments Department, Ministry of Home Security.

- b -

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

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

Where the M' and D' have the same meaning as M and D but apply to the additional weapon. An additional term occurs in the exponent for each additional weapon. There is little practical value in attempting an analysis where more than two weapons are used.

- c -

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

By AK-A NARA, Date 2/27/11

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

HEADQUARTERS TWENTIETH AIR FORCE
Operations Analysis Section
APO 234, c/o Postmaster
San Francisco, California

II-E

31 August 1945.

WEAPON ANALYSIS REPORT NO. WA-4

This is one of a series of weapons analyses by the Operations Analysis Section, Headquarters, Twentieth Air Force. Each report discusses the weapon effectiveness achieved in a single mission of the Twentieth Air Force or one or more of its bombardment units.

The purpose of each analysis is to determine the effectiveness of the particular bomb and fuze combination or combination of bombs used on the type of target attacked. From a series of such analyses it is anticipated that sufficient data will be accumulated to furnish firm planning factors upon which to base the selection of the best weapons for future attacks. The procedures used in the analysis are discussed in Appendix "A" of the report.

Leroy A. Brothers
LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

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

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

31 August 1945

WEAPON ANALYSIS REPORT NO. WA-4

SUBJECT: Effectiveness of the 4,000# L.C. Bomb.

Mission No. 284

Target: 90:25 - 263A, Sumitoma Metal Industry, Osaka

Date of Attack: 24 July 1945.

Summary

The purpose of this study was to obtain a measure of the effectiveness of the 4,000# L.C. bomb against medium heavy industrial targets.

The mean area of effectiveness (MAE) of the 4,000# L.C. bomb against this type of target was found to be 0.86 acres/ton, or 37,500 sq. ft/ton. These figures include the damage due to H.E. plus fire as it is thought on the average the fire bonus due to H.E. will be fairly consistent for any one type of industry. Thus, it is only proper that it should be included in the computations in order to determine a firm planning factor.

1. Mission Plan. The plan called for two bombardment groups consisting of a total of 66 aircraft to be airborne carrying three (3) 4,000# L.C. bombs each (fuzed Inst. nose, N.D. tail). It was estimated that at least 56 aircraft would reach the primary target and that 40% of their bombs would fall within 1,000 feet of the assigned M.P.I. (see attached damage plot). This would result in 67 bombs hitting within the 1,000 ft. circle. With these assumptions it was expected that the target would suffer 66% structural damage. Planned altitude of attack was 19,000 ft.

2. The Attack. Ninety (90) aircraft of the 58th Wing were airborne and eighty (80) of them bombed the primary target. Two hundred-forty (240) 4,000# L.C. bombs were aimed at the target.

Table 1 compares actual execution with the plan for the mission.

Table 1

	Plan	Execution
No. A/C Airborne	66	90
No. A/C Bombing P.T.	56	80
No. Bombs within 1,000 ft. of assigned M.P.I.	67	79
Fraction of Damage* (structural) in portion of Target within 1,000 ft. Circle about M.P.I.	66%	90%

3. The Damage. All the buildings in the target except one suffered damage, either structural or superficial. Buildings with less than 4,000 sq ft. area were omitted. Table 2 summarizes the damage.

* See definition in Section 4.

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

Table 2

	Entire Target Area	Within Target Area & Enclosed by 1,000 ft. Circle
Total Undamaged Floor Area (Sq. Ft.)	1,842,700	1,592,800
Total Structural Damage (Sq. Ft.)	1,662,700	1,443,200
Percent Structural Damage	90	90
Total Superficial Damage (Sq. Ft.)	86,800	73,100
Percent Superficial Damage	4.7	4.6

Full itemization of the damage, building by building, is shown on the accompanying damage schedule.

4. The Analysis. The effectiveness of the 4,000# L.C. bombs was calculated. The unit of measure used was the mean area of effectiveness (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of a specified kind (visible structural damage plus visible serious internal damage to building or contents without structural damage used for this purpose). The MAE is expressed in acres per ton (or thousands of square feet per ton) and is obtained by solving the following equation for M:

$$F = 1 - e^{-MD}$$

Where F = fraction of damage, in this analysis the total visible structural damage (including visible serious internal damage to building or contents without structural damage) divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (acres/ton)

D = density of bombs achieved (tons/acre)

e = base of Napierian logarithms (2.72 approx.)

For further discussion of the equation and the procedures of weapon analysis see Appendix "A".

5. The results. The computation of the MAE of the 4,000# L.C. bomb against target 263A is shown in Table 3. The area of damage and the bomb density were taken from the attached damage assessment. The damage and the bomb hits were located with the aid of fair post-attack photographs and may be considered to have a good degree of reliability.

The formula used in computing the MAE (see Section 4) is derived on the assumption of uniform density of bomb fall in the target area. Under conditions approximating this assumption it gives reliable results. An inspection of the damage plot reveals that the distribution of bomb hits is very uniform, thus giving reliance to the computed value of the MAE.

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Table 3

Area of Target	Density of Bombs in Target	Total Floor Area of Buildings	Area of Structural Damage	Fraction of Structural Damage	MAE	
					Acres/ton	1,000 sq. ft./ton
105.0	1.88	42.4	36.2	0.90	0.86	37.5

Richard D. Burson
RICHARD D. BURSON,
Operations Analyst.

J. Virgil Proctor
J. VIRGIL PROCTOR,
Operations Analyst.

APPROVED:

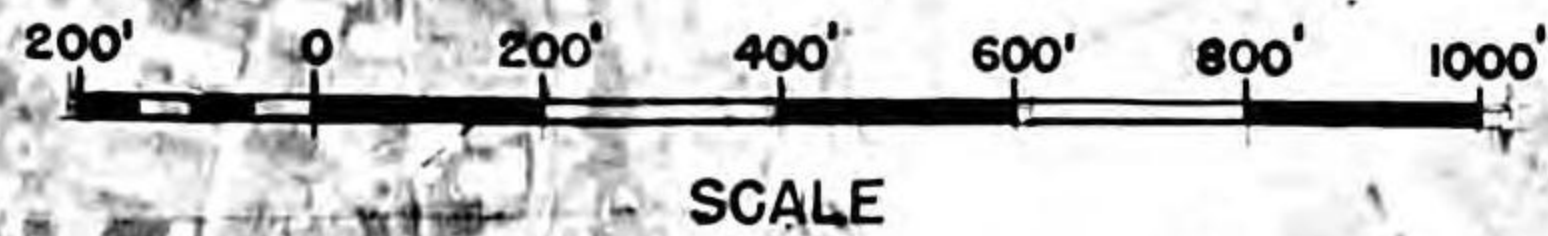
Leroy A. Brothers
LEROY A. BROTHERS,
Chief,
Operations Analysis Section.

(CONFIDENTIAL)



DAMAGE LEGEND		
AREAS OF VISIBLE DAMAGE		
STRUCTURAL	CAUSE	SUPERFICIAL
	H.E.	
	FIRE	
	H.E. + FIRE	
	CAUSE NOT ASSIGNED	
	PRIOR DAMAGE NOT REPAIRED	
HIGH EXPLOSIVE BOMBS		
	BOMB CERTAIN WITH CRATER	
	BOMB CERTAIN WITHOUT CRATER	
	BOMB INFERRED	
REMARKS: RELIABILITY OF BOMB PLOT GOOD.		

DAMAGE ASSESSMENT FOR WEAPON ANALYSIS
 MISSION 284
 TARGET 90.25-263A
 HEADQUARTERS TWENTIETH AIR FORCE
 OPERATIONS ANALYSIS SECTION
 29 AUGUST, 1945



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HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO

284

TARGET NO

90.25 - 263A

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 2 OF 5 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							489.1					427.4		6.2							55.3	
29		Unidentified	120	60	7.2	1	7.2	18	D	C	V4	7.2									Destroyed	
30		Warehouse	105	65	6.8	1	6.8	18	D	C	V4	6.8									Destroyed	
30A		Warehouse	130	65	8.5	1	8.5	18	D	C	V4	8.5									Destroyed	
31		Foundry	270	65	17.5	1	17.5	35	B1	N	V4	17.5				11.7					S. end structurally damaged interior damage not severe	
			130	25	3.3	1	20.8	35	B1	N	V4	5.0										
34		Foundry	180	85	15.4	1	15.4	25	B2	N	V4					1.4					Damage not serious or beyond repair	
35	a	Stores	180	90	16.2	1	16.2	20	A2.3	C	V4	16.2									Destroyed	
	b	"	290	72	21.2	1	21.2	30	A2.3	C	V4	21.2									"	
35A		Unidentified	110	50	5.5	1	5.5	12	D	C	V4	5.5									Destroyed	
36		Unidentified	81	69	5.3	1	5.3	20	D	C	V4	5.3									Destroyed	
36A		Unidentified	97	65	6.3	1	6.3	24	D	C	V4	6.3									Destroyed	
37		Unidentified	81	65	5.3	1	5.3	20	D	C	V4	5.3									Destroyed	
38		Unidentified Work Shop	254	60	15.2	2	30.4	37	B2	N	V2	30.4									Destroyed	
39		Foundry or Forge	120	130	15.6	1	15.6	40	B1	N	V2	15.6									Destroyed	
40		Machine Shop	113	57	6.5	1	6.5	24	A1.1	N	V4	11.3									Destroyed	
			100	48	4.8	1	11.3	24	A1.1	N	V4	11.3										
41		Unidentified	90	48	4.3	1	4.3	30	A1.1	N	V4	15.1									Destroyed	
			120	90	10.8	1	15.1	30	A1.1	N	V4	15.1										
43		Unidentified Work Shop	195	72	14.2	1	14.2	18	A2.3	C	V4	14.2									Destroyed	
44		Unidentified Work Shop	140	45	6.3	1	6.3	12	D	C	V4	1.8								4.5	Destroyed	
45		Unidentified Work	140	80	11.2	2	22.4	45	B2	C	V3A									11.2	Top floor old damage only	
46		Machine Shop or As- sembly	243	90	21.8	1	21.8	24	C1.3	N	V4A	27.3				17.1					Severe damage internal over 50% of floor area	
			275	140	38.5	1	38.5	24	C1.3	N	V4A	27.3										
			90	33	3.0	1	3.0	24	C1.3	N	V4A	27.3										
			120	50	6.0	1	6.0	24	C1.3	N	V4A	27.3										
SUB-TOTALS							792.2					630.4		6.2		30.2				71.2		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R= FIRE RESISTANT

N=NON-COMBUSTIBLE

C=COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND
H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV

7-73-5 *Structural

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO
284TARGET NO
90.25 - 263A

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 3 OF 5 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							792.2					630.4		6.2		30.2				71.2		
47		Stores	130	40	5.2	2	10.4	30	E2	C	V3					5.2					Top floor damaged only	
49		Office or Store	146	58	8.5	2	17.0	30	E2	C	V3					8.5					Top floor damaged only	
50		Office	146	58	8.5															25.4		
			73	58	4.2	2	25.4	30	E2	C	V3											
53		Stores or Work Shop	90	73	6.6	1	6.6	15	A2.3	C	V4	3.3				3.3					Interior damage not severe	
56		Office or Store	140	57	8.0	2	16.0	25	E2	C	V3					8.0					Top floor damaged only	
57		Office or Store	145	57	8.3	1	8.3	25	D	N	V4										Undamaged	
58		Machine Shop	200	180	36.0	1	36.0	24	B2	N	V2	36.0									Destroyed	
60		Office	130	57	7.4	1	7.4	18	D	C	V4					7.4					Interior damage not severe	
62		Machine Shop or Assembly	575	200	115.0	1	115.0	25	C1.2	N	V4A			115.0							Destroyed	
64		Store or Work Shop	100	77	7.7	1	7.7	12	D	C	V4			7.7							Destroyed	
65		Store or Work Shop	100	53	5.3	1	5.3	18	D	C	V4			5.3							Destroyed	
66		Store or Work Shop	100	77	7.7	1	7.7	12	D	C	V4									7.7		
67		Store or Work Shop	115	73	8.4	1	8.4	24	D	C	V4	8.4									Destroyed	
68		Small Work Shop	73	65	4.7	1	4.7	20	D	C	V4	4.7									Destroyed	
69		Possible Furnace House	150	105	15.8	1	15.8	24	A2.3	N	V4			7.9						7.9	Destroyed	
70		Possible Furnace House	150	105	15.8	1	15.8	24	A2.3	N	V4			15.8							Destroyed	
71		Store or Work Shop	130	39	4.7	1	4.7	15	D	C	V4	4.7									Destroyed	
72		Store or Work Shop	190	36	6.9	1	6.9	24	D	C	V4	6.9									Destroyed	
73		Store or Work Shop	120	40	4.8	2	9.6	30	E2	C	V3	9.6									Destroyed	
74		Possible Rolling Mill	400	190	76.0																	
			355	165	58.5																	
			80	35	2.8																	
			60	60	3.6	1	140.9	35	B1	N	V2	140.9									Destroyed	
SUB-TOTALS							1261.8					844.9		157.9		62.6				112.2		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R=FIRE RESISTANT

N=NON-COMBUSTIBLE

C=COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/REV.

7-18-59 *Structural

(CONFIDENTIAL)

**Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION

MISSION NO
284TARGET NO
90.25 - 263A

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 4 OF 5 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTIBILITY	H.E. VULNERABILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							1261.8					844.9	157.9			62.6				112.2		
75		Store or Work Shop	154	90	13.9																	
			120	16	1.9	1	15.8	24	A1.1	N	V4	15.8									Destroyed	
76		Store or Work Shop	105	85	8.9	1	8.9	18	D	C	V4	8.9									Destroyed	
77		Store or Work Shop	120	40	4.8	2	9.6	35	B2	C	V3	9.6									Destroyed	
79		Rolling Mill	526	166	87.5																	
			526	122	64.2																	
			247	40	17.1																	
			105	73	7.7	1	176.5	35	F1	N	V2	142.1								34.4	6.7 old superficial damage now structural; destroyed	
80		Store or Office	121	53	6.4	1	6.4	-	D	C	V4	6.4									Destroyed	
82		Unidentified Work Sp	174	85	14.8	1	14.8	-	A2.1	N	V4									14.8		
83	a	Work Shop & Rolling Mill	340	113	38.4	1																
			275	73	20.0	1																
			200	40	8.0	1																
	b	" " "	105	121	12.7	1	75.1	35	B1	N	V2	53.7				11.9				4.5	9.0 old superficial damage interior damage severe over 90% of floor area (b) Destroyed	
			243	73	17.7	1																
			130	120	15.6	1	33.3	25	B1	N	V2	33.3										
84		Unidentified Work Shop	166	77	12.8	1	12.8	24	A2.3	C	V4				12.8							Building completely gutted
86	a	Store or Work Shop	122	65	8.0	1	8.0	15	D	C	V4	8.0										Destroyed
	b	" " "	122	50	6.1	1	6.1	15	D	C	V4	6.1										"
87		Unidentified	97	62	6.0	1	6.0	20	D	R	V4	6.0										Destroyed
90		Unidentified Work Shop	90	80	7.2	1																
			90	57	5.1	1																
			170	90	15.3	1	27.6	18	A2.3	N	V4									27.6		No new damage
91		Office or Stores	126	50	6.3	1	6.3	18	D	C	V4	6.3										Destroyed
94	a	Engineering WorkSp	235	65	15.3	1	15.3	20	B2	N	V2	15.3										Destroyed
	b	" " "	178	120	21.4	1																
			250	114	28.5	1	49.9	30	B1	N	V2	49.9										Destroyed
	c	" " "	126	60	7.6	1	7.6	15	A2.3	N	V4	7.6										Destroyed
94A		Unidentified	130	110	14.3																	
			65	57	3.7	1	18.0	15	A2.3	N	V4	5.7				12.3						Internal damage probably severe over entire floor area
95		Boilerhouse	80	90	7.2	1	7.2	30	D	N	V4	7.2										Destroyed
SUB-TOTALS							1771.0					1226.8	170.7			86.8				193.5		
GRAND TOTALS																						

ALL AREAS ARE GIVEN IN 1000'S SQ.FT. R= FIRE RESISTANT N=NON-COMBUSTIBLE C= COMBUSTIBLE FOR DEFINITION OF CONSTRUCTION TYPES AND H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

*Structural

(CONFIDENTIAL) **Includes visible serious int. damage to bldg. or contents w/o struct. damage

(CONFIDENTIAL)

**HEADQUARTERS TWENTIETH AIR FORCE
OPERATIONS ANALYSIS SECTION**

MISSION NO

284

TARGET NO

90.25 - 263A

INDUSTRIAL DAMAGE SCHEDULE FOR WEAPON ANALYSIS

SHEET NO 5 OF 5 SHEETS

BUILDINGS												AREAS OF VISIBLE DAMAGE								DESCRIPTION OF DAMAGE		
NUMBER	SUB-DIV.	OCCUPANCY	LENGTH FT.	WIDTH FT.	PLAN AREA	NUMBER OF FLOORS	FLOOR AREA	HEIGHT TO EAVE	CONSTR. TYPE	COMBUSTI- BILITY	H.E. VULNERA- BILITY	STRUCTURAL **				SUPERFICIAL					OLD DAMAGE NOT * REPAIRED	
												H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN	H.E.	FIRE	H.E. + FIRE	CAUSE NOT KNOWN			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
Sub-Totals Brought Forward							1771.0					1226.8		170.7		86.8				193.5		
96		Store or Work Shop	126	45	5.7	1	5.7	14	D	C	V4	5.7									Destroyed	
97		Store or Work Shop	80	45	3.6	1	3.6	20	D	C	V4	3.6									Destroyed	
99		Store or Work Shop	114	65	7.4	1	7.4	18	D	C	V4			7.4							Destroyed	
100		Store or Work Shop	186	40	7.5	1	7.5	15	D	C	V4			7.5							Destroyed	
101	a	Store or Work Shop	114	65	7.4	1	7.4	18	D	C	V4	7.4									Destroyed	
	b		70	65	4.5	1	4.5	18	D	C	V4	4.5									Destroyed	
102		Store or Work Shop	85	53	4.5	1	4.5	15	D	C	V4	4.5									Destroyed	
103		Unidentified	85	65	5.5	1	5.5	20	D	C	V4									5.5		
104		Store or Work Shop	105	65	6.8	1	6.8	-	D	C	V4										6.8	
109		Store or Work Shop	146	90	13.1	1	13.1	24	R2.3	C	V4	6.6									6.5	
111		Machine Shop or As- smebly	438	400	175.0	1	175.0	20	C1.3	N	V4A			175.0							Frame seriously damaged, but remains standing	
112		Store or Work Shop	140	70	9.8	1	9.8	15	D	C	V4			9.8							Destroyed	
113		Store or Work Shop	110	60	6.6	1	6.6	15	D	C	V4			6.6							Destroyed	
114	a	Store or Work Shop	134	40	5.4	1	5.4	18	D	C	V4			5.4							Destroyed	
	b		85	40	3.4	1	3.4	18	D	C	V4			3.4							Destroyed	
116		Unidentified	122	37	4.5	1	4.5	12	D	C	V4	4.5									Destroyed	
118		Unidentified Work Shop	85	90	7.7	1	7.7	12	D	C	V4			7.7							Destroyed	
119		Store or Work Shop	73	77	5.6	1	5.6	12	D	C	V4			5.6							Destroyed	
SUB-TOTALS																						
GRAND TOTALS							2055.0						1263.6		399.1		86.8				212.3	

ALL AREAS ARE GIVEN IN 1000'S SQ.FT.

R= FIRE RESISTANT

N=NON-COMBUSTIBLE

C=COMBUSTIBLE

FOR DEFINITION OF CONSTRUCTION TYPES AND
H.E. VULNERABILITY SYMBOLS SEE MEMO JTG/M/3/1 REV.

7-18-59 *Structural

(CONFIDENTIAL)

**Includes visible serious int. damage to bldg. or contents w/o struct. damage

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

Appendix "A"

PROCEDURES USED IN WEAPON ANALYSIS

1. Definition of Weapon Analysis. A weapon analysis is a study relating the damage achieved in a bombing attack to the weapon or weapon combination to which it may be attributed.

2. Limitations of Weapon Analysis. Due to the inherent nature of bombing and the varied character of targets, resulting in relatively wide variations in results achieved from attack to attack, the results of the analysis of a single attack cannot be accepted unqualifiedly. However, data accumulated from analyses of several attacks under relatively similar conditions will have sufficient stability to furnish adequate planning factors.

b. Where the combination of bombs or bombs and fuzings is not rather carefully controlled it becomes practically impossible to sort out the damage and attribute it to the weapon causing it. Accordingly weapon analyses are attempted only for the "controlled attacks" or for those attacks in which sufficient control was in fact accomplished to promise a measure of success in obtaining reliable results.

3. Procedure. The following procedure is followed in weapon analysis:

a. Damage Assessment. A special damage assessment is made using the following categories of damage, defined as stated:

(1) Visible Structural Damage. Destruction, callapse, or serious distortion (over 12 inches, vertical or horizontal) of roof trusses, beams, girders, columns or load-bearing walls.

(2) Visible serious internal damage to buildings or contents.

(3) Visible Superficial Damage. Damage to roofing, roof lights and secondary members such as purlins which are easily replaced and are not essential to the stability of the building; minor disturbance of roofing is not included.

Each of these categories is further subdivided as to cause, as follows:

- (4) H.E.
- (5) Fire
- (6) H.E. and Fire
- (7) Cause not known.

b. Determination of Density of Bombs. On the damage plot are also shown the bombs falling within the target area. All available photography is used, pre-attack and post-attack reconnaissance and all strike-attack. When it is necessary to resort to computed bomb fall, as in the cases where clustered I.B. are used or the target is heavily obscured by smoke, a distinction is made between bombs located visually and those calculated. The estimated reliability of the plot is clearly stated in each case.

- a -

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



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

c. Effectiveness Calculations. The structural damage plus the serious internal damage to building or contents without structural is used in calculating the effectiveness of weapon, for the following reasons:

(1) From careful studies of the damage suffered by British factories due to German bombing it was determined that the most usable measurable quantity relating bombing to loss of production (the ultimate goal) is visible structural damage; it must be visible on photo cover to be measurable.

(2) Our attacks on Japanese targets have yielded a considerable amount of visible serious internal damage without structural damage. This damage is as important in stopping production as is structural damage.

The unit of measure of effectiveness is the mean area of effectiveness in acres per ton (MAE or M), defined as the area within which a given type of construction may be expected to suffer damage of specified kind (defined above). If a target were attacked with a single bomb-fuze combination and consisted of a very large area containing a great many identical buildings with identical contents, and both buildings and bombs (all making direct hits) were widely and uniformly spaced throughout the area the MAE would be a constant and would equal the average damage per ton. Since these conditions never occur in practice it is necessary to solve the following equation for M,

$$M = 1 - e^{-MD} \quad (\text{For the case in which a single bomb-fuze combination is used})$$

Where

F = fraction of damage, in this analysis the total damage as defined above divided by the total undamaged floor area of the target before the attack.

M = mean area of effectiveness (Acres/Ton)

D = density of bombs achieved (Tons/Acre)

e = base of Napierian logarithms (= 2.72 approx.)

This formula attempts to account for near-misses as well as direct hits and also for overlap where two bombs hit close together. It was derived by the British-American Target Analysis Unit at Princes Risborough, England* and has more recently been in use by the Joint Target Group in Washington and by this Section in its bomb selection calculations.

Where more than one bomb-fuze combination are used the following equation may be used:

$$F = 1 - e^{-MD} - M'D'$$

*For derivation see REN 284 and REN 331, Research and Experiments Department, Ministry of Home Security.

- b -

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

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Where the M' and D' have the same meaning as M and D but apply to the additional weapon. An additional term occurs in the exponent for each additional weapon. There is little practical value in attempting an analysis where more than two weapons are used.

- c -

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