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SCTM 23-59(12)

PRESSURE TEST STUDY OF THE MK 25 MOD O WARHEAD

L. L. Keller, Jr, 1246

ABSTRACT

This is a report of the study conducted using the results of the pressure tests of the war reserve units of the Mk 25 Mod O warhead to confirm the 6 month storage pressure test interval now specified in the test procedures. This study concerns only those units produced at Pantex. Refer to SCTM 262-58(12) for a similar study performed on units produced at Sugar.

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SUMMARY

A 195-unit sample of the war reserve units of the Mk 25 Mod O warhead produced at Pantex was selected at random from the units now in the field. This selection was truly random except for the deletion of units with pressure histories so short as to cause considerable inaccuracies in the calculations. The data from the pressure test reports of these weapons were tabulated and analyzed statistically to determine the leakage characteristics of the warheads.

The results of the study showed that the average pressure loss for the 195 sample units over a 6-month period was 1.48 psi, and that we may have 99 percent confidence that 96.7 percent of all units produced under the same manufacturing conditions as the sample units can be expected to show a pressure loss over a six-month period of 5.09 psi or less.

On the basis of these results, it is confirmed that the pressure test interval of 6 months is satisfactory. This statement is made with a high level of confidence that each weapon will be fully protected against electrical arcing and the effects of contaminants and moisture at all times.

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PRESSURE TEST STUDY OF THE MK 25 MOD O WARHEAD

Purpose of Study

The purpose of this study was to analyze the leakage characteristics of the Mk 25 Mod O warhead and to determine if a six-month interval between pressure tests can be allowed and still insure that all units remain at a safe positive pressure at all times.

Introduction

In order to prevent failure or improper operation of a warhead due to electrical arcing or the effects of contaminants and moisture acting on warhead components, it is necessary that a positive pressure be maintained in the warhead at all times. To insure that this condition exists, arbitrary levels of pressurization and pressure test procedures were established by the warhead design organization during the early stages of the warhead development program. These procedures prescribed that pressure tests be made upon initial receipt and during assembly of a warhead to a missile, prior to storage of a warhead, before and after all flights of a warhead, and at regular 30-day intervals. Under these procedures, units which showed a pressure of 12 psig or above were accepted; units which showed a pressure of 5-12 psig were pressurized to 12-15 psig and accepted; and units which showed a pressure of less than 5 psig were pressurized to 12-15 psig, then checked 7 days later and either accepted or rejected according to the pressure loss during the 7 days after pressurization as compared to a table of acceptable pressure losses.

On May 15, 1958, the committee revised these procedures. The new procedures prescribe that pressure tests be performed upon initial receipt of a weapon, before and after the weapon is shipped, before it goes into storage, before and after all flights of the weapon, and at regular 30-day intervals.

Each test will be evaluated as follows:

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1. If the pressure is 8 psig or above, the weapon is to be accepted and pressurized to 15 ± 1 psig.

2. If the pressure is below 8 and above 1 psig, the weapon is to be pressurized to 15 ± 1 psig, then 1-2 hours later the pressure is to be read and recorded, and if the pressure at this time is:
   a. Eight psig or above, the weapon is to undergo a 7-day pressure test;
   b. Less than 8 psig, the weapon is to be rejected to a maintenance site for repair.

3. If the pressure is 1 psig or below, the weapon is to be returned to the AEC if the time elapsed since the last pressurization was unknown or exceeded 30 days. The weapon is to be rejected if a pressure test was performed during the preceding 30 days. If any one weapon is rejected more than twice, it is to be returned to the AEC.

A basic design objective of Sandia Corporation is to require a minimum amount of testing on a warhead. In line with this objective, a study was made when sufficient data was available on units produced at Sugar. An extension of the test period to a six-month interval was made on the basis of this study. (See SCTM 262-58(12).)

This study of the pressure tests was made to determine if Pantex-produced units are also reliable enough to allow the six-month storage pressure test interval.

Details of Study

A 195-unit sample was selected at random from the war reserve units that have been produced at Pantex. The information from the pressure test reports of these units have been tabulated for the selected test period. Each of the pressure readings was adjusted to 75°F to eliminate the effect of temperature changes between tests. No compensation was made for changes in atmospheric pressure over the test period since this data was not available, and its omission was not considered a serious error.

The tabulated data were then used to calculate the rate at which pressure leaked from each unit (in psi/month) and the total pressure loss of each unit over a six-month period at the calculated leak rate. This information was then analyzed statistically in order to predict what pressure losses may be expected for any unit produced under the same manufacturing conditions the sample units were produced under.

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However, in order to statistically compare the leak rates of the different units, there had to be some common basis of comparison between the units. If the adjusted pressure in every unit had at some time been equal to some arbitrary standard value such as 15 psig, then a comparison of leak rates between the units would have been valid because a common starting point had been established. The exact time at which each unit was at the common initial pressure would be unimportant as long as the leak rate for each unit was calculated from the same initial pressure.

There was, however, no single adjusted pressure that was common to all units. A pressure leak rate was still calculated for each unit, but the initial pressures used for these calculations varied between units. If some method were available to correct each leak rate calculated from some p_1 (internal pressure) to the value the leak rate would have been had the p_1 been 15 psig, then again a comparison of the various leak rates, all corrected to a p_1 of 15 psig, would be valid.

However, the rate at which air will leak from any system depends on the pressure differential (Δp) within and surrounding the system, and the size and shape of the area through which the air escapes. It is assumed that the escape area for any one unit remains constant; and therefore, the leak rate for that unit depends only on the pressure differential, and will increase as Δp increases and decrease as Δp decreases.

The theoretical weight rate of flow (w, in lb/sec) for compressible flow is

$$w = A\sqrt{2g\,\frac{k}{k-1}\cdot\frac{p_1}{v_1}\left[\left(\frac{p_2}{p_1}\right)^{2/k} - \left(\frac{p_2}{p_1}\right)^{(k+1)/k}\right]} \qquad (1)$$

where

w = weight rate of flow, lb/sec,

A = area of cross section of jet, ft^2,

g = ratio of 1 slug to 1 pound = 32.17, dimensionless,

k = ratio of specific heats = 1.4 for air, dimensionless,

p_1 = internal pressure, psfa,

v_1 = initial specific volume, ft^3/lb,

p_2 = exhaust pressure, psfa, and

[redacted]

The equation of state for gases shows that

$$pv = RT, \tag{2}$$

where

p = pressure of gas, psfa,

v = specific volume of gas, ft^3/lb,

R = gas constant (53.35 for air), ft lb/lb/^oF, and

T = absolute temp = observed temp + 460, ^oF abs.

If p_1 is known, v_1 can be found from Equation 2. If p_2 is assumed to be equal to 13.90 psi standard atmospheric pressure, for an average unit elevation of 1500 ft, and A is arbitrarily assumed to be 1 ft^2, Equation 1 can be solved for w, the theoretical weight rate of flow of air exhausting to the atmosphere from an ideal system whose area of escape is 1 ft^2 and whose initial pressure is p_1. For calculations of flow for actual units an orifice coefficient (C) must also be included. This coefficient, however, has been disregarded here because it would be extremely difficult to determine and would vary between units and, as Equation 3 will show, would cancel out anyway.

A graph of the solutions to Equation 1 for p_1 varying from 1 to 34 psig (Fig. 1) shows that w increases at a decreasing rate as p_1 increases. So if p_2 (exhaust pressure) is assumed constant for every unit, then the leak rate for each unit will increase as p_1 increases, but the increase will be at a decreasing rate. Therefore, corrections of leak rates to a standard initial pressure of 15 psig cannot be straight line corrections but must follow a curve similar to that of Fig. 1. The exact curve any one unit must follow will be of the same family of curves as Fig. 1, but will vary as the values of A and t vary.

For all further calculations the following symbols will apply:

p_i = initial recorded internal pressure in unit adjusted to 76^oF, psia,

P_f = final recorded internal pressure in unit adjusted to 76^oF, psig,

p_c = constant internal pressure of 15 psig to which leak rate will be corrected, psia,

p_2 = constant exhaust pressure of 13.90 psia,

W_1 = theoretical weight rate of flow for p_i, lb/sec,

W_c = theoretical weight rate of flow for p_c, lb/sec,

LR_i = actual leak rate as calculated from recorded data, psi/month,

LR_c = leak rate corrected to p_c, psi/month,

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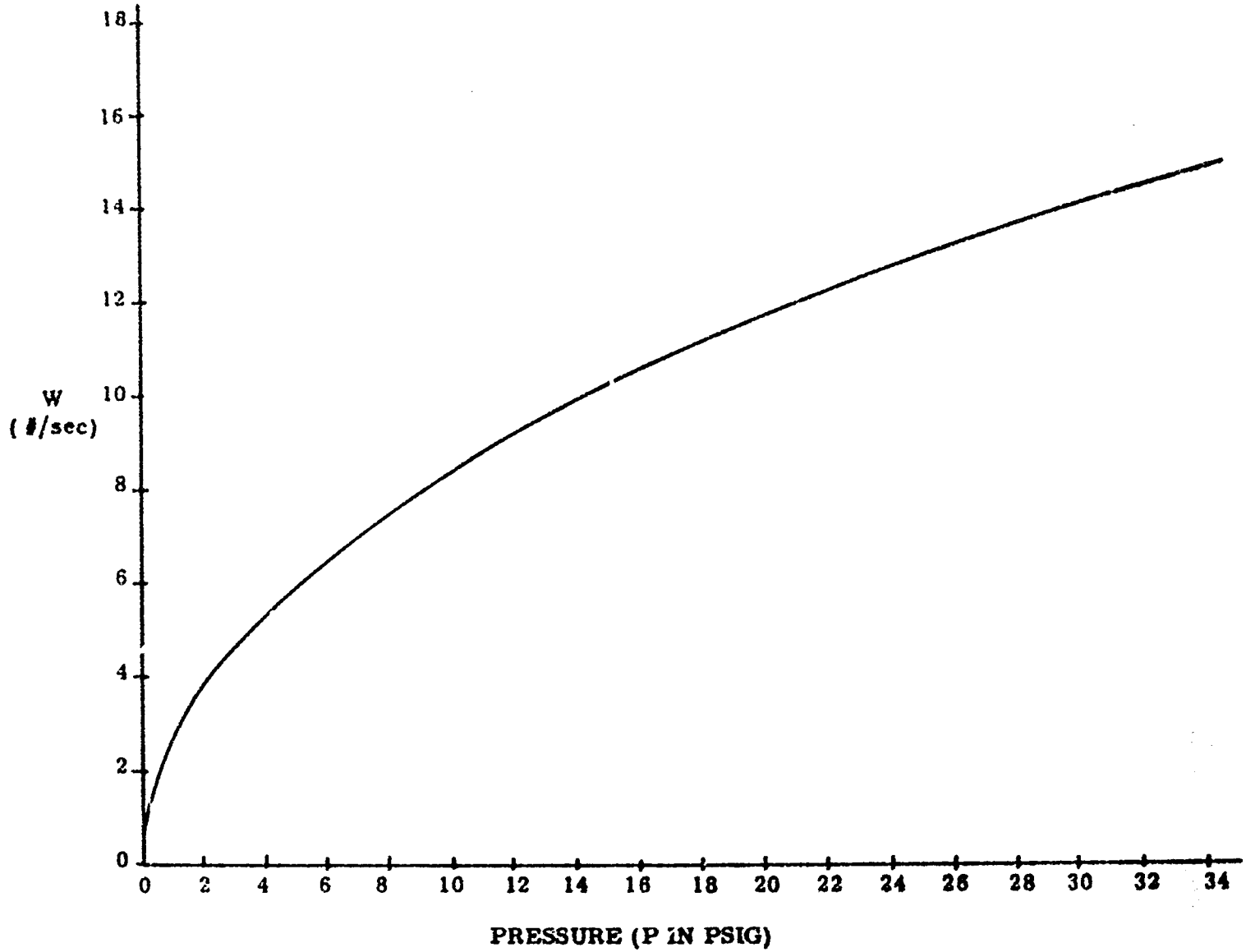

Figure 1 -- Theoretical weight rate of flow versus differential pressure

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v_i = specific volume for p_i, ft^3/lb,

v_c = specific volume for p_c, ft^3/lb, and

t = observed temperature at p_i, ^oF.

If it can be shown that

$$\frac{LR_c}{LR_i} = \frac{W_c}{W_i}, \tag{3}$$

then the corrected leak rate for each unit could be calculated and a valid comparison of leak rates made.

$$(3) + (1),\ \frac{LR_c}{LR_i} = \frac{W_c}{W_i} = \frac{A\sqrt{2g\frac{k}{k-1}\cdot\frac{p_c}{v_c}\left[\left(\frac{p_2}{p_c}\right)^{2/k} - \left(\frac{p_2}{p_c}\right)^{(k+1)/k}\right]}}{A\sqrt{2g\frac{k}{k-1}\cdot\frac{p_i}{v_i}\left[\left(\frac{p_2}{p_1}\right)^{2/k} - \left(\frac{p_2}{p_1}\right)^{(k+1)/k}\right]}}$$

or

$$\frac{LR_c^2}{LR_i^2} = \frac{\frac{p_c}{v_c}\left[\left(\frac{p_2}{p_c}\right)^{2/k} - \left(\frac{p_2}{p_c}\right)^{(k+1)/k}\right]}{\frac{p_i}{v_i}\left[\left(\frac{p_2}{p_i}\right)^{2/k} - \left(\frac{p_2}{p_i}\right)^{(k+1)/k}\right]}$$

Since

p_c = 28.90 psia, constant,

p_2 = 13.90 psia, constant,

$2/k$ = 1.429, constant,

$(k + 1)/k$ = 1.714, constant,

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and substituting $\frac{RT}{p_c}$ for v_c, and $\frac{RT}{p_i}$ for v_i, Equation 3 reduces to

$$\frac{LR_c^{\,2}}{LR_i^{\,2}} = \frac{p_c\left[0.0665\right]p_c}{p_i\left[\left(\frac{p_2}{p_i}\right)^{1.429} - \left(\frac{p_2}{p_i}\right)^{1.714}\right]p_i}$$

$$= \frac{(28.90)^2\left[0.0665\right]}{p_i^{\,2}\left[\left(\frac{p_2}{p_i}\right)^{1.429} - \left(\frac{p_2}{p_i}\right)^{1.714}\right]} = \frac{55.21}{p_i^{\,2}\left[\left(\frac{p_2}{p_i}\right)^{1.429} - \left(\frac{p_2}{p_i}\right)^{1.714}\right]}$$

$$LR_c = \sqrt{\frac{(55.21)\,(LR_i)^2}{p_i^{\,2}\left[\left(\frac{p_2}{p_i}\right)^{1.429} - \left(\frac{p_2}{p_i}\right)^{1.714}\right]}} \qquad (4)$$

This equation shows that the leak rate of a unit will vary as an exponential power of p_i and will follow one of the family of curves defined by the curve of Fig. 1. Although Equation 4 has not been proved mathematically, even if it is not a true relationship it will provide an excellent approximation of what actually occurs, for as Fig. 2 shows, that portion of the curve in which the corrections are made (between p_i = 11 to 17 psig) is very nearly a straight line. This fact gives much support to the assumption of Equation 4. (For a sample calculation using Equation 4 see Appendix A.)

For simplicity in the correction of data, Equation 4 was reduced to the form

$$LR_c = K\,LR_i$$

where

$$K = \frac{7.43}{\sqrt{p_i^{\,2}\left[\left(\frac{p_2}{p_i}\right)^{1.429} - \left(\frac{p_2}{p_i}\right)^{1.714}\right]}} \qquad (5)$$

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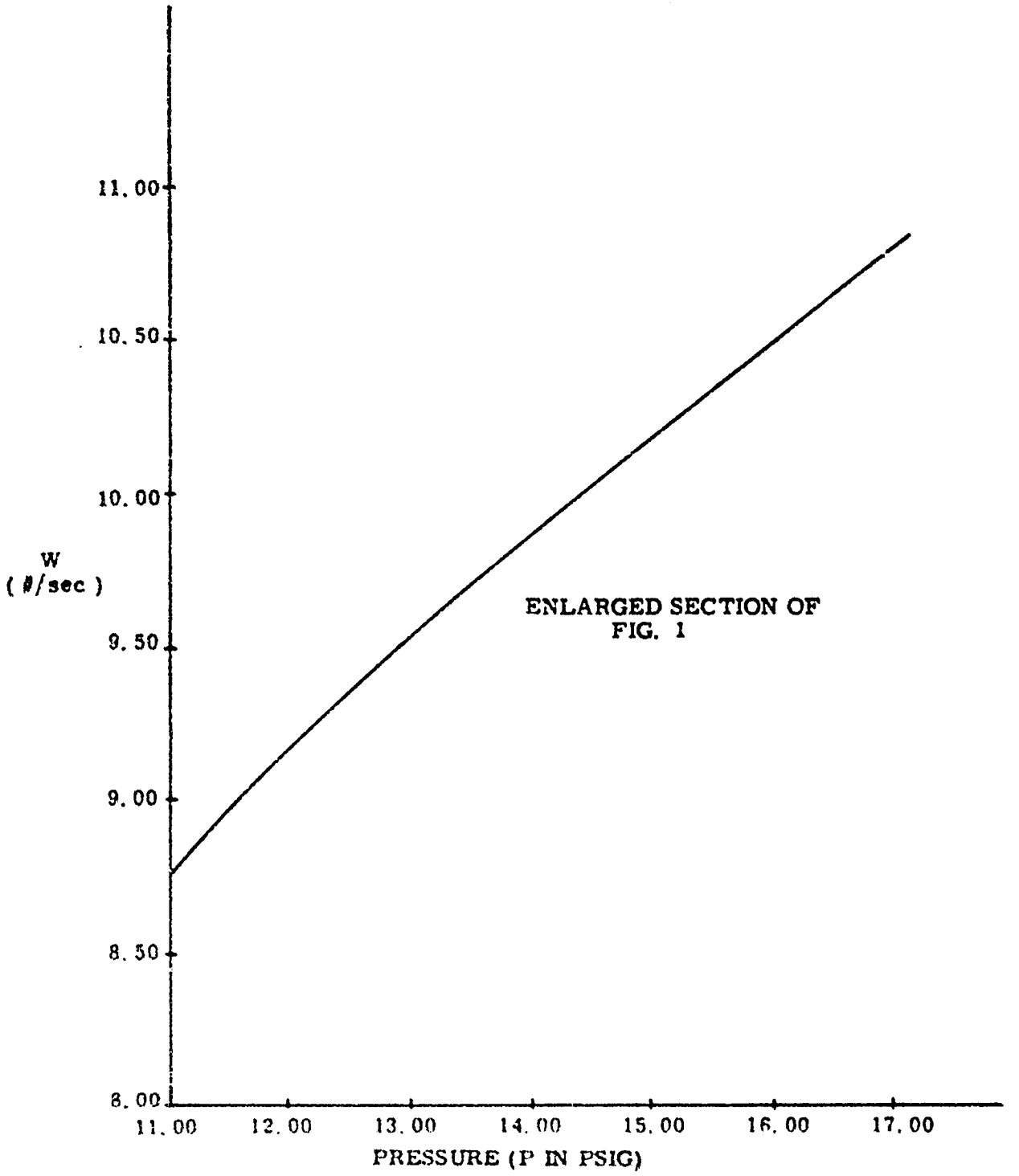

Figure 2 -- Theoretical weight rate of flow versus differential pressure

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by assuming values for p_i it was possible to plot a curve of K vs p_i, Fig. 3. This permits the use of Equation 5 directly knowing the LR_i and having selected the K from Fig. 3 corresponding to the P_i (psia).

All leak rates were corrected by this method; and the pressure loss for six months was then calculated for each unit from its leak rate. The results of these calculations are shown in Appendix B, and from this information the statistical study was made.

Results

The average corrected leak rate for the 195 units was 0.247 psi/month, and the average pressure loss for 6 months 1.48 psi. New test procedures now accept pressures as low as 8 psig and specify pressurization to 15 $\pm$ 1 psig.

Technical Memorandum 66A-57-51 was utilized for determining the confidence level because the method has great generality (no assumptions are made as to the form of the underlying distribution). Figure 4 (distribution of the pressure losses of the 195-unit sample) was prepared to illustrate the actual distribution. A study of Tech Memo 66A-57-51 shows that we may have 99 percent confidence that 96.7 percent of all units produced under the same manufacturing conditions the sample units were produced under can be expected to show a pressure loss over a six-month period of 5.09 psi or less if the initial pressure is 15 psig. It can be expected then, with 99 percent confidence, that only 1 out of 20 units will drop below 14.00 - 5.09, or 8.91 psig. This confidence level takes into account the 1 unit which lost 19.44 psi. The magnitude of this leak indicates that rework is required and preferable to the frequent repressurizations, which would probably occur under the 30-day frequency check.

These results allow us to have a high level of confidence that all units will maintain a positive pressure over any six-month period.

Conclusions

On the basis of the results of this pressure study, it is confirmed that a six-month pressure test interval for the Mk 25 Mod O warhead is satisfactory. This statement is made with a high level of confidence that all weapons will be protected by a positive pressure

at all times. Further support is given to this conclusion by the fact that the 8-psig pressure limit is not a minimum safe limit. Any positive pressure will provide protection for the warhead, and the desiccant placed in every weapon provides further protection for a limited time should any weapon ever lose all positive pressure.

This six-month pressure test interval pertains only to undisturbed storage in an assembled or unassembled condition, and does not alter the additional requirement for pressure tests upon receipt of a weapon, before and after the weapon is shipped, before it goes into storage at assembly or disassembly, and before and after all flights of the weapon.

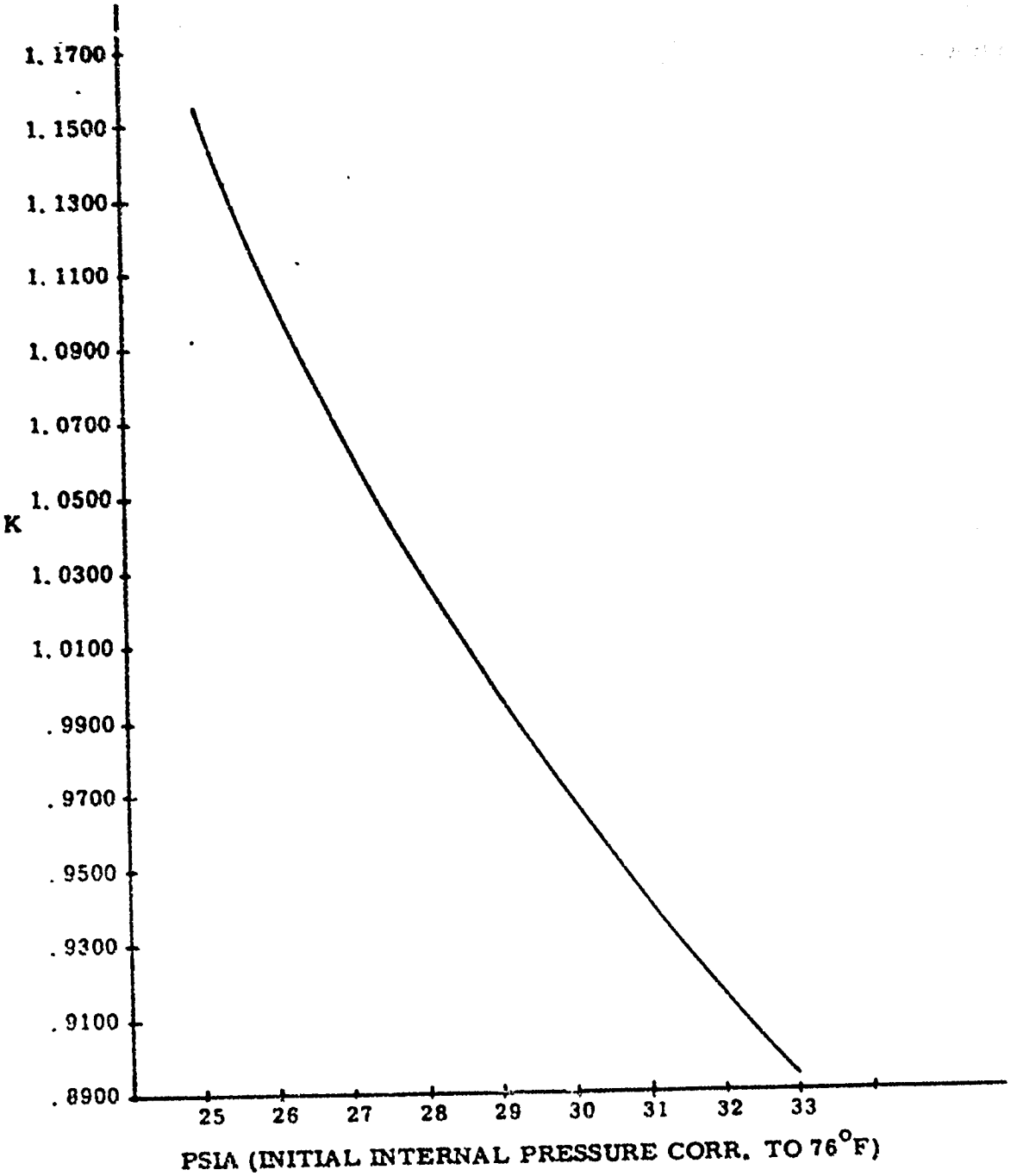

Figure 3 -- Pressure correction factor

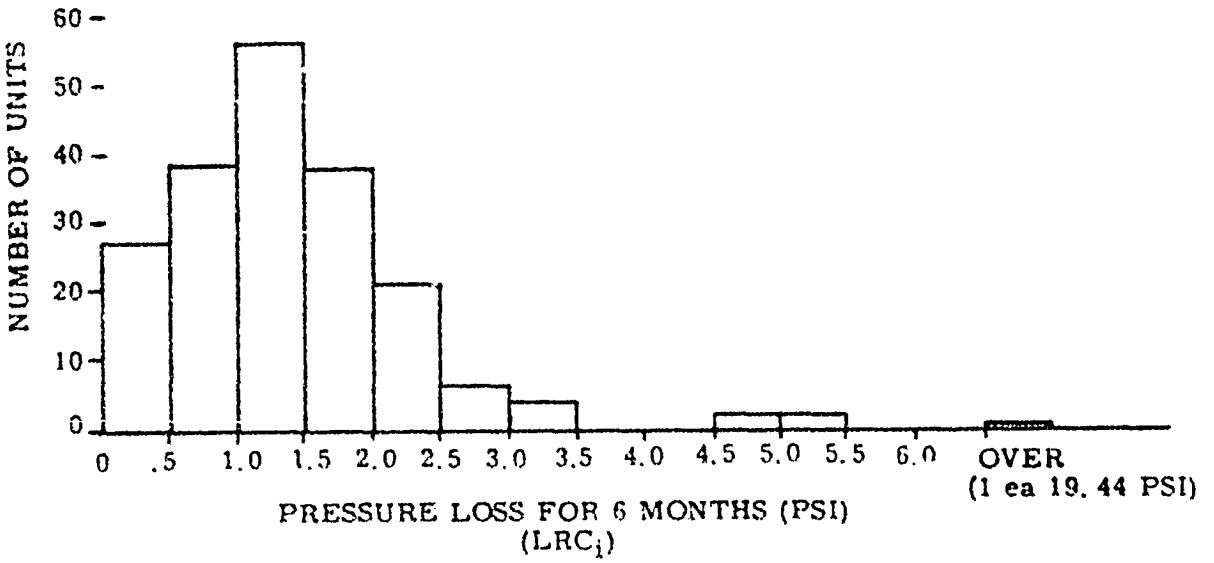

Figure 4 -- Distribution of pressure loss by intervals

APPENDIX A

Sample Data and Calculation for Unit No. 665742

Date	Pressure (psig)	Temperature (°F)	Pressure adjusted to 76°F
January 12, 1958	14.00	50	15.4
February 12, 1958	14.00	50	15.4
March 11, 1958	13.75	42	15.65
April 8, 1958	14.00	54	15.25
May 13, 1958	14.00	56	15.10
June 13, 1958	14.25	64	14.90
July 10, 1958	14.50	71	14.75
August 10, 1958	14.75	71	15.0

Sample calculation for LR_c:

pi = 15.4 + 13.9 = 29.30 psia January 12, 1958

pf = 15.0 + 13.9 = 28.90 psia August 10, 1958

ΔP = 29.30 - 28.90 = 0.40 psi

Days elapsed = 8/10/58 - 1/12/58 = 210

Months elapsed = 210 ÷ 30 = 7.0

Leak rate (LR) = 0.40 ÷ 7.0 = 0.057 psi/month

LRc = K (LR) = (0.988) (0.057) = 0.0563 psi/month (from Equation 5),

or

$$LRc = \sqrt{\frac{(.057)(55.21)}{(29.30)^2\left[\left(\frac{13.9}{29.30}\right)^{1.429} - \left(\frac{13.9}{29.30}\right)^{1.714}\right]}}$$

= 0.0563 psi/month (from Equation 4).

Pressure loss for 6 months = 6(LRc) = 6(.0563) = <u>0.833 psi</u>

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APPENDIX B

Mk 25 Mod 0 Pressure Leak Rates (War reserve units - Pantex)

Unit No.	Adj. Pres. Loss for 6 Mos.	Unit No.	Adj. Pres. Loss for 6 Mos.	Unit No.	Adj. Pres. Loss for 6 Mos.	Unit No.	Adj. Pres. Loss for 6 Mos.
103185	1.083	333734	2.235	517506	0.955	769827	5.06
104854	1.647	337332	1.130	523524	2.592	770299	1.059
108648	-0-	348047	0.825	528923	1.839	773322	2.125
109713	-0-	356355	-0-	530947	1.780	776636	0.477
117733	1.007	370902	1.750	537438	0.823	778565	0.181
121954	0.555	372886	0.797	537603	0.290	779326	1.161
133743	0.340	373094	1.091	539435	1.018	780672	0.824
139534	3.430	373837	2.932	548758	0.448	781564	2.060
140847	0.813	376535	2.900	549118	1.314	785484	0.469
143957	1.200	383136	1.111	555735	1.106	791354	1.568
146212	1.923	385176	0.935	560334	1.438	793337	2.245
150239	2.390	386934	1.875	566112	0.914	793383	1.687
153154	1.346	389815	1.753	566447	0.879	800015	1.511
155504	1.660	391612	1.068	573493	0.790	804179	1.957
157123	1.421	393717	4.810	599197	2.296	805203	0.408
170125	1.329	393735	0.209	602067	-0-	807355	2.250
170646	1.020	397494	0.488	605577	1.198	807587	1.143
178863	0.415	398093	0.883	609127	0.781	826207	2.227
183496	0.626	405784	1.226	617957	1.830	826295	2.293
208333	-0-	408975	1.370	620419	0.819	830306	1.844
208887	0.770	412036	2.285	621487	1.841	838957	1.830
217403	1.658	416253	1.452	622194	2.300	839457	1.407
221697	2.567	418337	0.520	624015	1.072	844552	1.361
223794	0.403	423875	0.954	633817	2.225	849388	2.090
229613	1.885	430872	0.925	642465	0.689	850005	0.352
229696	0.878	432655	0.937	659846	1.686	854597	1.867
237114	0.780	438798	0.988	662045	1.832	855519	1.881
240166	3.112	439847	1.342	665742	0.338	858063	1.052
240755	0.662	442563	2.310	666924	1.593	860289	1.122
245452	1.298	444893	1.430	672453	1.173	860345	0.726
250814	2.505	446376	1.410	675517	1.037	869657	1.307
262666	19.440	458685	1.397	679063	1.399	872296	2.568
273505	3.280	460953	0.746	683486	1.794	875803	1.800
276697	-0-	461189	1.634	685605	0.962	885753	2.195
278326	1.576	466819	1.542	685669	0.625	886797	1.328
280112	-0-	469946	5.000	691035	1.007	887435	0.750
288273	0.173	471837	0.712	697383	0.766	897514	1.886
292004	1.293	472206	2.233	697607	3.088	900227	1.622
295334	1.219	474199	1.702	718468	1.771	903087	2.175
307986	1.804	484112	1.008	718505	1.286	916733	0.933
310967	1.582	487268	1.178	721605	2.260	924193	1.313
314447	1.118	498740	0.954	740417	0.357	926679	1.497
315392	0.382	498566	1.722	741386	1.850	927332	0.299
317375	2.415	511027	1.373	749065	4.510	945322	1.255
318089	0.996	511677	1.492	752412	0.152	947898	1.175
318557	2.290	513544	0.937	757553	1.738	952497	1.870
321453	0.099	516187	1.486	759784	1.460	977895	1.032
325249	2.465	516459	0.519	761646	1.272	992779	1.994
329757	0.356	517469	0.805	763912	1.061		

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