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Technical Memorandum

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283-54-51

MAXIMIZED PROBABILITIES OF WARHEAD DAMAGE (PRIOR TO DETONATION) ASSOCIATED WITH CERTAIN CONTACT FUZE SYSTEMS FOR THE XW-5/F-101 (U)

MCC 4/8/01

C. R. McAllister

ABSTRACT

The maximized probabilities of damage to the warhead (prior to detonation), which arise from terrain-situated objects in the target complex, are calculated for four contact fuze capabilities (two design proposals and two suggested designs). The calculated results show that, for the higher impact angles, both of the contact fuze design proposals for the XW-5/F-101 weapon lead to probabilities of warhead damage prior to detonation in the neighborhood of 0.050. If a choice must be made between the two design proposals, System 2 (using six MC-300 impact crystals mounted on a ring at station 98.50) is to be preferred, simply because the arrangement more nearly satisfies the assumptions implicit in the calculations. A suggested design using eight impact crystals all mounted at station 98.50 (System 3) would yield damage probabilities in the same neighborhood as those of the preferred design proposal (System 2), and, in addition, would have advantages of simplicity and reliability not enjoyed by either of the design proposals. A better solution to the problem, in the sense of decreased probability of damage, is provided by the second suggested design (System 4) in which the contact fuze capability is provided by a sensitive ring, mounted at station 98.50, with a sensitive region extending to the rear toward the major diameter of the weapon. The resulting reduction in probability of damage is a direct function of the rearward extent of the sensitive region, up to a certain poin

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INTRODUCTION

A memorandum[1], dated November 2, 1954, from E. H. Draper, 1240, to K. W. Erickson, 5130, requested that answers to the following specific questions be provided for the XW-5/F-101 weapon:

1. The probability of impact of any kind on a spike by this weapon.

2. The probability of warhead damage prior to detonation, due to a spike-type impact for each of two design proposals for the contact fuze capability.

3. The probability of warhead damage prior to detonation, due to a corner or edge-type of impact, for each of the two design proposals.

Reference 1 additionally requested comments and recommendations pertinent to the XW-5/F-101 or to either of the two design proposals for contact fuze capability. This memorandum provides the answers and comments requested in Reference 1.

The two design proposals for the contact fuze capability (mentioned in 2 and 3 above) are designated in this memorandum as Systems 1 and 2. Two suggested designs (referred to as Systems 3 and 4) for the contact fuze capability are also considered and the probabilities of damage associated with the modifications are discussed.

CALCULATION METHODS AND ASSUMPTIONS

Calculations of the probabilities of damage* prior to detonation for the impact conditions specified in the INTRODUCTION were carried out in accordance with the philosophies and procedures described in SC-2875 (TR)[2]. Note that assumptions of nondeformable edges and unbreakable spikes lead to these probabilities.

Since proposed delivery techniques for the XW-5/F-101 weapon include LABS-type deliveries[3], the calculated probabilities are presented in this memorandum as functions of the impact angle of the weapon; i.e., no single probability of damage is necessarily characteristic of the XW-5/F-101 for a given type of delivery. The proposed locations of the MC-300 impact crystals for the design proposals for the contact fuze capability are shown in the sketches of Fig. 1. The impact crystals at Station 98.50 are mounted on a ring three inches deep. Impact at Station 95.50, within the inner diameter of the ring, will not excite the impact crystals. Because of the thin skin construction of the weapon, shock conduction through the skin is negligible[1]. The reliabilities of the impact crystals, networks,

*Damage is defined to be penetration of the weapon case sufficient to damage vital components of the warhead.

and other components of the contact fuze systems are assumed to be unity for the purposes of the calculations.

The procedures of Reference 2 require that the geometries of the contact fuze sensitive regions (on the weapon case) are such that their forward projections are (approximately) annular. It is assumed that the two design proposals (Systems 1 and 2) for the XW-5/F-101 provide sensitive-region geometries having annular forward projections, and no distinction between the two systems is made in performing the probability calculations. It is, therefore, impossible to compare Systems 1 and 2 on the basis of probability arguments unless it can be established that one or more of the following factors exists to force a choice between the two design proposals:

1. The geometry of the sensitive region of one system more nearly satisfies the assumption of an annular forward projection.

2. The arrangement of the MC-300 impact crystals and associated networks of one system is more reliable.

3. Some factor, other than the specific probabilities of this memorandum, exists to force a choice between System 1 and System 2.

The various formulas and measures used in the calculations are not reproduced in this memorandum because of the complicated nature of the calculation procedures; for those who are interested, the entire set of computations is available in the files of Section 5131-1. The geometry of, and measures for, the XW-5/F-101 weapon were assumed to be in accordance with the data appearing in SC-3245 (TR)[3]. It was assumed that the fuel tank in the forward section did not constitute a vital component and its presence or absence was not essential to the calculations.

Flight characteristics of the weapon were taken from the data of Reference 3. A five-degree angle of attack was assumed to be maximum for the weapon. The calculated probabilities of damaging penetration are maximized probabilities for a composite target from a strategic target complex. Calculations were performed for impact angles of 15, 30, 45, 60, 75, 90, 105, and 120 degrees*. The probability function is a continuous function of the impact angle, over the range considered, and the function is symmetric about 90 degrees.

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*Impact angles greater than 90 degrees come into existence only because a reference system is taken with respect to the direction of the delivery aircraft at approach.

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Fig. 1 -- Arrangement of impact crystals for XW-5/F-101 design proposals (Systems 1 and 2)

RESULTS

In answer to question one of the INTRODUCTION, the maximized probabilities of impact of the weapon on any kind of spike-like object were calculated over the range of impact angles from 15 to 120 degrees. The calculated values are listed in Table I and are shown graphically in Fig. 2. It should be noted,however, that in the consideration of sensitive region geometry for impact fuzing devices, spike-like objects comprise relatively few of the objects in the totality of objects which can lead to damaging penetration of the warhead prior to detonation. The probabilities associated with impact on the edges of surfaces (not the surfaces themselves) are more than five times the probabilities associated with impact on spikes. Consequently, in the philosophy of contact fuze geometries, the first consideration (after the obvious one of protection against surface impacts) is protection against impact with the edges of surfaces. Caution must be used in attempting an interpretation of the values listed in Table I and shown in Fig. 2; the probability values given do not give the whole story.

TABLE I

Maximized Probability of Impact of the XW-5/F-101 Weapon on Any Kind of Spike-Like Object

Impact angle (degrees)	Maximized Probability
15	0.130
30	0.081
45	0.066
60	0.059
75	0.056
90	0.055
105	0.056
120	0.059

In reply to questions two and three of the INTRODUCTION, the calculated values of the maximized probabilities in question are listed in Table II and plotted in Fig. 3. (Total probability of damaging penetration is included in Table II and Fig. 3 for later reference.) Again, it must be remembered that the probabilities associated with impact on the edges of surfaces are more than five times the probabilities associated with impact on spikes and for the specific arrangement of impact devices under consideration (Systems 1 and 2), the probabilities associated with damage by edge-type impacts are roughly two times the probabilities associated with spike-type impacts over the range of impact angles.

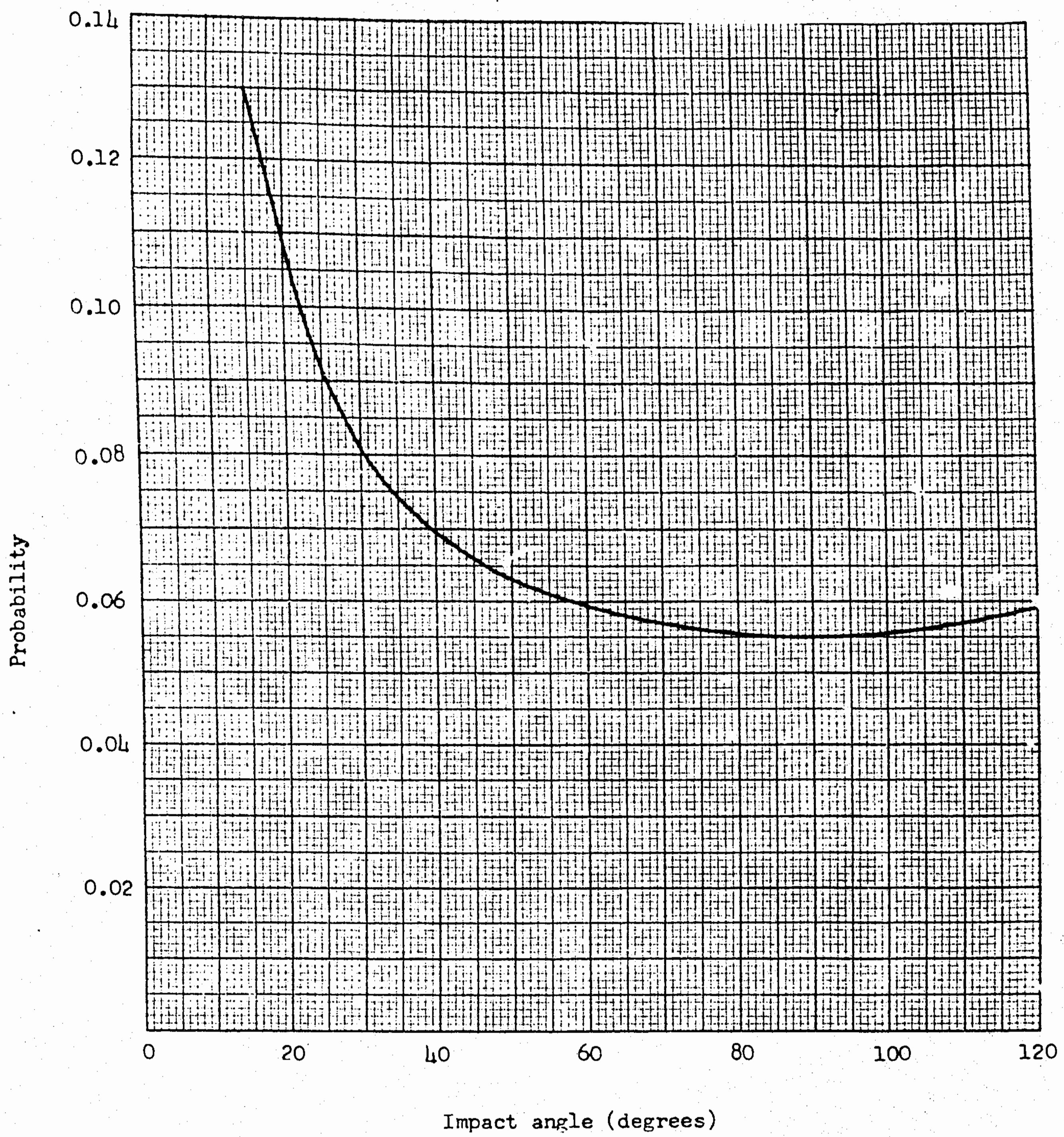

Fig. 2 -- Maximized probability of impact on spike-like object versus impact angle for XW-5/F-101 weapon

TABLE II

Maximized Probabilities of Warhead Damage Prior to Detonation for the XW-5/F-101 Weapon with System 1 or System 2 Contact Fuze Capability

Impact angle (degrees)	Maximized probabilities of damage: Impact on spikes	Impact on edges	Impacts of all types
15	0.022	0.102	0.123
30	0.021	0.054	0.075
45	0.018	0.039	0.058
60	0.017	0.033	0.050
75	0.017	0.030	0.046
90	0.017	0.029	0.046
105	0.017	0.030	0.046
120	0.017	0.033	0.050

COMMENTS AND RECOMMENDATIONS

In the calculations of the maximized probabilities of damage presented in the preceding section, the fundamental assumption was that no gaps existed in the sensitive region geometries, the forward projections of which were annular. If this assumption is violated, the results are, of course, vitiated, and higher probabilities would be expected. Because of the fact that the XW-5/F-101 weapon has a thin skin, the assumption that no gaps exist in the sensitive region is questionable for the arrangement of four MC-300 impact crystals at Station 98.50 (System 1). (It may also be questionable for the arrangement of System 2). Two suggested designs (System 3 and 4) for the contact fuze capability were investigated as to associated probabilities of damage to the warhead prior to detonation.

One method to provide at least one annular projection of sensitivity for the same number of MC-300 impact crystals and networks (assuming that the reliability of the contact fuze system is unity) would be to remove the impact crystals at Station 30.00 and mount all eight crystals in two networks at Station 98.50, as shown for System 3 in Fig. 4. The calculated values of the maximized probabilities of warhead damage prior to detonation for the XW-5/F-101 weapon with System 3 contact fuze capability are listed in Table III and shown graphically in Fig. 5.

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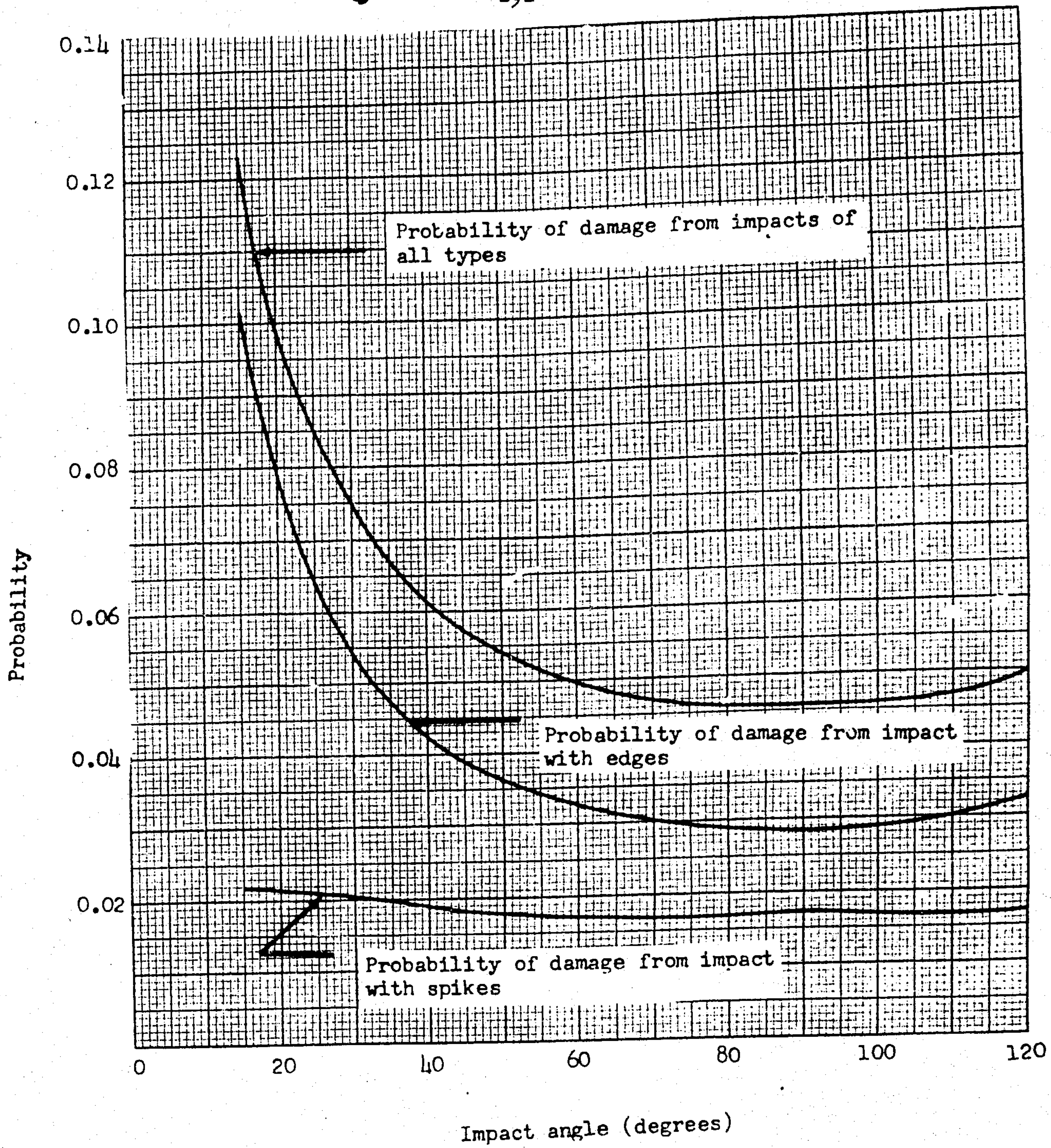

Fig. 3 -- Maximized probabilities of damage to warhead prior to detonation versus impact angle; for XW-5/F-101 weapon with Systems 1 or 2 contact fuze capability

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TABLE III

Maximized Probabilities of Warhead Damages Prior to Detonation for the XW-5/F-101 Weapon with System 3 Contact Fuze Capability

Impact angle (degrees)	Maximized Probability of Damage impacts of all types
15	0.127
30	0.081
45	0.063
60	0.055
75	0.052
90	0.052
105	0.052
120	0.055

A comparison of the over-all probabilities of damage for Systems 1 and 2 (Table II) and for System 3 (Table III) shows that the increase in probability of damage for System 3 is of the order of 0.005. Whether or not this increase is significant depends on more criteria than simply the absolute probabilities under consideration. If it is true that the arrangement of impact crystals in either Systems 1 and 2 does not provide an annulus of sensitivity at Station 98.50, then the increase (if any) in over-all probability of damage for System 3 as compared to System 1 and 2 is considerably less than the order of 0.005 and is probably not significant.

Another advantage of System 3 that must be taken into account is the simplicity of having just one mounting station for the impact crystals rather than the two separate mounting stations used in Systems 1 and 2.

The foregoing discussion has been predicated upon a completely reliable contact fuze system. If one assumes, however, that one network of impact crystals fails, then System 3 with eight crystals mounted at station 98.50 has a decided superiority over the two design proposals (Systems 1 and 2). The major contributions to the probabilities of damage attributable to impacts forward of Station 98.50 are the consequence of penetrations of the weapon case between Stations 30.00 and 98.50 rather than penetrations between Station 0.00 and 30.00. In case of failure of one crystal network of System 1, the two MC-300 impact crystals remaining sensitive (in the other network) at Station 98.50 probably would not provide a sensitive region geometry which would have a complete annulus as its forward projection, and, in fact, edges would probably have to be taken into account in the probability expressions. If edges must be taken into account (in addition to taking spikes into account) for an annular forward projection having gaps, the probabilities of damage would be considerably increased.

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Fig. 4 -- Arrangement of impact crystals for XW-5/F-101 suggested design (System 3)

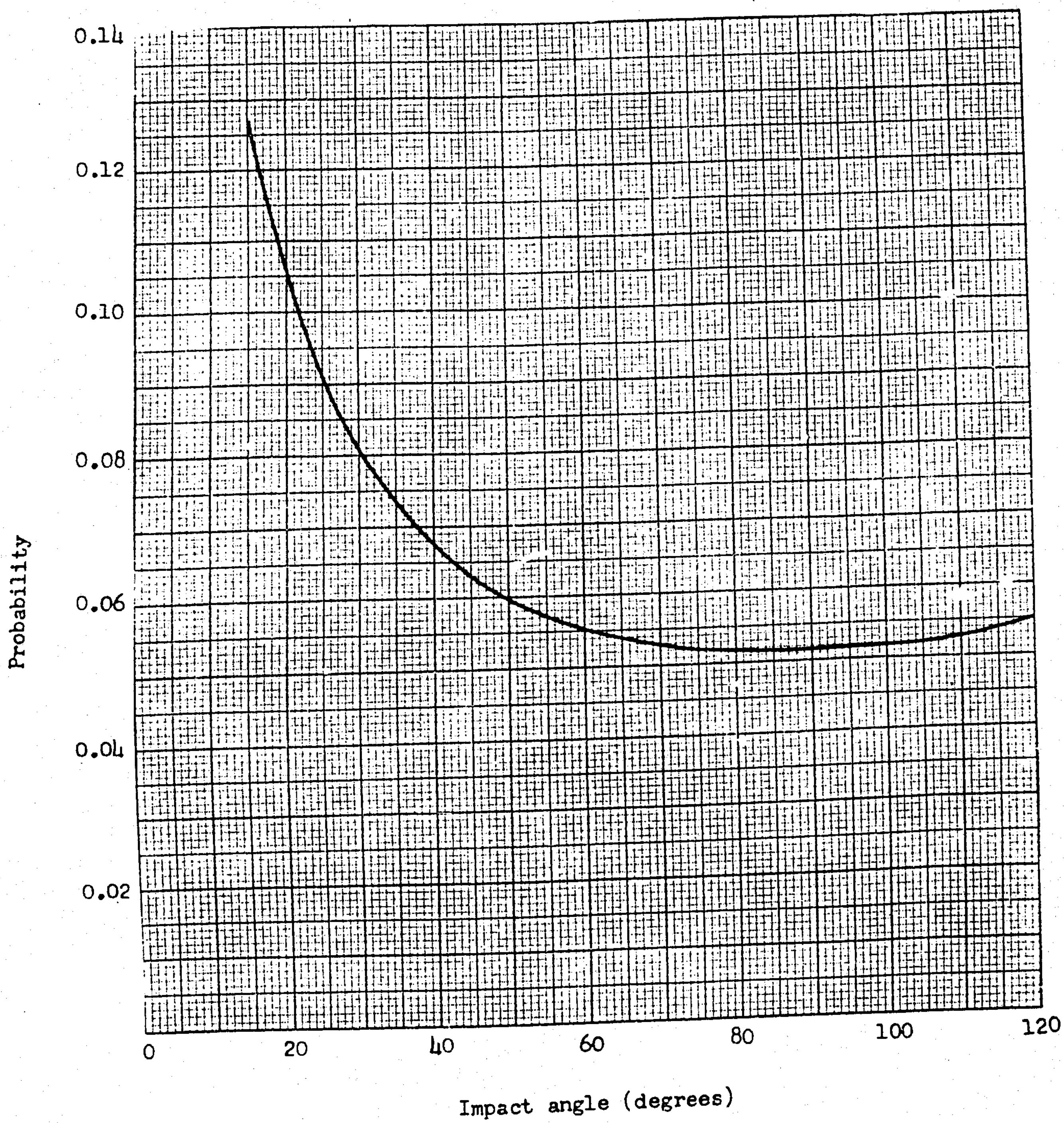

Fig. 5 -- Maximized probability of damage to warhead prior to detonation versus impact angle; for XW-5/F-101 weapon with System 3 contact fuze capability

It is possible that the above statements may also be pertinent to the other design proposal (System 2) since only three MC-300 impact crystals would remain sensitive at Station 98.50 in case of failure of one crystal network. On the other hand, failure of one crystal network of System 3 would leave four MC-300 impact crystals sensitive at Stations 98.50 and therefore would more nearly provide for a sensitive region geometry without gaps and no account would have to be taken of impact with edges in the probability expressions for damage due to impacts on the nose region. Note that the 0.005 increase in probability of damage for System 3 (as compared to Systems 1 and 2) is of the same order as the probability of failure of one network.

On the basis of the foregoing discussion it would appear that the suggested design (System 3) using eight MC-300 impact crystals mounted at Station 98.50 and connected in two networks should be seriously considered as competition for the two design proposals (System 1 and 2), particularly if the assumption of annular forward projections of the sensitive regions fails to be satisfied for the two design proposals.

Another consideration in the study of contact fuze capability for the XW-5/F-101 weapon is the relative contribution to the total probability of warhead damage of impacts on the nose region (forward of Sta 98.50) and of impacts on the rear region (aft of Sta 98.50). A comparison of these probabilities for the design proposal contact fuze capabilities (assuming annular forward projections of the sensitive region) is provided by Table IV.

TABLE IV

Maximized Probabilities of Warhead Damage Prior to Detonation for XW-5/F-101 Weapon with Design Proposal Contact Fuze Capabilities

	Maximized probability of damage	
Impact angle (degrees)	Impact on nose region (forward of Sta 98.50)	Impact on rear region (aft of Sta 98.50)
15	0.006	0.117
30	0.011	0.064
45	0.010	0.047
60	0.010	0.040
75	0.010	0.037
90	0.010	0.036
105	0.010	0.037
120	0.010	0.040

Note that the contribution to the total probability of warhead damage from impact on the rear region is at least three times the contribution from impacts on the nose region.

Ideally, a double-shell type system could provide the contact fuze capability for the XW-5/F-101, or any other, atomic weapon. If a double-shell type system is not feasible, the next choice of contact fuze system would consist of ring-type protection (designated as System 4), as indicated for the XW-5/F-101 weapon in Fig. 6. Note that the sensitive ring covers most of the rear region to the vicinity of the maximum diameter of the weapon case and all of the nose region with the exception of access space for the inflight insertion mechanism (IFI). The required rearward extent of the sensitive ring is a function of the following considerations:

1. Expected angles of attack,
2. Geometry of the contact fuze arrangement,
3. Sensitivity of the contact fuzes,
4. Transmission characteristics of the sensitive ring,
5. Delay time from impact to firing,
6. Geometry of the warhead, and
7. Amount of damage (penetration) the warhead can sustain without degradation of performance.

Note that all of the above considerations imply that the sensitive ring need not extend rearward all the way to the maximum diameter of the weapon. Furthermore, the probabilities of damage associated with impacts on the rear region diminish markedly with the additional protection afforded by the sensitive ring arrangement. The effect of rearward extension of the sensitive ring on the probability of warhead damage resulting from impacts on the rear region is illustrated by the calculated values listed in Table V and plotted in Fig. 7. The probability of damaging penetration decreases with rearward extent of the sensitive region of the sensitive ring mounted at Station 98.50.

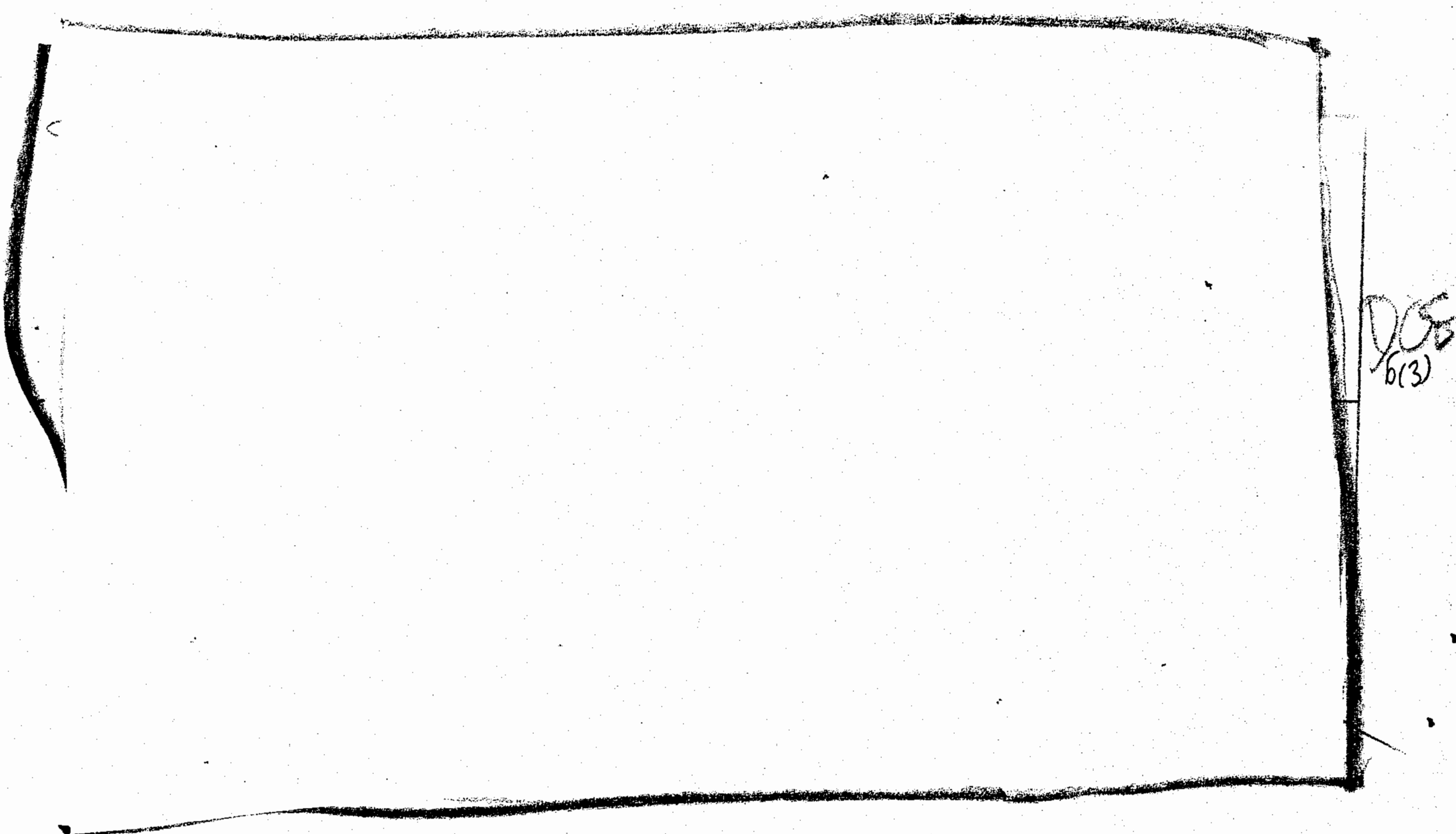

Fig. 6 -- Arrangement of ring-type contact fuze system for XW-5/F-101 suggested design (System 4)

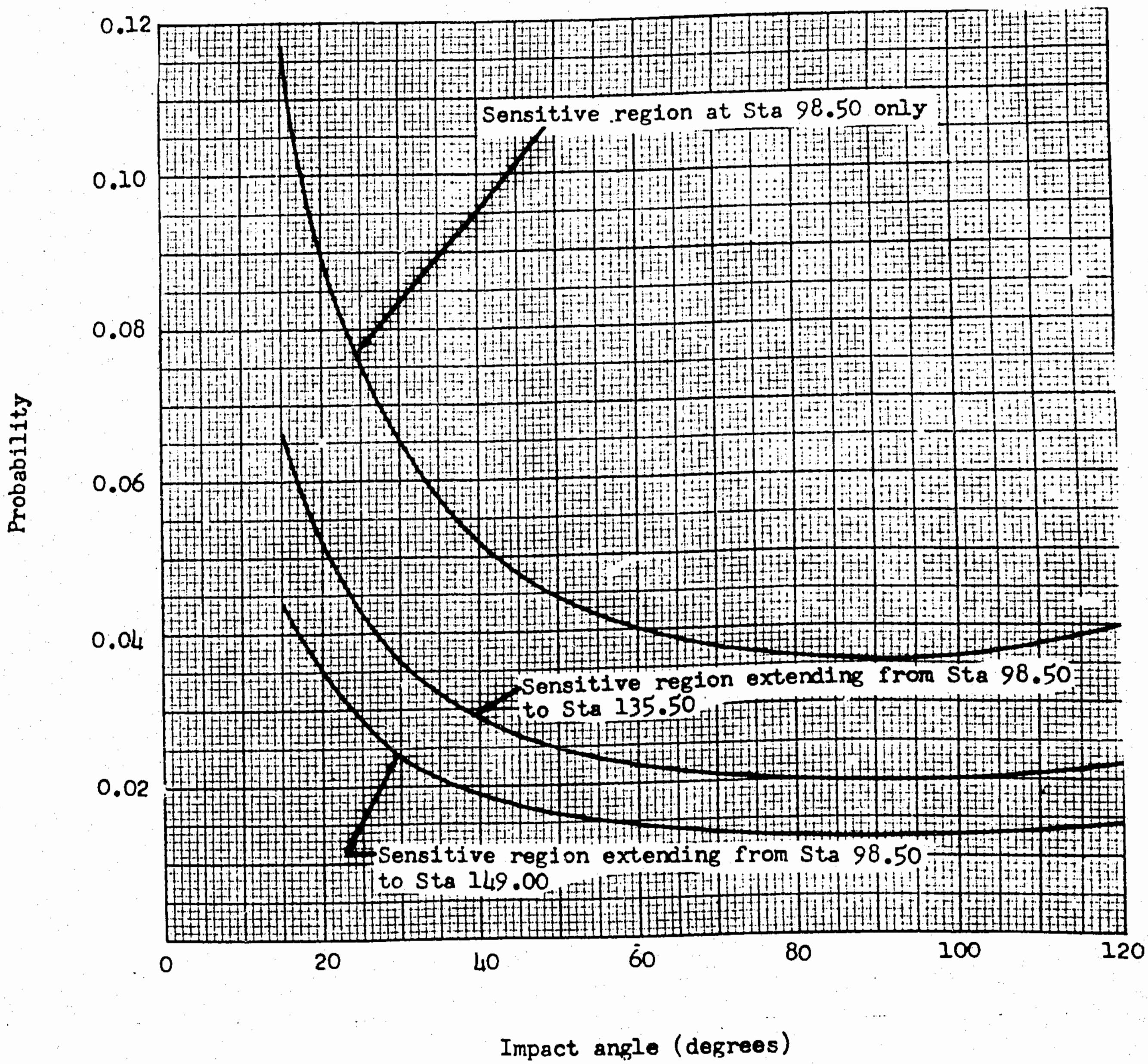

Fig. 7 -- Maximized probabilities of damage to warhead prior to detonation versus impact angle; for XW-5/F-101 weapon with System 4 contact fuze capability

TABLE V

Maximized Probabilities of Warhead Damage Prior to Detonation for XW-5/F-101 Weapon with System 4 Contact Fuze Capability

Impact angle (degrees)	Maximized probability of damage — Extent of rear sensitive region: Sta 98.50 only	Sta 98.50 to Sta 135.50	Sta 98.50 to Sta 149.00
15	0.117	0.066	0.044
30	0.064	0.036	0.024
45	0.047	0.027	0.017
60	0.040	0.022	0.014
75	0.037	0.020	0.013
90	0.036	0.020	0.013
105	0.037	0.020	0.013
120	0.040	0.022	0.014

In calculating the above probability values for System 4, it was assumed that the contour of the sensitive ring along its extent is approximately the same as that of the weapon case and that the material of the sensitive ring has sufficiently good transmission characteristics to give the assumed sensitivity for a given arrangement of impact crystals. Note that the extent of the rear sensitive region refers to the extent of sensitivity, not the simple geometric extent of the ring itself. Also, note that the addition of the annular plate attached to the sensitive ring at Station 98.50 serves to decrease the probabilities of damage from impacts on the nose region. Such an arrangement would be similar to that shown in Fig. 6.

The important consideration in the design of any contact fuze capability is the effect on the probability of damage to the warhead brought about by increasing the rearward extent of the sensitivity of the sensitive ring mounted at Station 98.50. It is clear that greater gains (i.e., decreased probability of warhead damage) are purchased by this method (System 4) than by the suggested design using eight impact crystals mounted at Station 98.50 (System 3).

CONCLUSIONS

The calculated results, presented in this memorandum, show that for the higher impact angles either of the design proposal contact fuze arrangements leads to probabilities of damages to vital components prior to detonation in the neighborhood of 0.050. If a choice must be made between the two proposed design systems, the one using six crystals per mounting is preferred, simply because the arrangement more nearly satisfies the assumptions implicit in the calculations.

In the Section titled COMMENTS AND RECOMMENDATIONS it was shown that a suggested design (System 3) for the contact fuze capability, using eight impact crystals mounted at Station 98.50, would yield probabilities in the neighborhood of the probabilities determined for either of the design proposals (Systems 1 and 2) and, in addition, has advantages of simplicity and reliability not present in either of the design proposals.

It was further shown that, in the sense of decreased probabilities of damage, a better solution to the problem is provided by a sensitive ring (mounted at Station 98.50) having a sensitive region extending rearward toward the major diameter of the weapon. The reduction in probability of damage to be attained from this suggested design (System 4) is a direct function of the rearward extent of the increased sensitive region, up to a certain point. No further reduction in probability of damage accrues from further extension of the sensitive region.

C. R. McALLISTER - 5132

REFERENCES

1. Memorandum, E. H. Draper, 1240, to K. W. Erickson, 5130, Probability Study on Impact Fuzing System of XW-5/F-101, November 2, 1954, Ref. Sym: 1240 (1685).

2. McAllister, C. R., On the Estimation of the Probability of Damage to Vital Components in Contact-Fuzed Atomic Weapons, Sandia Corporation, October 1954, SC-2875(TR).

3. Air Force Special Weapons Center, McDonnell Aircraft Corporation, and Sandia Corporation, XW-5/F-101 Weapon Status and Program Report, Sandia Corporation, August 11, 1954, SC-3245(TR).

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ADDENDUM

Sandia Corporation Technical Memorandum 283-54-51

(The author recommends that this addendum, prepared on 15 June 1955, be inserted following page 19 of the original Technical Memorandum.)

This addendum arises from a request* to re-evaluate the maximized probabilities of damage to the warhead (prior to detonation) for the XW-5/F101 weapon in light of new information from the latest gun test results.**

The essential changes between the calculations of Technical Memorandum 283-54-51 and those of this addendum are the following:

1. The angle of attack of the weapon is assumed to be at most 3 degrees for the recalculations, rather than the 5 degrees of the original calculations;

2. The sensitive region of the case is assumed to extend from forward of Station 30 to Station 120.00, rather than being simply two small annuli in the neighborhoods of Stations 30 and 98.5.

The calculations of the probabilities in question, with the changes listed above, result in essentially zero values for all impact angles. That is, the maximized probability of warhead damage prior to detonation may be quoted as zero for the XW-5/F101 weapon.

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* Memorandum, C. H. DeSelm, 1210 to K. W. Erickson, 5130, Probability Study on Impact Fuzing System of XW-5/F-101, Ref. Sym: 1210 (79), May 23, 1955.

** Rhodes, R. S., 1216, Crystal Impact Fuzing System Test on the XW-5/F-101 Type C Store, Technical Memorandum 114-55-12, May 31, 1955.

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