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Report on Screw Fastened Sheet Steel Connections for Canadian Steel Industries Construction Council, Volume I

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VOLUME I

REPORT ON

SCREW FASTENED SHEET STEEL CONNECTIONS

FOR

CANADIAN STEEL INDUSTRIES CONSTRUCTION COUNCIL

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ABSTRACT

Ultimate load data is presented from more than 1600 tests on sample connections made with different thicknesses of zinc-coated sheet steel and a variety of commonly used thread forming and self-drilling fasteners. The three fundamental loading conditions examined were pull-over, pull-out and single lap shear.

Empirical relationships have been developed which allow interpolation of the data within the range of sheet steel thicknesses tested.

Type AB and type A thread forming fasteners, and a number of different self-drilling fasteners were tested, in sizes from #14 (.250 in.) to #8 (.164 in.) diameter. Flat metal washers and a variety of sealing washers were also used in combination with the different fastener types and head styles.

The thicknesses of steel sheets ranged from .022 in. to .060 in. depending on the particular loading condition being tested. The sheet material was ductile and of medium strength and hardness.

All fastener connections tested under all loading conditions achieved higher failure loads with thicker steel sheets.

The #14 (.250 in.) diameter fasteners of each type gave significantly higher connection failure loads in most sheet thicknesses than the other fastener sizes. Connections with #12 (.216 in.), #10 (.190 in.) and #8 (.164 in.) diameter fasteners showed only marginal differences in ultimate load.

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PREFACE

This investigation was jointly sponsored by the Canadian Steel Industries Construction Council (CSICC) and Dominion Foundries & Steel Limited (DOFASCO). The advise and contributions to this work from the members of the Industry Research Subcommittee is gratefully acknowledged.

Special thanks are given to the fastener manufacturers for their advise and donation of samples for testing, and to Derek Tarlton of the Canadian Sheet Steel Building Institute (CSSBI) for his advice and assistance in preparing this report.

The self-drilling fasteners generally provided higher connection failure loads than the thread forming fasteners of equal diameter.

The addition of washers produced a noticeable and consistent failure load increase in the pull-over mode only.

Subjecting a connection to a fluctuating shear load resulted in a substantial failure load increase.

INTRODUCTION

Mechanical fasteners can be found in virtually every man-made mechanism, machine or structure. The variety of types, sizes and shapes is staggering; it is estimated that there are 1/2 million different "standard" and 3 million different "non-standard" fasteners used in the world. Many of these are screw fasteners, used to connect cold-formed steel sheet products to each other and to structural elements.

The use of both bolts and welding for structural connections has been extensively researched and design information is easily obtained from many sources. For sheet metal and self-drilling screws however, similar information is not so readily available. The designer must either rely entirely on the manufacturers to provide him with suitable fasteners for his particular design conditions, or conduct his own set of tests, or rely on previous practice and experience.

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Manufacturers have carried out tests in order that they may guarantee the performance of their product, but to the best of our knowledge, the test procedures varied and the information released to the user was sometimes of limited application.

This report contains ultimate load information and performance characteristics obtained from a large number of tests on some of the more common types and sizes of fasteners used in structural applications. It provides the designer with information which will enable him to select a type and size of fastener, giving him a better idea of the maximum loads attainable from a connection using that fastener and indicate to him the loading condition for which the connection is likely to be critical.

The fasteners chosen for these series of tests by no means cover the entire range available. The intention was only to obtain a general sampling of some of the more commonly used fasteners in the hope that in time this information will be expanded to encompass other fasteners of practical importance.

PULL-OVER

The pull-over test is designed to evaluate the load carrying capabilities of a screw-fastened connection between a thin steel sheet and a heavier structural section or element. The connection is subjected to a force perpendicular to the plane of interconnection, tending to pull the thin sheet over the head assembly of the fastener.

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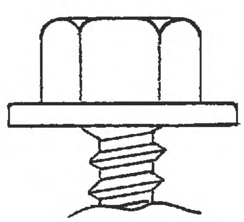
Some 340 samples were tested in pull-over with a variety of fasteners and washers, in different thicknesses of steel sheet. The results have been analysed in terms of diameter and rigidity (or bending resistance) of the fastener head assembly and the thickness of the sheet steel. These parameters, as well as the tensile strength of the steel sheet, are felt to have a significant effect on the pull-over failure load of a connection.

The test results confirm that the ultimate pull-over load of a screw-fastened connection increases with increasing steel sheet thickness.

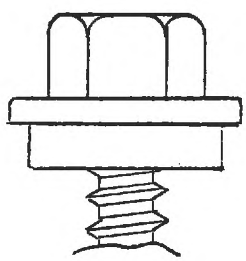
Although sheet mechanical properties were not under investigation, there was a 17 percent difference in tensile strength between two sheet samples of equal thickness. There was a small but consistent failure load increase attributed to the higher strength sheet.

The pull-over strength of a connection may be increased in several different ways:

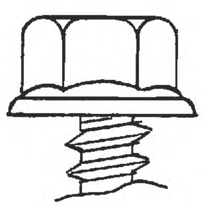


(i) The addition of a rigid thick flat metal washer (i.e. one that will withstand the bending forces with little or no deformation) can increase the pull-over strength by up to 67 percent. (Figure A-I) The actual percentage increase will largely depend on the thichness of the sheet steel under the washer. These add-on washers were also observed to give better results with thicker steel sheets. In some instances, when the sharp edge of a rigid washer contacted a thin steel sheet, the washer acted as a punch, shearing a disc out of the sheet. (Figure A-VII[g]). This occurred at a load slightly below that of the common failure mode.

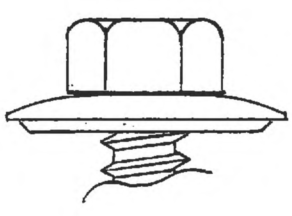
(ii) The addition of a neoprene sealing washer generally resulted in a 5 to 10 percent decrease in the failure load of a connection. This was mainly due to the neoprene extending beyond the outer edge of the washer or fastener head when tightened, preventing contact between sheet and fastener head as the sheet was deformed over it. The bite of the head against the sheet is effectively reduced and tensile sheet failure is allowed to occur uninterrupted at a slightly reduced load. (Figure A-I)



(iii) A hex-washer-headed fastener (i.e. a hex-head with an integral washer) produced a pull-over load increase of up to 60 percent over a regular hex-headed fastener of similar type and diameter. (Figure A-I)



(iv) Thin metal conical washers made of galvanized steel with bonded rubber seals increased the connection failure load 10 to 30 percent over that obtained with plain hex-headed fasteners.



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(As compared to the 67 percent maximum increase with thick metal washers.) Although these washers had a larger clamping area, they had less bending resistance and deformed more easily under pull-over action. (Figure A-I)

The actual connection failure loads are tabulated in Appendix A Table A-I.

The action of wind on a building results in a negative wind pressure, generally on the leeward side, and subjects the cladding to uplift forces. These pressures, which act on roofs as well as walls, put cladding fasteners into a pull-over loading condition.

Examination of Table A-I for pull-over mode reveals that in all cases the ultimate loads were in excess of fastener design loads based on calculations of maximum uplift for pitched roofs under normal climatic conditions for the Hamilton area. Even with modification factors of 2.25 to 3 for imperfect workmanship and long term loading, the failure loads per fastener are still higher than calculated valves.

PULL-OUT

The pull-out test series provides ultimate load information on screw-fastened connections made between two thin sheet steel elements. As in the case of pull-over, the connection is subjected to a force perpendicular to the plane of interconnection. The test fixture has been designed so that failure occurs by the gradual and extremely localized deformation of the bottom sheet, as the fastener threads are disengaged from the hole into which they were screwed. (Figure A-VII [j]).

Some 310 samples have been tested in pull-out with a variety of fastener types and sizes, in different thicknesses of sheet steel. In this case the results were analysed in terms of fastener diameter and thread type, predrilled hole diameter and sheet steel thickness.

Again, the results confirm that the thicker the sheet into which the fastener is screwed, the greater will be the connection failure load. (Figure A-II) In the thicker sheets, the amount of material that engages the thread is greater and therefore more material must be deformed or sheared if a pull-out failure is to occur.

In the range of sheet thicknesses tested, the number of threads engaging the sheet did not influence the ultimate load of the connection as much as the amount of overlap between the thread and the sheet (i.e. the height of the threads).

This overlap is greatest in fasteners with fewer threads per inch and/or where the predrilled hole diameter is less than or equal to the fastener minor diameter. Samples exhibiting these characteristics produced higher pull-out failure loads.

Of the fastener diameters tested, the #14 (.250 in.) of all types consistently gave higher ultimate loads than the #12 (.216 in.), #10 (.190 in.), #8 (.164 in.) diameters, in all sheet thicknesses. Results for the #12, #10 and #8 fastener sizes were generally grouped very close together with a maximum difference of only 80 lbs. per fastener between them (i.e. less than 13 percent total variation). (Figure A-III)

The reasons for this are:

(i) The difference between fastener minor diameter and the recommended predrilled hole diameter is consistently less with #14 fasteners than with the smaller diameters.

(ii) There is generally greater thread depth with the #14 diameters. Both of these conditions lead to better engagement with #14 fasteners and small engagement differences between the other diameters.

Connections with self-drilling fasteners more consistently exhibited higher pull-out failure loads in thicker sheets than thread forming screws. This is the case because the manufacturers of self-drilling fasteners are able to control the size of the predrilled hole, since they provide the drill on the end of the fastener. In many instances, in particular for stitching applications (i.e. two thin sheets connected together) the drill diameter is less than the minor diameter of the threaded section. This gives rise to an interference fit and assures maximum thread engagement. This effect has also been achieved by providing a slightly tapered shank. If the amount of interference is large enough, work hardening of the steel sheet in the vicinity of the hole may be initiated, thereby increasing its resistance to bending and shear.

In some instances of type AB and more commonly type A, in thinner sheets, the predrilled hole diameters recommended in American Standard B18.6.4 Appendix VII also provide for this interference fit. The result is a marked increase in the connection pull-out failure load.

The actual results are tabulated in Appendix A Table A-I.

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The results for each fastener type and diameter have been plotted by computer and a third order polynomial curve has been developed to fit the data. The coefficients of these polynomial expressions are given in Table A-II and allow for accurate interpolation of the data. Extrapolation of the data may give erroneous information and is not recommended at this stage.

SHEAR

In the shear test series, screw-fastened connections between two thin steel sheets in a single lap configuration were evaluated. The connections were subjected to forces parallel, initially, to the plane of interconnection and failure occurred in a number of different ways, depending on the thicknesses of the two sheets used.

(i) The most common mode of failure was the tilting of the fastener in the direction of the applied force and the elongation of the hole in the sheet. For samples of unequal thickness, (the thinner sheet always under the fastener head) there was a build-up of material under the head and ultimate failure resulted by the thinner sheet tearing or curling up over the head of the fastener. For samples of equal thickness this material build-up was observed in the bottom sheet and failure by disengagement of the inclined fastener out of the bottom sheet occurred. (Figure A-VII [n])

(ii) In connections made between two of the thicker sheets (i.e. .0485 in. to .060 in. etc.) and fastened with a #8 (.164 in.) diameter or a #10 (.190 in.) diameter fastener, the heads of one or both fasteners, on occasion, sheared off. In the case where only one of the two fasteners sheared off, it was generally the one closer to the free end of the sheet directly under the head. (Figure A-VII [0]) A noticeable drop in ultimate load was associated with samples failing in this mode.

(iii) In some instances, where thin sheets were connected to thicker ones (i.e. .025 in. to .060 in.) by a #14 (.250 in.) diameter fastener, a tensile sheet failure would occur in the thinner sample at the location of the second fastener from the free end. (Figure A-VII[n])

Some 960 samples have been tested in shear with a variety of types and sizes of fasteners in different sheet steel thickness combinations. Of these samples, 162 had previously been subjected to a cyclic loading to enable dynamic effects to be examined.

The test results confirm that the thicker sheets gave higher connection shear failure loads. Connections made between two .060 in. thick sheets produced higher failure loads than connections between .025 in. and .060 in. thick sheets which, in turn, produced higher failure loads than connections between .025 in. and .025 in. thick sheets.

In most sheet thicknesses, all #14 (.250 in.) diameter fasteners gave higher connection shear failure loads than the smaller diameters. The maximum difference in failure load between connections using a #10 (.190 in.) and those using a #8 (.164 in.) diameter fastener was 170 pounds per fastener (i.e. less than 12 percent total variation).

The addition of flat metal and rubber sealing washers to these shear connection fasteners made differences of less than 10 percent to the results. No consistencies were observed in these differences, thus the presence of a washer can be said to have little beneficial effect on the shear strength of the connection.

The effect of a fluctuating shear load on the connections was investigated by applying 75 percent of the previously determined static shear failure load and returning to zero. This was repeated at a frequency of 20 Hz for 5,000 cycles and the sample retested statically. The result was a consistent failure load increase of 18 percent to 50 percent, apparently due to work hardening of the material around the hole.

The ultimate loads recorded for each fastener connection have been plotted by computer and empirical relations derived, which enable interpolation of the data. Extrapolation is not recommended as the continuation of the relationship is uncertain.

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Coefficients for these empirical relations are tabulated in Appendix A Table A-II. Actual results are given in Appendix A Table A-I.

RECOMMENDATIONS

It was not the intention of this project to determine whether any particular fastener, washer or combination was superior. The information obtained is by no means comprehensive and more extensive research is recommended before reliable design standards can be established. The following recommendations are intended to point out some areas of importance and to act as a guideline for further research.

1. Investigate the relationship between pull-over strength and fastener head or washer diameter for a larger range of sheet steel thicknesses, mechanical properties and sheet profiles.

2. Determine at which load intolerable permanent deflections occur in the sheet as it is drawn over the fastener head. This may then be a criterion by which all pull-over results can be evaluated for design purposes.

3. Expand the present pull-out and static shear data by incorporating thicker sheets and different material strengths.

4. Examine the effect of varying the driving torque on all connections and loading conditions.

5. Determine the optimum relationship between predrilled hole diameter, fastener size and driving torque.

6. Investigate further the effect of fluctuating loads by varying the frequency and the total number of cycles, not only for shear but for pull-out and pull-over loading conditions as well.

7. Investigate different combinations of the three fundamental loading conditions (e.g. combined shear and pull-out or pull-over).

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APPENDIX A

APPENDIX A

EXPLANATION OF USE

Appendix A contains all the data collected during the test program. Table A-I presents the mean ultimate loads for the various fastener and washer combinations (listed on the left side of the table) for the fundamental loading conditions and sheet steel thicknesses (shown across the top of the table).

To determine the ultimate strength of a particular fastener:

(i) Locate the fastener in the left hand columns.

(ii) Choose the appropriate washer, if any, from column number 4.

(iii) Proceed across the table to the loading condition of interest.

(iv) Locate the appropriate sheet steel thickness within that loading condition.

(v) Read the ultimate load directly.

This table also permits the examination of the ultimate loads for a fastener connection under all loading conditions. This will reveal the weakest condition and probable failure mode.

If the exact sheet thickness desired is not represented in Table A-I, refer to Table A-II which gives the coefficients of a polynomial expression permitting interpolation of the data. It must be emphasized, however, that only interpolation is valid. Extrapolation beyond the test range may give false and misleading information.

Data comparison graphs have been provided as a supplement to the text to enable examination of the relationships between ultimate load and sheet thickness for various fastener types and diameters etc. in the different loading conditions.

Appendix C contains similar information plotted by computer, and exact relationships and data correlation can be seen.

Detailed test information i.e. test procedures, material and fastener specifications, etc. is presented in Appendix B.

Appendices B and C are presented under separate cover in Volume II.

MEAN ULTIMATE LOAD PER FASTENER (POUNDS) — TABLE A-I

FASTENER DIAMETER	THREAD TYPE	HEAD TYPE	ADD-ON WASHER	PULL-OVER * .022" (26 GA)	PULL-OVER .023" (26 GA)	PULL-OVER * .0239" (24 GA)	PULL-OVER .0278" (24 GA)	PULL-OUT .0312" (22 GA)	PULL-OUT .0402" (20 GA)	PULL-OUT .051" (18 GA)	PULL-OUT .061" (16 GA)	STATIC SHEAR SHEET-TO-SHEET .025" (24 GA)	STATIC SHEAR SHEET-TO-SHEET .033" (22 GA)	STATIC SHEAR SHEET-TO-SHEET .038" (20 GA)	STATIC SHEAR SHEET-TO-SHEET .0485" (18 GA)	STATIC SHEAR SHEET-TO-PLATE .025" (24 GA)	STATIC SHEAR SHEET-TO-PLATE .033" (22 GA)	STATIC SHEAR SHEET-TO-PLATE .038" (20 GA)	STATIC SHEAR SHEET-TO-PLATE .0485" (18 GA)	DYNAMIC SHEAR SHEET-TO-SHEET .033" (22 GA)	DYNAMIC SHEAR SHEET-TO-SHEET .0485" (18 GA)	DYNAMIC SHEAR SHEET-TO-PLATE .033" (22 GA)	DYNAMIC SHEAR SHEET-TO-PLATE .0485" (18 GA)
# 8	A	PAN	—					276	347	441		386	596	708	1036	753	1200	1226	1327				
# 8	A	PAN	FLAT METAL					276	347	441		453	624	755	1082	880	1161	1189	1374				
# 8	AB	H.W.H.	—					288	368	464	552	413	594	783	1020	760	1174	1286	1140				
# 8	AB	H.W.H.	FLAT METAL					288	368	464	552	469	614	785	1032	866	1075	1044	1068				
# 8	TEKS/2F	H.W.H.	—					273	344	496	565	373	573	683	1019	800	1111	1194	1253				
# 8	TEKS/2F	H.W.H.	TWIN SEAL					273	344	496	565	362	593	711	1114	939	1204	1303	1473				
# 8	C	H.W.H.	—					213	356	421	534												
#10	A	PAN	—					336	401	447	488	423	673	790	1073	764	1242	1341	1376	1415	2150	2570	2520
#10	A	PAN	FLAT & NEOPRENE					336	401	447	488	464	670	829	1221	813	1195	1320	1514	1343	2450	2325	2942
#10	AB	PAN	—					273	344	452	557	429	580	743	1035	800	1307	1329	1507	1280		2303	3300
#10	AB	PAN	FLAT & NEOPRENE					273	344	452	557	378	573	731	1110	925	1171	1204	1427	1200		2563	2600
#10	TEKS/1 STITCH	H.W.H.	—									432	609	762	1149	805	1283	1371	1449	1300	2473	2617	2990
#10	TEKS/1 STITCH	H.W.H.	TWIN SEAL									411	601	725	1156	942	1255	1324	1482	1237	2677	2763	3033
#10	TEKS/2	H.W.H.	—					250	371	500	604												
#10	TEKS/3	H.W.H.	—					229	304	443	559												
#12	AB	H.H.	—					279	353	492	556												
#12	TEKS/2 MB/HT	H.W.H.	—					263	384	501	617												
#12	TEKS/2 MB/HT	H.W.H.	TWIN SEAL					263	384	501	617	465	655	802	1207	962	1326	1457	1647				
#12	TEKS/3 PAN.MATCH	PLASTIC HEAD	—	701	666	807	895																
#12	TEKS/4	H.W.H.	—	667	628	861	855																
#14	A	H.W.H.	—					347	423	573	699	515	670	861	1268	921	1400	1547	1581	1363	2417	2703	3240
#14	A	H.W.H.	GALV. & RUBBER					347	423	573	699	463	671	767	1220	1064	1388	1538	1695	1342	2480	2575	3213
#14	AB	H.H.	—	609	643	817	801	350	402	538	633	418	582	834	1375	762	1409	1601	1851	1310	2950	2810	4033
#14	AB	H.H.	FLAT METAL	1107	944	1313	1453	350	402	538	633												
#14	AB	H.H.	FLAT & NEOPRENE	943	855	1161	1283	350	402	538	633												
#14	AB	H.W.H.	GALV. & RUBBER	764	773	899	1056	350	402	538	633	445	586	759	1400	1055	1397	1611	2011	1257	2917	2833	4167
#14	AB	H.W.H.	—	976	1011	1236	1377	350	402	538	633	454	641	849	1303	1055	1358	1408	1591	1517	3033	2743	3353
#14	AB	H.W.H.	FLAT METAL	1161	992	1371	1572	350	402	538	633												
#14	AB	H.W.H.	FLAT & NEOPRENE	1053	944	1262	1279	350	402	538	633												
#14	AB	H.W.H.	GALV. & RUBBER	1081	1068	1337	1401	350	402	538	633												
#14	TEKS/1 STITCH	H.W.H.	—									604	909	1141	1692	702	1058	1644	1852	2037	3437	2280	3820
#14	TEKS/1 STITCH	H.W.H.	TWIN SEAL									473	722	1056	1494	927	1234	1567	2069	1390	2957	2723	3950
#14	TEKS/2 MB	H.W.H.	—					416	523	617	856												
#14	TEKS/3	H.W.H.	—	936	944	1096	1203		381	485	598												
#14	TEKS/3	H.W.H.	TWIN SEAL	1107	1061	1372	1472		381	485	598												

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POLYNOMIAL COEFFICIENTS FOR INTERPOLATION OF ULTIMATE STRENGTH DATA

TABLE A-II-(i)

FASTENER DIA.	THREAD TYPE	HEAD TYPE	PULL-OUT				SHEAR							
							SHEET-TO-SHEET				SHEET-TO-PLATE			
			A $(\times 10^3)$	B $(\times 10^5)$	C $(\times 10^7)$	D $(\times 10^7)$	A $(\times 10^4)$	B $(\times 10^6)$	C $(\times 10^7)$	D $(\times 10^8)$	A $(\times 10^4)$	B $(\times 10^6)$	C $(\times 10^8)$	D $(\times 10^9)$
#8	A	PAN	-.961	.714	-.132	.897	-.342	.313	-.826	.767	-1.18	1.07	-.287	.253
#8	AB	H.W.H.	-.684	.572	-.108	.777	.0562	-.0577	.289	-.311	-.659	.571	-.135	.103
#8	TEKS/2F	H.W.H.	1.44	-.943	.235	-1.70	-.325	.299	-.792	.741	-.564	.522	-.133	.112
#10	A	PAN	-.885	.752	-.148	1.01	-.411	.368	-.953	.856	-.959	.845	-.216	.183
#10	AB	PAN	-.414	.401	-.0768	.609	.0288	-.0192	.137	-.134	-1.40	1.26	-.343	.306
#10	TEKS/1 STITCH	H.W.H.					-.130	.127	-.302	.298	-1.06	.946	-.247	.213
#10	TEKS/2	H.W.H.	-1.01	.686	-.116	.762								
#10	TEKS/3	H.W.H.	.469	-.279	.0818	-.555								
#12	AB	H.H.	.919	-.585	.158	-1.18								
#12	TEKS/2 MB/HT	H.W.H.	-1.82	1.27	-.248	1.74								
#14	A	H.W.H.	.910	-.515	.136	-.931	.0652	-.0422	.189	-.155	-.803	.710	-.175	.143
#14	AB	H.H.					.181	-.158	.526	-.447	-1.23	1.07	-.273	.234
#14	AB	H.W.H.	.672	-.323	.0875	-.592	.00548	.00139	.0759	-.0514	-.697	.680	-.184	.165
#14	TEKS/1 STITCH	H.W.H.					-.283	.259	-.622	.581	.983	-.962	.319	-.319
#14	TEKS/2 MB/HT	H.W.H.	-1.44	1.14	-.231	1.71								
#14	TEKS/3	H.W.H.	-.222	.282	-.0484	.392								

POLYNOMIAL COEFFICIENTS FOR FASTENER TESTS WITH NO WASHERS

POLYNOMIAL OF THE FORM

$Y = A + Bx + Cx^2 + Dx^3$

WHERE X = LEAST SHEET STEEL THICKNESS,
Y = ULTIMATE LOAD PER FASTENER

NOTE: APPLIES TO THE FOLLOWING SHEET STEEL THICKNESS RANGES ONLY

PULL-OUT	.0312	to	.0610
SHEAR	.0275	to	.0640

TABLE A-II-(ii)

POLYNOMIAL COEFFICIENTS FOR INTERPOLATION OF ULTIMATE STRENGTH DATA

FASTENER DIA.	THREAD TYPE	HEAD TYPE	PULL-OUT				SHEAR							
							SHEET-TO-SHEET				SHEET-TO-PLATE			
			A ($x10^3$)	B ($x10^5$)	C ($x10^7$)	D ($x10^7$)	A ($x10^4$)	B ($x10^6$)	C ($x10^7$)	D ($x10^8$)	A ($x10^4$)	B ($x10^6$)	C ($x10^8$)	D ($x10^9$)
#8	A	PAN	-.961	.714	-.132	.897	-.154	.152	-.371	.351	-.721	.693	-.189	.171
#8	AB	H.W.H.	-.684	.572	-.108	.777	.0979	-.0811	.327	-.325	-.869	.836	-.233	.211
#8	TEKS/2F	H.W.H.	1.44	-.943	.235	-1.70	-.416	.377	-1.01	.954	-.410	.408	-.104	.0899
#10	A	PAN	-.885	.752	-.148	1.01	-.187	.177	-.429	.406	-.474	.423	-.0984	.0780
#10	AB	PAN	-.414	.401	-.0768	.609	-.164	.150	-.354	.337	-.622	.614	-.169	.155
#10	TEKS/1 STITCH	H.W.H.					-.447	.407	-1.11	1.05	-.652	.623	-.165	.145
#10	TEKS/2	H.W.H.	-1.01	.686	-.116	.762								
#10	TEKS/3	H.W.H.	.469	-.279	.0818	-.555								
#12	AB	H.H.	.919	-.585	.158	-1.18								
#12	TEKS/2 MB/HT	H.W.H.	-1.82	1.27	-.248	1.74	-.191	.186	-.474	.461	-.597	.559	-.141	.121
#14	A	H.W.H.	.910	-.515	.136	-.931	-.449	.427	-1.20	1.16	-.381	.373	-.0876	.0703
#14	AB	H.H.					-.0760	.0986	-.292	.375	-.334	.333	-.0787	.0678
#14	AB	H.W.H.	.672	-.323	.0875	-.592								
#14	TEKS/1 STITCH	H.W.H.					.277	-.273	.963	-.938	.119	-.0949	.0463	-.0473
#14	TEKS/2 MB/HT	H.W.H.	-1.44	1.14	-.231	1.71								
#14	TEKS/3	H.W.H.	-.222	.282	-.0484	.392								

POLYNOMIAL COEFFICIENTS FOR FASTENER TESTS WITH WASHERS

POLYNOMIAL OF THE FORM
$Y = A + Bx + Cx^2 + Dx^3$
WHERE · X = LEAST SHEET STEEL THICKNESS
Y = ULTIMATE LOAD PER FASTENER

NOTE: APPLIES TO THE FOLLOWING SHEET STEEL THICKNESS RANGES ONLY

PULL-OUT	.0312	to	.0610
SHEAR	.0276	to	.0640

. . . 22

CONVERSION TABLE

From Inches into Millimetres

TABLE A-III

Inch	0	1	2	3	4	5	6	7	8	9	10	11	12	Inch
	—	25.400	50.800	76.200	101.600	127.000	152.400	177.800	203.200	228.600	254.000	279.400	304.800	
1/64	0.397	25.797	51.197	76.597	101.997	127.397	152.797	178.197	203.597	228.997	254.397	279.797	305.197	1/64
1/32	0.794	26.194	51.594	76.994	102.394	127.794	153.194	178.594	203.994	229.394	254.794	280.194	305.594	1/32
3/64	1.191	26.591	51.991	77.391	102.791	128.191	153.591	178.991	204.391	229.791	255.191	280.591	305.991	3/64
1/16	1.588	26.988	52.388	77.788	103.188	128.588	153.988	179.388	204.788	230.188	255.588	280.988	306.388	1/16
5/64	1.984	27.384	52.784	78.184	103.584	128.984	154.384	179.784	205.184	230.584	255.984	281.384	306.784	5/64
3/32	2.381	27.781	53.181	78.581	103.981	129.381	154.781	180.181	205.581	230.981	256.381	281.781	307.181	3/32
7/64	2.778	28.178	53.578	78.978	104.378	129.778	155.178	180.578	205.978	231.378	256.778	282.178	307.578	7/64
1/8	3.175	28.575	53.975	79.375	104.775	130.175	155.575	180.975	206.375	231.775	257.175	282.575	307.975	1/8
9/64	3.572	28.972	54.372	79.772	105.172	130.572	155.972	181.372	206.772	232.172	257.572	282.972	308.372	9/64
5/32	3.969	29.369	54.769	80.169	105.569	130.969	156.369	181.769	207.169	232.569	257.969	283.369	308.769	5/32
11/64	4.366	29.766	55.166	80.566	105.966	131.366	156.766	182.166	207.566	232.966	258.366	283.766	309.166	11/64
3/16	4.763	30.163	55.563	80.963	106.363	131.763	157.163	182.563	207.963	233.363	258.763	284.163	309.563	3/16
13/64	5.159	30.559	55.959	81.359	106.759	132.159	157.559	182.959	208.359	233.759	259.159	284.559	309.959	13/64
7/32	5.556	30.956	56.356	81.756	107.156	132.556	157.956	183.356	208.756	234.156	259.556	284.956	310.356	7/32
15/64	5.953	31.353	56.753	82.153	107.553	132.953	158.353	183.753	209.153	234.553	259.953	285.353	310.753	15/64
1/4	6.350	31.750	57.150	82.550	107.950	133.350	158.750	184.150	209.550	234.950	260.350	285.750	311.150	1/4
17/64	6.747	32.147	57.547	82.947	108.347	133.747	159.147	184.547	209.947	235.347	260.747	286.147	311.547	17/64
9/32	7.144	32.544	57.944	83.344	108.744	134.144	159.544	184.944	210.344	235.744	261.144	286.544	311.944	9/32
19/64	7.541	32.941	58.341	83.741	109.141	134.541	159.941	185.341	210.741	236.141	261.541	286.941	312.341	19/64
5/16	7.938	33.338	58.738	84.138	109.538	134.938	160.338	185.738	211.138	236.538	261.938	287.338	312.738	5/16
21/64	8.334	33.734	59.134	84.534	109.934	135.334	160.734	186.134	211.534	236.934	262.334	287.734	313.134	21/64
11/32	8.731	34.131	59.531	84.931	110.331	135.731	161.131	186.531	211.931	237.331	262.731	288.131	313.531	11/32
23/64	9.128	34.528	59.928	85.328	110.728	136.128	161.528	186.928	212.328	237.728	263.128	288.528	313.928	23/64
3/8	9.525	34.925	60.325	85.725	111.125	136.525	161.925	187.325	212.725	238.125	263.525	288.925	314.325	3/8
25/64	9.922	35.322	60.722	86.122	111.522	136.922	162.322	187.722	213.122	238.522	263.922	289.322	314.722	25/64
13/32	10.319	35.719	61.119	86.519	111.919	137.319	162.719	188.119	213.519	238.919	264.319	289.719	315.119	13/32
27/64	10.716	36.116	61.516	86.916	112.316	137.716	163.116	188.516	213.916	239.316	264.716	290.116	315.516	27/64
7/16	11.113	36.513	61.913	87.313	112.713	138.113	163.513	188.913	214.313	239.713	265.113	290.513	315.913	7/16
29/64	11.509	36.909	62.309	87.709	113.109	138.509	163.909	189.309	214.709	240.109	265.509	290.909	316.309	29/64
15/32	11.906	37.306	62.706	88.106	113.506	138.906	164.306	189.706	215.106	240.506	265.906	291.306	316.706	15/32
31/64	12.303	37.703	63.103	88.503	113.903	139.303	164.703	190.103	215.503	240.903	266.303	291.703	317.103	31/64
1/2	12.700	38.100	63.500	88.900	114.300	139.700	165.100	190.500	215.900	241.300	266.700	292.100	317.500	1/2
33/64	13.097	38.497	63.897	89.297	114.697	140.097	165.497	190.897	216.297	241.697	267.097	292.497	317.897	33/64
17/32	13.494	38.894	64.294	89.694	115.094	140.494	165.894	191.294	216.694	242.094	267.494	292.894	318.294	17/32
35/64	13.891	39.291	64.691	90.091	115.491	140.891	166.291	191.691	217.091	242.491	267.891	293.291	318.691	35/64
9/16	14.288	39.688	65.088	90.488	115.888	141.288	166.688	192.088	217.488	242.888	268.288	293.688	319.088	9/16
37/64	14.684	40.084	65.484	90.884	116.284	141.684	167.084	192.484	217.884	243.284	268.684	294.084	319.484	37/64
19/32	15.081	40.481	65.881	91.281	116.681	142.081	167.481	192.881	218.281	243.681	269.081	294.481	319.881	19/32
39/64	15.478	40.878	66.278	91.678	117.078	142.478	167.878	193.278	218.678	244.078	269.478	294.878	320.278	39/64
5/8	15.875	41.275	66.675	92.075	117.475	142.875	168.275	193.675	219.075	244.475	269.875	295.275	320.675	5/8
41/64	16.272	41.672	67.072	92.472	117.872	143.272	168.672	194.072	219.472	244.872	270.272	295.672	321.072	41/64
21/32	16.669	42.069	67.469	92.869	118.269	143.669	169.069	194.469	219.869	245.269	270.669	296.069	321.469	21/32
43/64	17.066	42.466	67.866	93.266	118.666	144.066	169.466	194.866	220.266	245.666	271.066	296.466	321.866	43/64
11/16	17.463	42.863	68.263	93.663	119.063	144.463	169.863	195.263	220.663	246.063	271.463	296.863	322.263	11/16
45/64	17.859	43.259	68.659	94.059	119.459	144.859	170.259	195.659	221.059	246.459	271.859	297.259	322.659	45/64
23/32	18.256	43.656	69.056	94.456	119.856	145.256	170.656	196.056	221.456	246.856	272.256	297.656	323.056	23/32
47/64	18.653	44.053	69.453	94.853	120.253	145.653	171.053	196.453	221.853	247.253	272.653	298.053	323.453	47/64
3/4	19.050	44.450	69.850	95.250	120.650	146.050	171.450	196.850	222.250	247.650	273.050	298.450	323.850	3/4
49/64	19.447	44.847	70.247	95.647	121.047	146.447	171.847	197.247	222.647	248.047	273.447	298.847	324.247	49/64
25/32	19.844	45.244	70.644	96.044	121.444	146.844	172.244	197.644	223.044	248.444	273.844	299.244	324.644	25/32
51/64	20.241	45.641	71.041	96.441	121.841	147.241	172.641	198.041	223.441	248.841	274.241	299.641	325.041	51/64
13/16	20.638	46.038	71.438	96.838	122.238	147.638	173.038	198.438	223.838	249.238	274.638	300.038	325.438	13/16
53/64	21.034	46.434	71.834	97.234	122.634	148.034	173.434	198.834	224.234	249.634	275.034	300.434	325.834	53/64
27/32	21.431	46.831	72.231	97.631	123.031	148.431	173.831	199.231	224.631	250.031	275.431	300.831	326.231	27/32
55/64	21.828	47.228	72.628	98.028	123.428	148.828	174.228	199.628	225.028	250.428	275.828	301.228	326.628	55/64
7/8	22.225	47.625	73.025	98.425	123.825	149.225	174.625	200.025	225.425	250.825	276.225	301.625	327.025	7/8
57/64	22.622	48.022	73.422	98.822	124.222	149.622	175.022	200.422	225.822	251.222	276.622	302.022	327.422	57/64
29/32	23.019	48.419	73.819	99.219	124.619	150.019	175.419	200.819	226.219	251.619	277.019	302.419	327.819	29/32
59/64	23.416	48.816	74.216	99.616	125.016	150.416	175.816	201.216	226.616	252.016	277.416	302.816	328.216	59/64
15/16	23.813	49.213	74.613	100.013	125.413	150.813	176.213	201.613	227.013	252.413	277.813	303.213	328.613	15/16
61/64	24.209	49.609	75.009	100.409	125.809	151.209	176.609	202.009	227.409	252.809	278.209	303.609	329.009	61/64
31/32	24.606	50.006	75.406	100.806	126.206	151.606	177.006	202.406	227.806	253.206	278.606	304.006	329.406	31/32
63/64	25.003	50.403	75.803	101.203	126.603	152.003	177.403	202.803	228.203	253.603	279.003	304.403	329.803	63/64

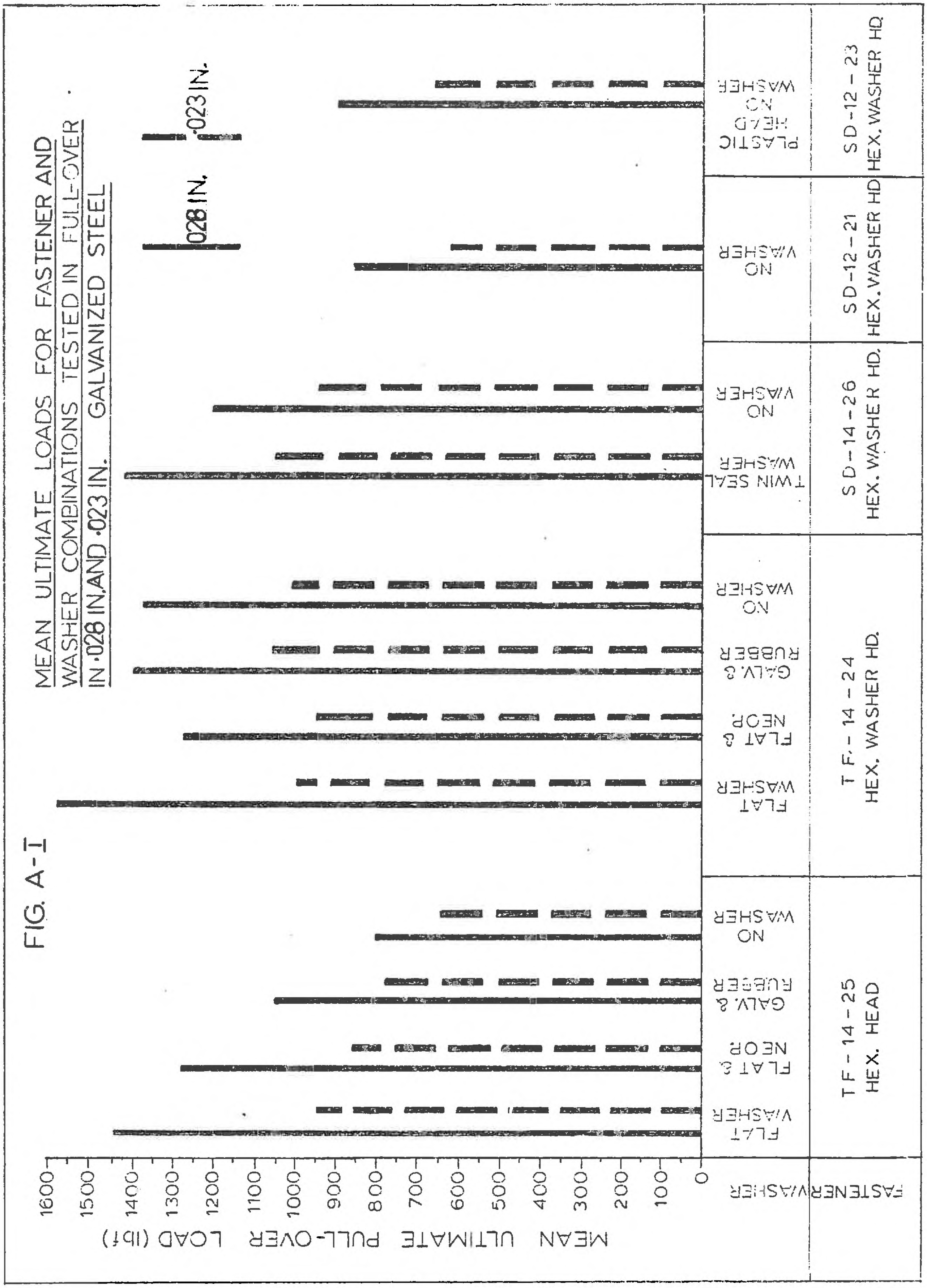
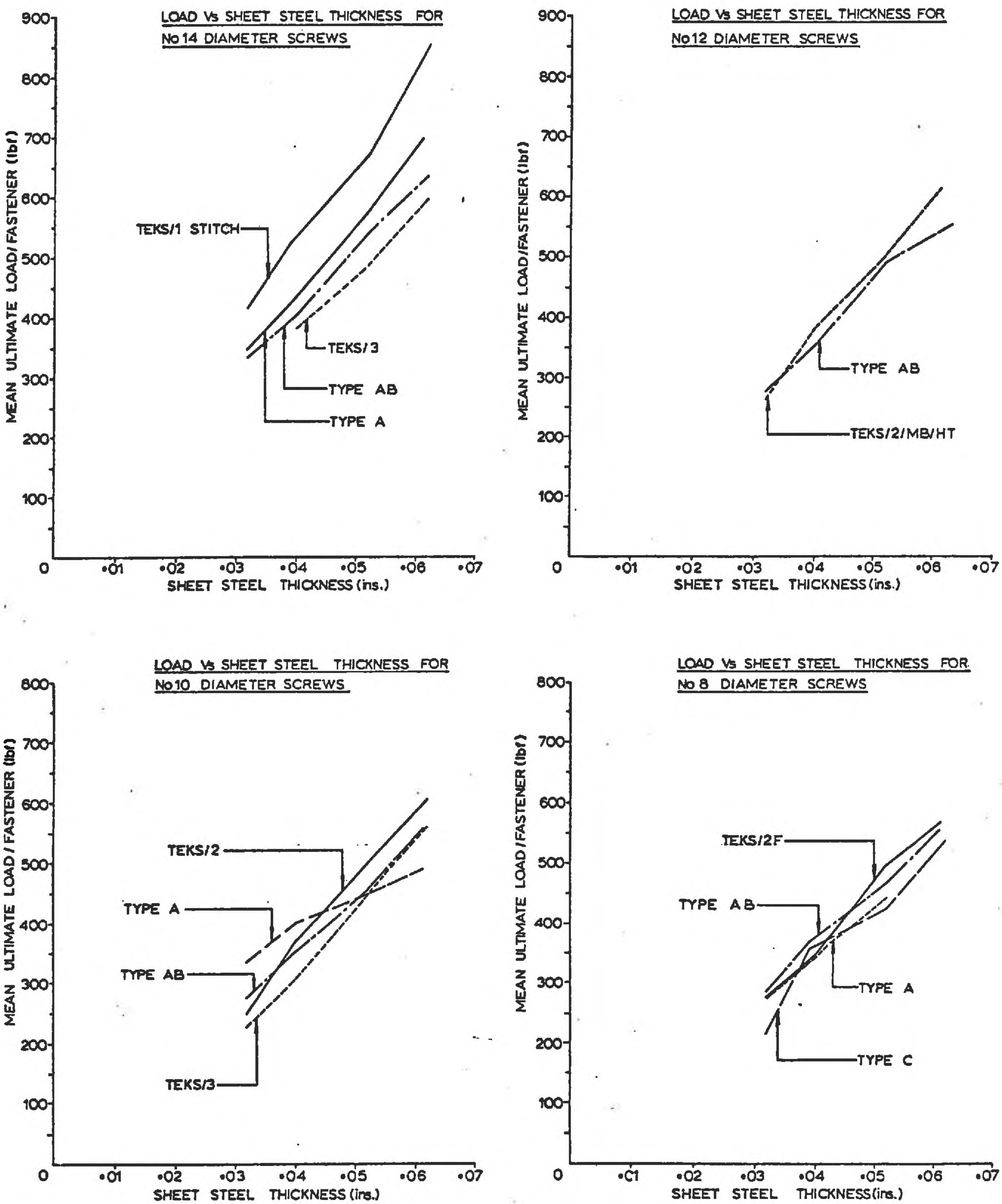


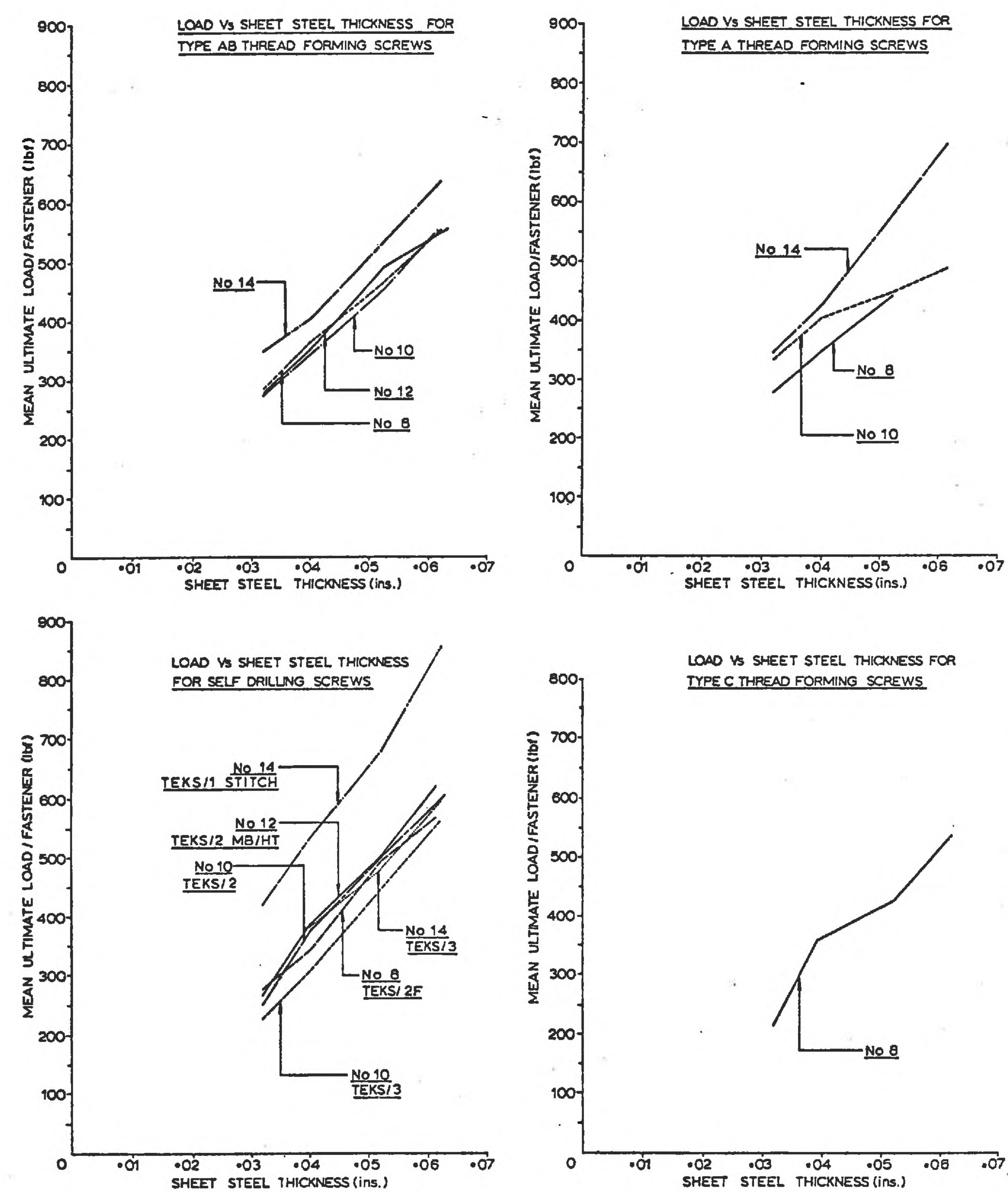
FIG. A-I

MEAN ULTIMATE LOADS FOR FASTENER AND WASHER COMBINATIONS TESTED IN PULL-OVER IN .028 IN. AND .023 IN. GALVANIZED STEEL



LOAD Vs SHEET STEEL THICKNESS RELATIONSHIPS FOR FASTENERS TESTED IN PULL-OUT AND GROUPED ACCORDING TO DIAMETER

FIGURE A-II



LOAD Vs SHEET STEEL THICKNESS RELATIONSHIPS FOR FASTENERS TESTED

FIGURE A-III IN PULL-OUT AND GROUPED ACCORDING TO TYPE

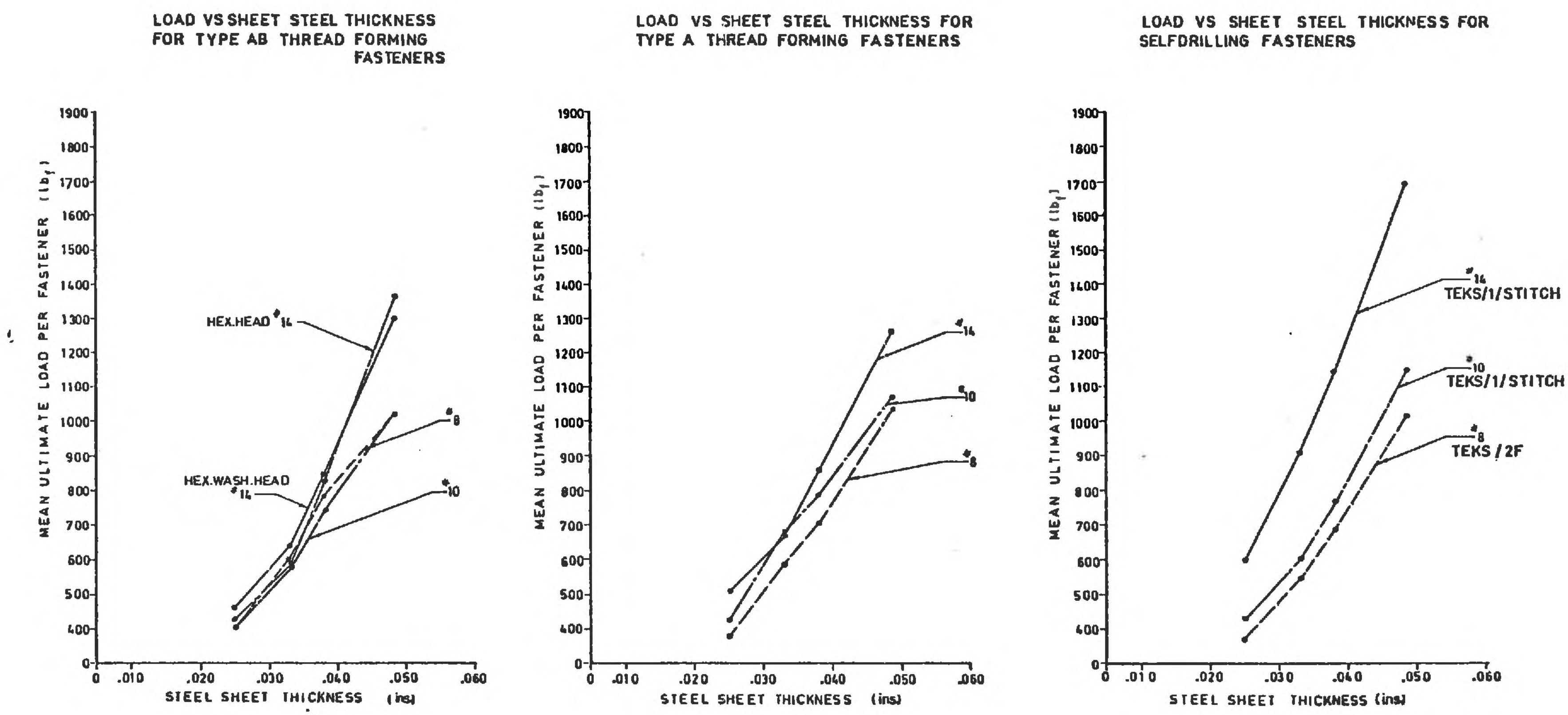


FIGURE A-IV LOAD VS SHEET STEEL THICKNESS FOR SINGLE LAP SHEAR CONNECTIONS BETWEEN SHEETS OF EQUAL THICKNESS (NO WASHERS)

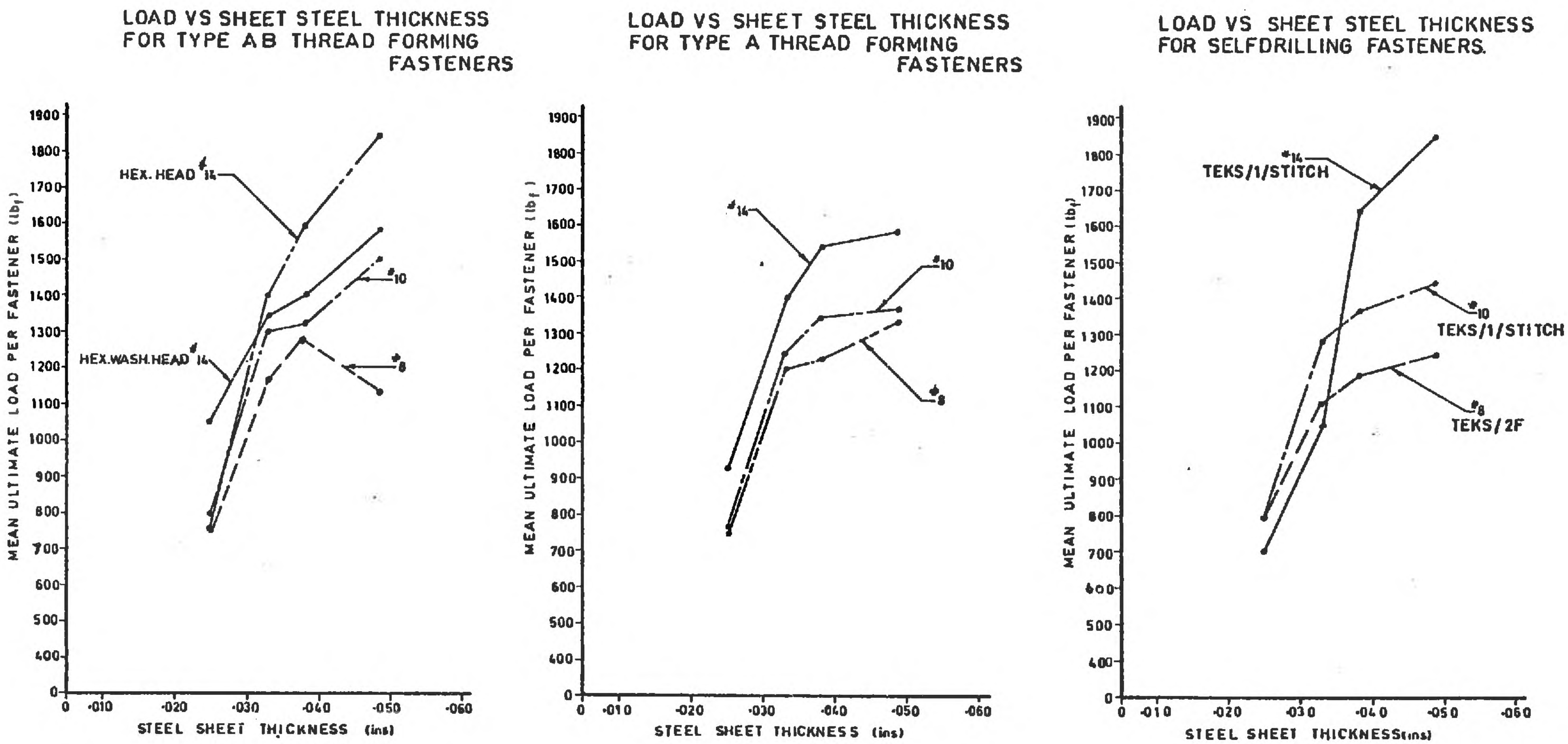
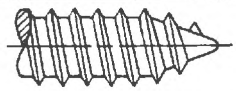
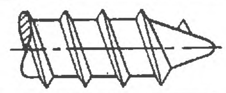
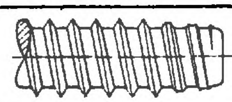
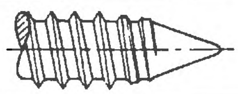
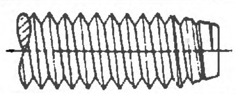
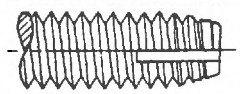
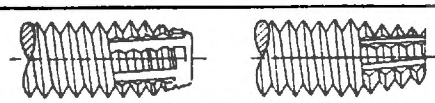
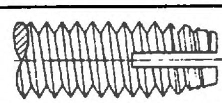
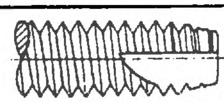
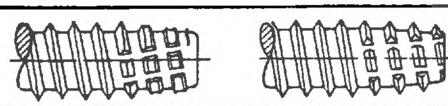
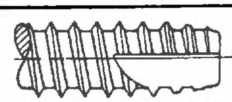
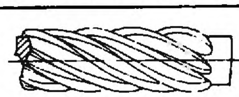


FIGURE A·V LOAD VS SHEET STEEL THICKNESS FOR SINGLE LAP SHEAR CONNECTIONS BETWEEN VARIOUS SHEET THICKNESSES NEXT TO THE FASTENER HEAD AND A 16 GAUGE (0.060") BOTTOM SHEET. (NO WASHERS.)

NOMENCLATURE OF TAPPING SCREWS

(1965 Draft Revision of American Standard B18.6.4 - 1958)

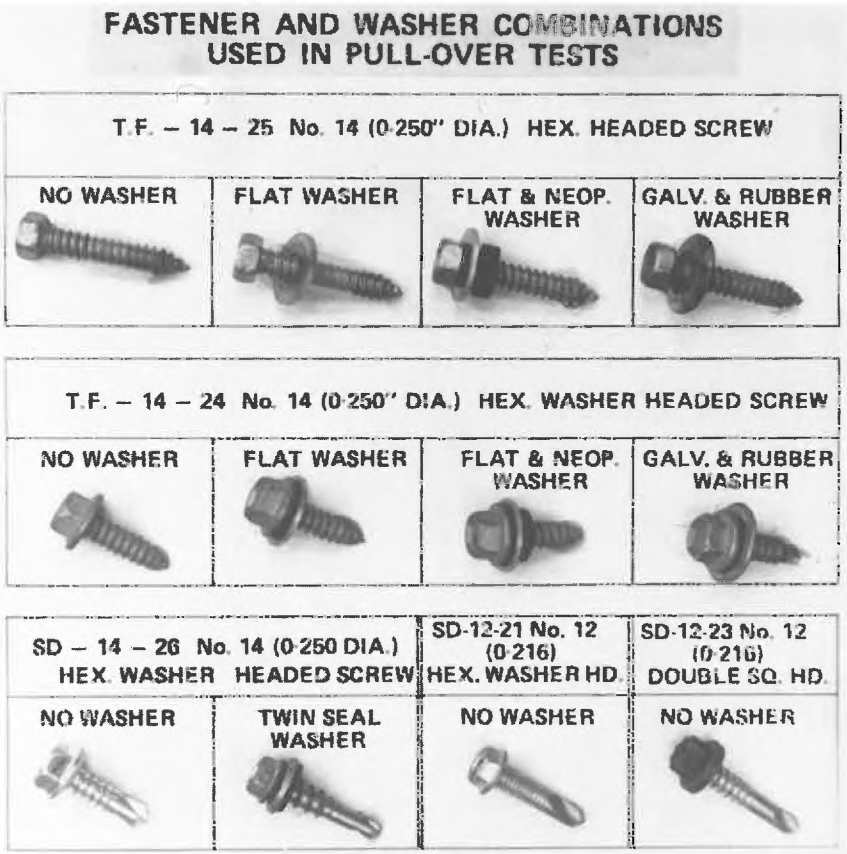
TYPE	A S A	MANUF.
	AB	AB
	A	A
	B	B
	BP	BP
	C	C
	D	1
	F	F
	G	G
	T	23
	BF	BF
	BT	25
	U	U

ABBREVIATIONS

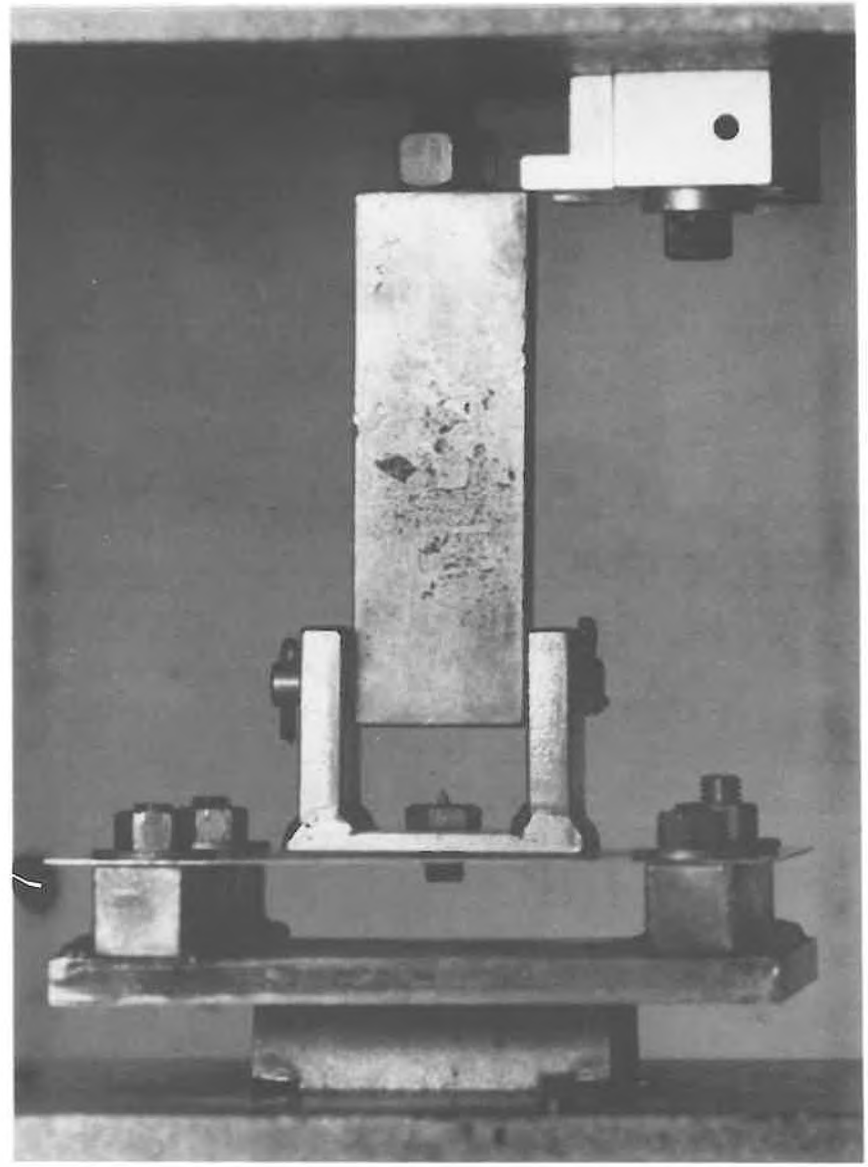
Galv.	-	Galvanized
Galv. & Rubber	-	Galvanized & Rubber
H.H.	-	Hex-Head
H.W.H.	-	Hex-Washer Head
Neop.	-	Neoprene
Pan. Match	-	Panel Match

DEFINITIONS

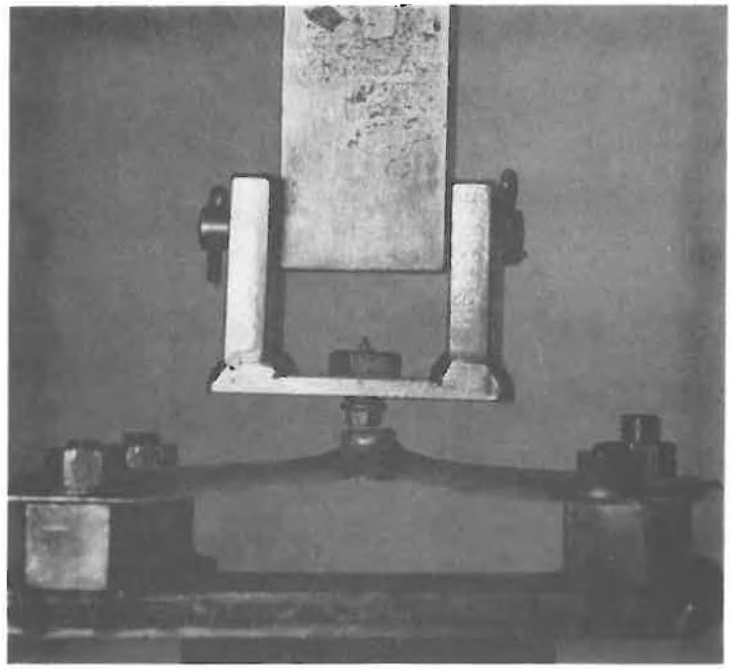
Mean ultimate failure load refers to the arithmetic mean load determined from 5 repititions of each test.



A-VII(a) Fastener and Washer Combinations Tested Under Pull-Over Load Conditions

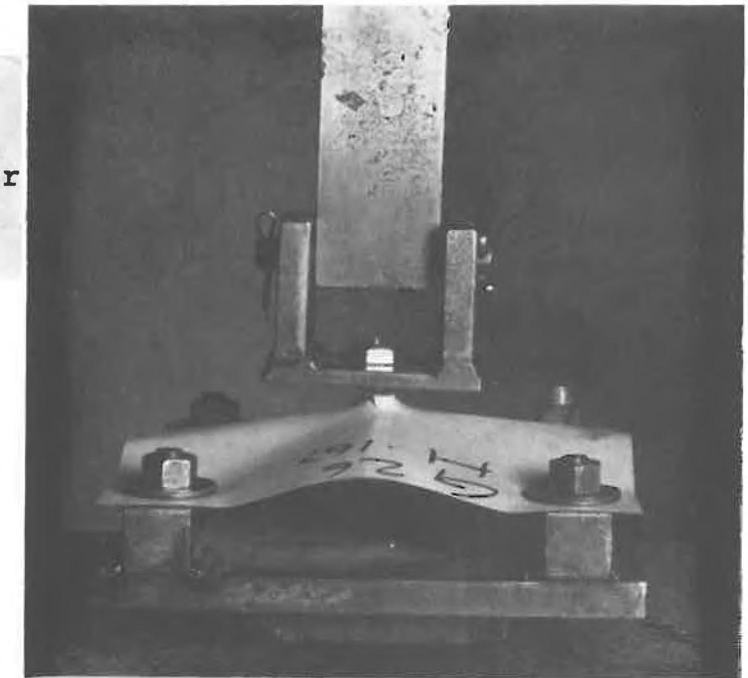


A-VII(b) Pull-Over Test Fixture With Sample Installed. Note the Interchangeable Hexagonal Insert in the Loading Channel



A-VII(c) Conventional Failure Mode in .060 in. Thick Sheet. Note the Slight Overall Sheet Deformation, Localize Necking and Tensile Sheet Failure.

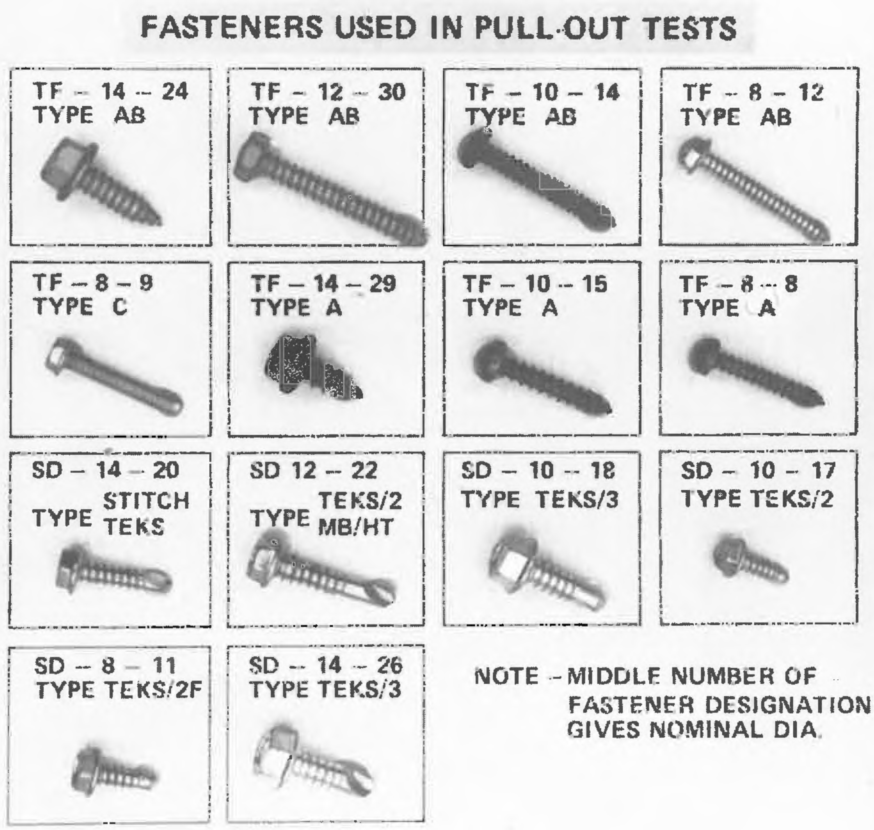
A-VII(d) Sheet Failure by Thinning and Tearing in the Vicinity of the Hole.



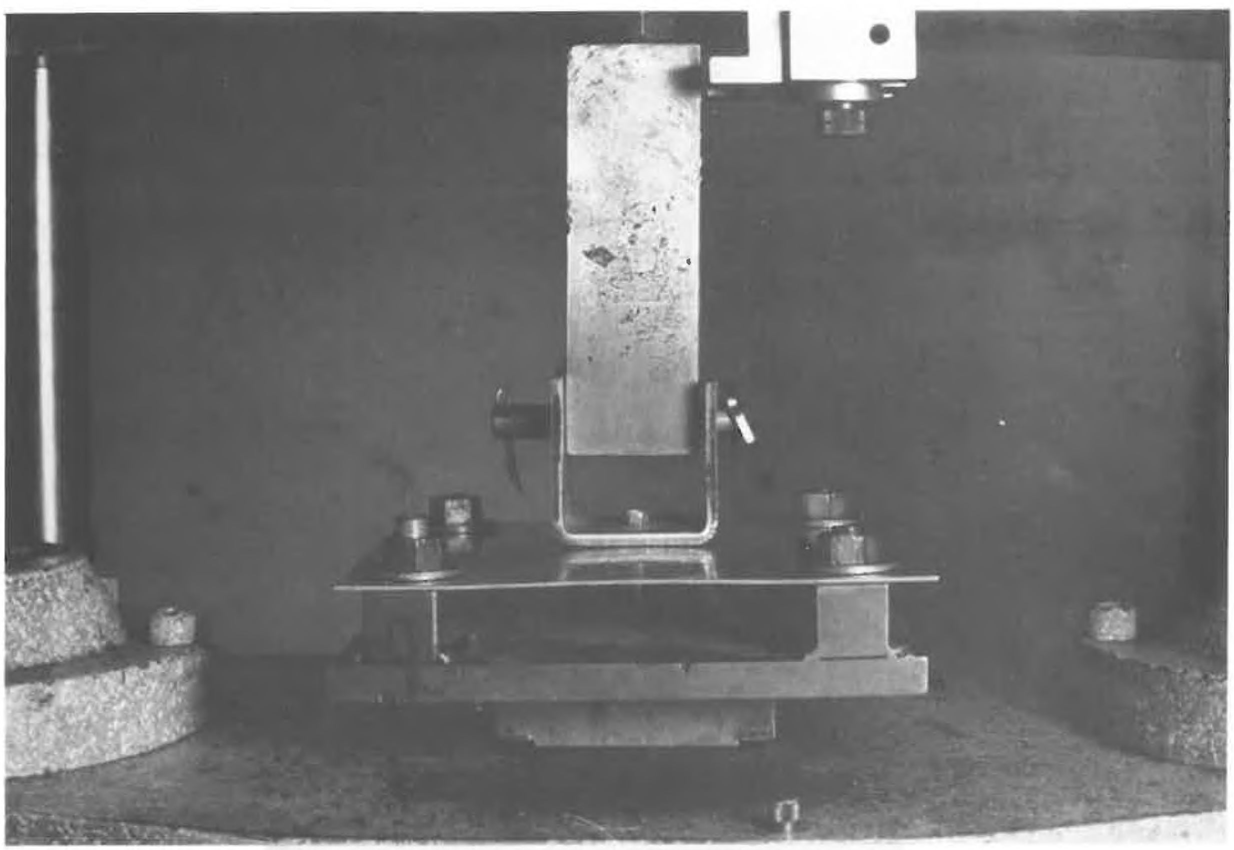
A-VII(e) Failure Mode in .022 in. Thick Sheet. Sheet Deformations are Large and the Connection Washer Sheared a Disc from the Sheet.

A-VII(f) Punch-Out Failure in .022 in. Thick Sheet.

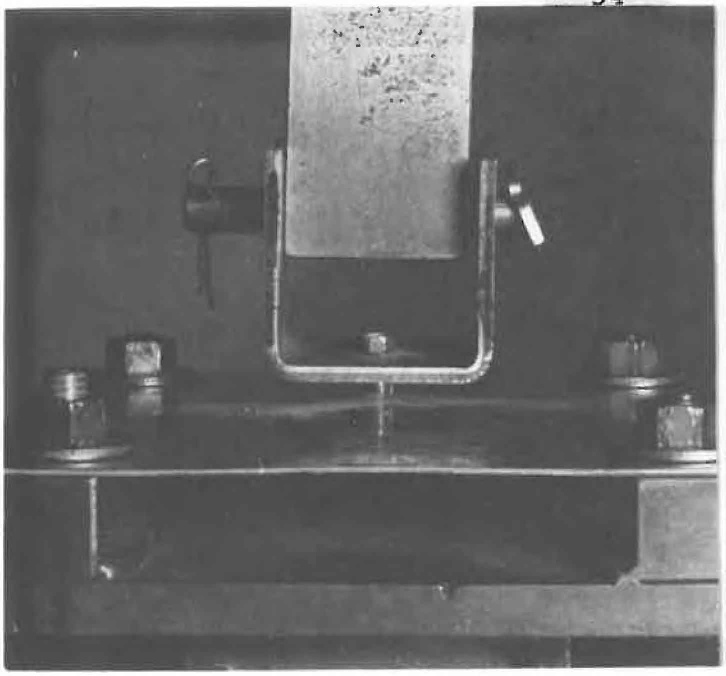
A-VII(g) Fastener and Washer Samples that Produced Punch-Out Failures in .022 in. Thick Sheet.



A-VII(h) Fasteners Tested Under
Pull-Out Load Conditions.



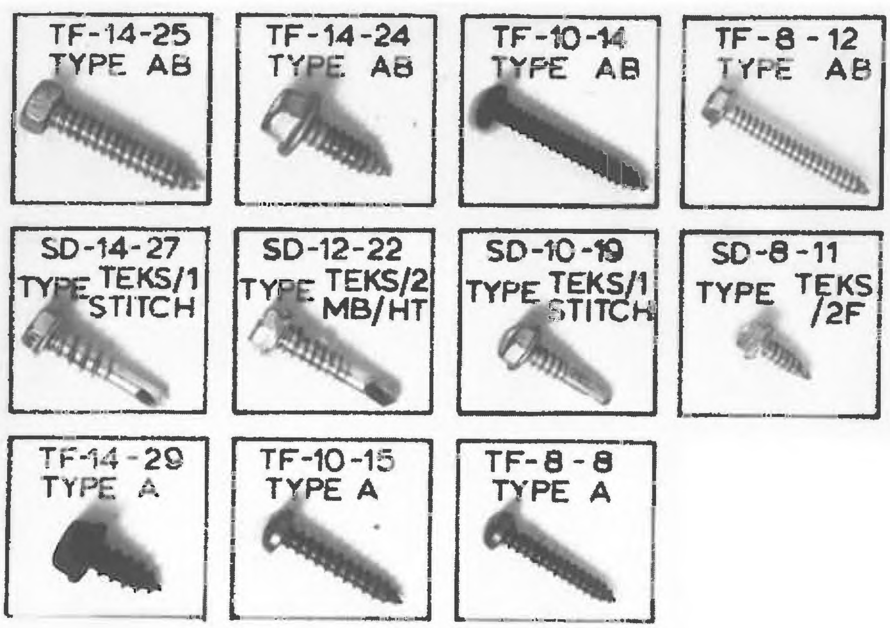
A-VII(i) Pull-Out Test Fixture in
Tensile Testing Machine.



A-VII(j) Typical Failure by Threads Disengaging from Sheet.

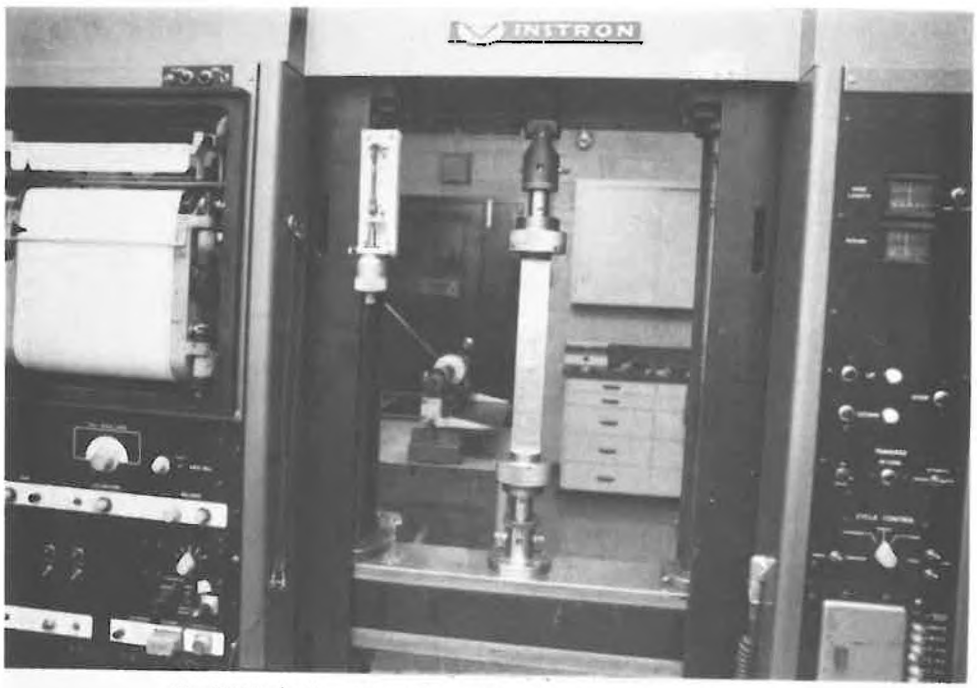
A-VII(k) At Failure the Sheet Experienced Extremely Local Bending and Partial Shearing of Some Material Around the Periphery of the Hole.

FASTENERS USED IN SHEAR TESTS

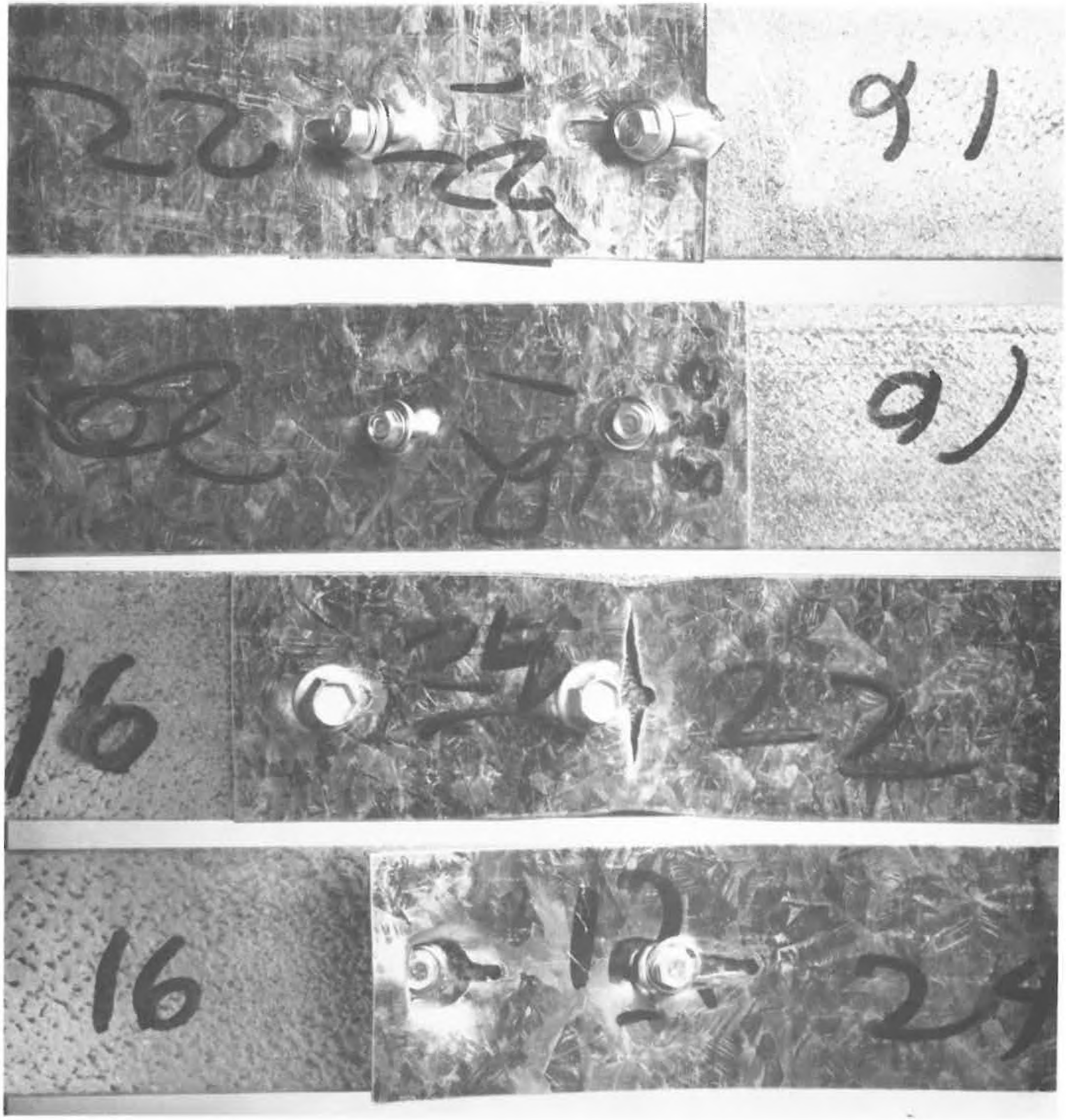


NOTE - MIDDLE NUMBER OF FASTENER DESIGNATION GIVES NOMINAL DIAMETER

A-VII(l) Fasteners Tested Under Static and Dynamic Shear Load Conditions. Sealing Washers (as shown in A-VII(a)) were also Tested with these Fasteners.



A-VII(m) Static Shear Test Sample Installed in Tensile Testing Machine.



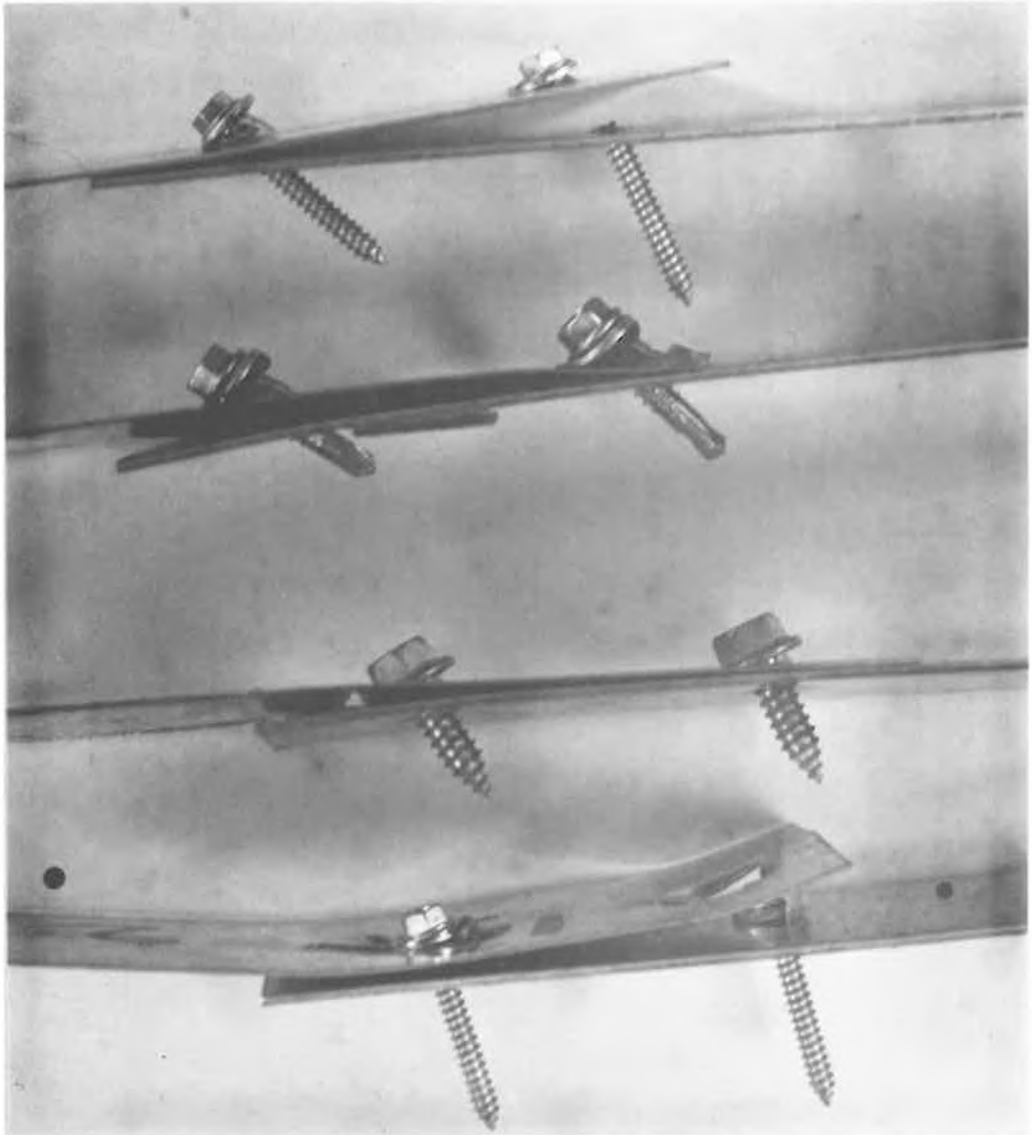
-VII(n) & (o) Typical Shear Failure Modes:
(i) Bearing Failure with Thin Top Sheet Curling up at Free End.
(ii) Tensile Failure in Thin Top Sheet.
(iii) Bearing Failure.
(iv) Shear Failure in One Fastener.

(iv)

(iii)

(ii)

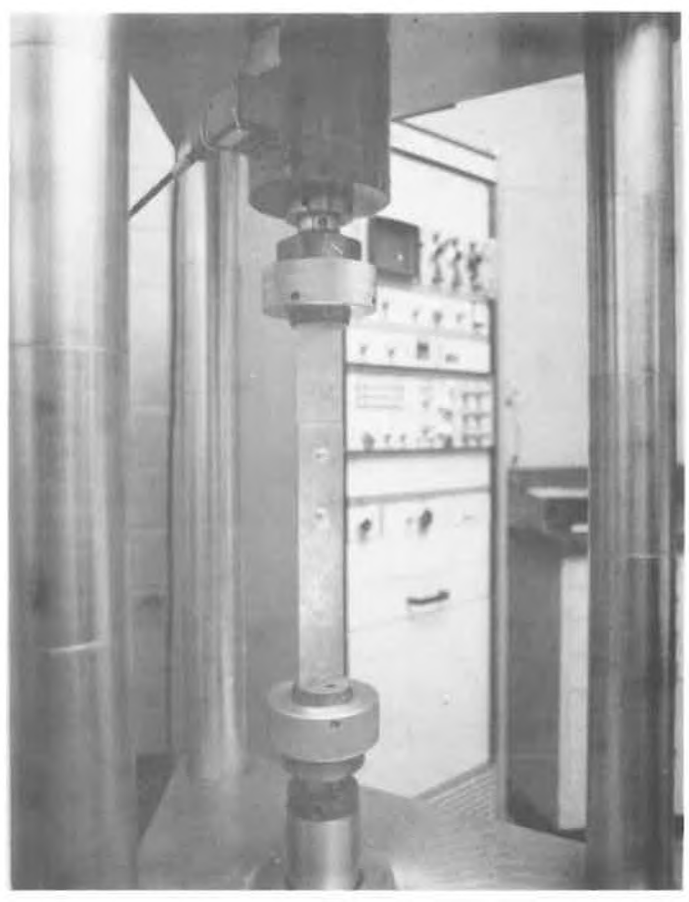
(i)



A-VII-(o)

A-VII(p) Dynamic Shear Test Fixture Installed in M.T.S. Fatigue Testing Machine. The Sample Grips were Specially

Designed to Prevent Loosening of the Jaws Upon Release or Reversal of the Load.



VOLUME II

REPORT ON

SCREW FASTENED SHEET STEEL CONNECTIONS

DETAILS

FOR

CANADIAN STEEL INDUSTRIES CONSTRUCTION COUNCIL

DATE: January, 1976

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APPENDIX B

APPENDIX B

B.1 SHEET STEEL MECHANICAL PROPERTIES

One parameter which greatly affects the performance of any fastener connection is the mechanical properties of the steel sheets. Since all failures occurred by deformation of the sheet, it's tensile strength and ductility are of prime importance. In order to examine the effects of sheet thickness more closely, mechanical properties were maintained as constant as possible. This was true for all samples of galvanized material. Unfortunately, the prefinished samples showed approximately 30 percent less ductility than the galvanized samples and had 22 percent and 40 percent greater yield strengths for.022 in. and .024 in. thicknesses respectively. Tables B-I, B-II and B-III give a full record of the mechanical properties of all test sheet samples.

In the pull-over and pull-out tests, a pure tensile force normal to the plane of interconnection is developed. This gives rise to membrane stresses which propogate radially out from the point of fastening, and consequently, sheet directionality is of little importance. In shear tests, however, directionality may be important because of the variation of sheet properties with rolling direction and therefore all sheet samples were cut with the long dimension coinciding with the rolling direction.

B.2 FASTENER AND WASHER SPECIFICATIONS

The fasteners used in this test series were considered to be "commonly used" by a variety of industries and were not of a specialized nature. It should be emphasized that these fasteners and washers by no means cover the entire range available for structural applications. There may be fasteners that give greater connection strengths and washers with better sealing characteristics. To limit the size of the project it was necessary to choose only a small representative sample.

The fasteners tested ranged in size from #14 (.250 in.) to #8 (.164 in.) and were generally of the thread forming type. The thicknesses of the test sheet (which did not exceed .060 in.) did not warrant the use of thread cutting screws. The action of the thread forming screw is to displace or form a thread in the material adjacent to the pilot hole. The closeness of fit offered by the thread forming screw gives good resistance to loosening (i.e. the material adjacent to the pilot hole is pushing back against the fastener). In applications such as engineered metal buildings where fluctuating winds and internal vibrations may frequently occur, this fastener type has a definite advantage. Also, the internal stresses set up in the structural members by the action of the thread forming screws are generally permissible in this application.

The thread cutting screws are generally used in thicker and/or harder material. They also give rise to disruptive internal stresses, by virtue of their cutting action, and they generally require higher driving torques than thread forming screws.

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The types of threads investigated in this test series were A and AB thread forming and self-drilling.

Tables B-IV and B-V give a complete breakdown of fastener and washer properties.

B.3 PREDRILLED HOLE SPECIFICATIONS

The pull-over sheet samples were provided with a clearance hole equal in diameter to the major diameter of the fastener. In pull-out and shear, where thread engagement was tested, the pilot hole diameters used were in accordance with the recommendations in American Standard B18.6.4 1965 Appendix VII.

For the self-drilling fasteners, a hole equal in diameter to the drill shank of the fastener was predrilled in the test sheets. This procedure was necessary since all fasteners were applied and torqued by hand.

B.4 DRIVE TORQUE

American Standard B18.6.4 1965 Appendix VII gives tables of recommended minimum torsional strengths for screw-fasteners according to diameter and thread type. The same requirements are specified in the SAE recommended practice J9336 "Mechanical and Quality Requirements for Tapping Screws". (Buildex Builders Guide Series 18 was useful in obtaining minimum torsional strengths for self-drilling fasteners.) These recommended values were used in lieu of performing torque tests on all the fasteners for a number of reasons: -

(i) The fasteners were not being researched.

(ii) Realistic conditions should be reproduced, therefore fasteners should be used "off the shelf".

(iii) By using these minimum values the lowest possible application torques would be tested.

If, during the sample preparation stage, any fastener torsion failures did occur, we were prepared to perform torque tests on those fasteners. However, no such failures occurred and this additional procedure was not required.

General practice indicates that an actual application torque of 60 percent to 70 percent of the minimum torsional strength of the fastener be used. We therefore chose 65 percent of the recommended minimum torsional strengths as our application torque.

In order to control this application torque, all screw samples were applied by hand and hand torqued. This is not a practical method of application. It was felt, however, that since this parameter was not under investigation it should be controlled as accurately as possible.

A short test series was undertaken to see if hand torquing the fasteners did produce a significant change in the ultimate strength of a connection. The results are presented in Table B-VI. The percentage differences for the .061 in. and .040 in. samples, tested in pull-out with a #14 (.250 in.) diameter type AB, hex-headed fastener, were -6.2 percent and +2.7 percent respectively. These differences were considered to be within experimental accuracy.

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B.5 TEST PROCEDURES

A research project sponsored by the American Iron Steel Institute, entitled "Mechanical Connections in Cold-Formed Steel: Comprehensive Test Procedures and Evaluation Methods" (8) has recently been completed by researchers at Cornell University, Ithaca, New York. The purpose of this investigation was to review and evaluate all existing test specifications for mechanically fastened connections, select test procedures suitable for industrial standards, and develop methods to evaluate the results obtained from the chosen standard procedure. These recommended testing procedures have been followed as closely as possible in this test series.

Pull-Over

General arrangements of the test fixture for pull-over and pull-out are shown in Figures B-I and B-II. The fixture consists of a base plate assembly to which the sheet steel test specimen was clamped. This base plate assembly was gripped firmly in the lower jaws of the tensile testing machine. A loading arm, gripped in the upper jaws of the tensile testing machine, was attached via a removable pin to the loading channel. The loading channel was the only part of the fixture that was different for pull-over and pull-out tests.

For pull-over testing, the loading channel was fabricated from 1/2 in. and 1/4 in. barstock. A 1/2 in. diameter threaded hole was provided in the base to accept a threaded insert.

A number of such inserts were made with a threaded hole through the center, prepared according to the requirements of the particular fastener to be tested. Thus, rather than change loading channels for each of a large number of different fasteners, the threaded insert needed only to be changed.

The pull-over test must be viewed with a certain amount of caution, however, since many simplifications have been made to arrive at a general testing fixture. There are a number of practical considerations which could greatly affect the results. The most important of these is rotation of the structural member to which the sheet is fastened. A typical channel of Z-shaped roof purlin, for example, may experience a degree of rotation under load. This rotation results in an eccentric loading on the fastener as well as a prying or peeling action, rather than an idealized uni-axial tensile force as developed in this test procedure.

Some work is being done at Cornell University on the effect of purlin rotation on the pull-over strength of roofing fasteners. In their recommended testing procedures (8) they note that a general simulation of this effect is difficult. If extreme accuracy is required, actual application conditions must be reproduced in the test set-up. As a half-way measure, a fastener placed eccentrically in the loading channel of the test rig will give an indication of rotation effects on a given connection.

In preparation for the test, the fastener was passed up through the clearance hole in the test sheet, threaded into the insert in the loading channel and hand tightened to the specified torque. The test sheet was placed over the studs on the base plate and nuts and washers securely tightened. The loading arm was lowered into the loading channel and the 1/2 in. diameter pin passed through the aligned holes. This pin was prevented from slipping out of the channel by flat washers and split pins on both ends.

The speed of testing is very important. The recommended procedures specify a rate of loading of 100 lbs. per minute during initial testing stages where sheet deformations are large and loads are small. As deformations become more localized in the vicinity of the fastener and the loads begin to increase rapidly, a displacement rate of 0.02 in. per minute is recommended. These rates have been selected to allow the propagation of uniform membrane stresses while reducing the time required per test.

Too fast a testing rate would result in impact loading. In such a case the physical phenomena would not be fully developed and the results could be extremely misleading.

<u>Pull-Out</u>

For the pull-out tests, a number of loading channel were made from 3/16 in. flat stock. For each size fastener a minimum clearance hole in the base of the channel was provided. (Four different sizes).

The fastener was applied through the clearance hole in the base of the channel and into the predrilled hole in the test sheet. Again, the fastener was tightened by hand to a specified torque and the sheet assembled on the fixture as previously described.

The rate of testing was the same as described for the pull-over test.

The sheet steel test specimens for pull-over and pull-out are shown in Figure B-IV. Maximum sample size was 8 X 8 in. and four 5/8 in. diameter holes were punched at 6 in. o.c. to facilitate clamping to the base plate. The fastener location hole in the center of the sheet was predrilled to the required size depending on the fastener being tested, the thickness of the test sheet and the type of test.

Shear

For the shear tests, the fixture consisted of a pair of grips, each containing a set of hardened jaws. (Figure B-III)

The samples were prepared according to Figure B-V. The steel sheet coupons were located in a jig so that the required holes could be drilled through both coupons simultaneously.

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Two fasteners were applied by hand from the same side of the sample and hand torqued to the required value.

The sample was inserted between the jaws and into a slot in the upper body of the grips which provided location and alignment. Snugging the collar up tight locked the jaws onto the sample.

As per the recommended procedures, the rate of separation of the two heads of the testing machine under load did not exceed either 0.05 in. per minute or 100 pounds per minute rate of loading, whichever was greater.

For the dynamic tests, the same procedures for sample preparation were followed and the same grips used.

The test sequence was to load the sample to 75 percent of its average static shear failure load as determined by earlier tests, and return the load to 0. This cycling was continued for 5000 cycles at a frequency of 20 Hz. After this period the sample was retested according to the static test procedures and the connection failure load recorded.

B.6 COMPARISON WITH PUBLISHED RESULTS

Pull-Over

There is little information available for comparing the results of the pull-over tests, and the data that has been published is rarely accompanied by adequate testing specifications. Buildex Division of ITW, in their Builders Guide Series 15 (2) brochure gives test results for a limited number of fasteners tested in pull-over and pull-out. Although these fasteners and washers are not identical to those we have tested, the information is included in Figure B-IV so that trends may be examined.

Our tests were limited to only two sheet thicknesses and comparison over a larger range is therefore not possible. However, our tests indicate a similar behaviour for fasteners with different sizes of heads and washers. (Figure B-VI)

Verification of the testing fixture by the authors of the recommended procedures (8) involved a limited number of pull-over tests using a #14 type A hex-headed fastener with a 0.020 in. thick x 5/8 in. O.D. metal-and-bonded neoprene washer. Our test results on a similar fastener with a 0.7 in. O.D. x .038 in. thick galvanized metal-and-bonded rubber washer are in good agreement. (i.e. Dofasco 773 lb., Cornell 784 lb., a difference of 1.3 percent.) Testing procedures and sheet properties for the above comparison were almost identical (i.e. .021 in. thick, 37 Ksi yield strength and 32 percent elongation in 2 in.)

Pull-Out

Data published by the authors of the recommended testing procedures (8) indicated the verification of the fixture by tests on a #14 type A fastener in pull-out, from .060 in. and .030 in. galvanized material of approximately the same mechanical properties as used in this test series. They did, however, use about half the tightening torque. Their tests produced pull-out values of 519 lb. and 274 lb. in

.060 in. and .030 in. sheets respectively, (35 percent and 27 percent lower than comparable results presented here. Some of this discrepancy could be attributed to the difference in torques.

Buildex Division of ITW[2] have also published data on pull-out tests performed on a #12 - 14 TEKS/2 fastener. The material they used in testing had a 50 ksi yield strength or 25 percent higher than the material in a comparable test. For .060 in. and .048 in. materials, they recorded 940 lb. and 730 lb. respectively, approximately 50 percent higher than the results obtained from this series. The difference in material properties has some effect on the results, but the lack of further test specifications limits the validity of a comparison.

Shear

The data available for comparisons of shear connections comes from Cornell University [8] where a number of tests were necessary to verify the testing procedures and from the National Swedish Building Research, Document D8:1973 [10] which presents design equations for predicting ultimate connection loads.

Table B-VII compares this data with our test results for a #14 (.250 in.) diameter type A thread forming fastener with a galvanized-and-bonded rubber sealing washer. Some of the Cornell tests, using the same fastener, were performed using steel sheets with thickness combinations differing from ours. In these instances, the closest values have been

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included and the differences are indicated in the table.

A number of the Cornell tests give ultimate loads which are approximately 200 pounds per fastener lower than ours and the remainder show good agreement.

If two steel sheets of different thicknesses are used in a connection, the Swedish formulae consider the properties of the thinner sheets only. Consequently, in such cases, they considerably under-estimate, the connection failure loads.

B.7 VARIANCE OF RESULTS

Five repetitions of each test were performed. The values appearing in Table A-I are arithmetic mean values. The coefficient of variation was calculated for each set of results according to the following statistical formulae:

$$V = \frac{S}{\bar{X}}$$

Where V = Coefficient of Variation

$\bar{X}$ = Mean

S = Standard Deviation

x = Discrete Value

n = Number of Discrete Values

$$S = \sqrt{\frac{\sum x^2 - 1/n \sum (x)^2}{n-1}}$$

The variance coefficients expressed as a percentage, averaged between 4 percent and 5 percent. This indicates very good agreement of results and little scatter. There were however, a number of isolated incidents where coefficients greater than 10 percent were calculated.

In pull-over, the tests with flat metal washers generally exhibited high variation. This may be partly due to the fact that the inside diameter of the washer was larger than the maximum fastener diameter. Exact alignment was therefore difficult and the slight eccentricities caused some scatter of results.

In pull-out and shear, when the thin sheets were being tested, high variations were also encountered. It is felt that, tightening fasteners to their specified torque in thin material is often difficult and the probability of overtorquing is high.

TABLE B-I	SHEET STEEL MECHANICAL PROPERTIES			PULL-OVER TEST	
NOMINAL GAUGE {ACTUAL THICKNESS} IN.	COATING	YIELD STRENGTH (ksi)	TENSILE STRENGTH (ksi)	PERCENT ELONGATION IN 2 IN.	HARDNESS ROCKWELL B
24 (0.0278)	G-90	39.4	52.3	33.5	56
24 (0.0239)	Prefinished	55.9	63.7	19.0	62
26 (0.0230)	G-90	39.7	51.0	30.0	58
26 (0.0220)	Prefinished	48.4	57.0	20.0	60

TABLE B-II	SHEET STEEL MECHANICAL PROPERTIES			PULL-OUT TEST	
NOMINAL GAUGE {ACTUAL THICKNESS} IN.	COATING	YIELD STRENGTH (ksi)	TENSILE STRENGTH (ksi)	PERCENT ELONGATION IN 2 IN.	HARDNESS ROCKWELL B
16 (0.0610)	G-90	41.0	51.5	30.0	56
18 (0.0510)	G-90	40.3	53.6	33.5	59
20 (0.0402)	G-90	40.2	50.4	34.0	56
22 (0.0312)	G-90	42.5	51.2	25.0	53

TABLE B-III	SHEET STEEL MECHANICAL PROPERTIES			SHEAR TEST	
NOMINAL GAUGE {ACTUAL THICKNESS} IN.	COATING	YIELD STRENGTH (ksi)	TENSILE STRENGTH (ksi)	PERCENT ELONGATION IN 2 IN.	HARDNESS ROCKWELL B
24 (0.025)	G-90	42.75	50.75	30.0	60
20 (0.038)	G-90	39.6	50.0	32.5	57
18 (0.0485)	G-90	36.6	46.9	31.0	58
22 (0.033)	G-90	36.2	46.75	30.0	50
16 (0.060)	G-90	36.6	47.5	35.0	57

TABLE B-IV

SPECIFICATIONS FOR SCREW FASTENERS

DESIGNATION	TYPE	FINISH	DIAMETER (IN)	THREAD TYPE	T.P.I.	LENGTH (IN)	HEAD TYPE	DRIVE PATTERN	POINT TYPE	WASHER TYPE	MINIMUM TORSIONAL STRENGTH (IN-LB) *	DRIVE TORQUE (IN-LB) **
T.F.-8-8	THREAD FORMING	PLAIN STEEL	#8 (.164)	A	15	1	PAN	SCRULOX	GIMLET	NONE	39	25.4
T.F.-8-12	THREAD FORMING	ZINC PLATED	#8 (.164)	AB	18	1-1/4	HEX WASHER	HEX	GIMLET	NONE	39	36.4
S.D.-8-11	SELF DRILLING	ZINC PLATED	#8 (.164)	TEKS/2F	18	1/2	HEX WASHER	HEX	S-12	NONE	42	27.3•
T.F.-8-9	THREAD FORMING	CADMIUM PLATED AND WAXED	#8 (.164)	C	32	1	INDENTED HEX WASHER	HEX	CHAMFER	NONE	42	27.3
T.F.-10-15	THREAD FORMING	PLAIN STEEL	#10 (.190)	A	12	1	PAN	ROBERTSON RECESS	GIMLET	NONE	48	31.2
T.F.-10-14	THREAD FORMING	PHOSPHATE	#10 (.190)	AB	16	1-1/4	PAN	PHILIPS RECESS	GIMLET	NONE	56	26.4
S.D.-10-19	SELF DRILLING	ZINC PLATED	#10 (.190)	TEKS/1/STITCH	16	3/4	HEX WASHER	HEX	S-12	NONE	61	39.7
S.D.-10-17	SELF DRILLING	ZINC PLATED	#10 (.190)	TEKS/2	16	1/2	HEX WASHER	HEX	S-12	NONE	61	39.7•
S.D.-10-18	SELF DRILLING	ZINC PLATED	#10 (.190)	TEKS/3	16	3/4	HEX WASHER	HEX	S-12	NONE	61	39.7•
T.F.-12-30	THREAD FORMING	MECHANICAL ZINC	#12 (.216)	AB	14	1-1/2	HEX	HEX	GIMLET	NONE	88	57.2
S.D.-12-22	SELF DRILLING	CADMIUM PLATED	#12 (.216)	TEKS/2/MB/HT	14	1	HEX WASHER	HEX	S-12	TWIN SEAL	92	59.8•
S.D.-12-23	SELF DRILLING PAN.MATCH	ZINC PLATED	#12 (.216)	TEKS/3	14	1	DOUBLE SQUARE	DOUBLE SQUARE	S-12	NONE	92	59.8•
S.D.-12-21	SELF DRILLING	CADMIUM PLATED	#12 (.216)	TEKS/4	24	7/8	HEX WASHER	HEX	S-12	NONE	100	65•
T.F.-14-29	THREAD FORMING	PHOSPHATE	#14 (.250)	A	10	5/8	INDENTED HEX WASHER	HEX	GIMLET	NONE	125	81.3
T.F.-14-25	THREAD FORMING	MECHANICAL ZINC	#14 (.250)	AB	13	1-1/4	HEX	HEX	GIMLET	NONE	142	92.3
T.F.-14-24	THREAD FORMING	MECHANICAL ZINC	#14 (.250)	AB	14	3/4	HEX WASHER	HEX	GIMLET	NONE	142	92.3
S.D.-14-27	SELF DRILLING	CADMIUM PLATED	#14 (.250)	TEKS/1/STITCH	10	1	HEX WASHER	HEX	S-12	TWIN SEAL	92	59.8•
S.D.-14-20	SELF DRILLING	CADMIUM PLATED	#14 (.250)	TEKS/2/MB	14	1	HEX WASHER	HEX	S-12	TWIN SEAL	92	59.8
S.D.-14-26	SELF DRILLING	CADMIUM PLATED	#14 (.250)	TEKS/3	14	3/4	HEX WASHER	HEX	S-12	NONE	150	97.5•

* MINIMUM TORSIONAL STRENGTH REQUIREMENTS PER AMERICAN STANDARD B18,6.4-1965

• VALUES GIVEN IN BUILDEX - BUILDERS GUIDE SERIES 18

** RULE-OF-THUMB FOR DETERMINING DRIVE TORQUES-65% OF MINIMUM TORSIONAL STRENGTH

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TABLE B-V WASHER SPECIFICATIONS

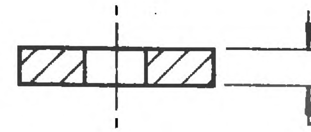
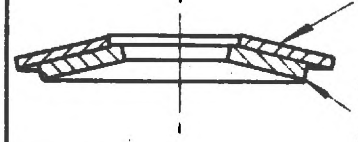
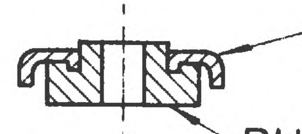
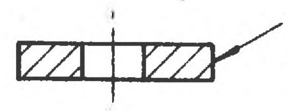
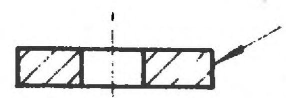
DESIGNATION	TYPE	MATERIAL	O/D (in.)	I/D (in.)	CROSS SECTION SKETCH
W-1	SEALING	NEOPRENE	29/64	7/32	 0.125
W-2	SEALING	RUBBER BONDED GALV. STEEL	0.70	7/32	 GALV. STEEL 0.038 THICK; BONDED RUBB. 0.060 THICK
W-3	DOUBLE SEALING	CADMIUM PLATED STEEL WITH RUBBER INSERT	5/8	7/32	 STEEL 0.040 THICK; RUBBER INSERT
W-4	FLAT	CADMIUM PLATED STEEL	5/8	9/32	 STEEL 0.051 THICK
W-5	FLAT	CADMIUM PLATED STEEL	1/2	7/32	 STEEL 0.060 THICK
W-6	FLAT	CADMIUM PLATED STEEL	7/16	3/16	 STEEL 0.050 THICK

TABLE B-VI

COMPARISON OF PULL-OUT RESULTS FOR A No14 TYPE AB, HEX. HEADED, FASTENER APPLIED BY HAND AND BY A POWER SCREWDRIVER

TEST SHEET THICKNESS (ins.)	MEAN PULL-OUT LOAD (lbf)			STANDARD DEVIATION		VARIANCE %	
	POWER DRIVEN (A)	HAND DRIVEN (B)	DIFFERENCE $\left(\frac{B-A}{B} \times 100\right)$ %	POWER DRIVEN	HAND DRIVEN	POWER DRIVEN	HAND DRIVEN
16 GA. (0·061)	636	599	− 6·2	15·9	13·3	2·5	2·2
20 GA. (0·040)	449	461	+ 2·7	11·3	44·6	2·5	9·6

NOTE SCREWDRIVER SPEED 1600 R.P.M.
TORQUE SETTING AT 80 ins lbs
SAMPLE SIZE N=10

SHEET "A" THICKNESS (IN.)	SHEET "B" THICKNESS (IN.)	ULTIMATE SHEAR LOAD / FASTENER (lb) DOFASCO	CORNELL UNIVERSITY	SWEDISH STANDARD
.0485 (.061)	.060 (.061)	1696	* 1737	901
.033	.060	1388	1125	604
.025 (.021)	.060 (.061)	1064	* 817	639
.033	.033	671	475	464
.025 (.021)	.025 (.021)	463	* 312	341

* RESULTS FROM TESTS IN SHEET THICKNESSES SHOWN IN PARENTHESIS

TABLE B-VII

COMPARISON OF ULTIMATE SHEAR LOADS WITH PUBLISHED DATA

FIG B-I

TEST FIXTURE FOR PULL-OVER TEST WITH SPECIMEN INSTALLED

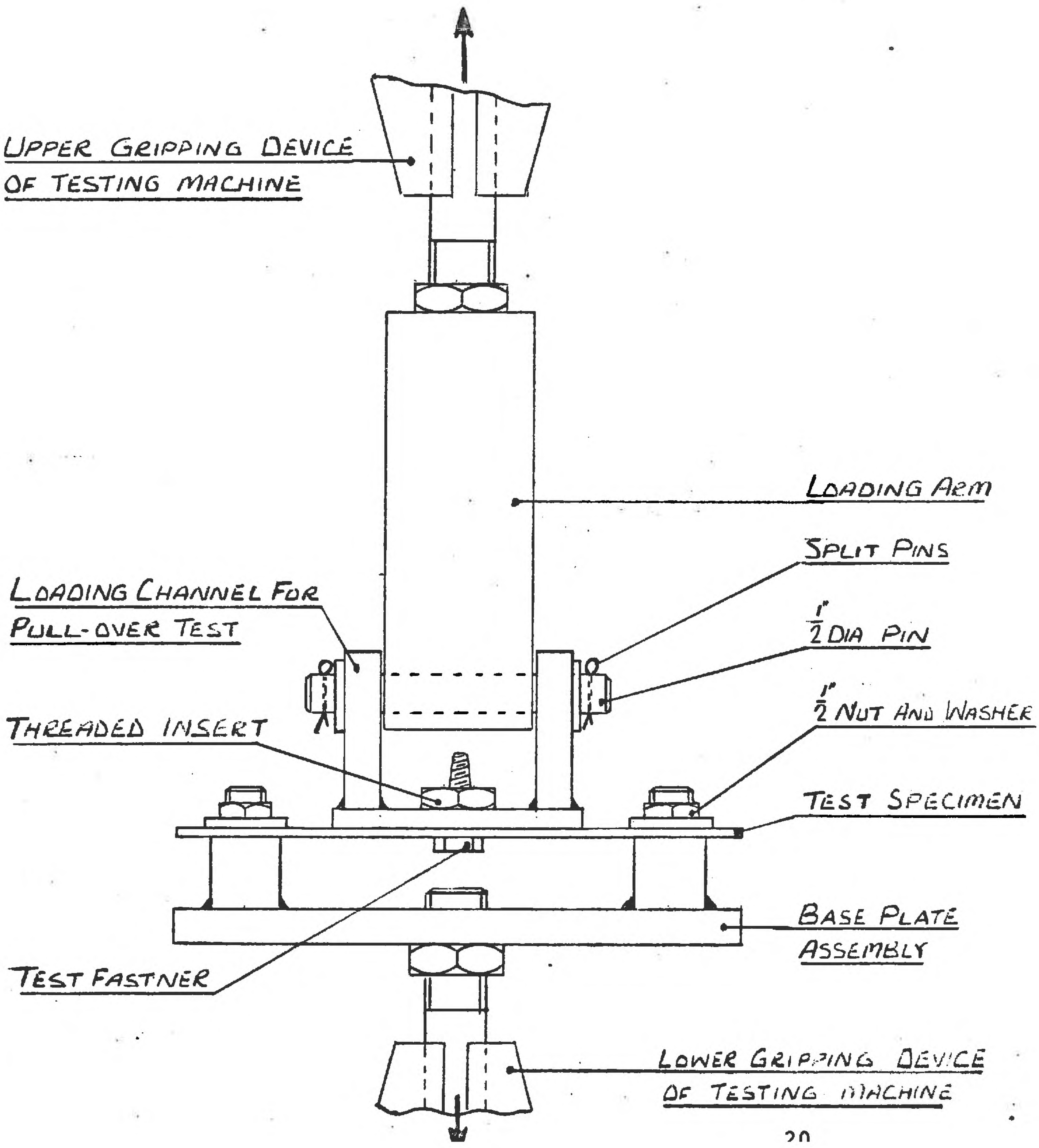
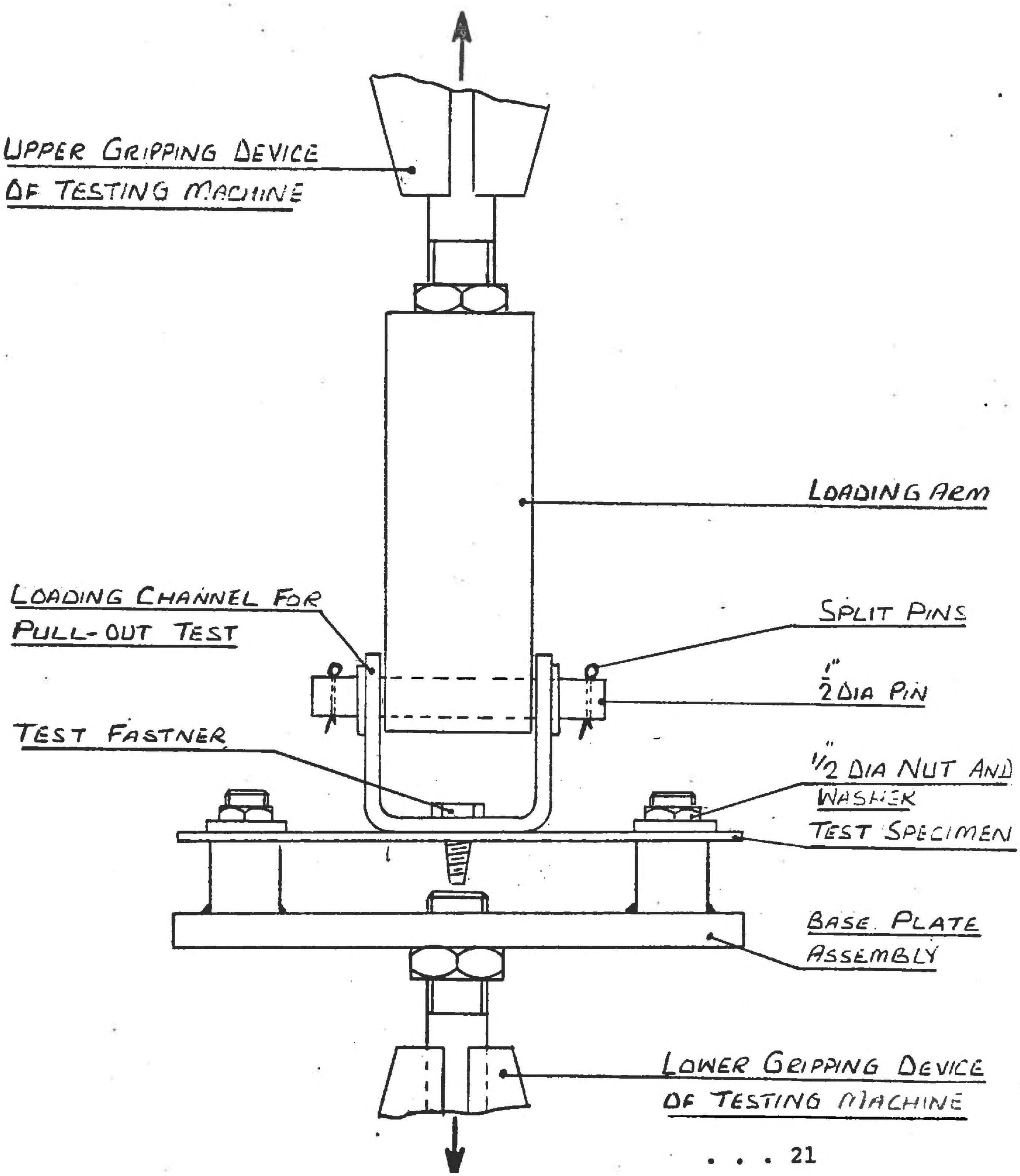


FIG. B-II

TEST FIXTURE FOR PULL-OUT TEST WITH SPECIMEN INSTALLED



TEST FIXTURE FOR SHEAR TEST WITH SPECIMEN INSTALLED

FIG. B-III

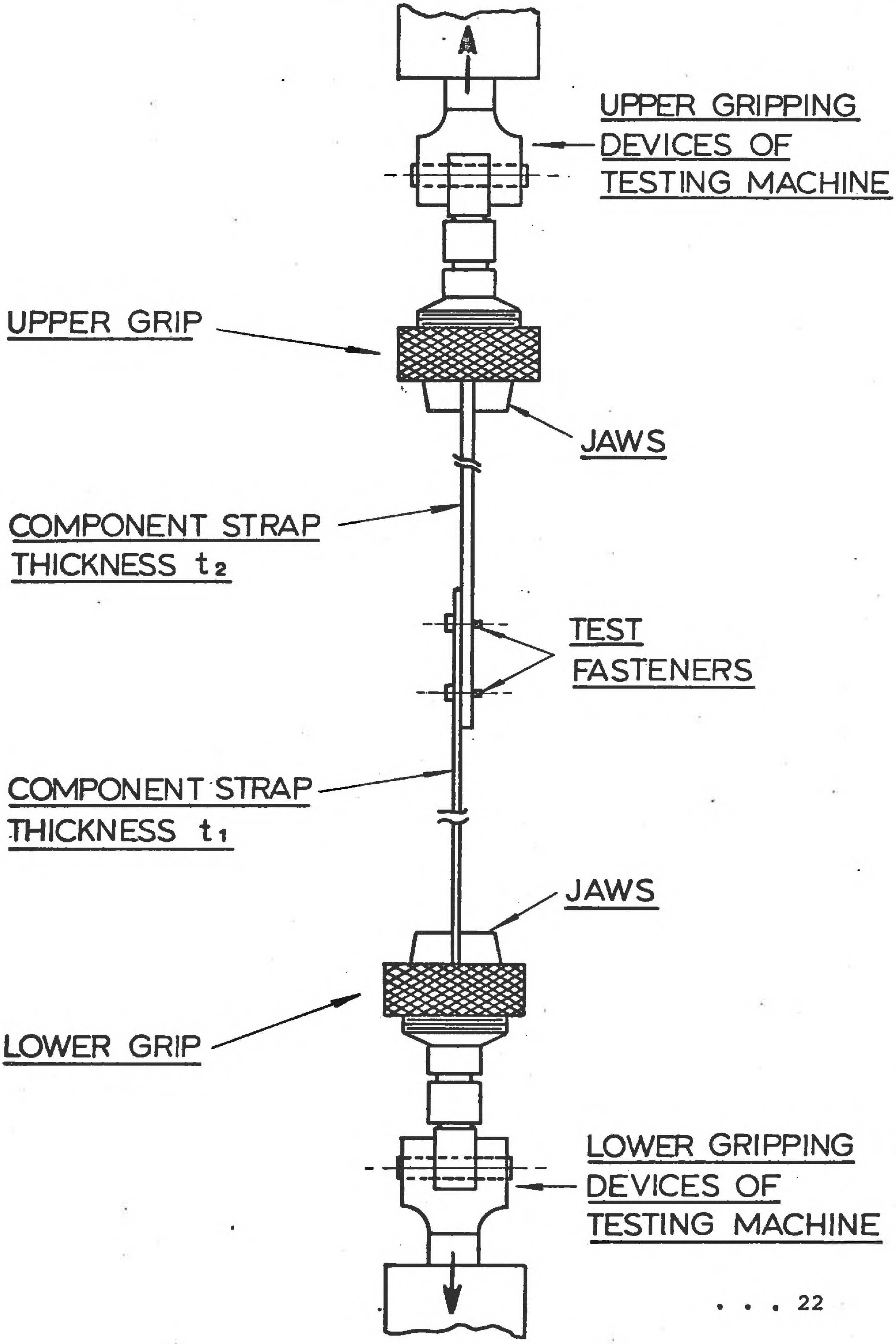


FIGURE B-IV

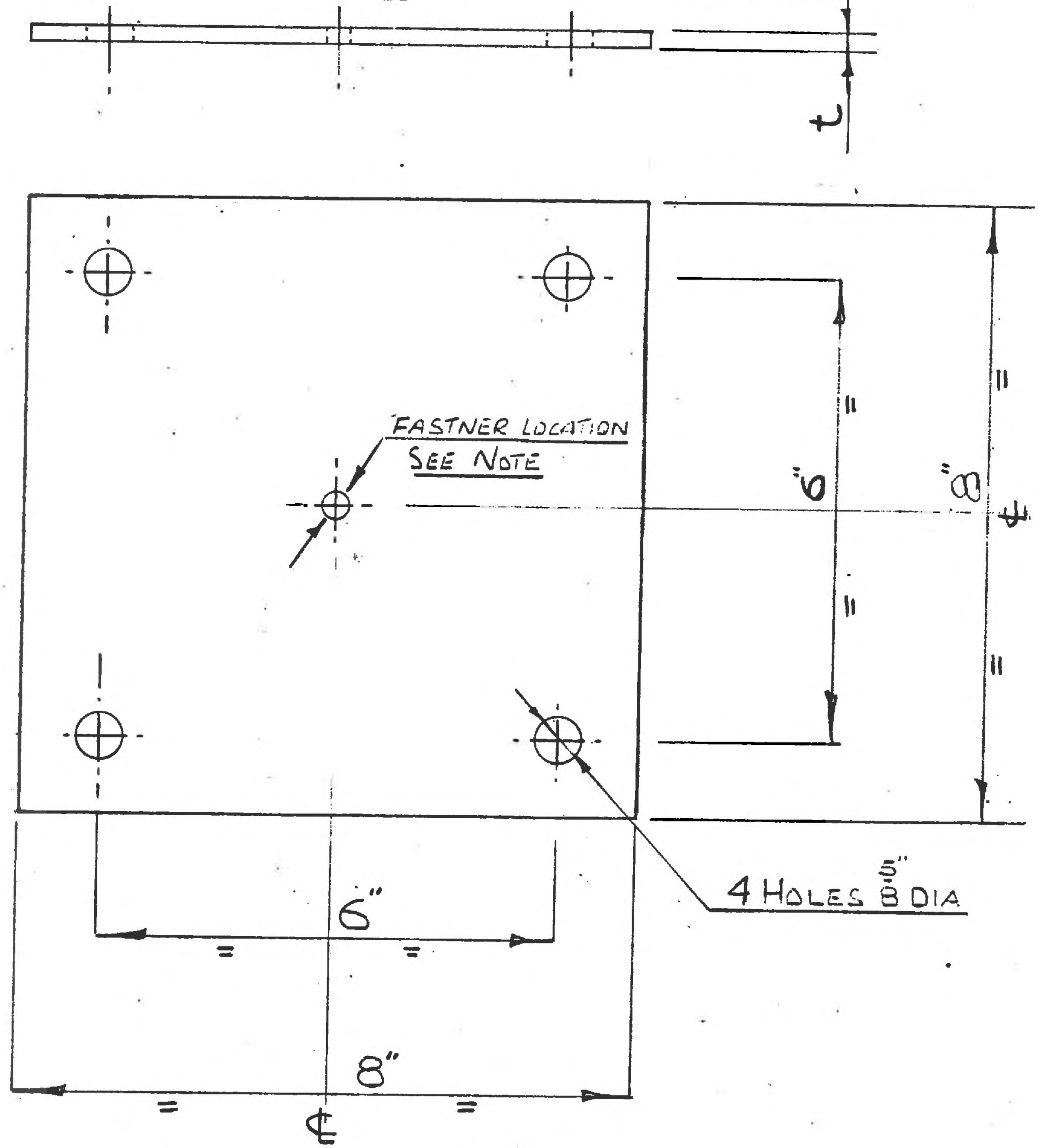


FIG. B-IV TEST SPECIMEN DIMENSIONS FOR FLAT SECTIONS TESTED IN PULL-OUT AND PULL-OVER

NOTE FASTNER LOCATION HOLE DIA. DEPENDS ON TYPE OF TEST AND DIAMETER OF FASTNER

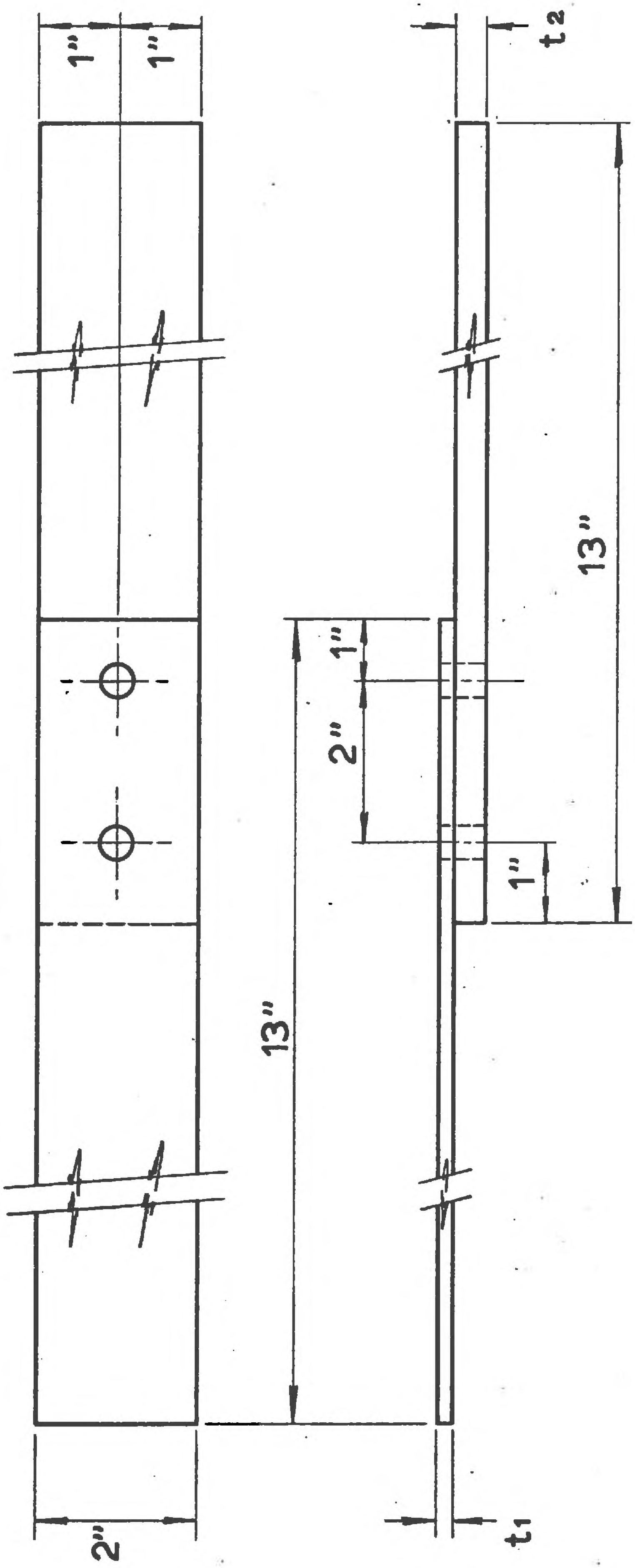
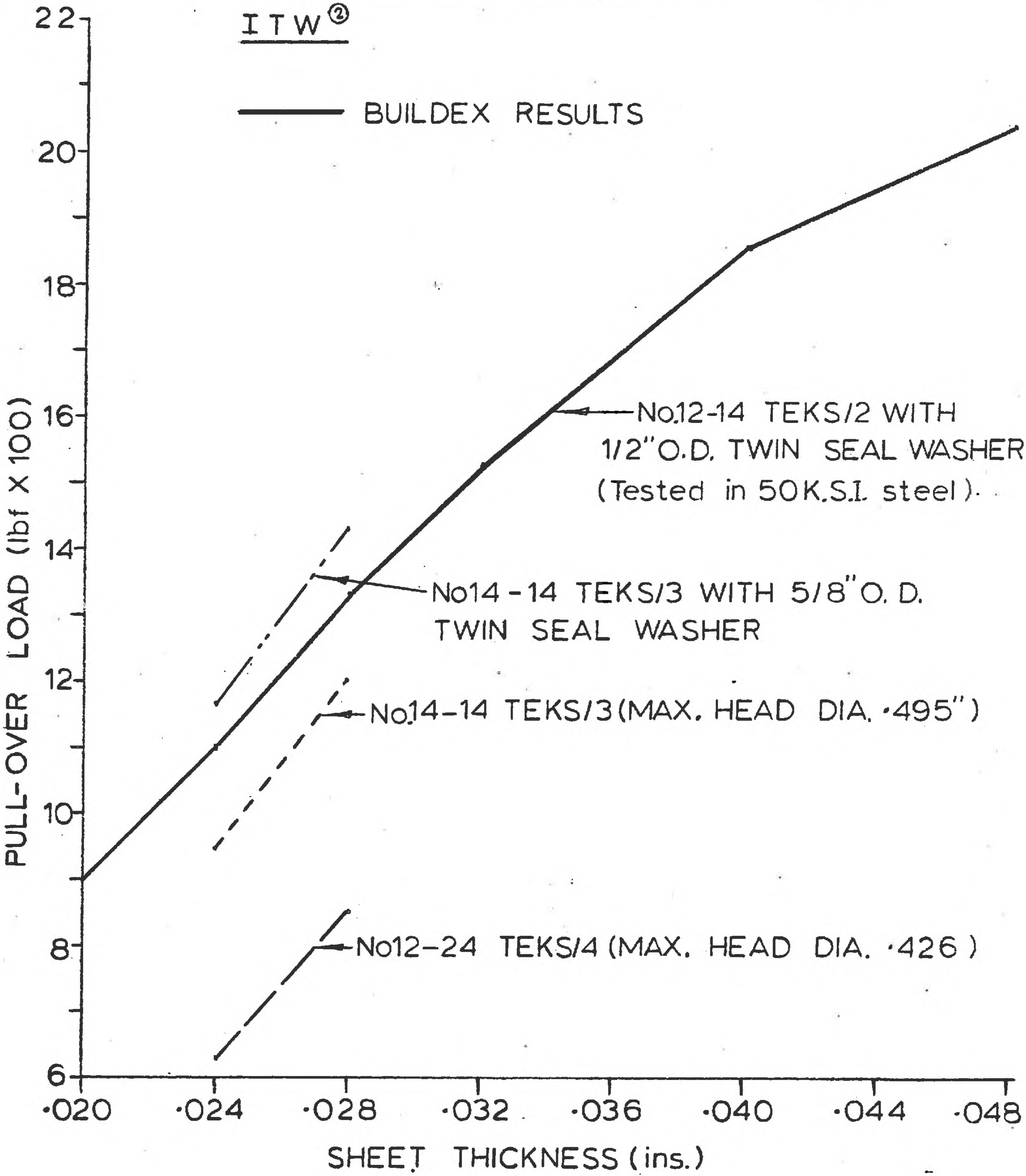
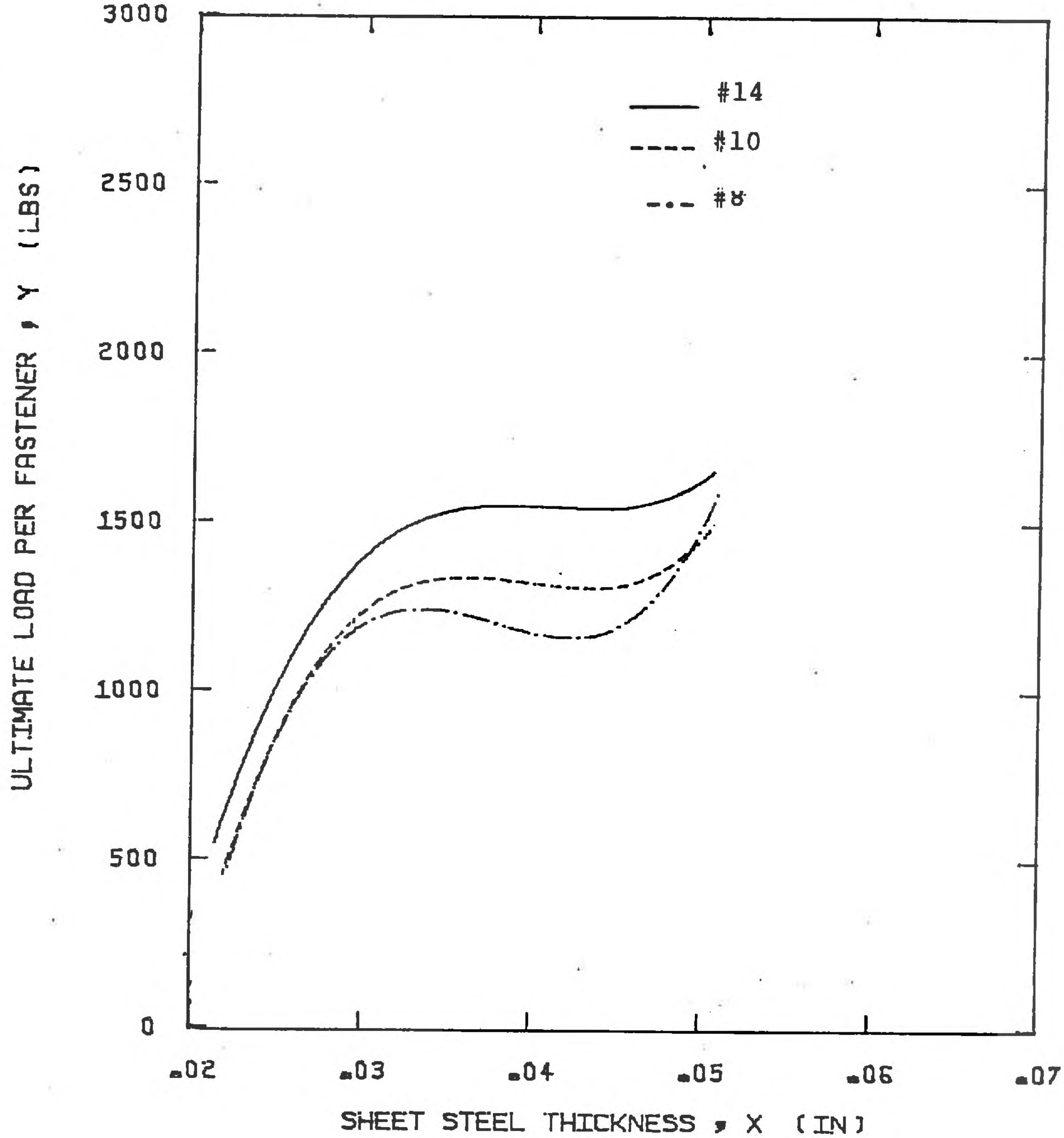


FIG. B-V SINGLE-SHEAR (LAP JOINT) TEST SPECIMEN DIMENSIONS

FIG. B-VI COMPARISON OF PULL-OVER RESULTS IN 40 ksi GALVANIZED SHEET WITH RESULTS PUBLISHED BY BUILDEX – DIVISION OF ITW[2]



APPENDIX C

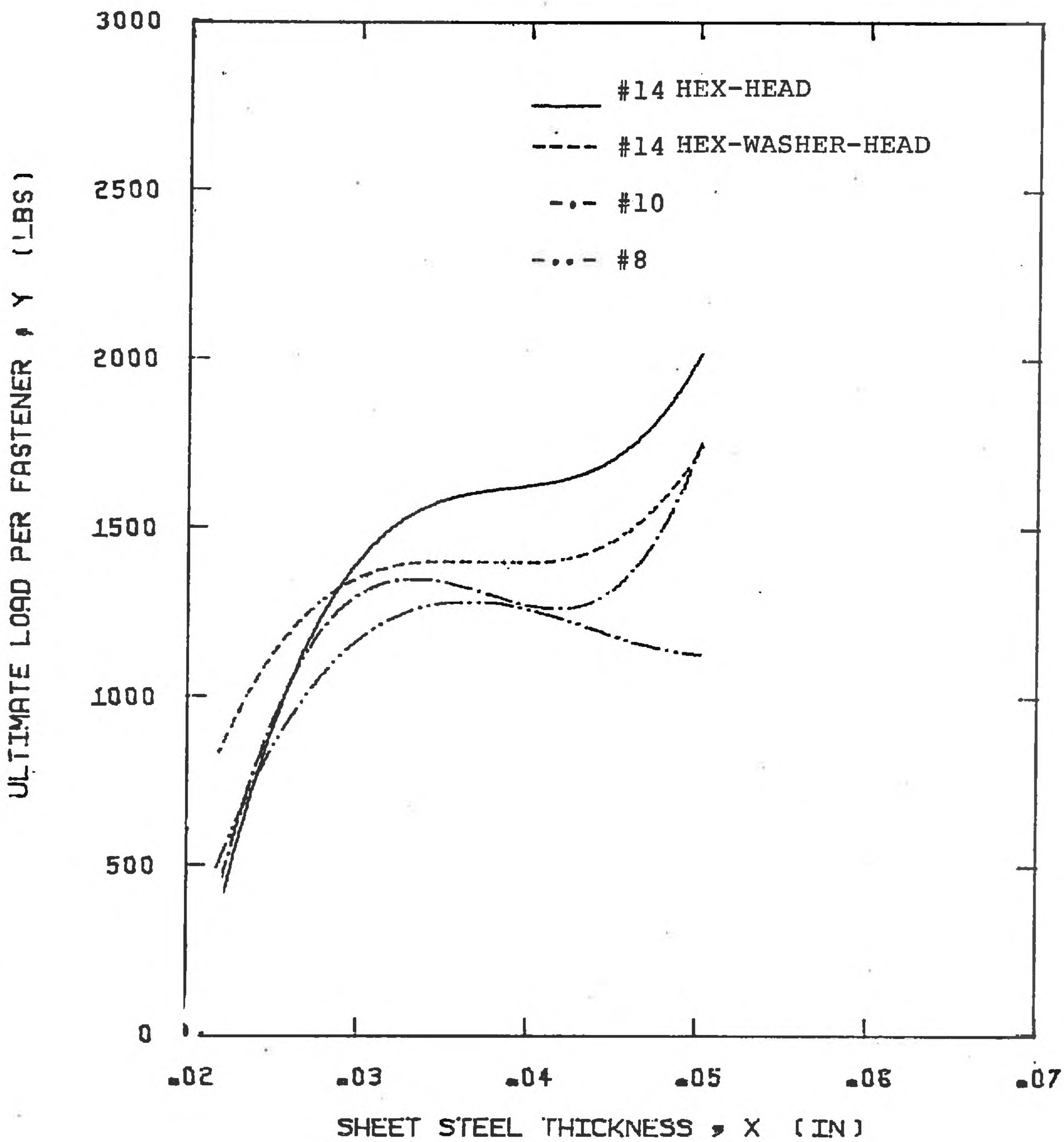


TYPE A

THREAD FORMING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

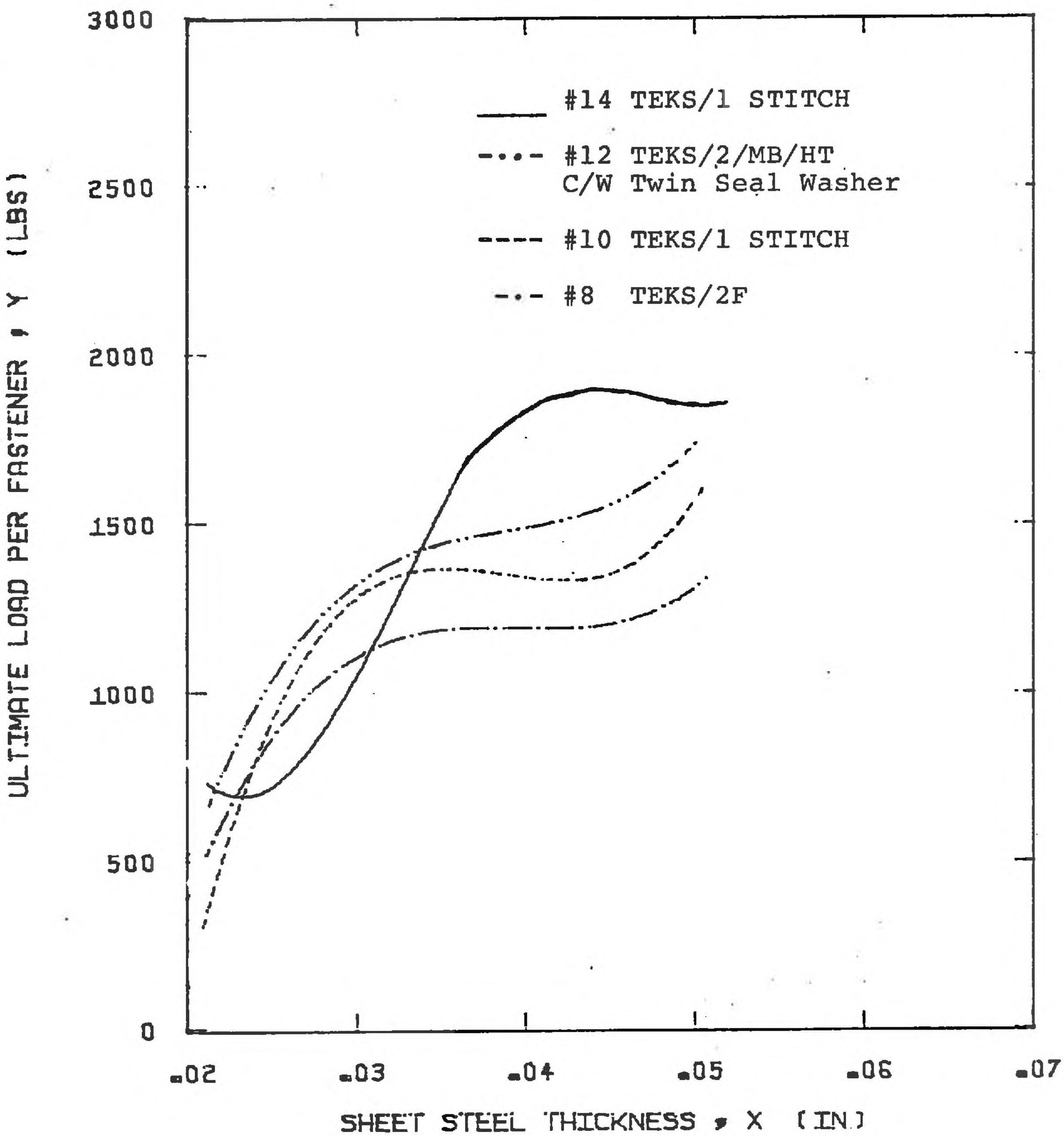


TYPE AB

THREAD FORMING

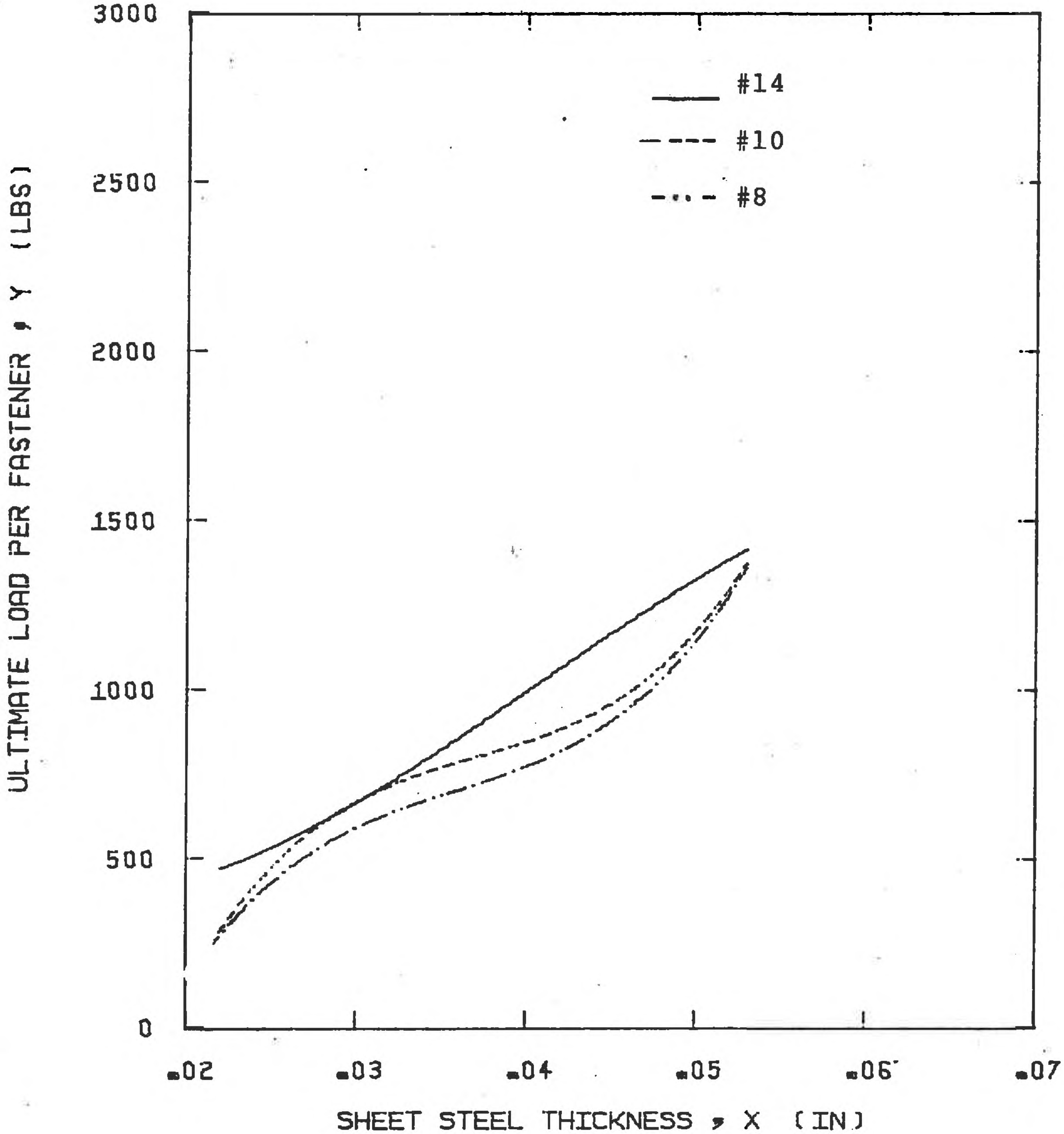
NO WASHER

Y = A + B X + C (X**2) + D (X**3)



SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

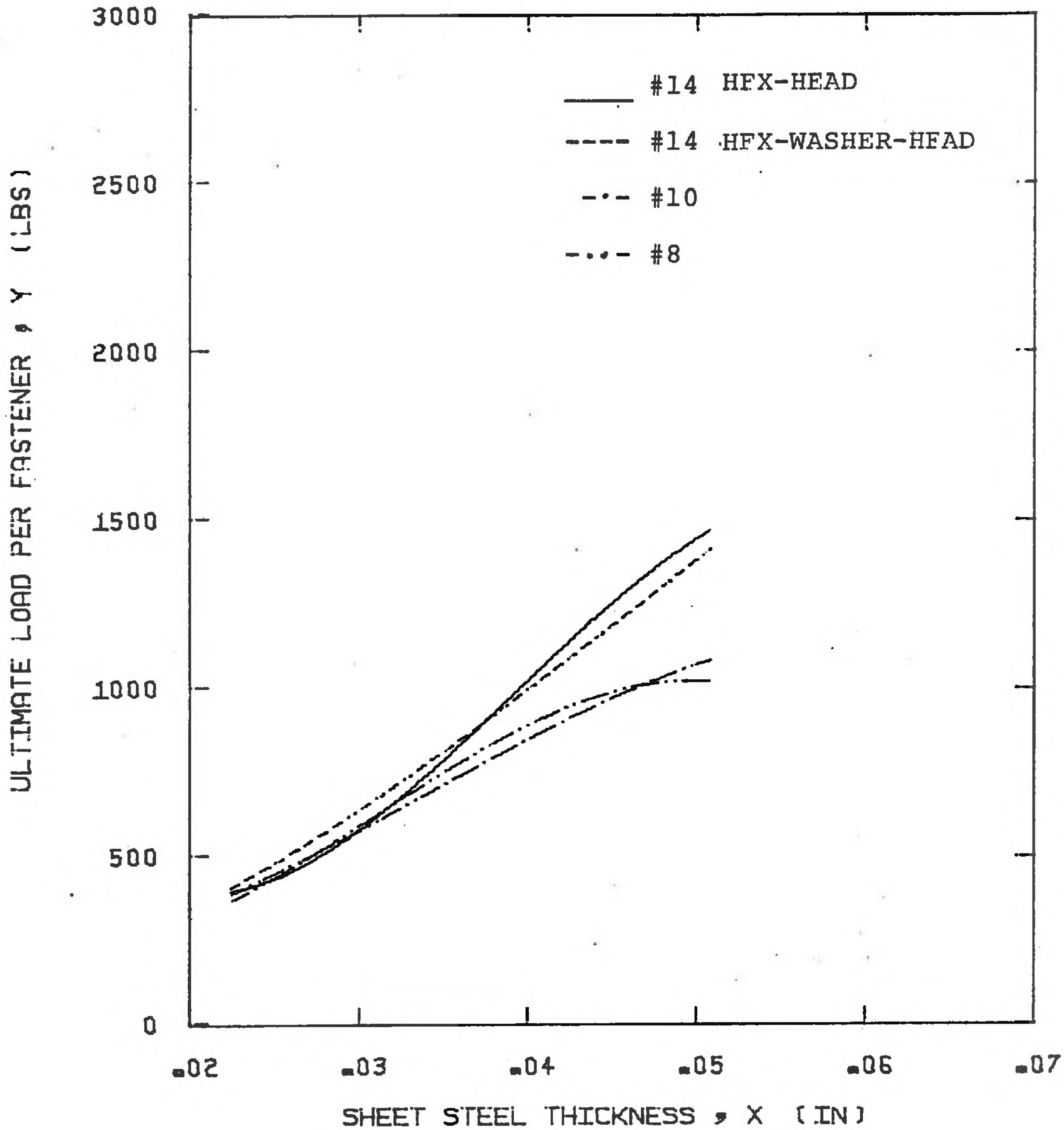


TYPE A

THREAD FORMING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

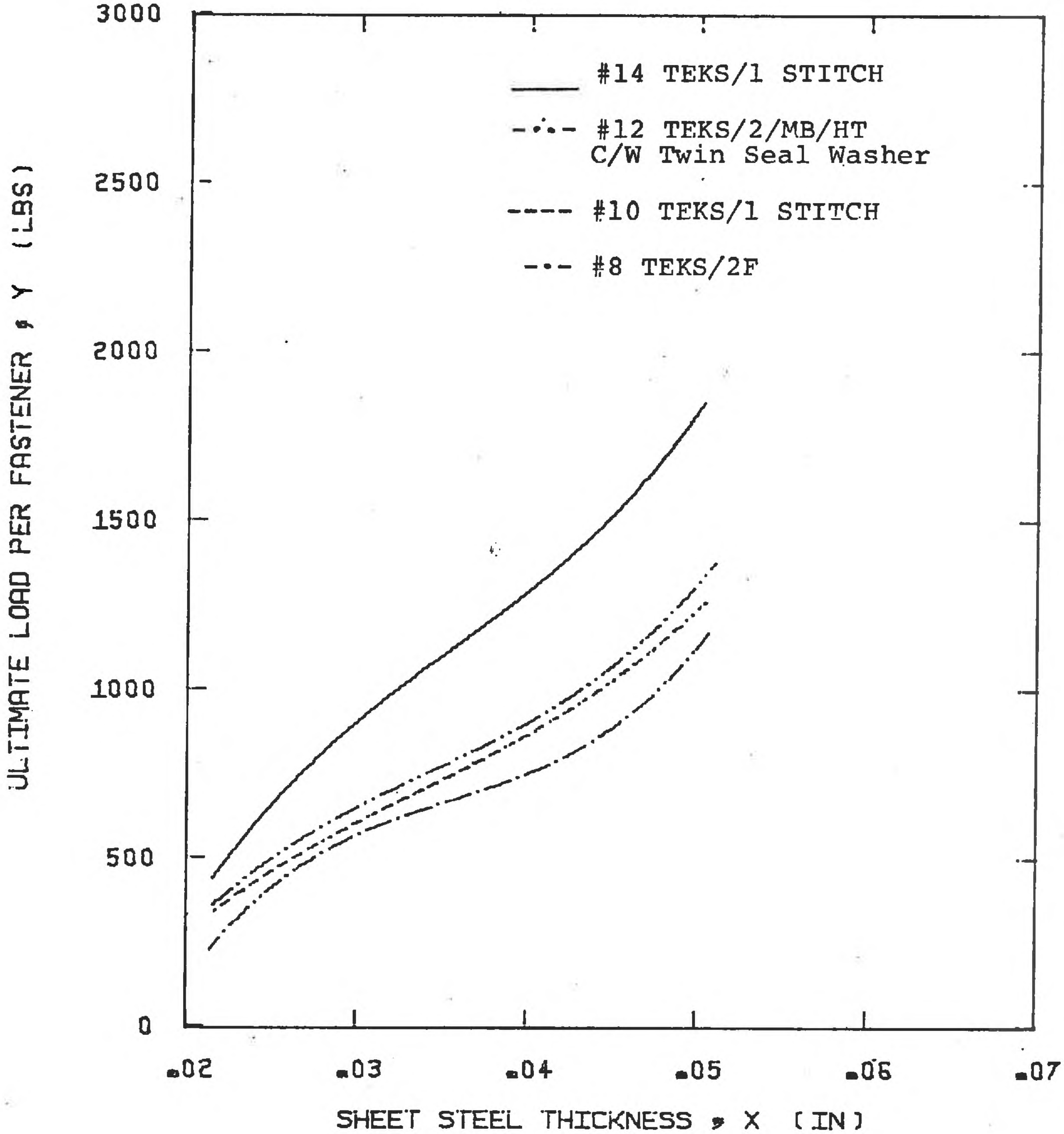


TYPE AB

THREAD FORMING

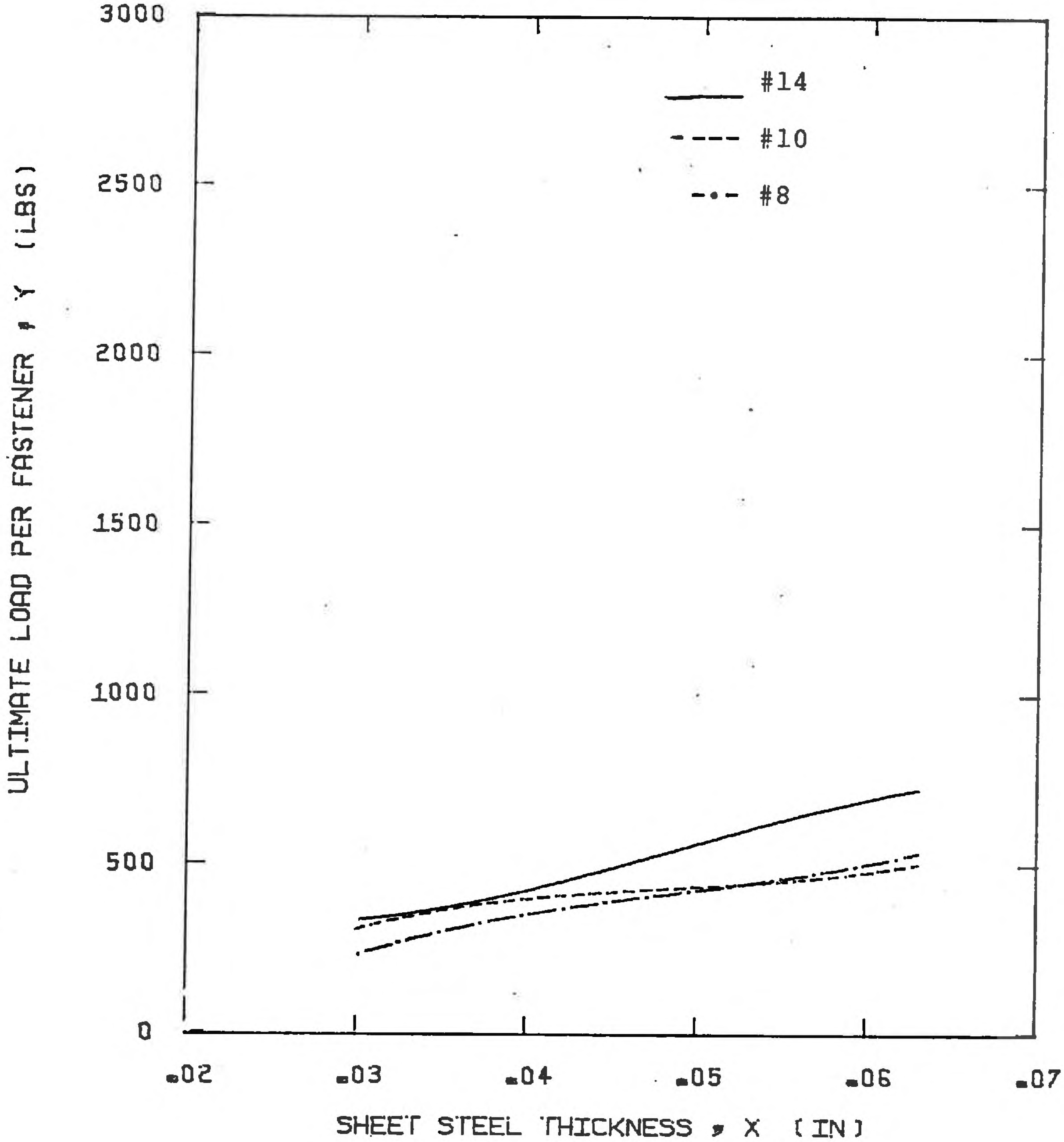
NO WASHER

Y = A + B X + C (X**2) + D (X**3)



SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

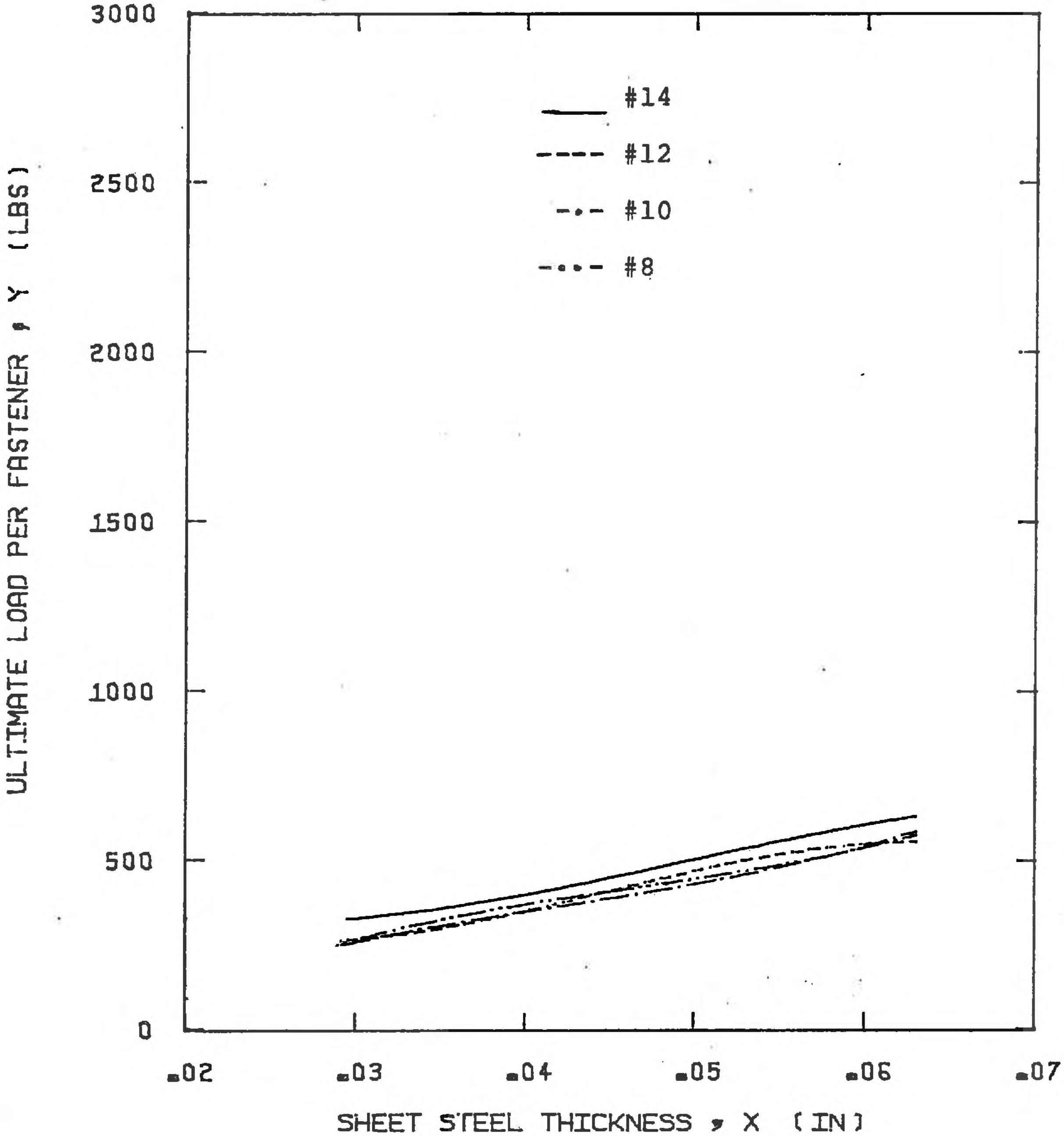


TYPE A

THREAD FORMING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

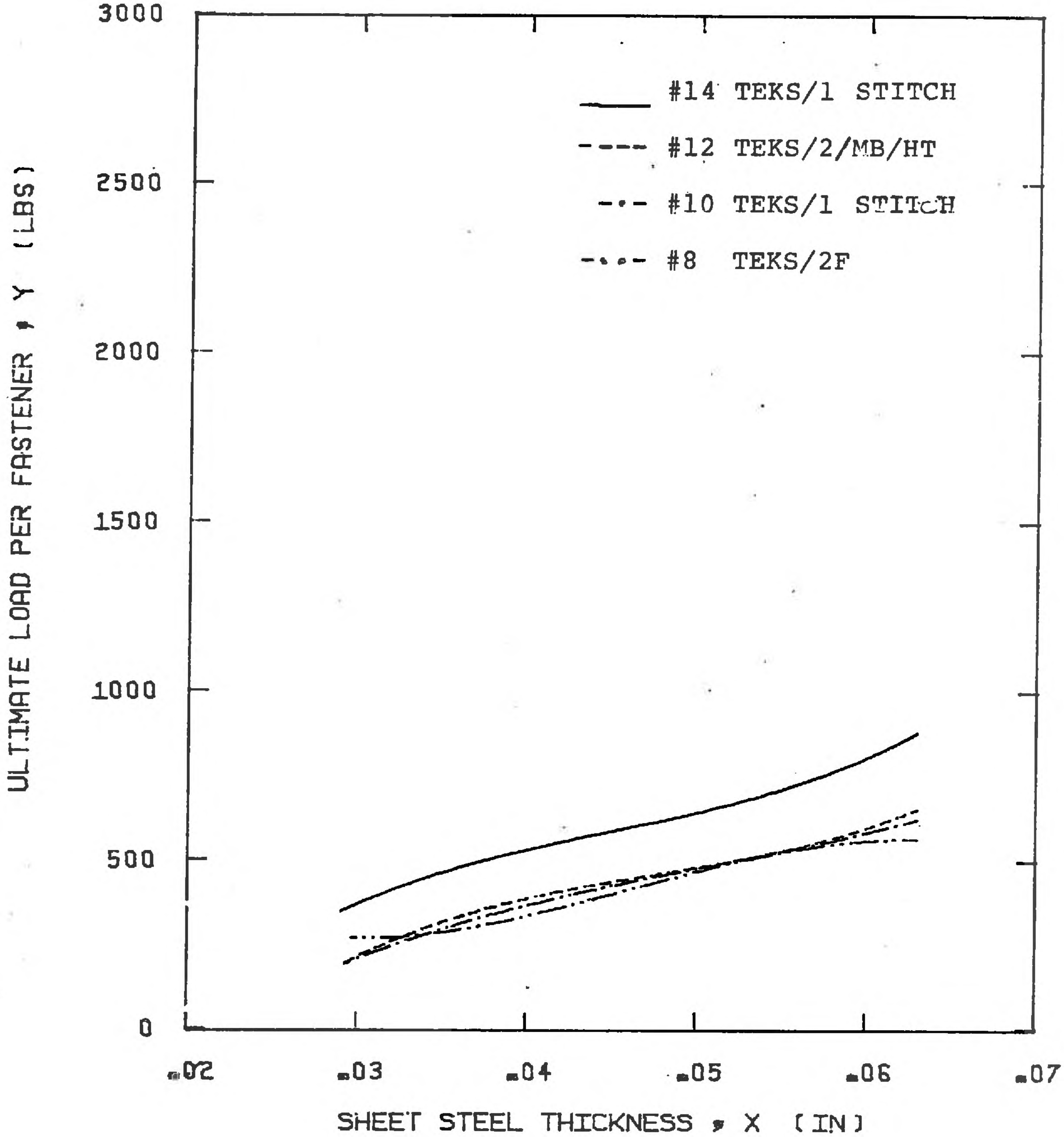


TYPE AB

THREAD FORMING

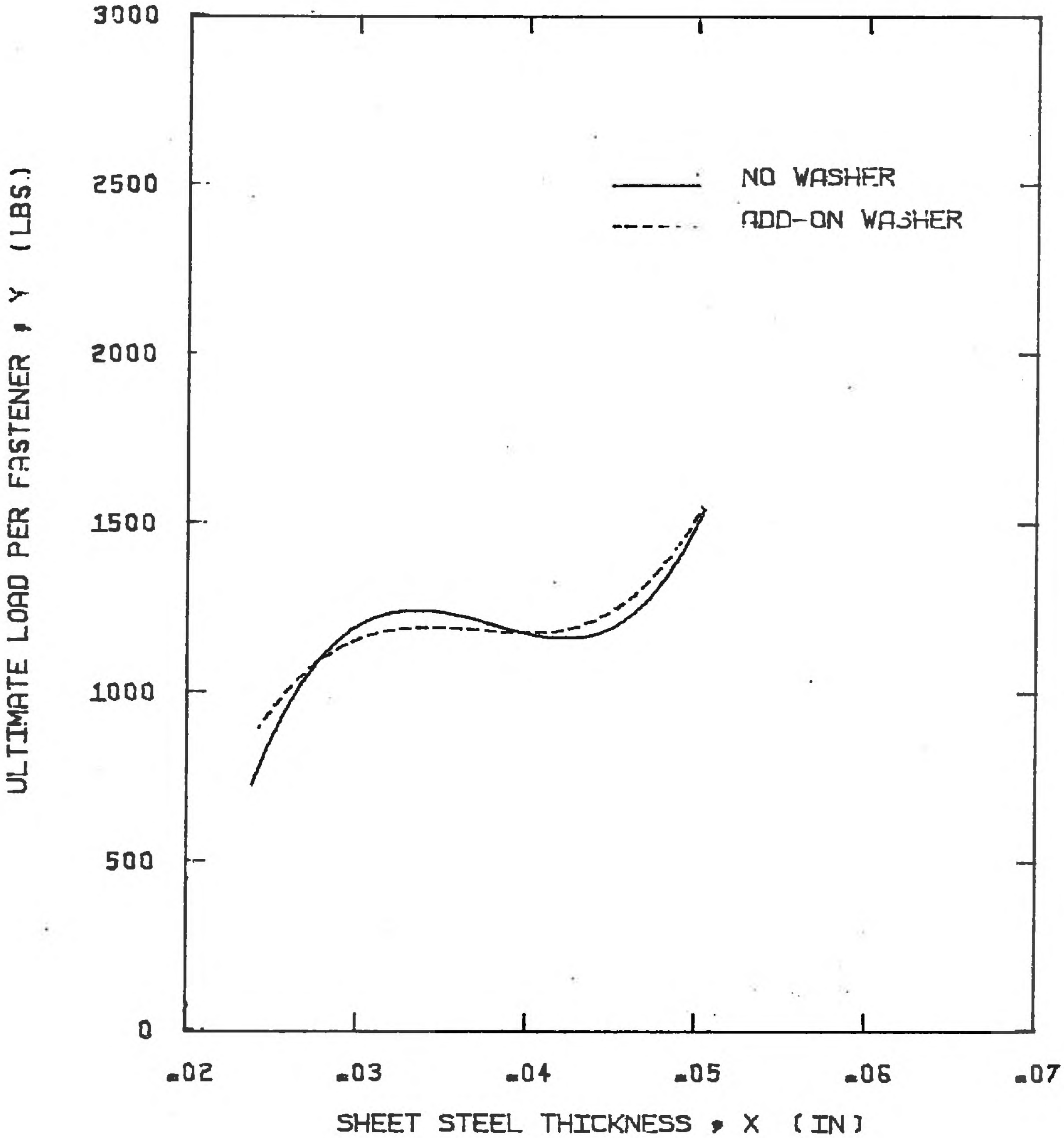
NO WASHER

Y = A + B X + C (X**2) + D (X**3)



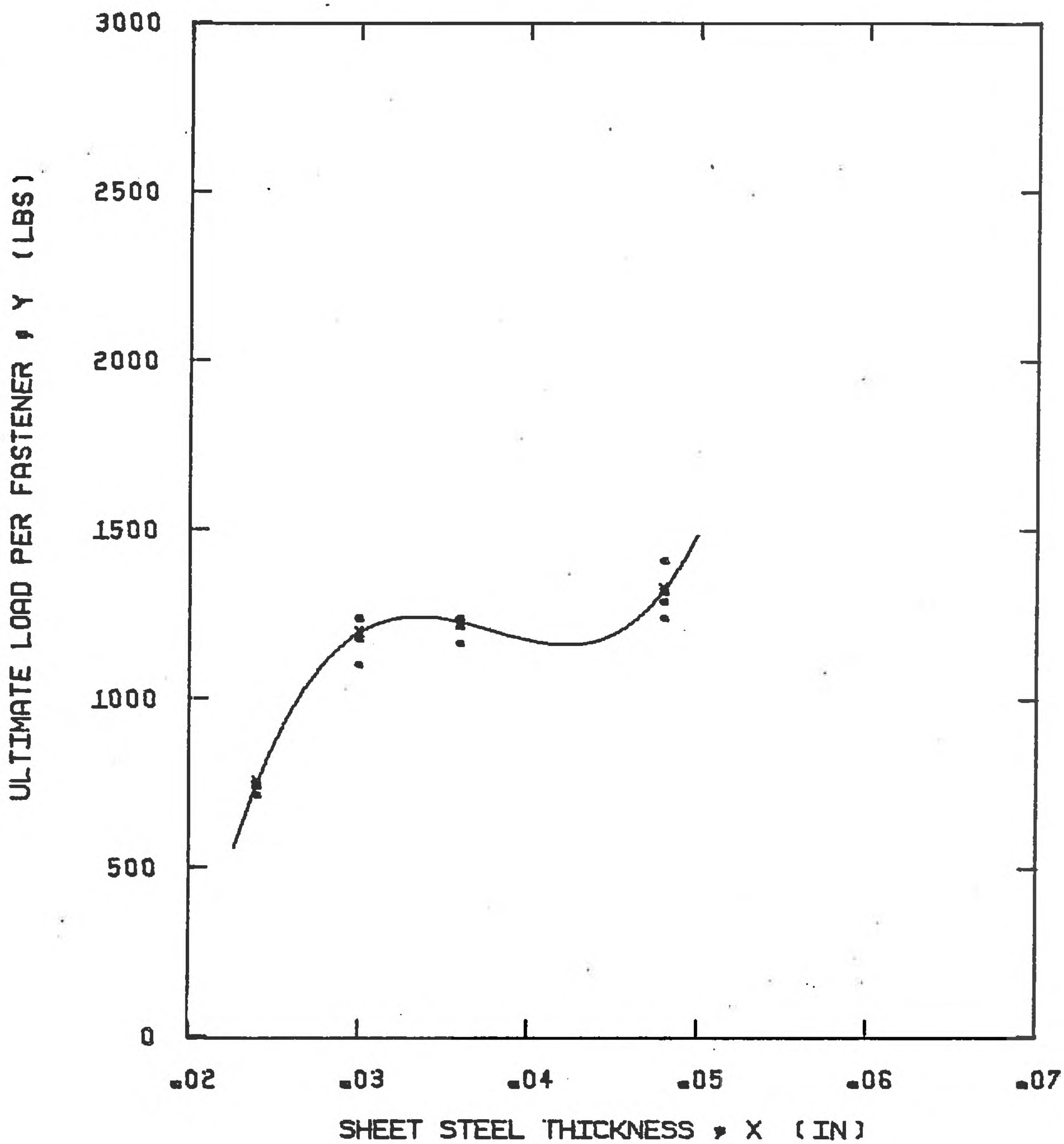
SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)



NUMBER 8 TYPE A 15TPI
THREAD FORMING

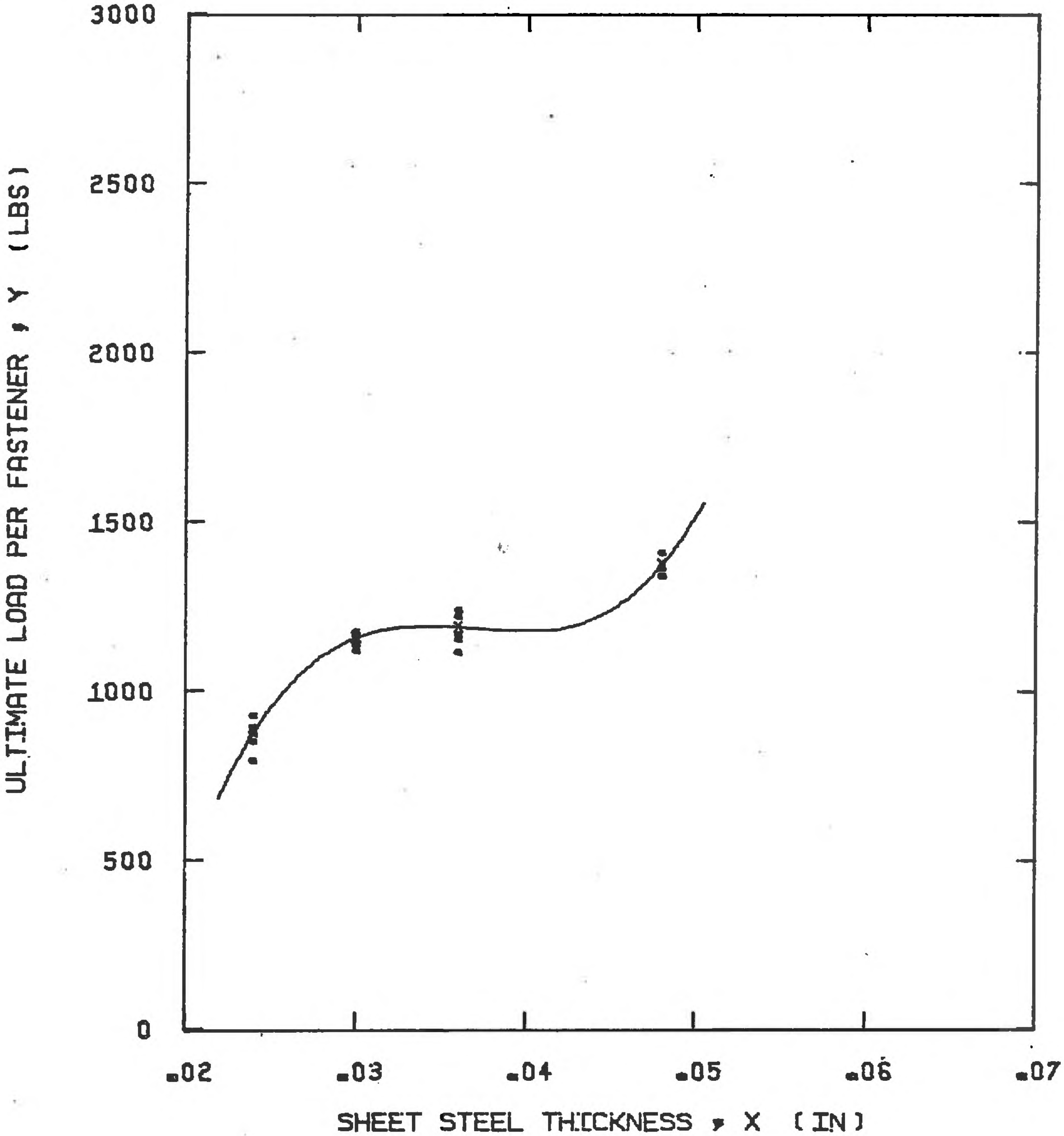
Y = A + B X + C (X**2) + D (X**3)



NUMBER 8 TYPE A 15TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

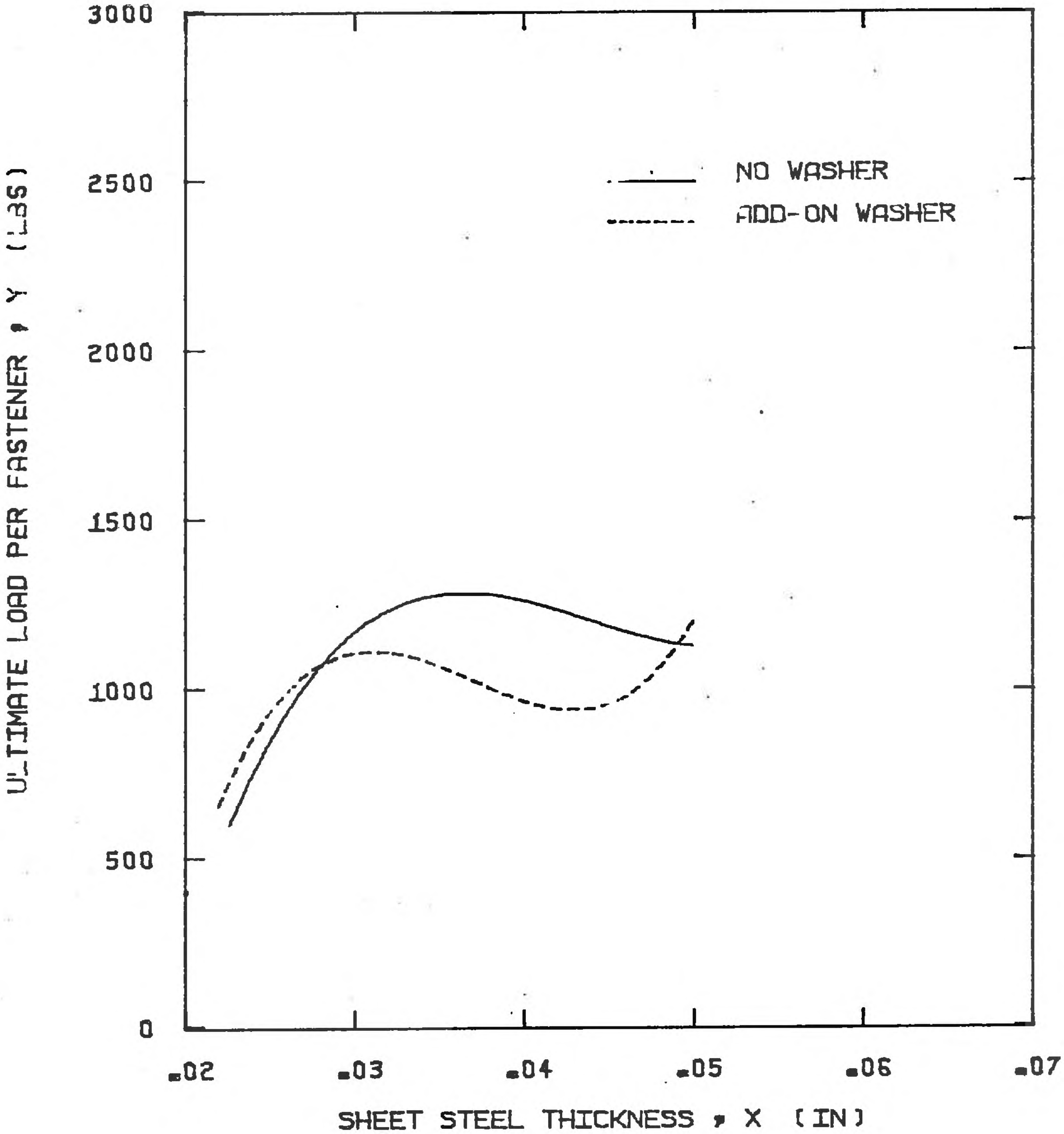
A = -.118E+05 B = .107E+07
C = -.287E+08 D = .253E+09



NUMBER 8 TYPE A 15TPI
THREAD FORMING
FLAT METAL WASHER

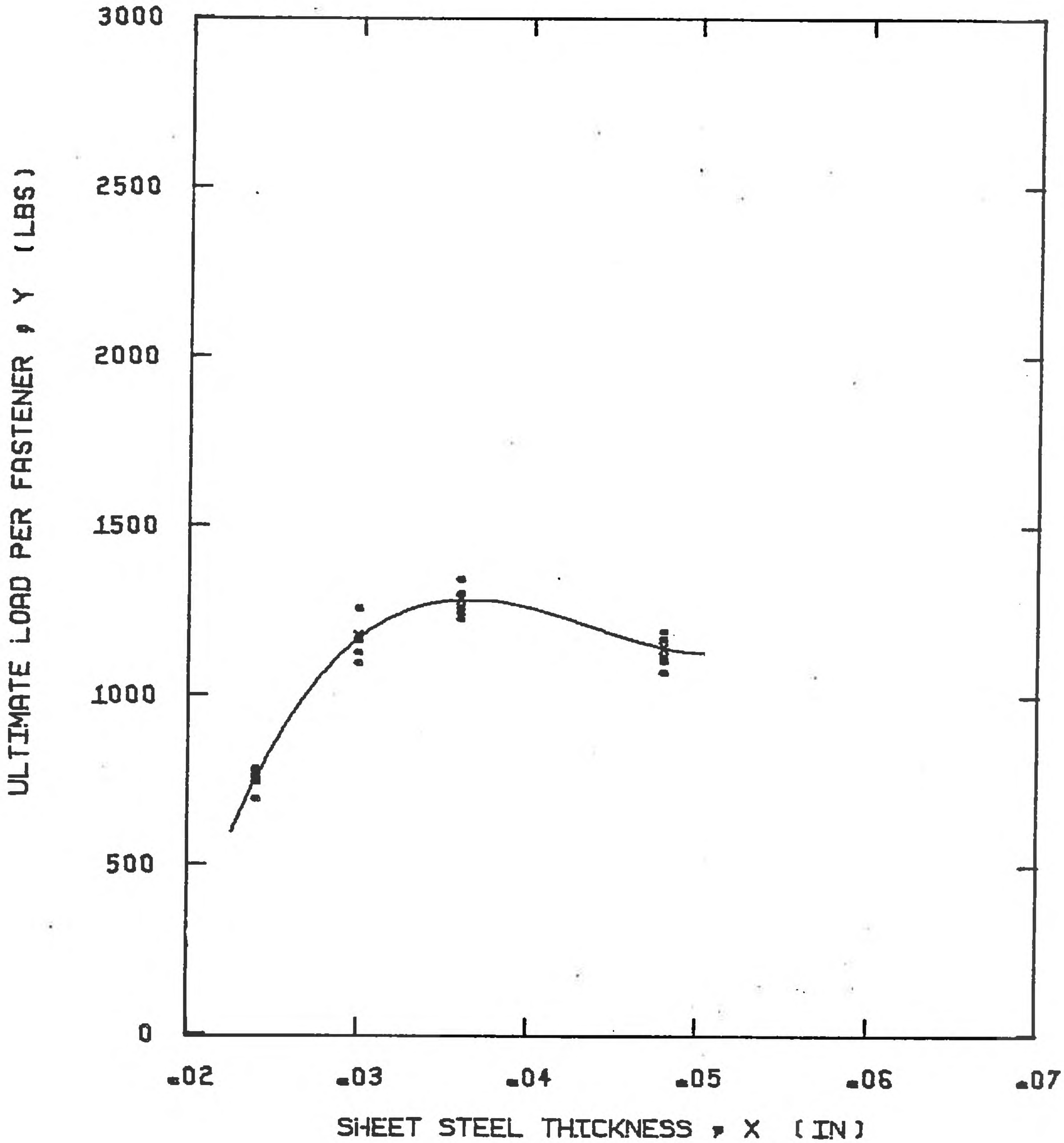
Y = A + B X + C (X**2) + D (X**3)

A = -.721E+04 B = .693E+06
C = -.189E+08 D = .171E+09



NUMBER 8 TYPE AB 18 TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

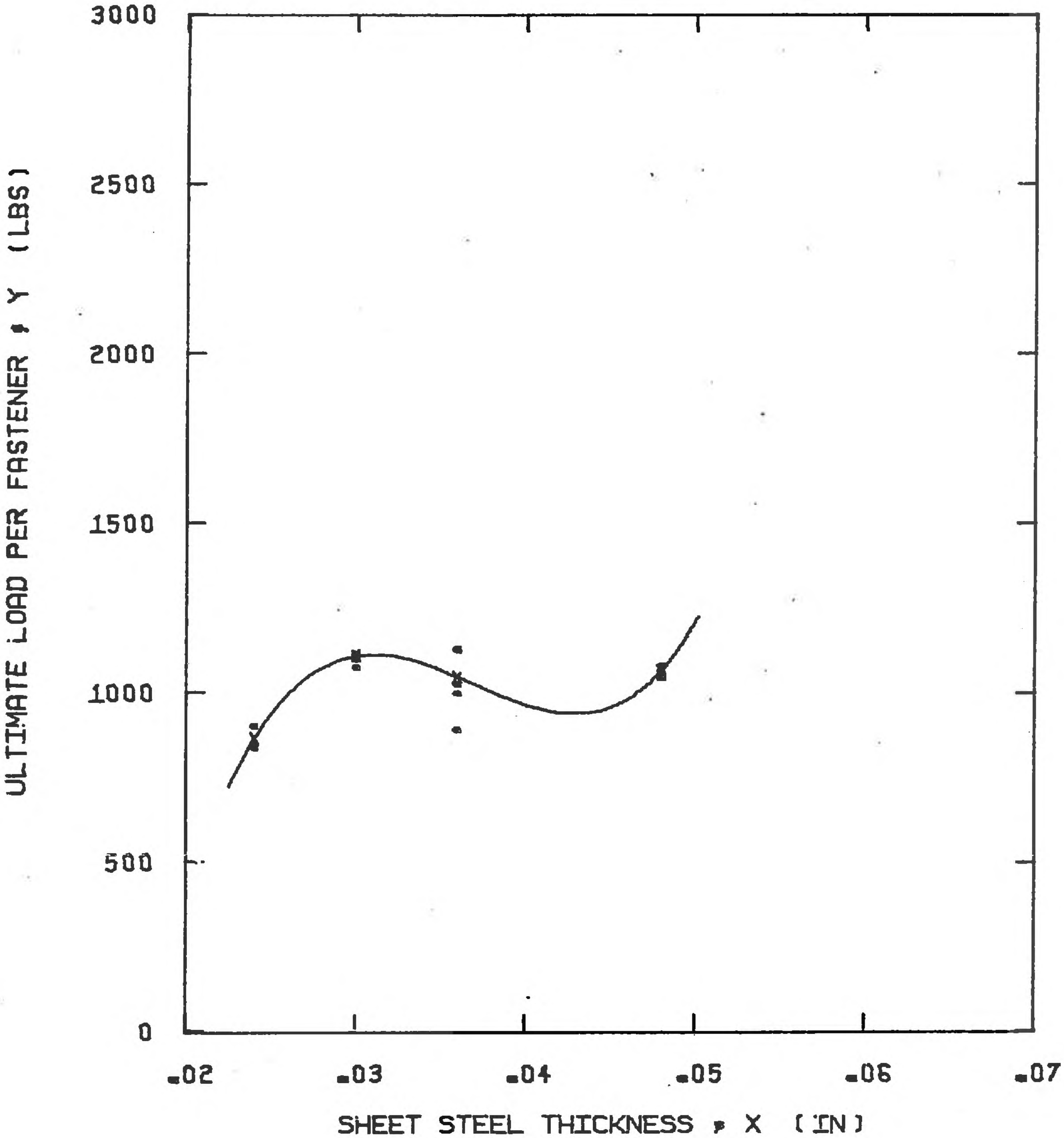


NUMBER 8 TYPE AB 18TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.659E+04 B = .571E+06

C = -.135E+08 D = .103E+09



NUMBER 8 TYPE AB 18TPI

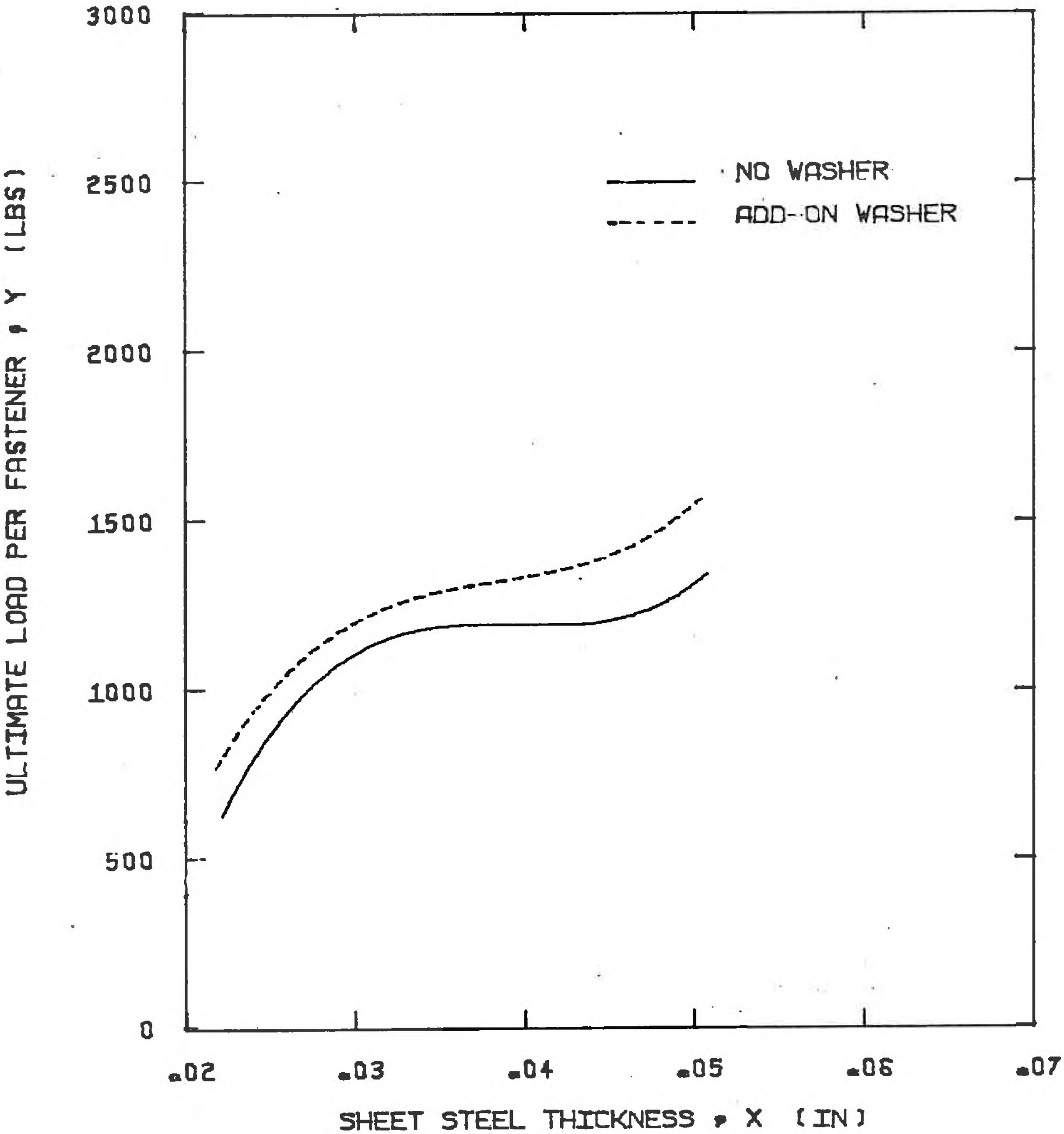
THREAD FORMING

FLAT WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.869E+04 B = .836E+06

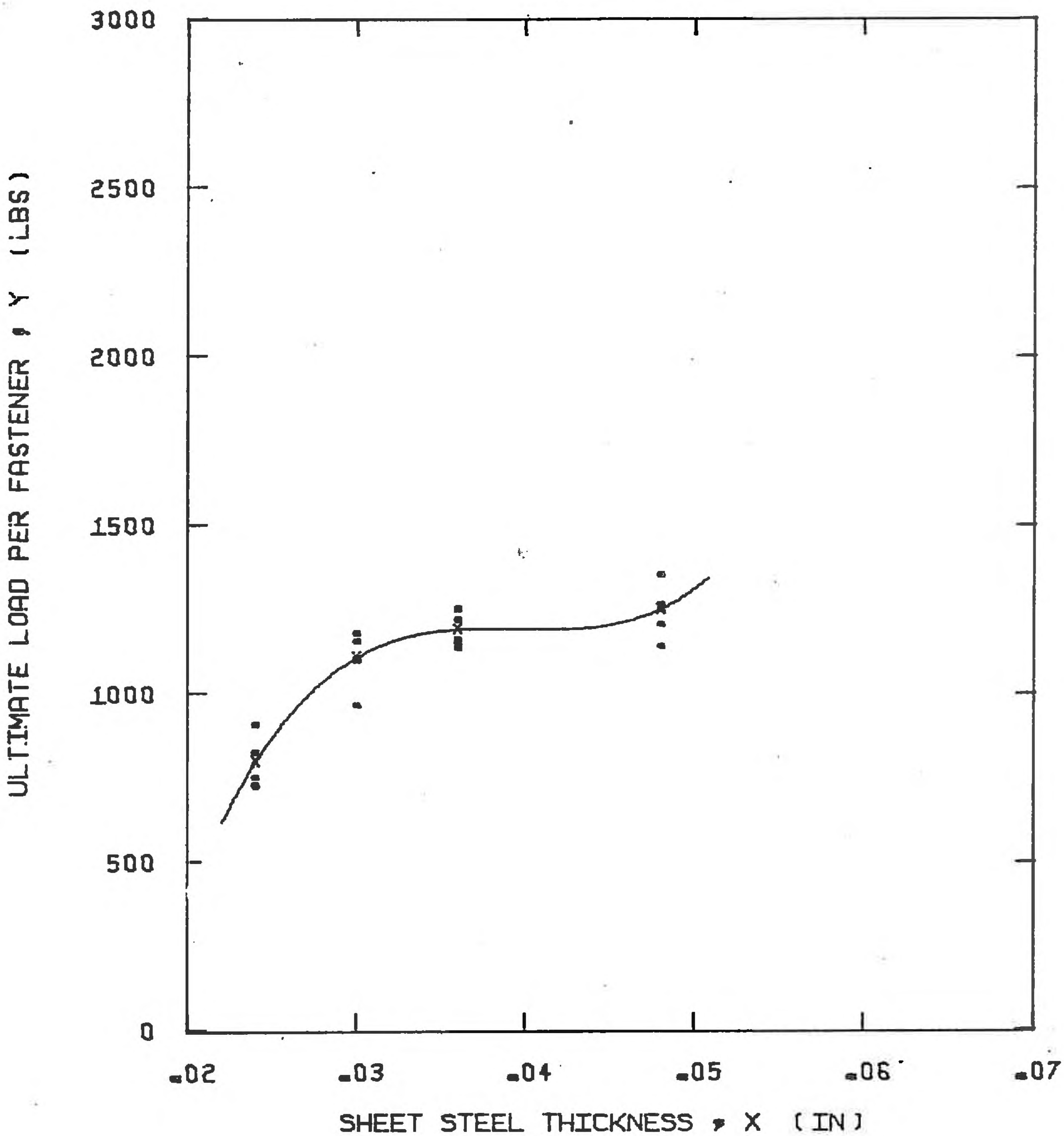
C = -.233E+08 D = .211E+09



NUMBER 8 TYPE TEKS/2F 18TPI

SELF DRILLING

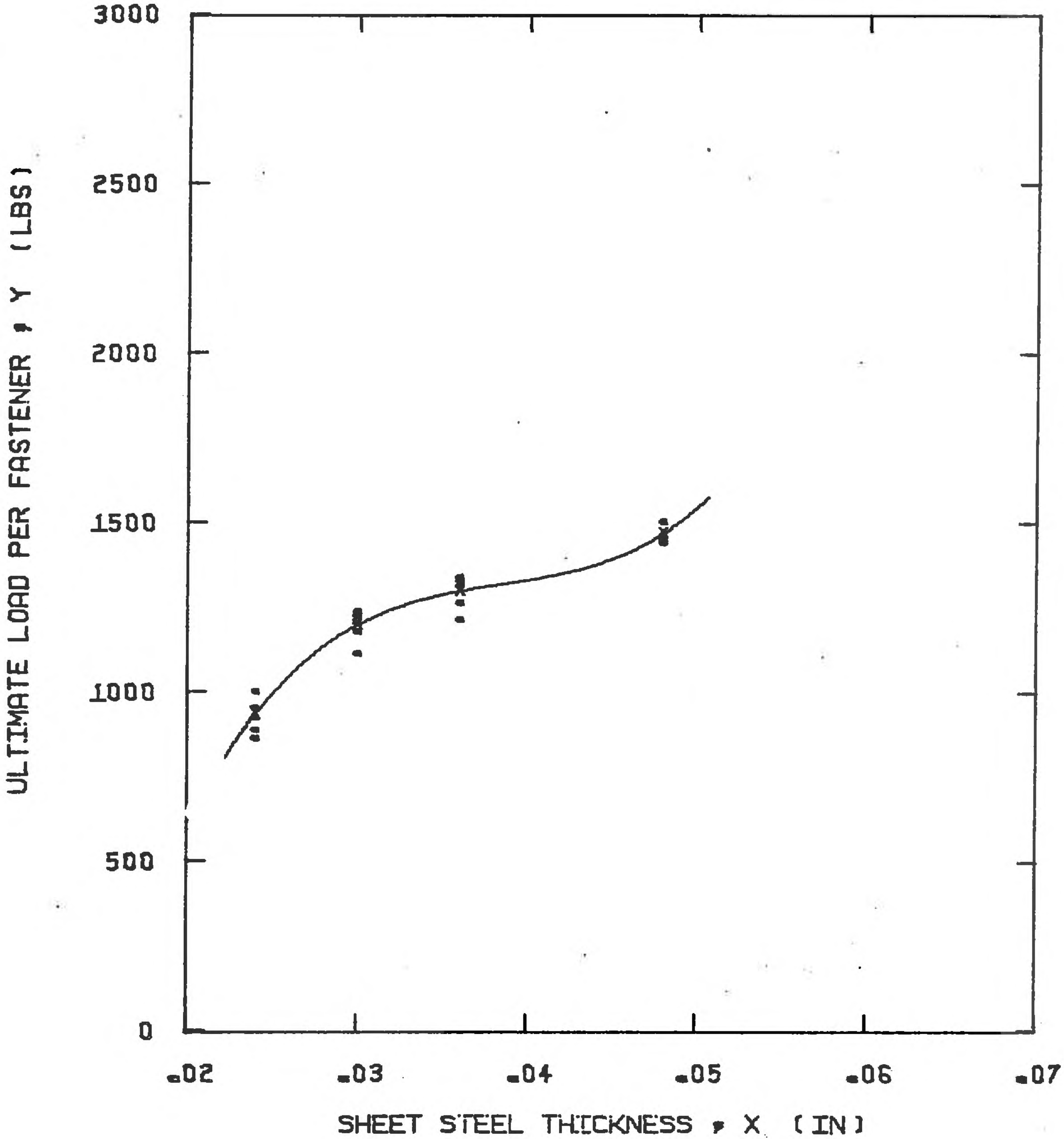
Y = A + B X + C (X++2) + D (X++3)



NUMBER 8 TYPE TEKS/2F 18TPI
SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A =	-.564E+04	B =	.522E+06
C =	-.133E+08	D =	.112E+09

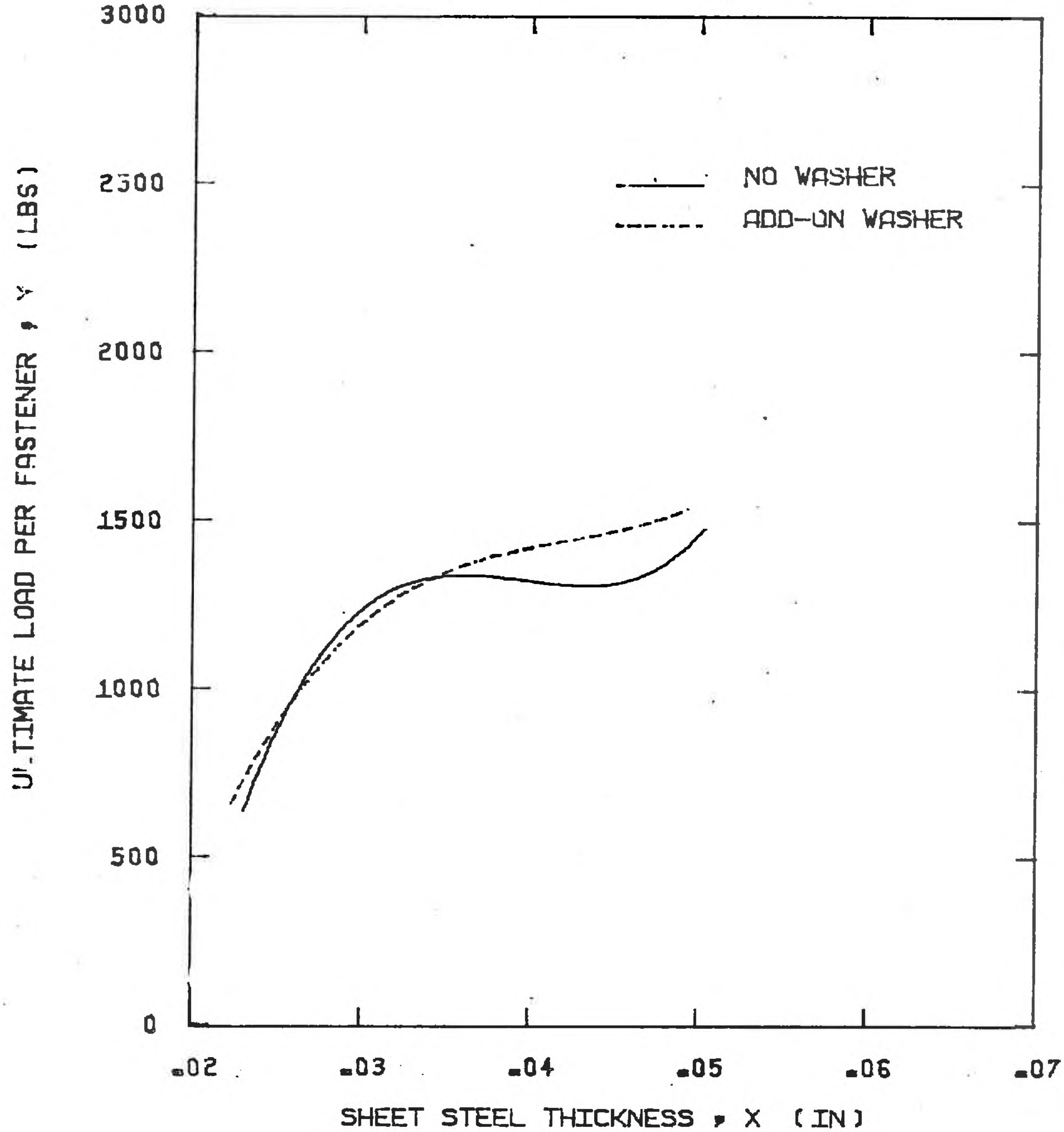


NUMBER 8 TYPE TEKS/2F 18 TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

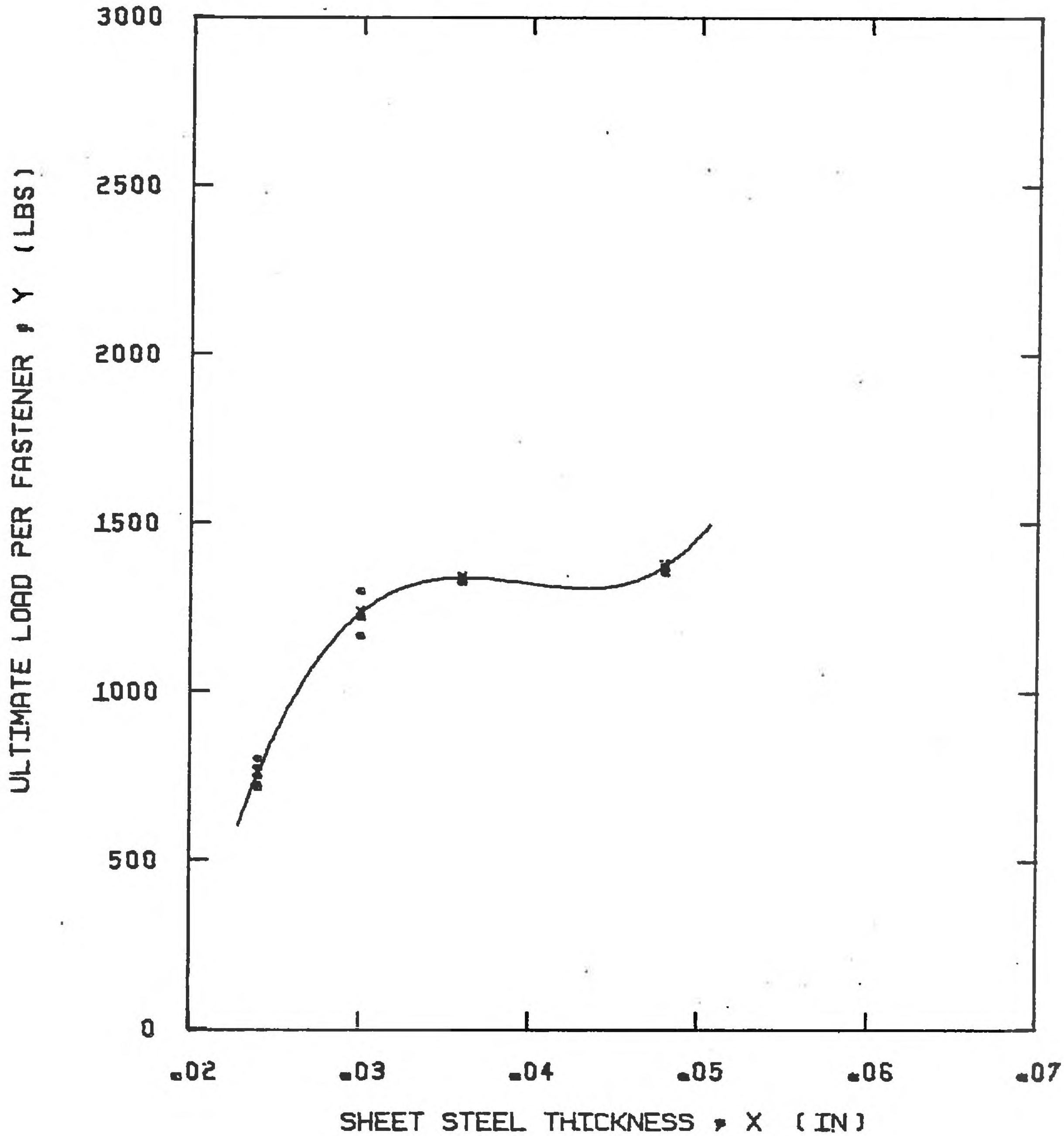
A = -.410E+04 B = .408E+06

C = -.104E+08 D = .899E+08



NUMBER 10 TYPE A 12TPI
THREAD FORMING

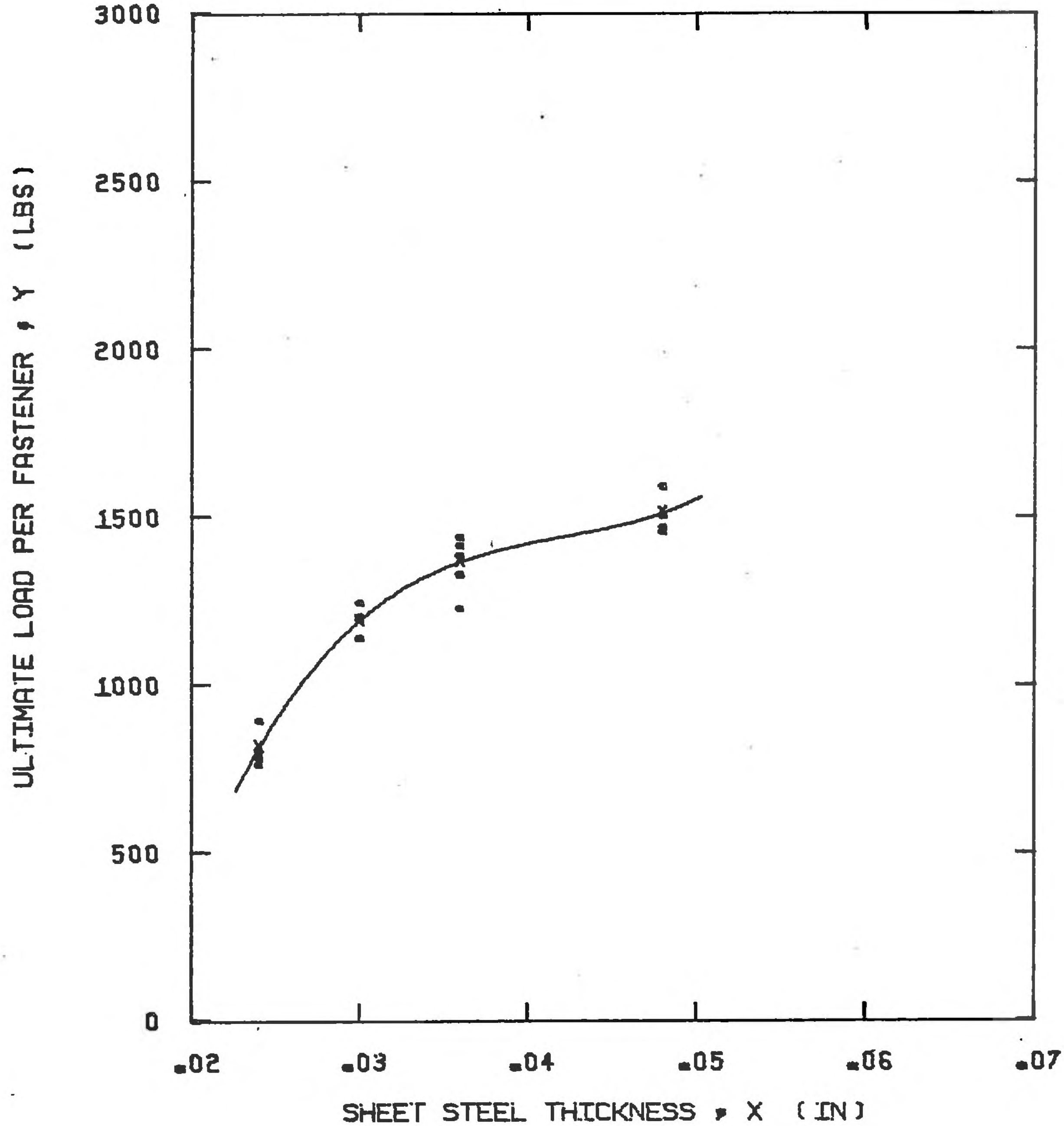
Y = A + B X + C (X**2) + D (X**3)



NUMBER 10 TYPE A 12TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.959E+04 B = .845E+06
C = -.216E+08 D = .183E+09



NUMBER 10 TYPE A 12TPI

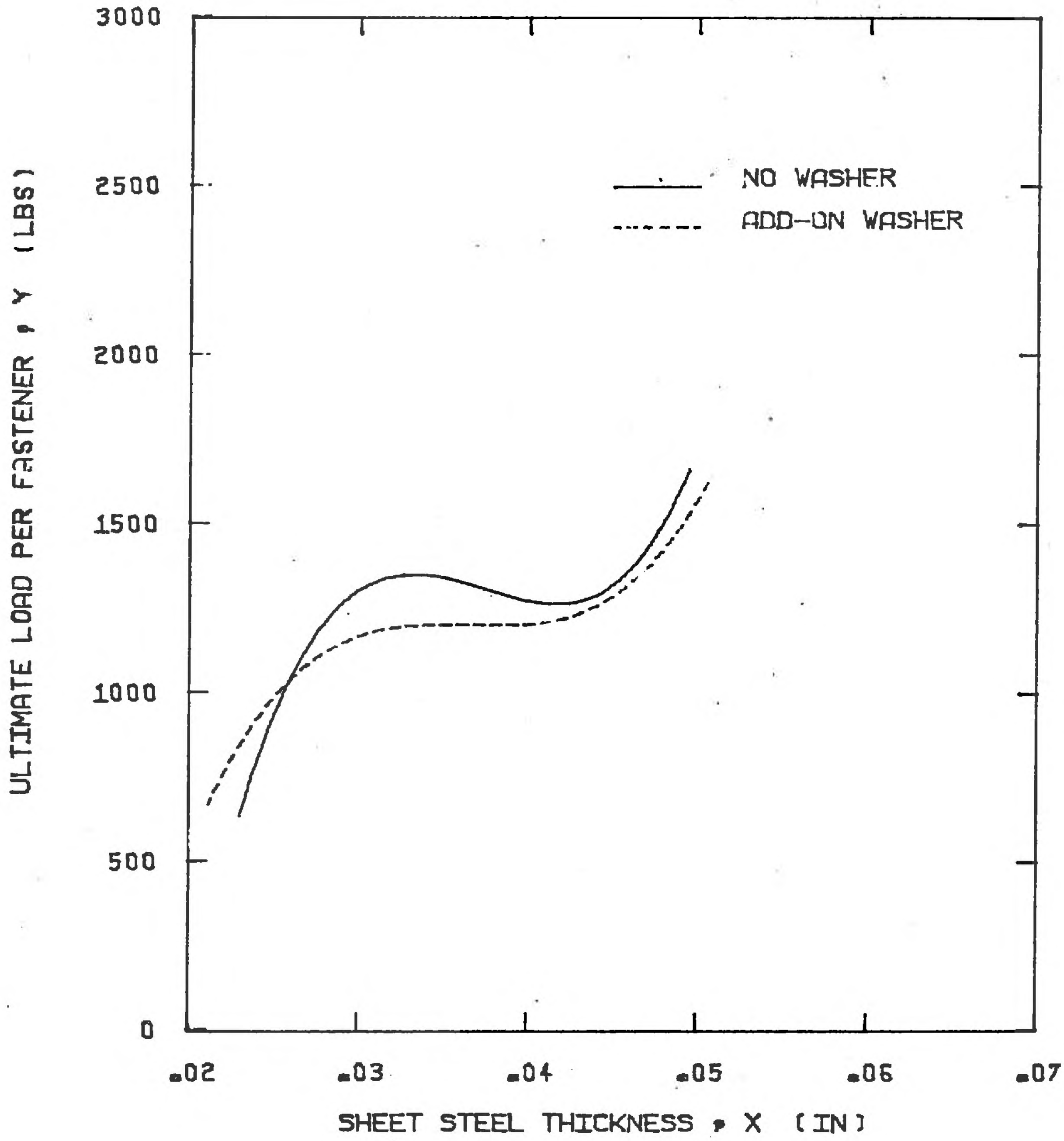
THREAD FORMING

FLAT METAL AND NEOPRENE WASHER

Y = A + B X + C (X**2) + D (X**3)

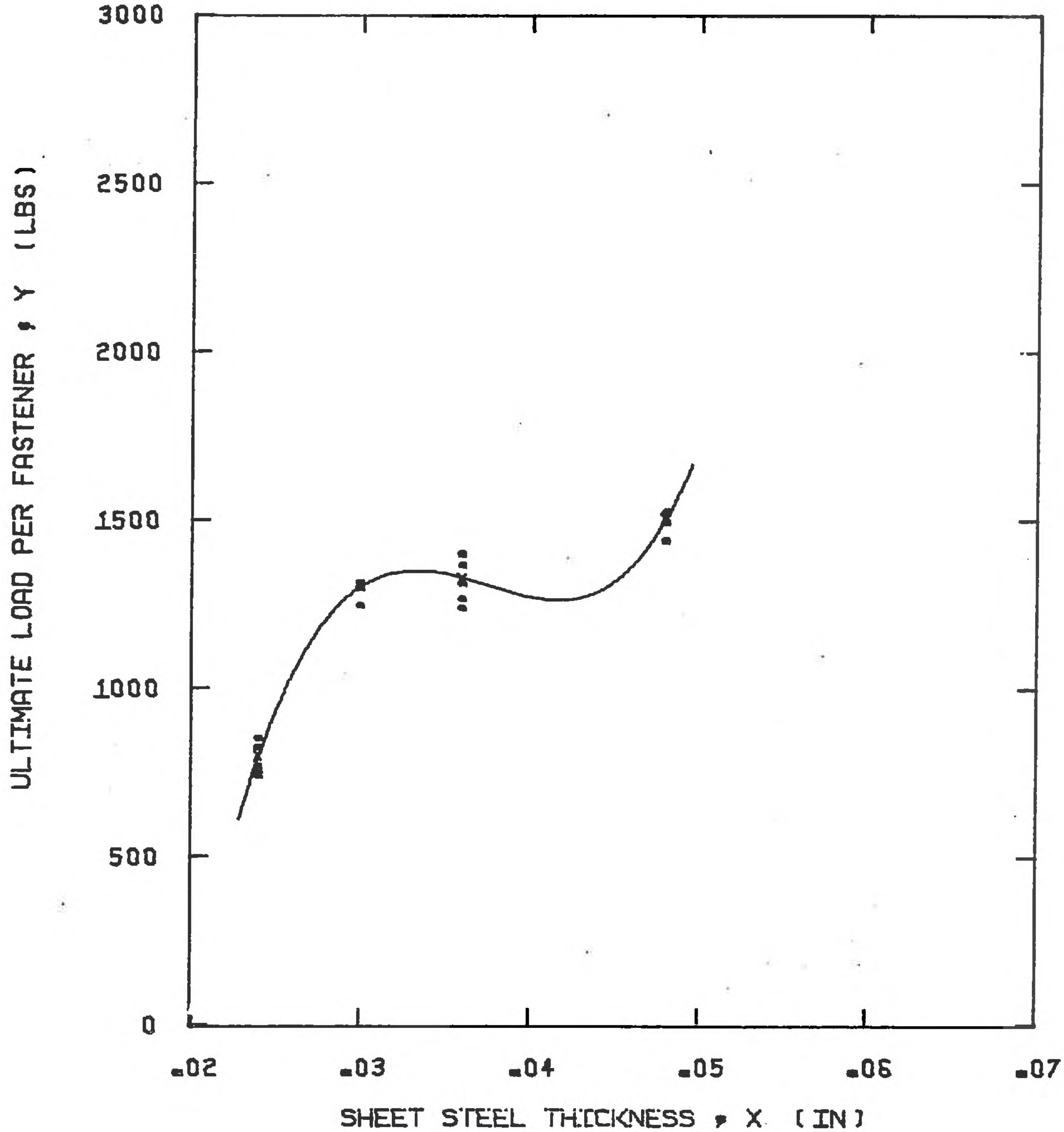
A = -.474E+04 B = .423E+06

C = -.984E+07 D = .780E+08



NUMBER 10 TYPE AB 16TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

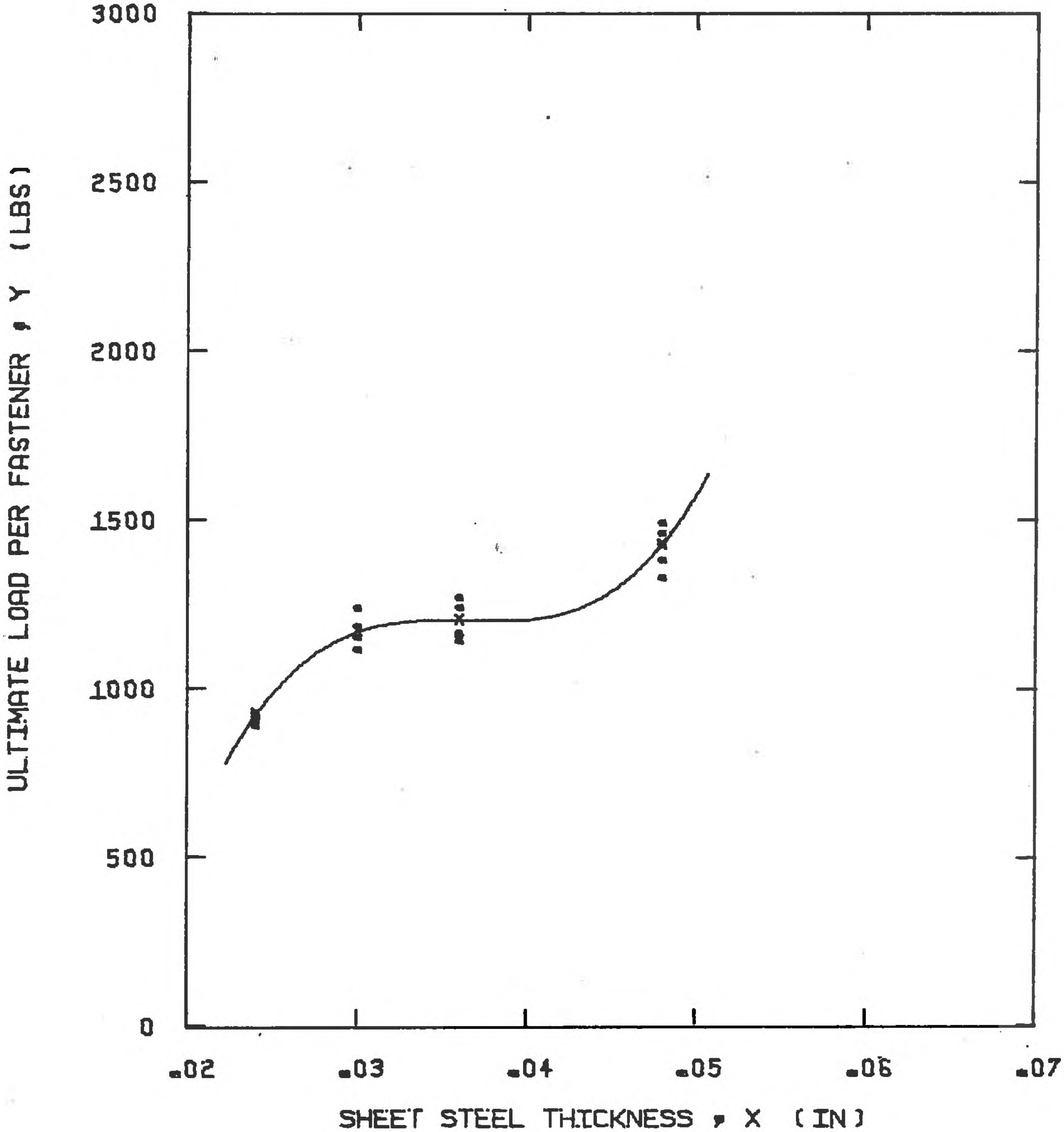


NUMBER 10 TYPE AB 16TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.140E+05 B = .126E+07

C = -.343E+08 D = .306E+09



NUMBER 10 TYPE AB 16TPI

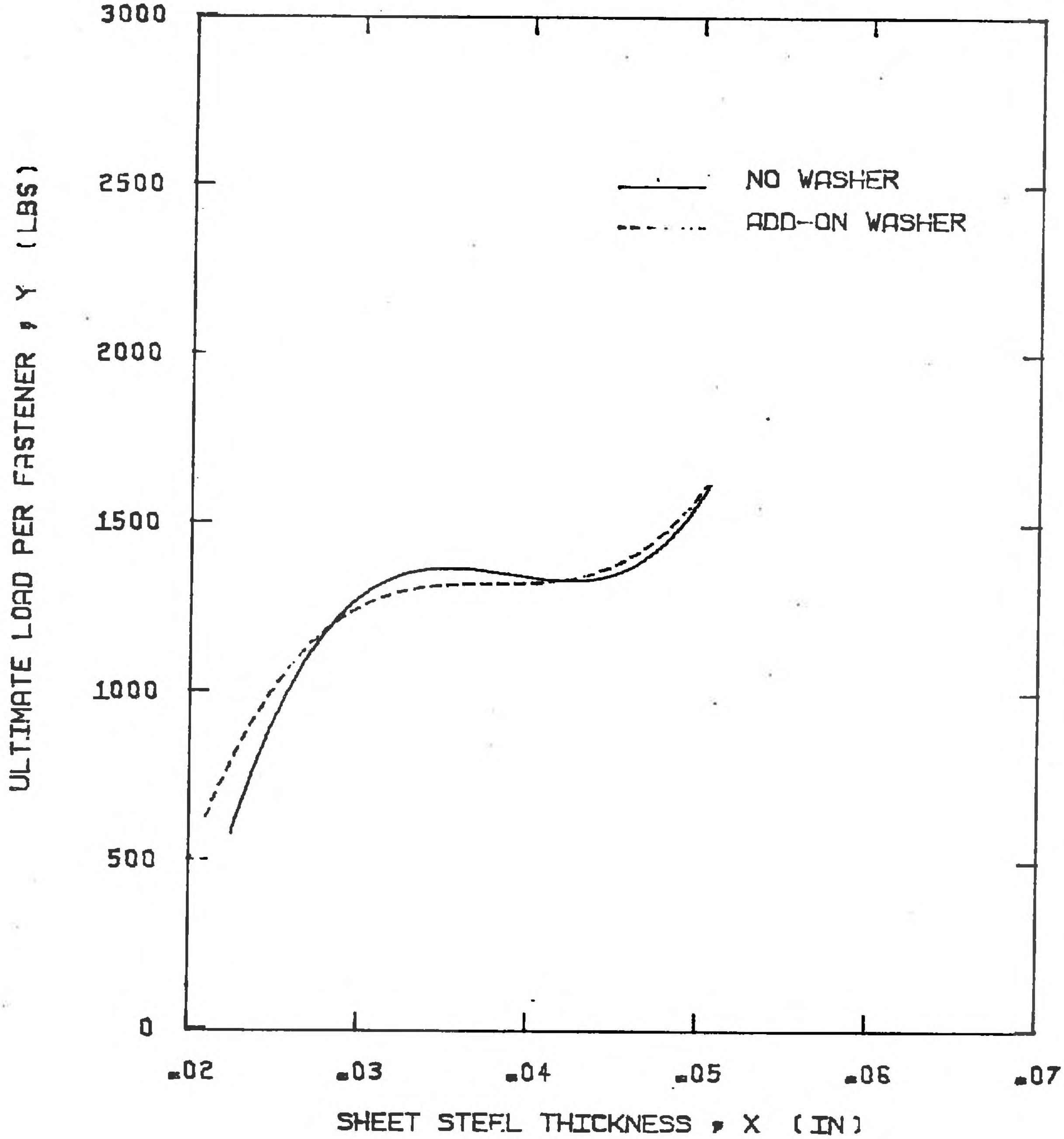
THREAD FORMING

FLAT METAL AND NEOPRENE WASHER

Y = A + B X + C (X**2) + D (X**3)

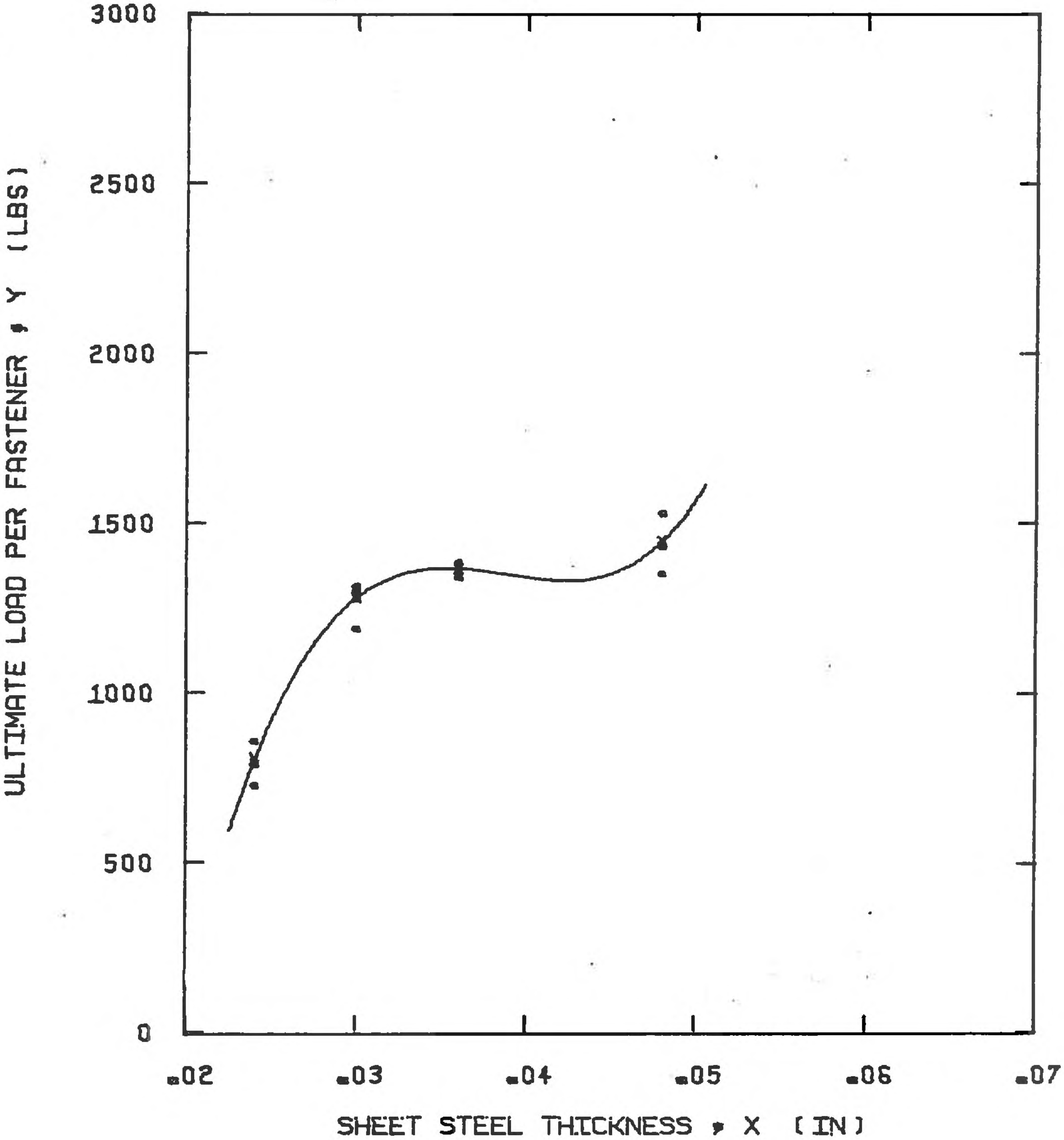
A = -.622E+04 B = .614E+06

C = -.169E+08 D = .155E+09



NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)



NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI

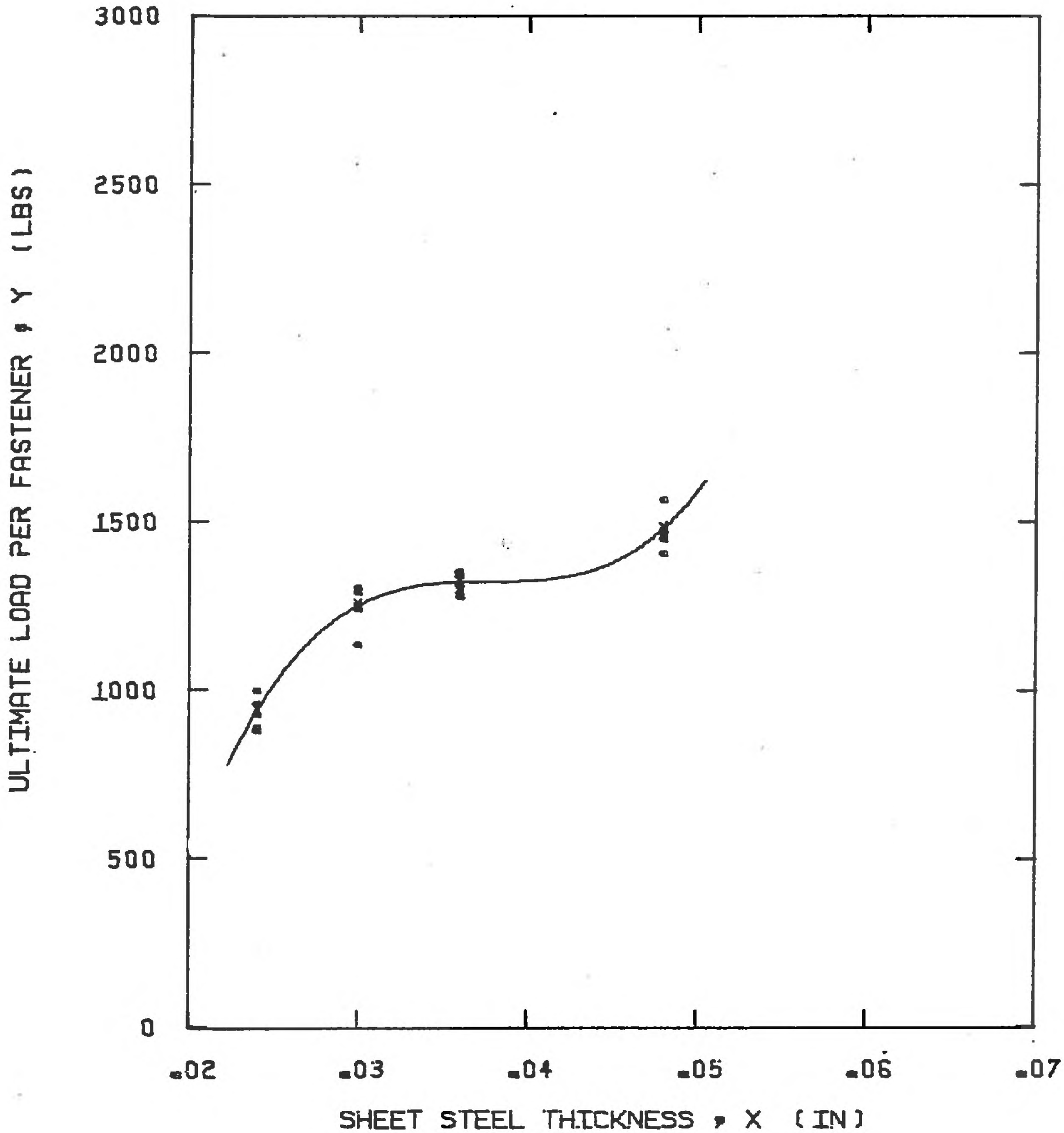
SELF DRILLING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.106E+05 B = .946E+06

C = -.247E+08 D = .213E+09

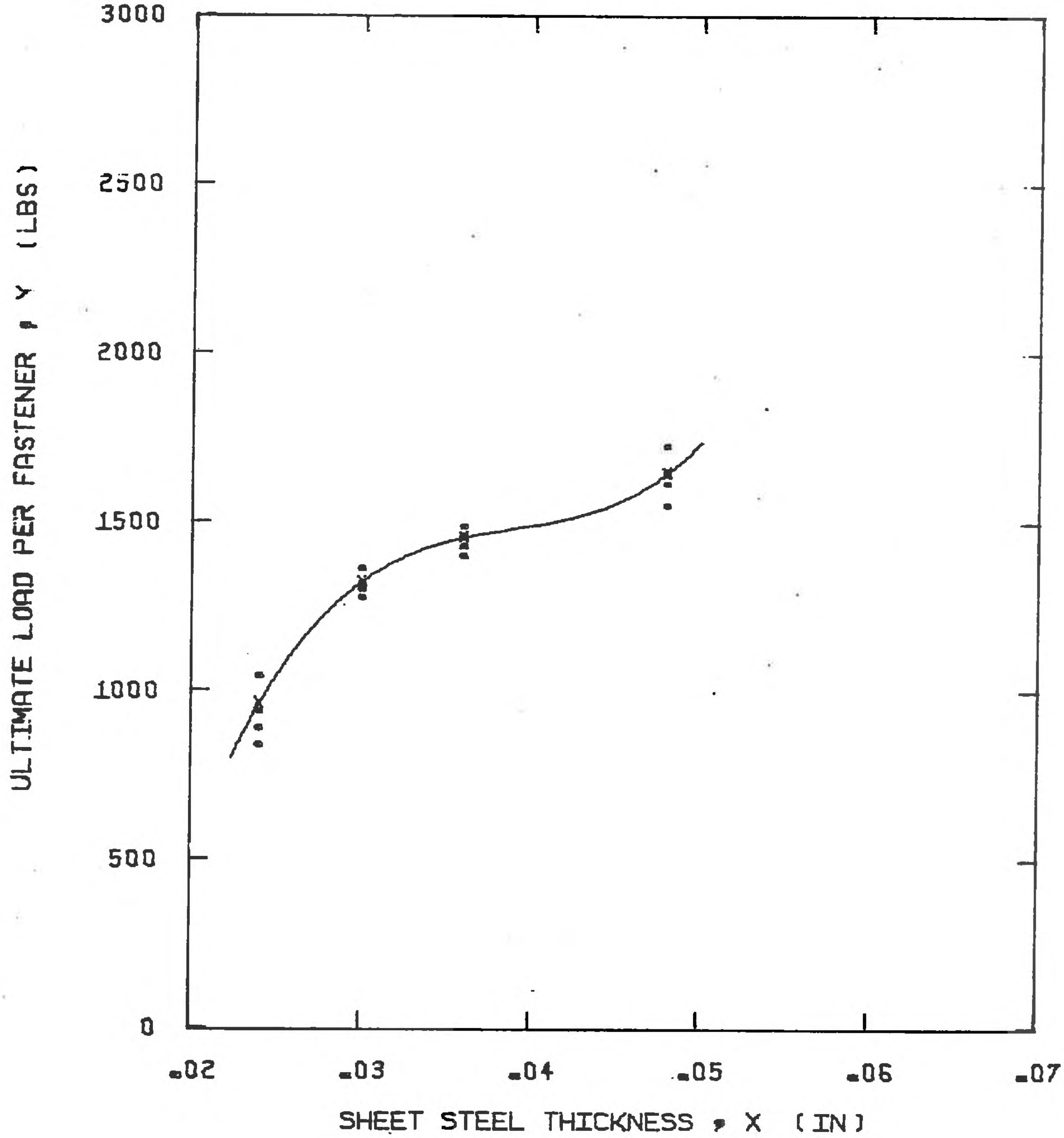


NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.652E+04 B = .623E+06

C = -.165E+08 D = .145E+09

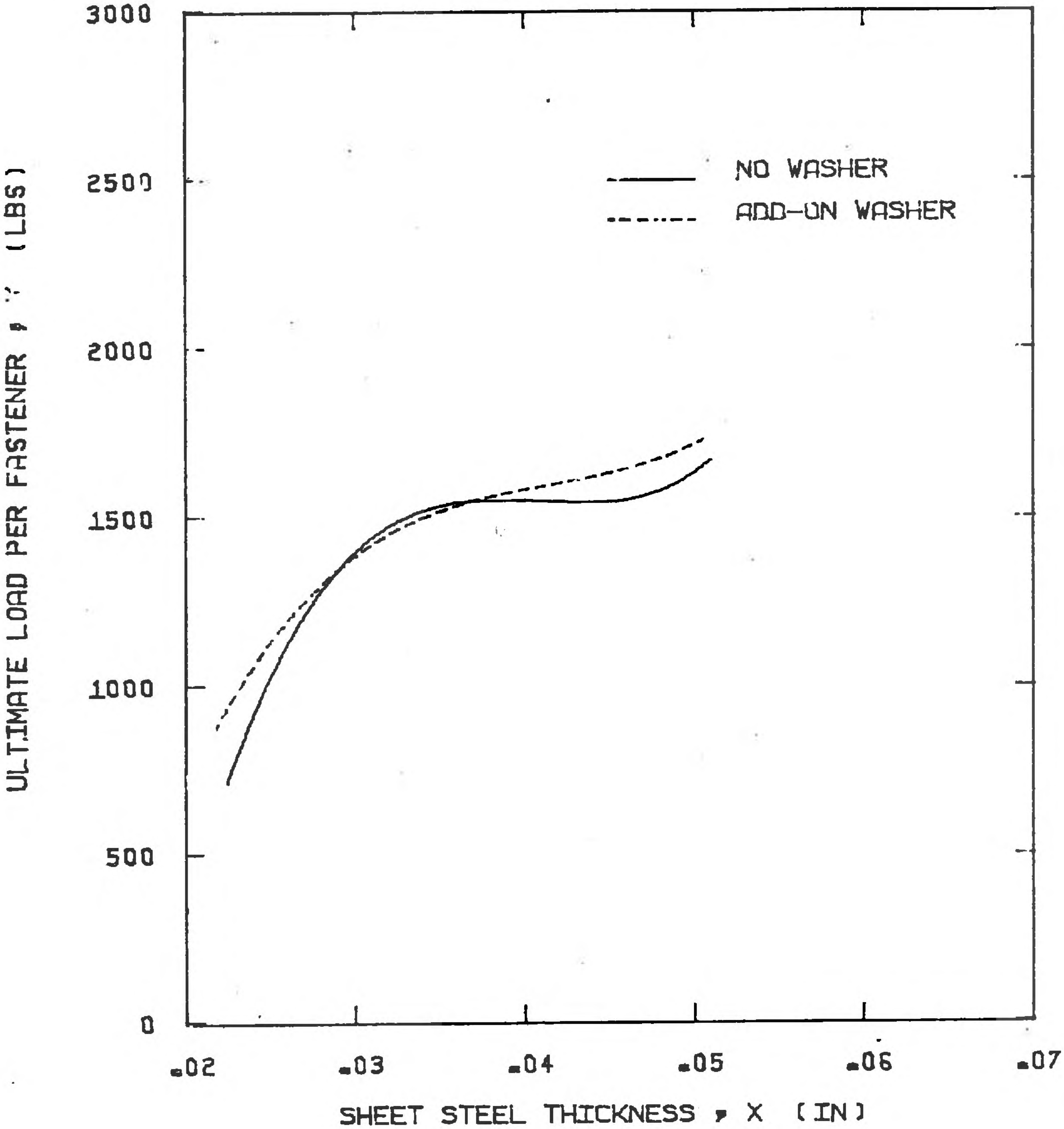


NUMBER 12 TYPE TEKS/2/MB/HT 14TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

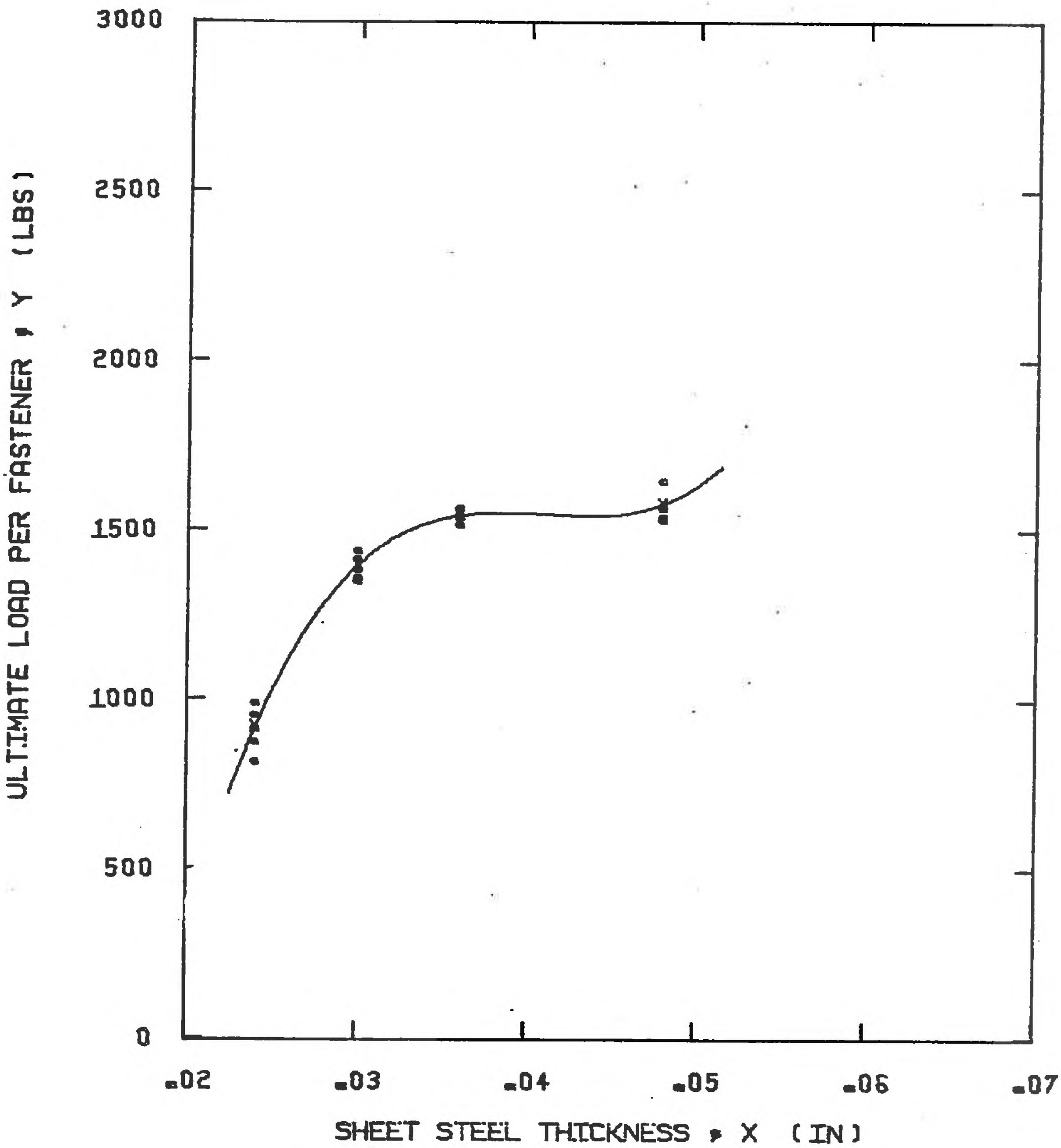
A = -.597E+04 B = .559E+06

C = -.141E+08 D = .121E+09



NUMBER 14 TYPE A 10TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

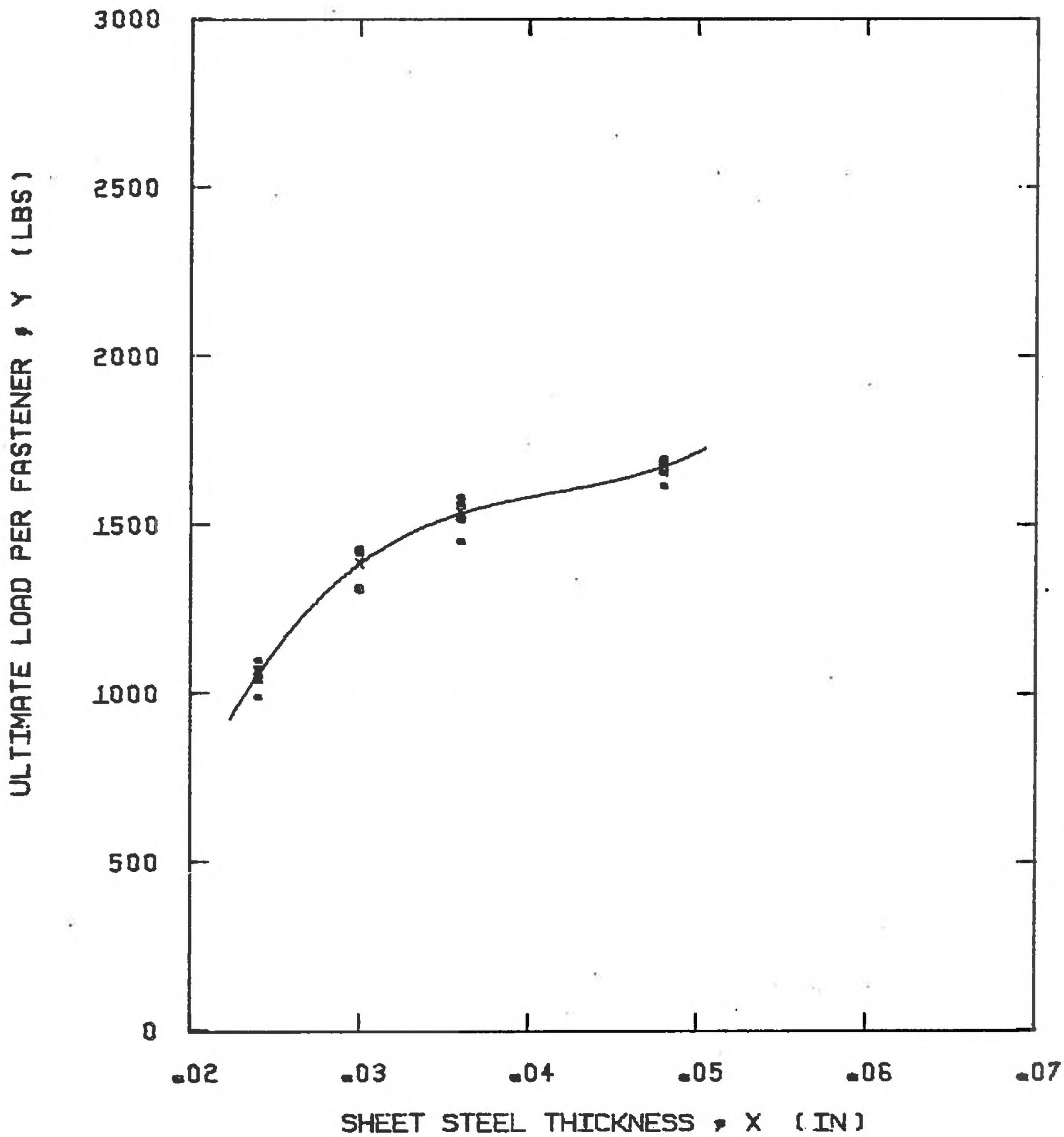


NUMBER 14 TYPE A 10TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.803E+04 B = .710E+06

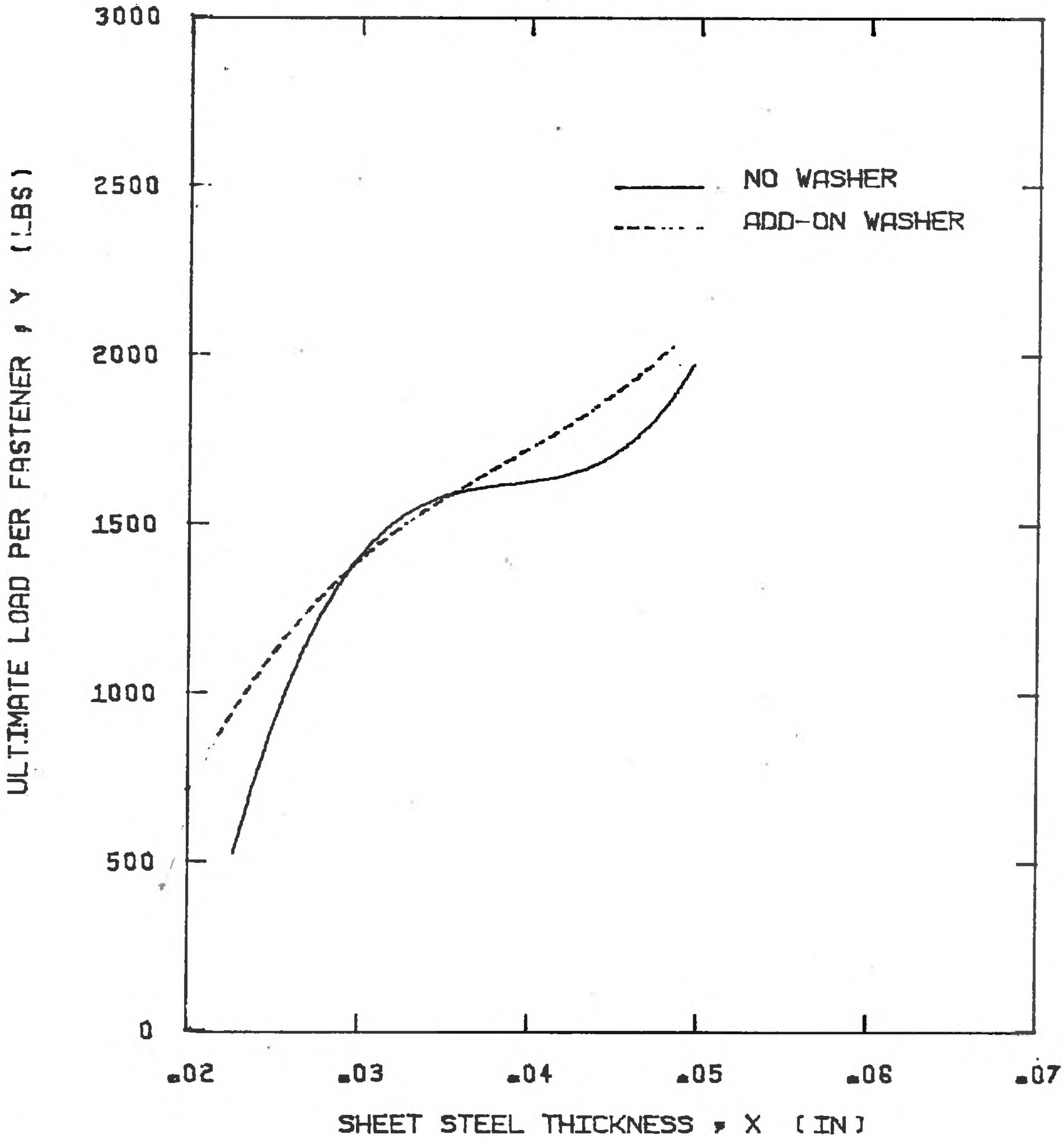
C = -.175E+08 D = .143E+09



NUMBER 14 TYPE A 10TPI
THREAD FORMING
GALVANIZED AND RUBBER WASHER

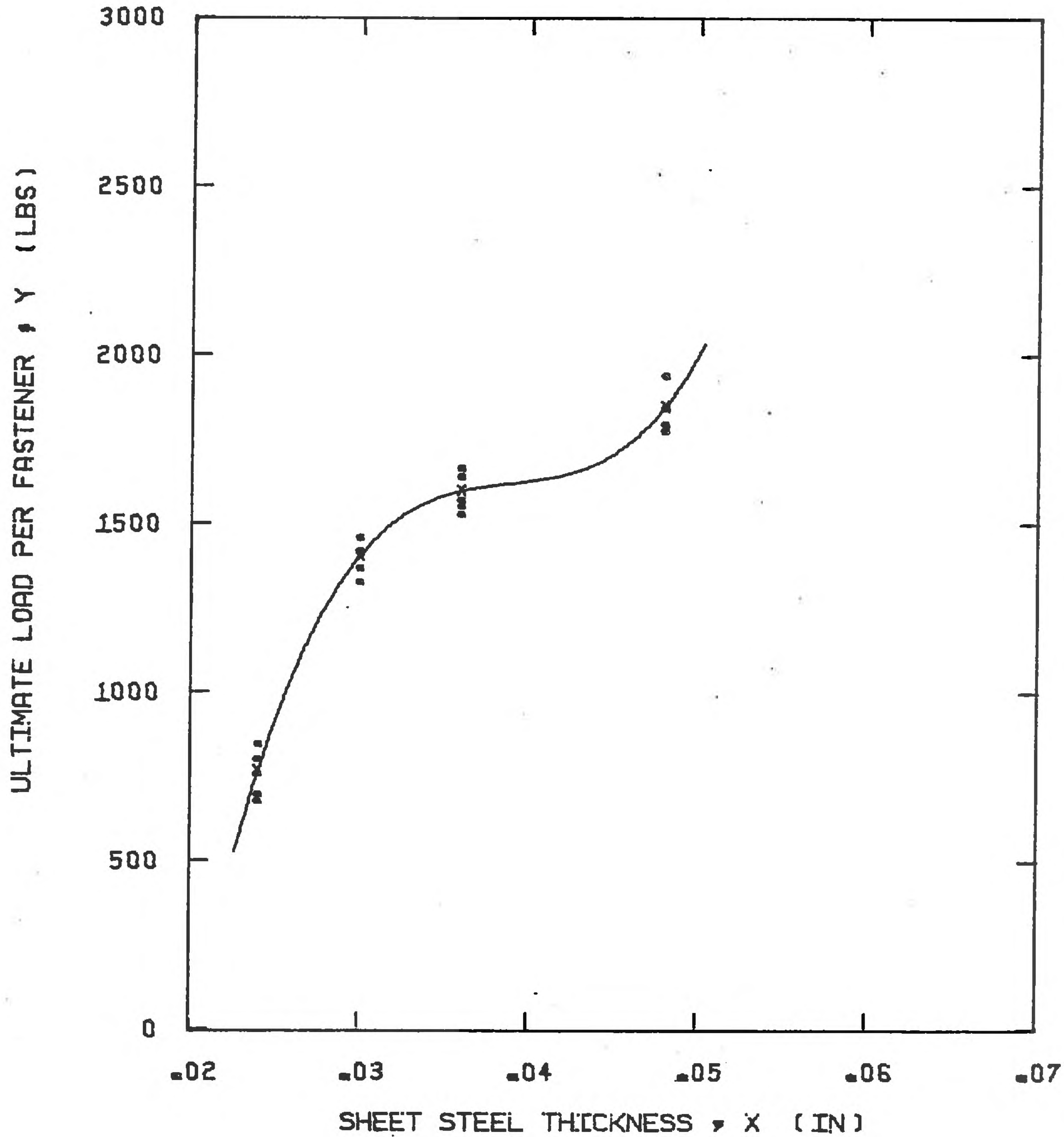
Y = A + B X + C (X**2) + D (X**3)

A = -.381E+04 B = .373E+06
C = -.876E+07 D = .703E+08



NUMBER 14 TYPE AB 14 TPI
THREAD FORMING

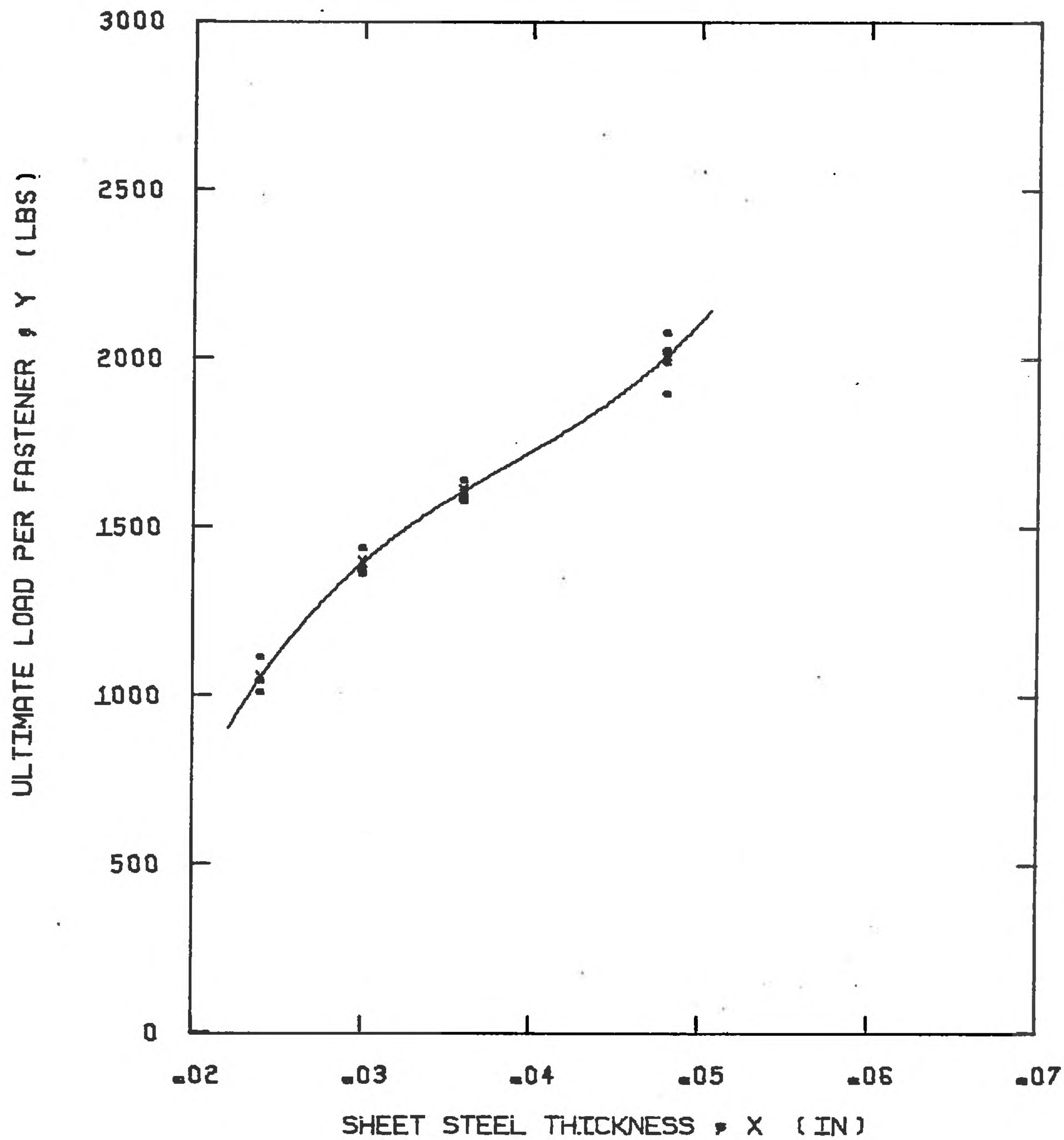
Y = A + B X + C (X**2) + D (X**3)



NUMBER 14 TYPE AB 14TPI H.H.
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A =	-.123E+05	B =	.107E+07
C =	-.273E+08	D =	.234E+09

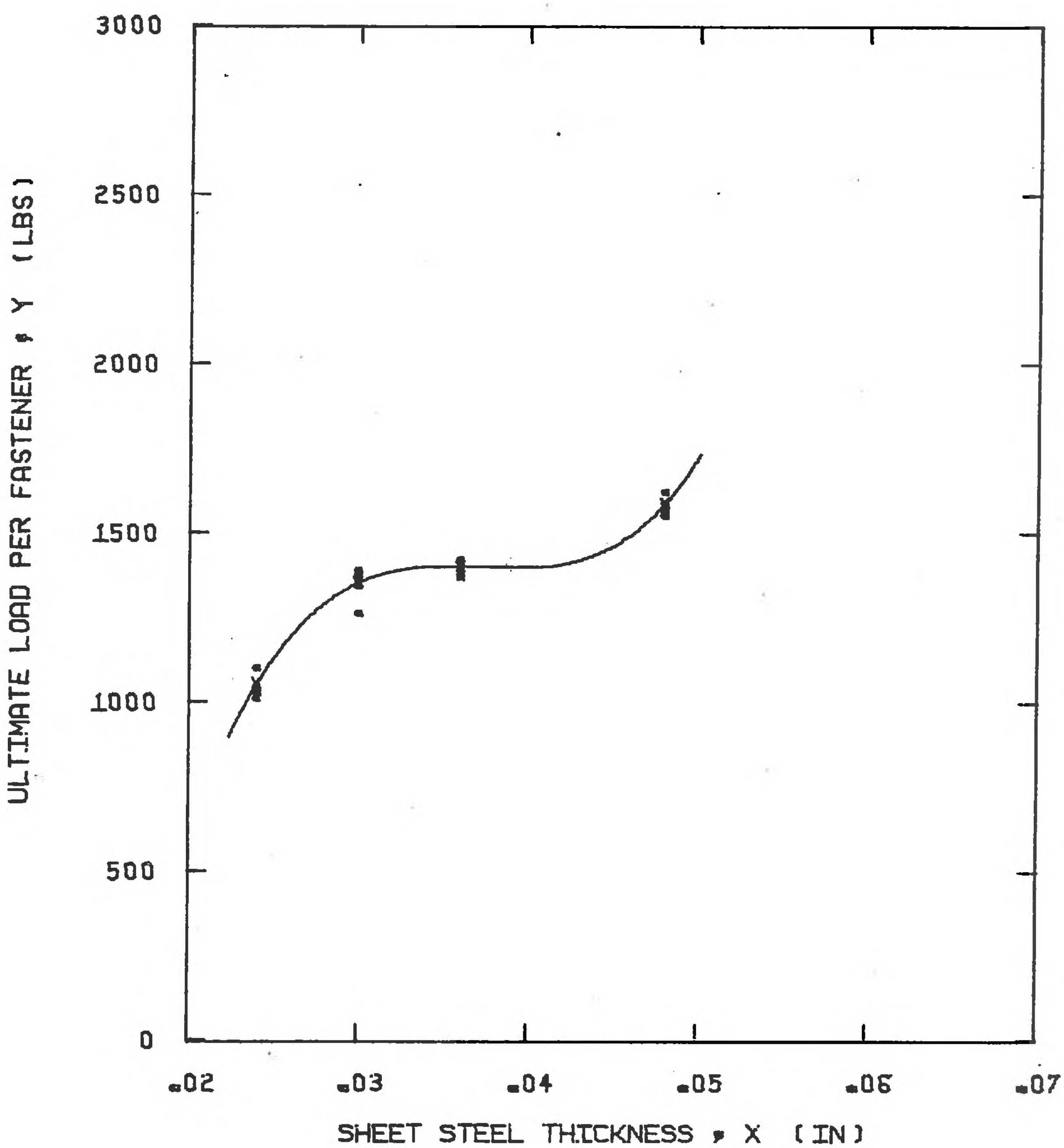


NUMBER 14 TYPE AB 14TPI H.H.
THREAD FORMING
GALVANIZED AND RUBBER WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.334E+04 B = .333E+06

C = -.787E+07 D = .678E+08

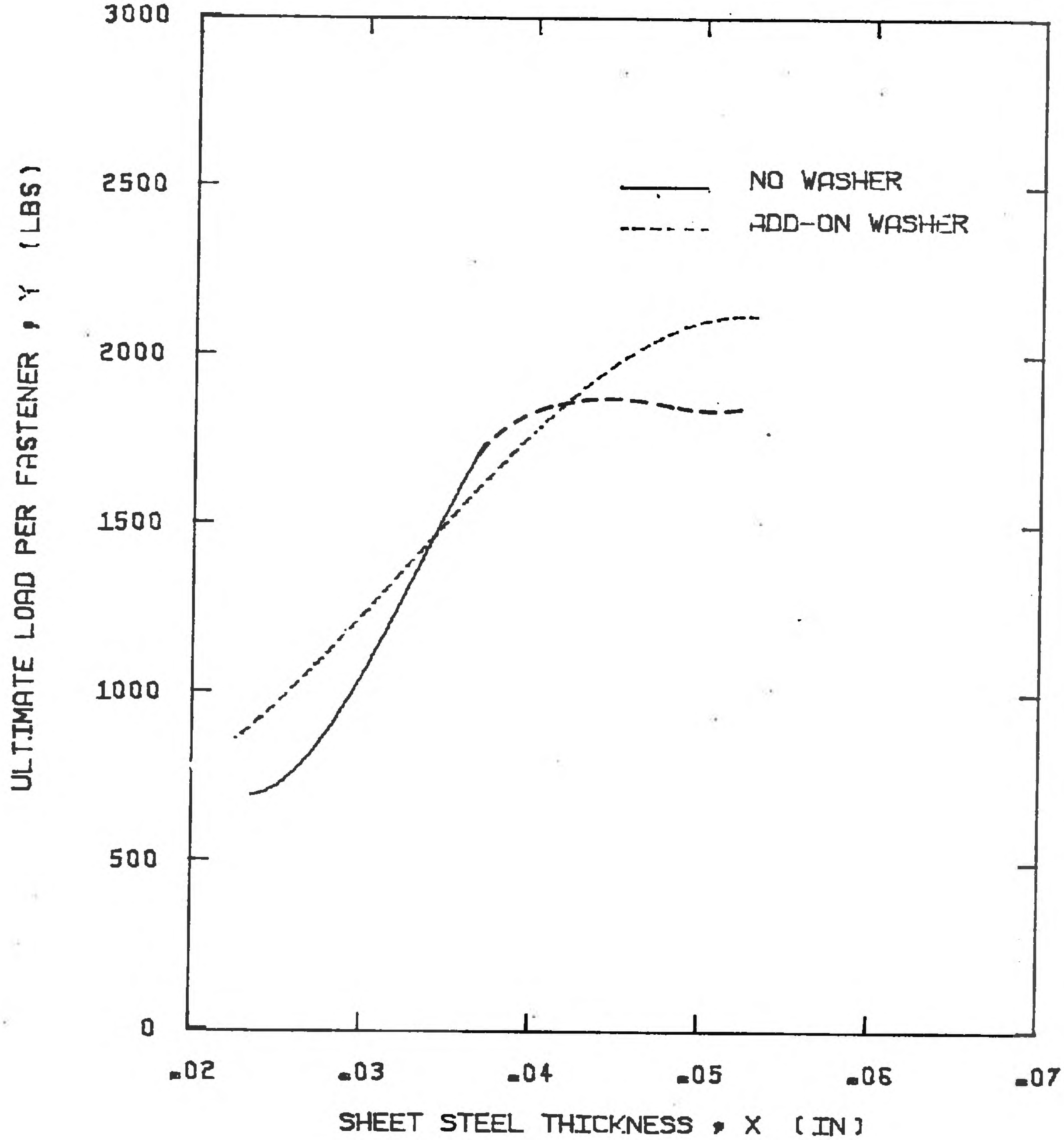


NUMBER 14 TYPE AB 14TPI H.W.H.
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

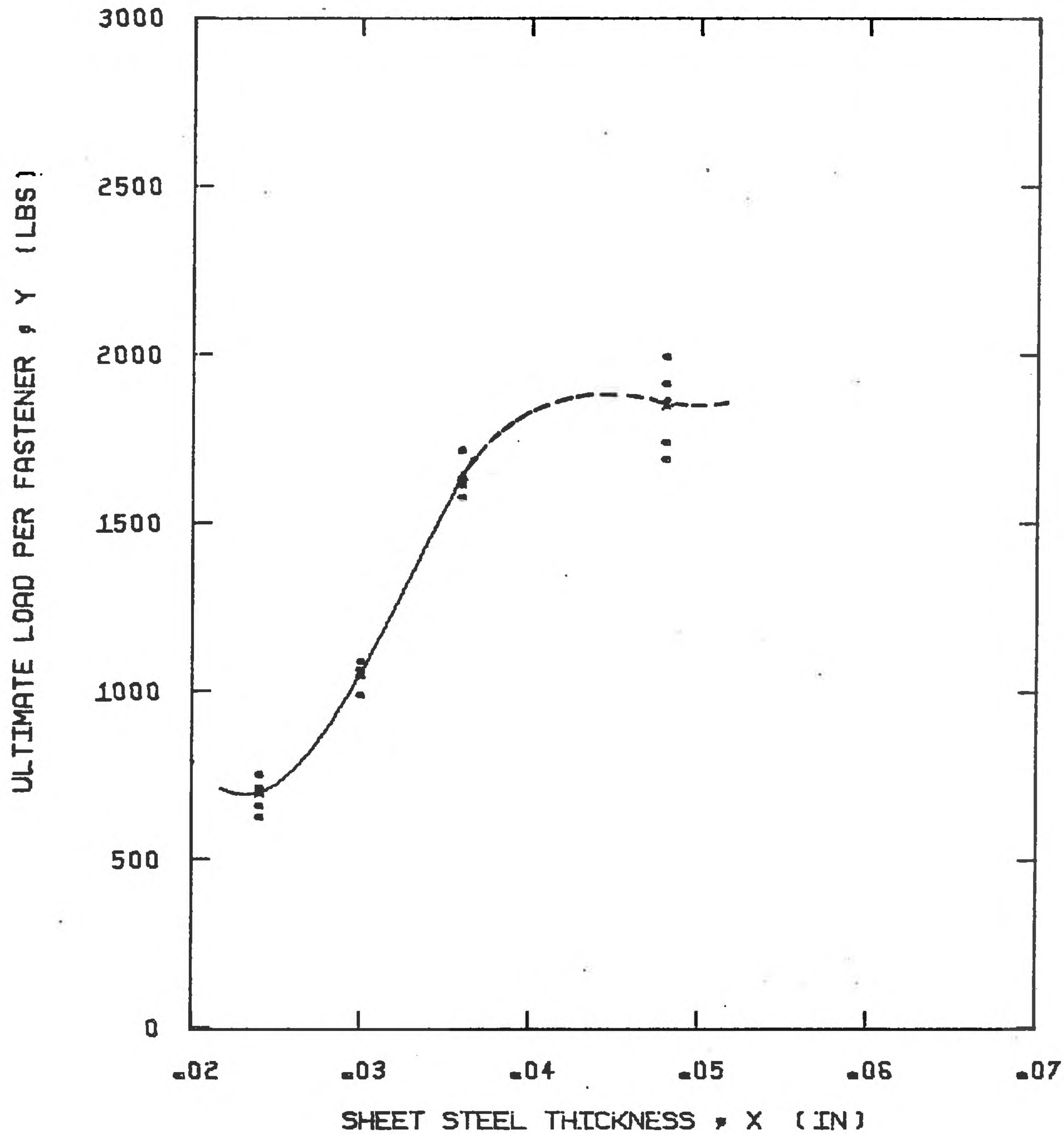
A = -.697E+04 B = .680E+06

C = -.184E+08 D = .165E+09



NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

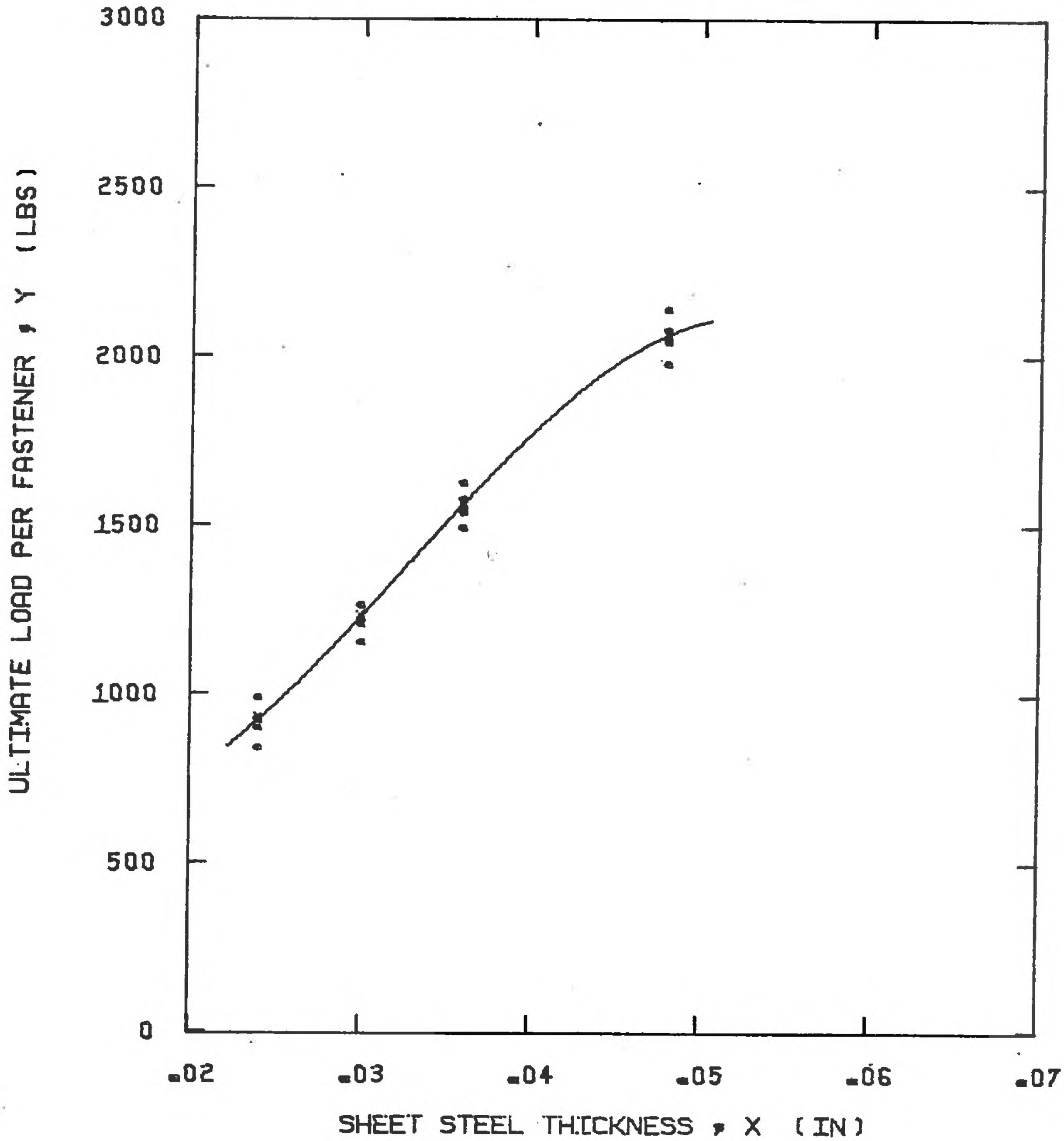


NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI
SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .983E+04 B = -.962E+06

C = .319E+08 D = -.319E+09

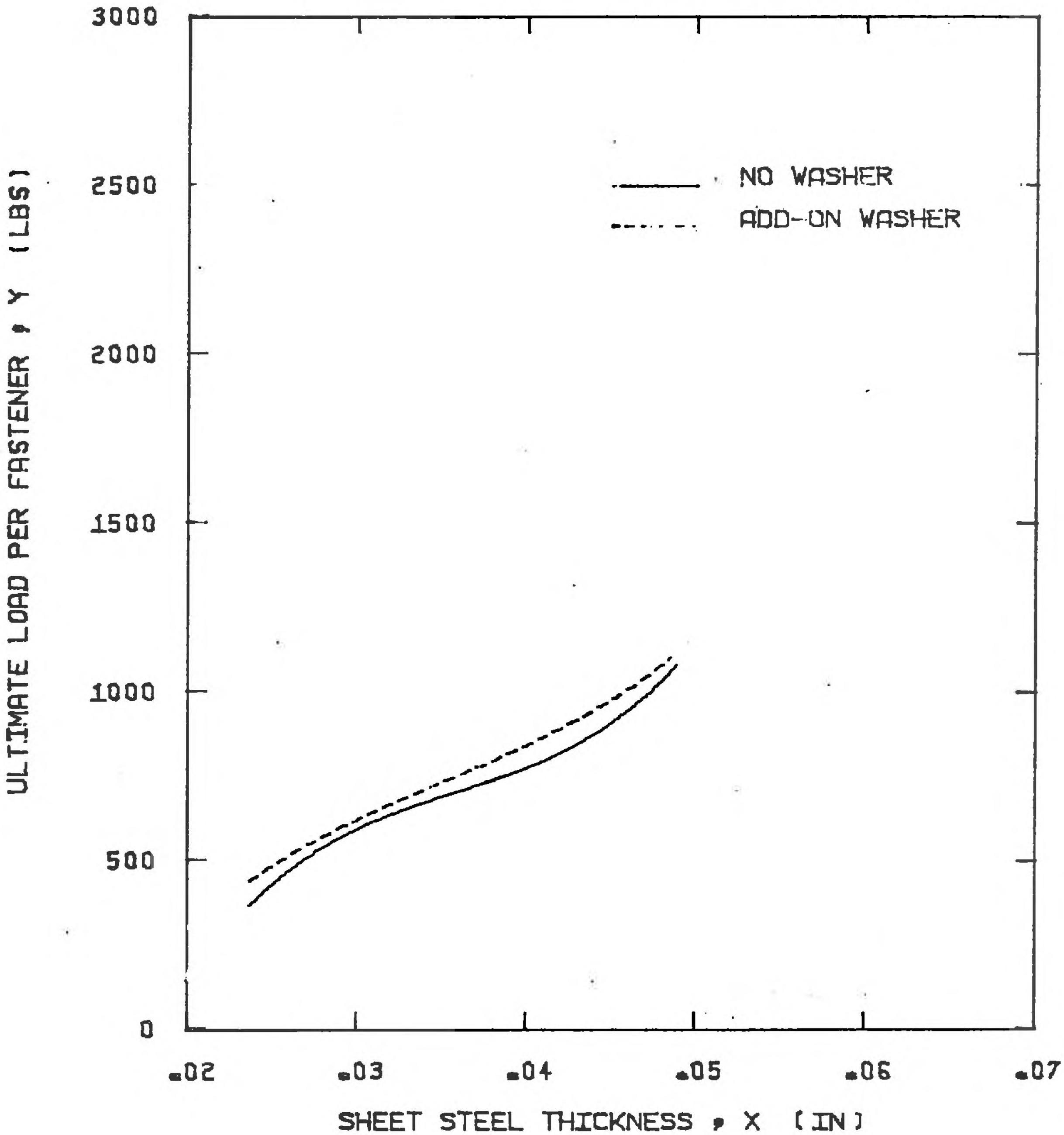


NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

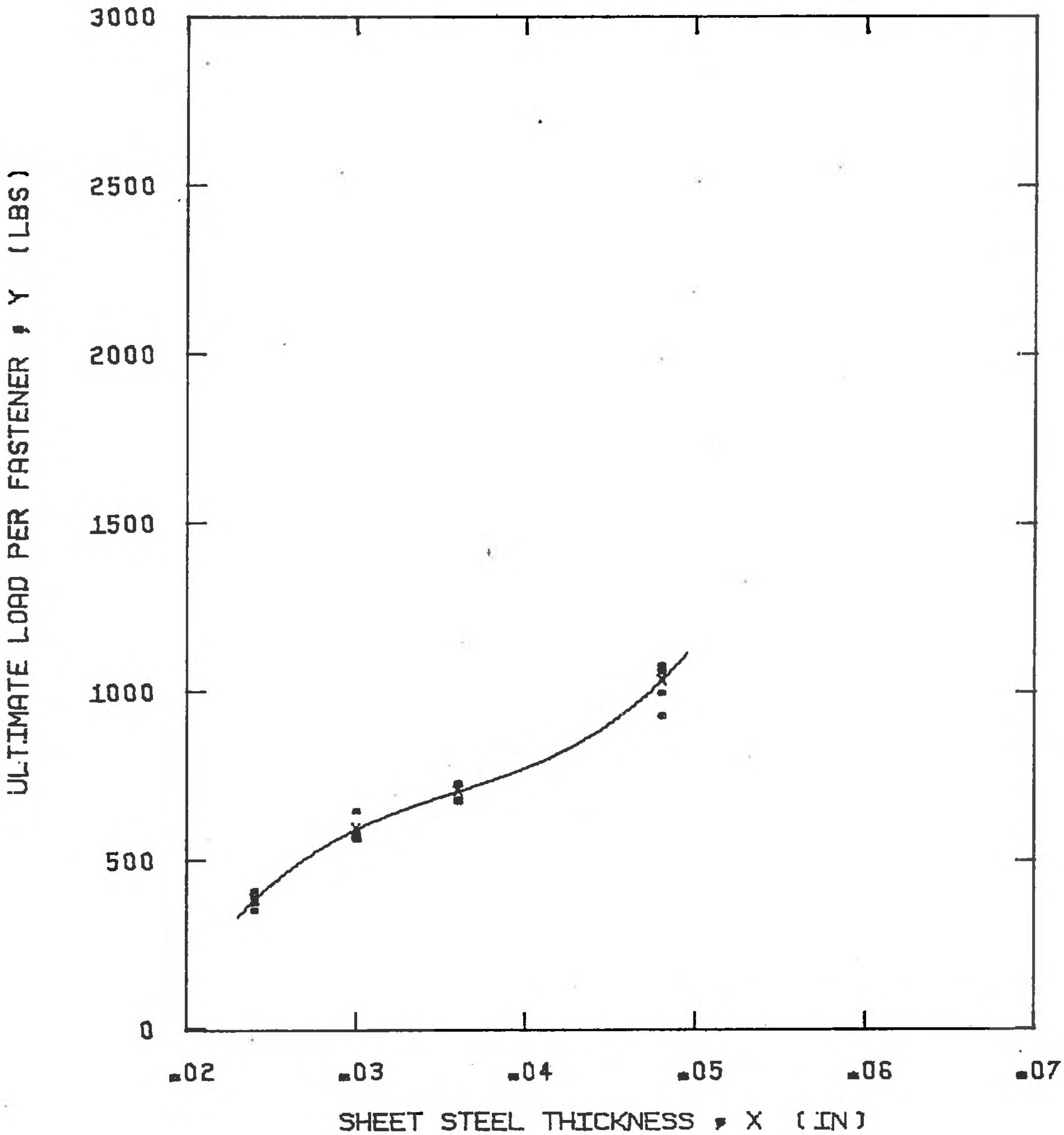
A = .119E+04 B = -.949E+05

C = .463E+07 D = -.473E+08



NUMBER 8 TYPE A 15TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)



NUMBER 8 TYPE A 15TPI

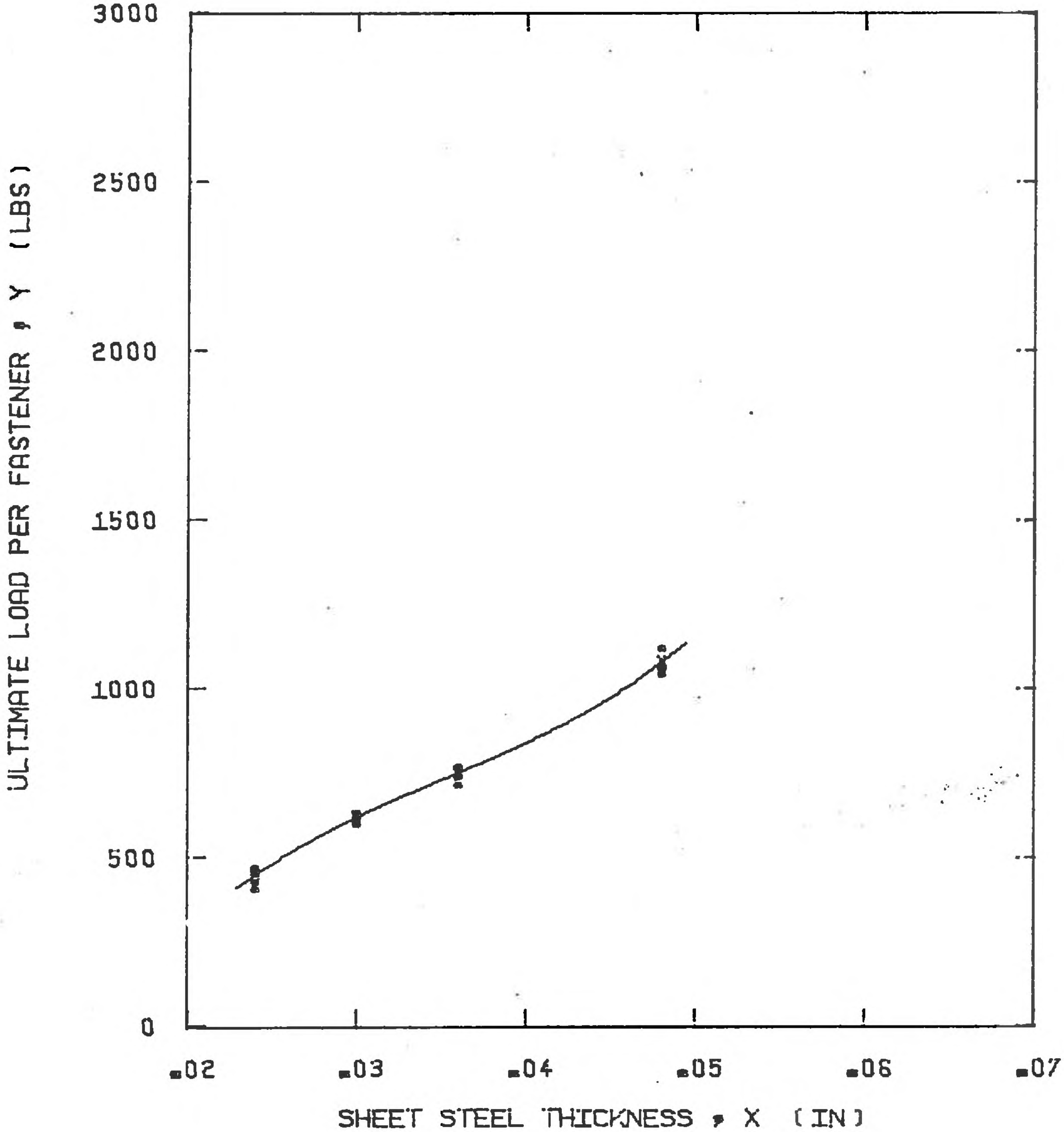
THREAD FORMING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.342E+04 B = .313E+06

C = -.826E+07 D = .767E+08

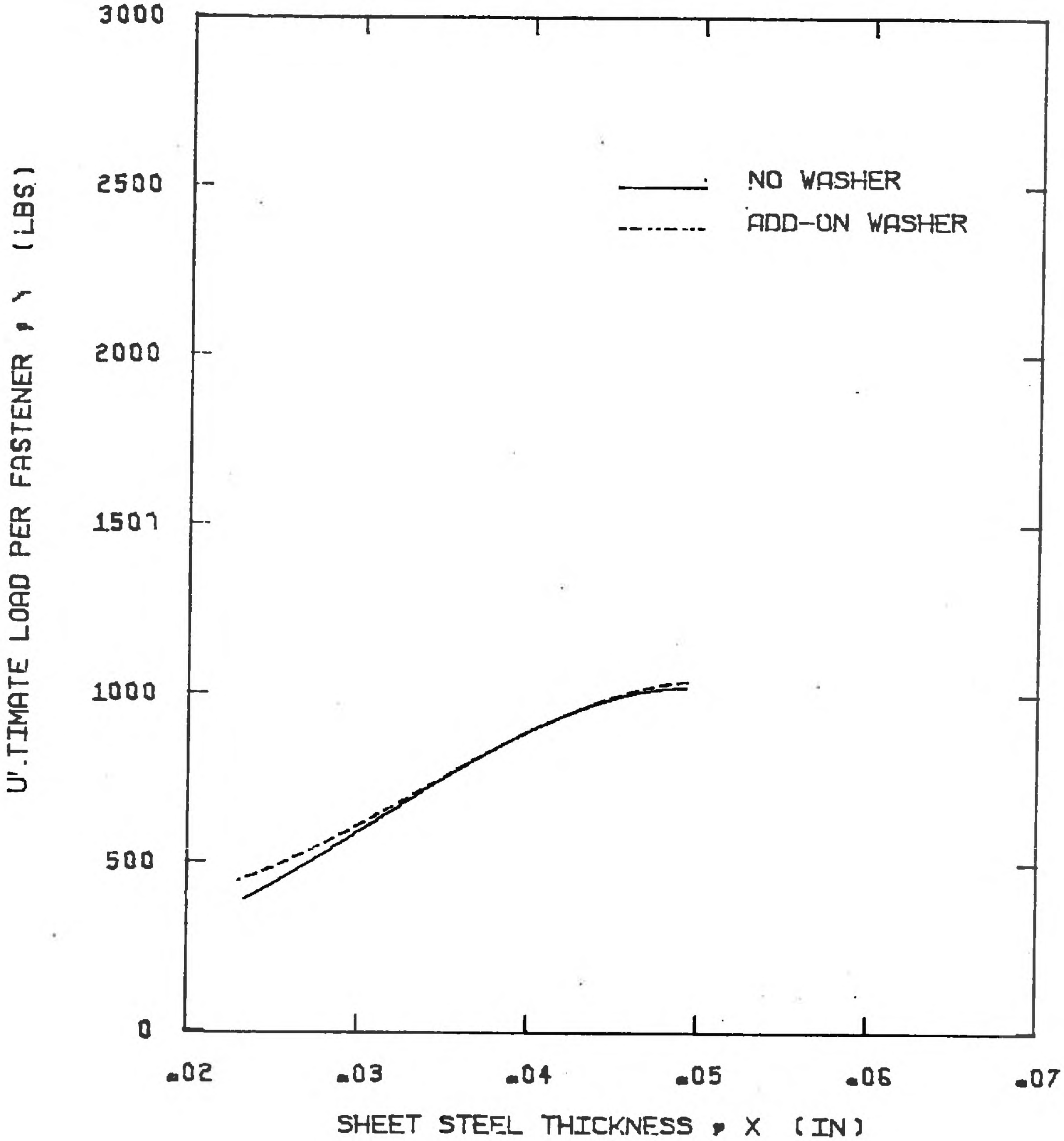


NUMBER 8 TYPE A 15TPI
THREAD FORMING
FLAT METAL WASHER

Y = A + B X + C (X**2) + D (X**3)

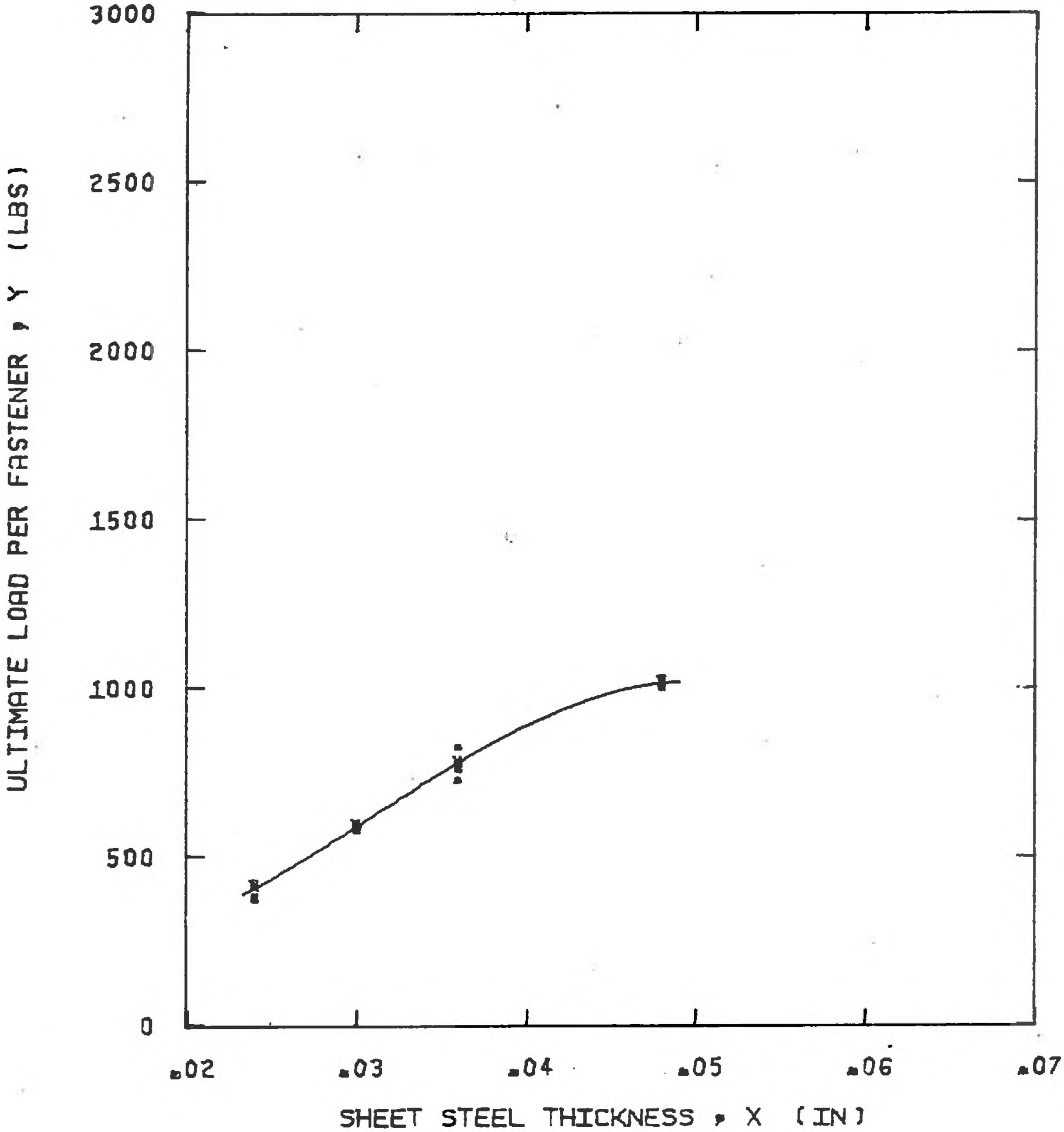
A = -.154E+04 B = .152E+06

C = -.371E+07 D = .351E+08



NUMBER 8 TYPE AB 18 TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

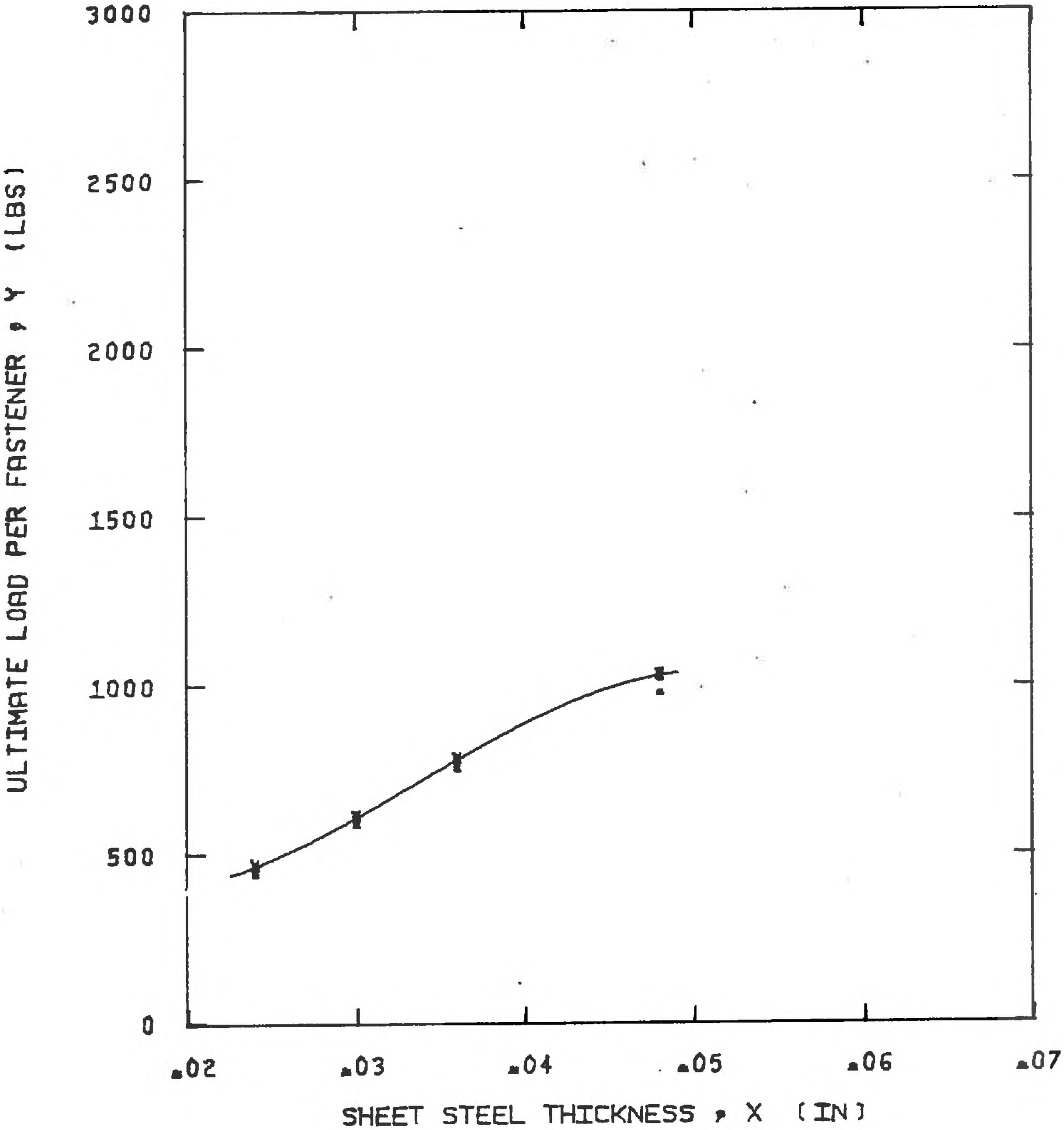


NUMBER 8 TYPE AB 18TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .562E+03 B = -.577E+05

C = .289E+07 D = -.311E+08



NUMBER 8 TYPE AB 18TPI

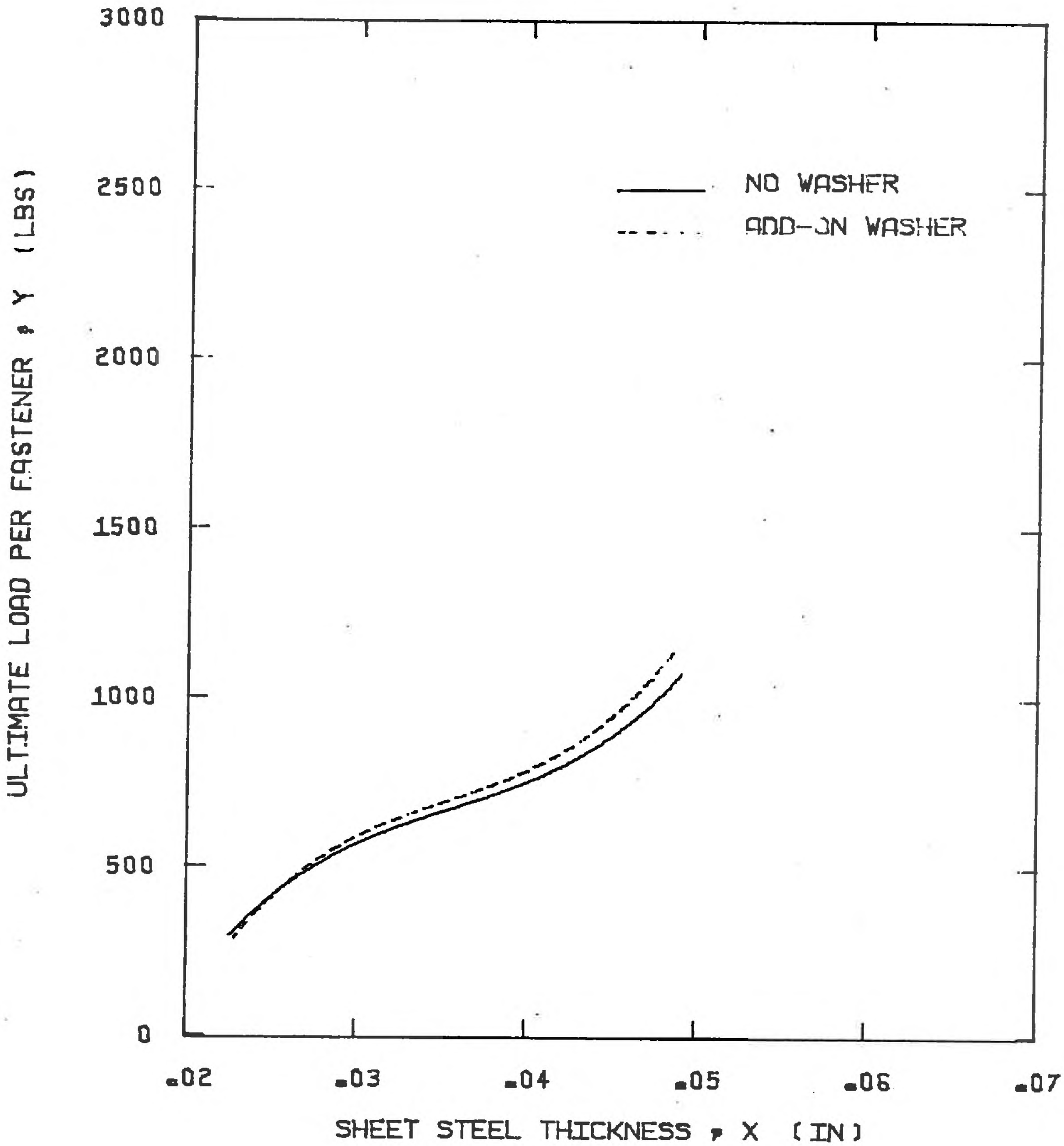
THREAD FORMING

FLAT METAL WASHER

Y = A + B X + C (X**2) + D (X**3)

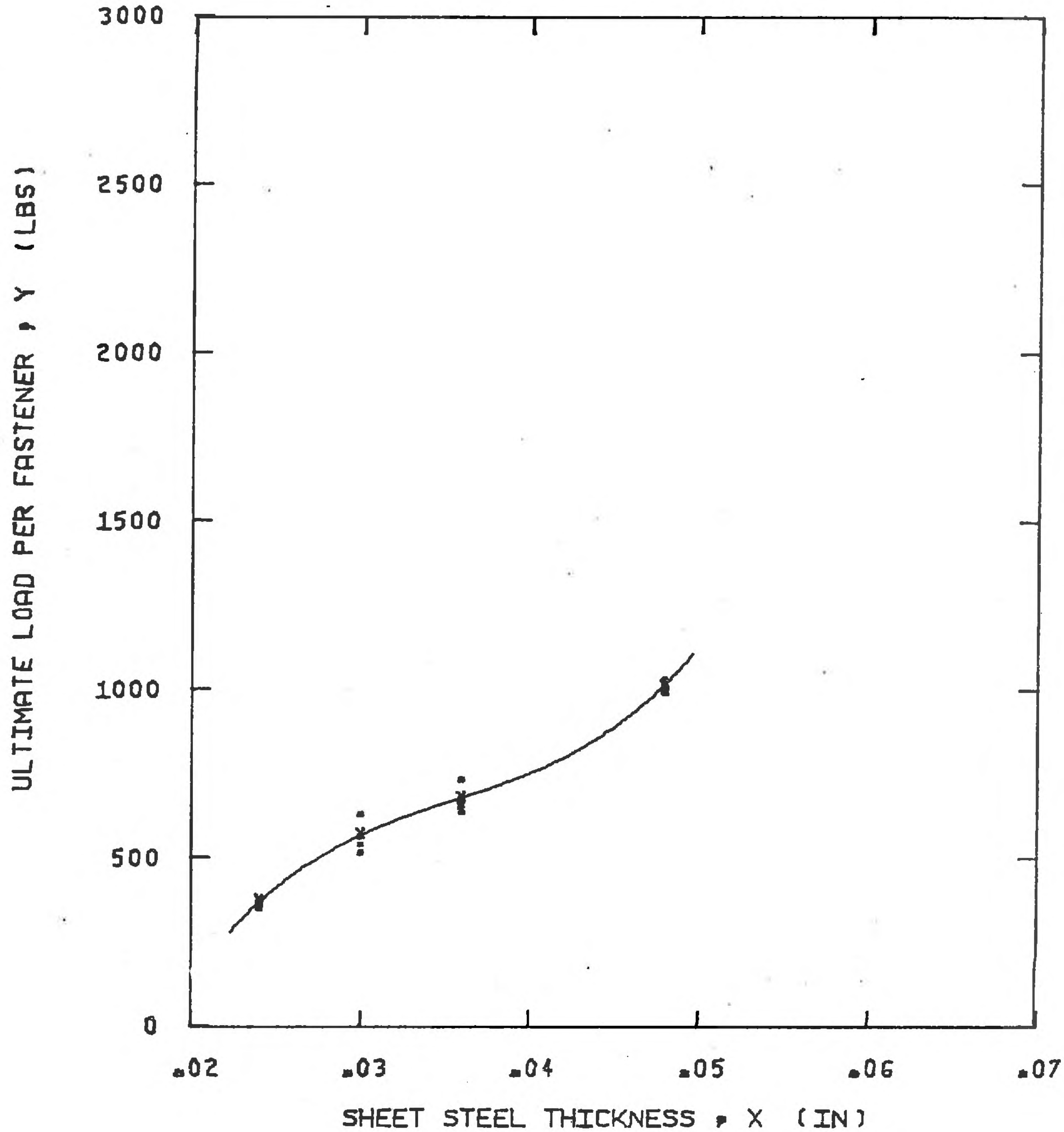
A = .979E+03 B = -.811E+05

C = .327E+07 D = -.325E+08



NUMBER 8 TYPE TEKS/2F 18TPI
SELF DRILLING

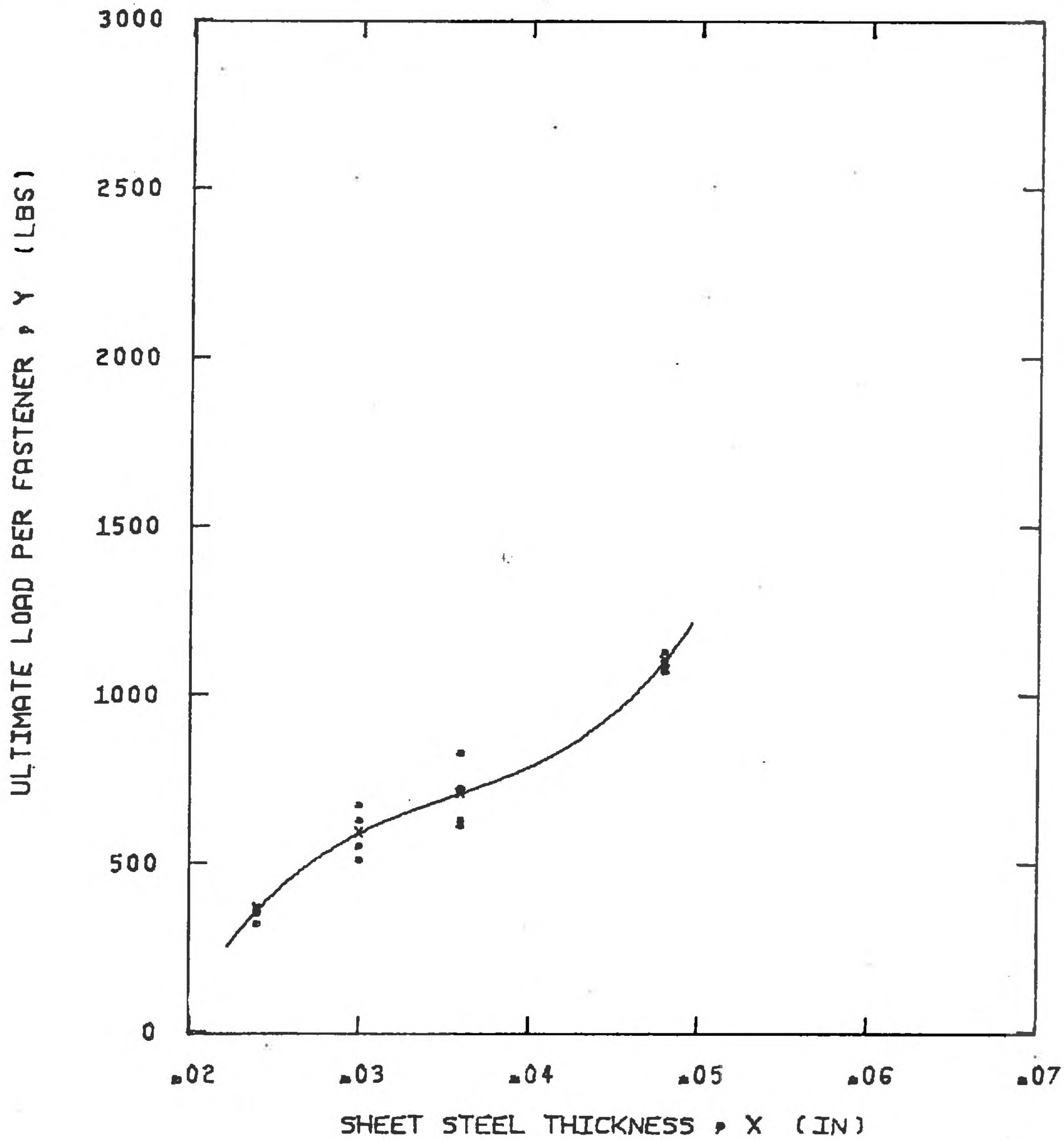
Y = A + B X + C (X**2) + D (X**3)



NUMBER 8 TYPE TEKS/2F 18TPI
SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

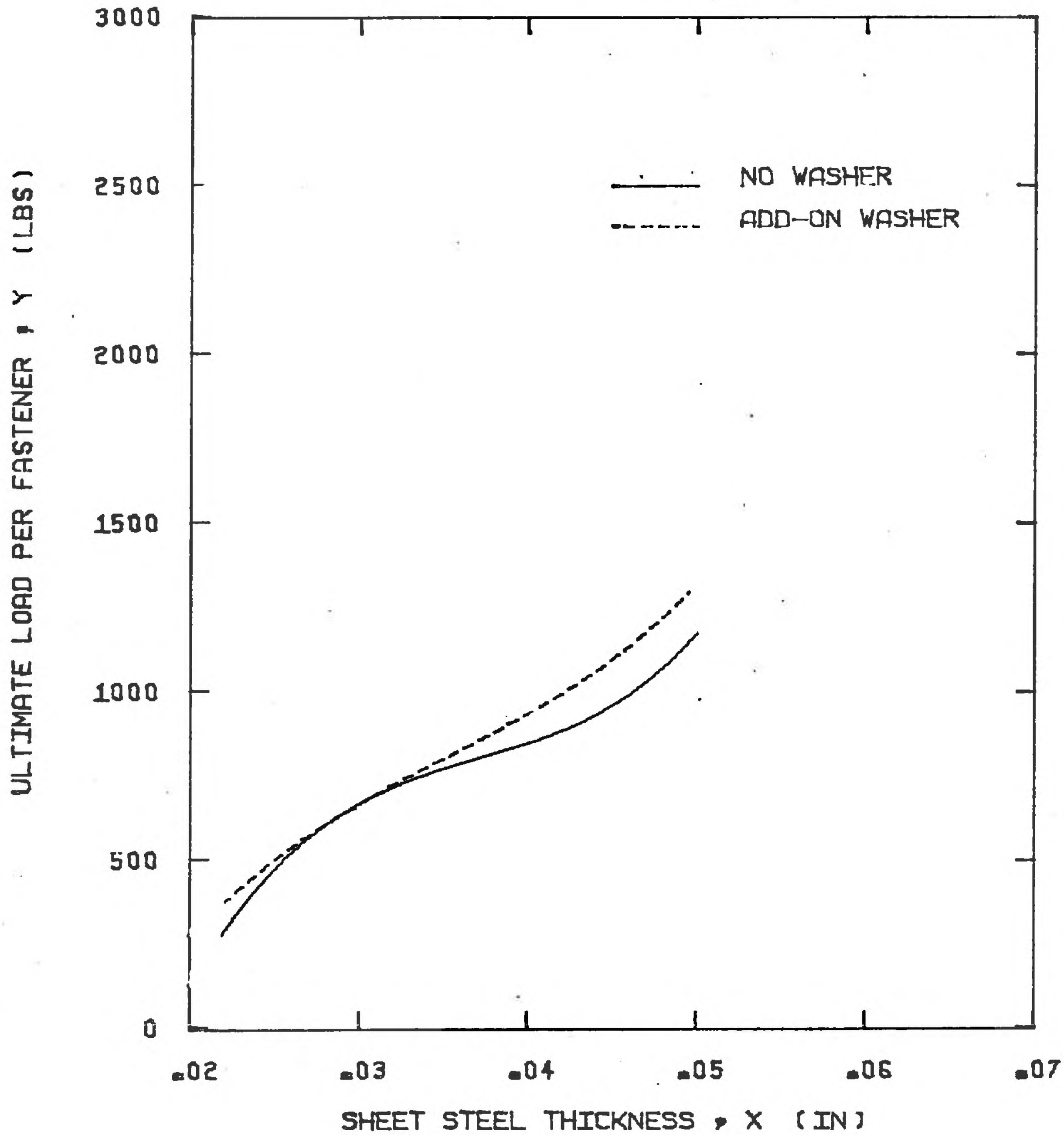
A =	-.325E+04	B =	.298E+06
C =	-.792E+07	D =	.741E+08



NUMBER 8 TYPE TEKS/2F 18TPI
SELF DRILLING
TWIN SEAL WASHER

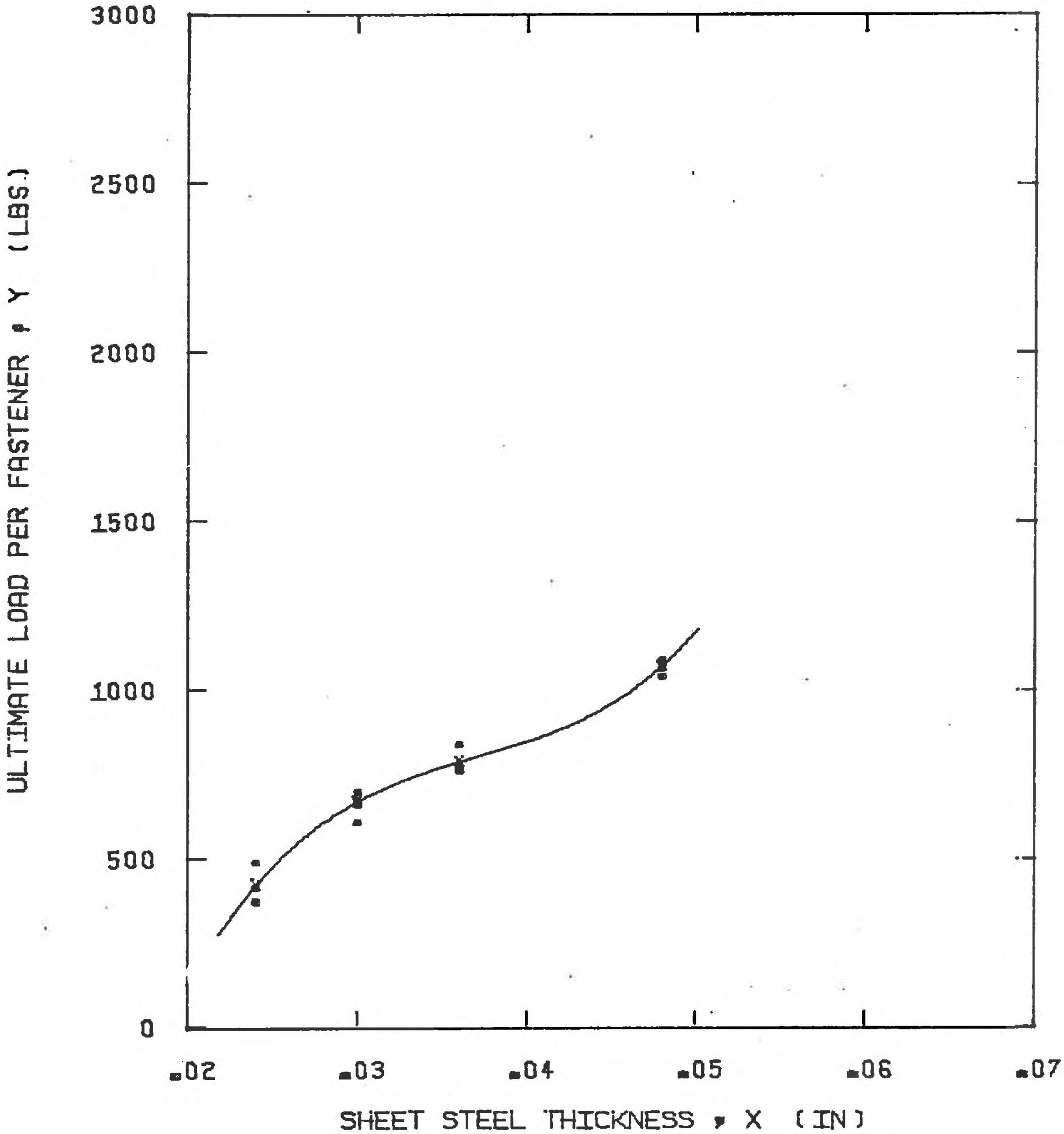
Y = A + B X + C (X**2) + D (X**3)

A =	-.416E+04	B =	.377E+06
C =	-.101E+08	D =	.954E+08



NUMBER 10 TYPE A 12TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

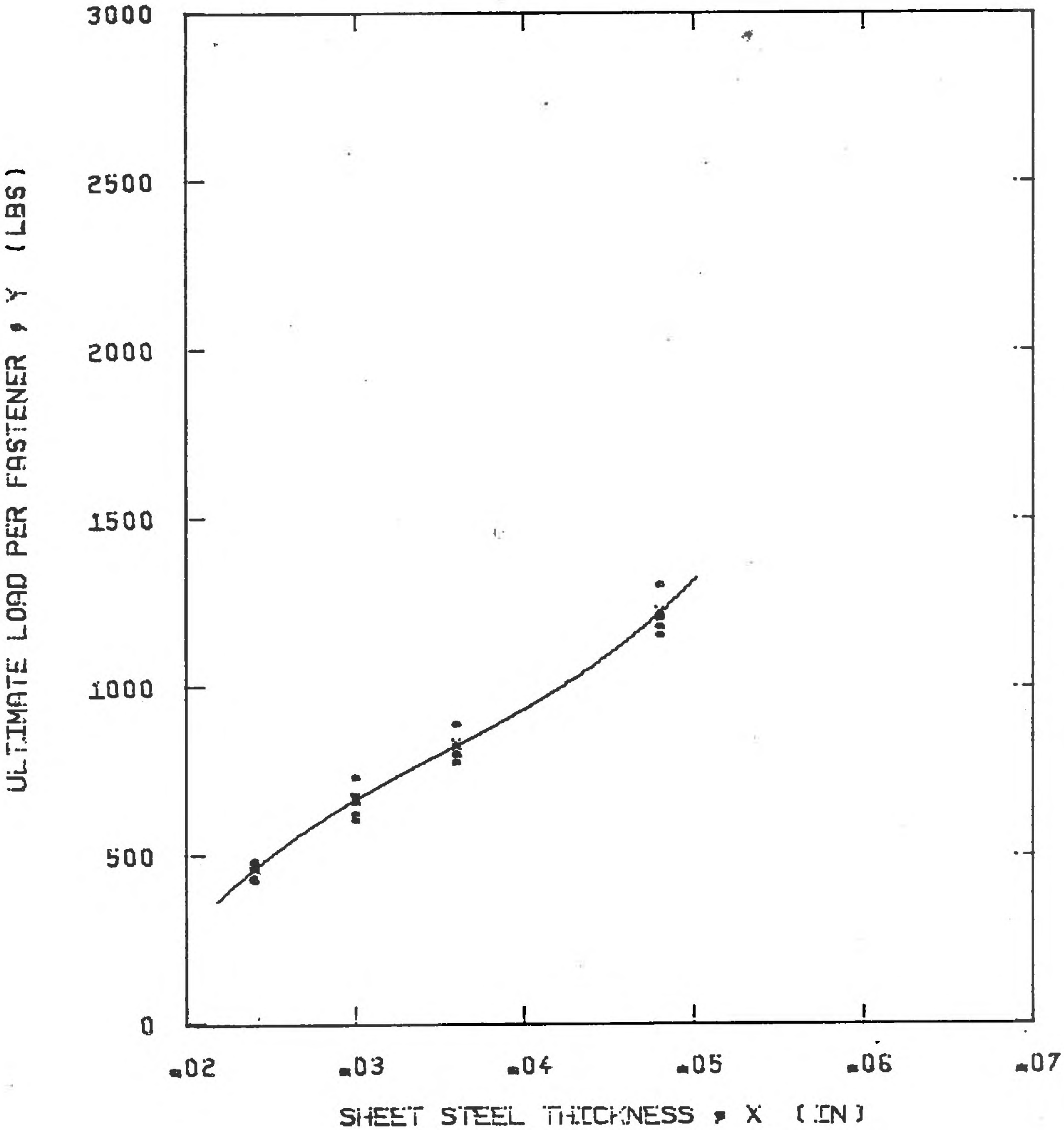


NUMBER 10 TYPE A 12TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.411E+04 B = .368E+06

C = -.953E+07 D = .856E+08



NUMBER 10 TYPE A 12TPI

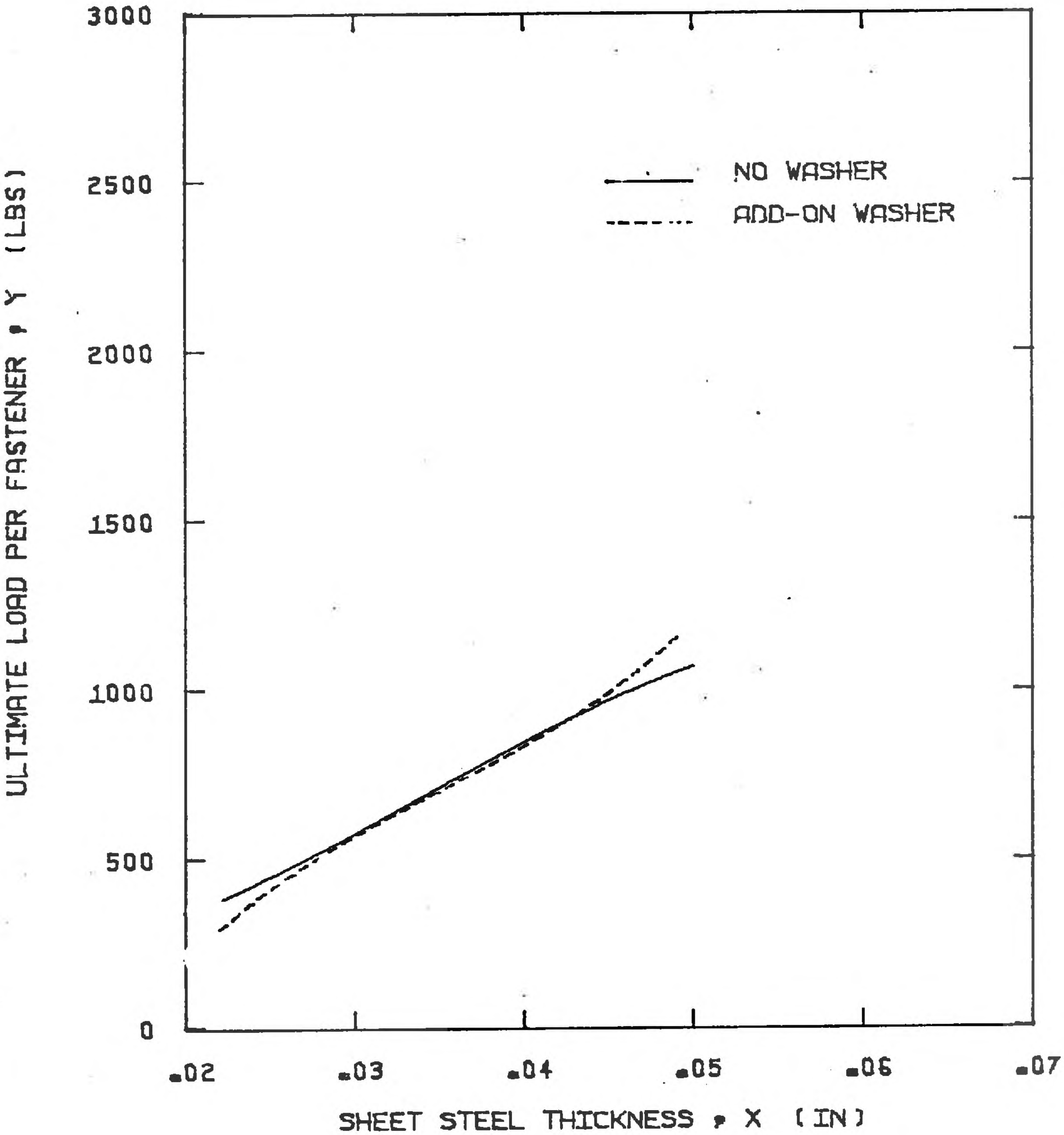
THREAD FORMING

FLAT METAL AND NEOPRENE WASHER

Y = A + B X + C (X**2) + D (X**3)

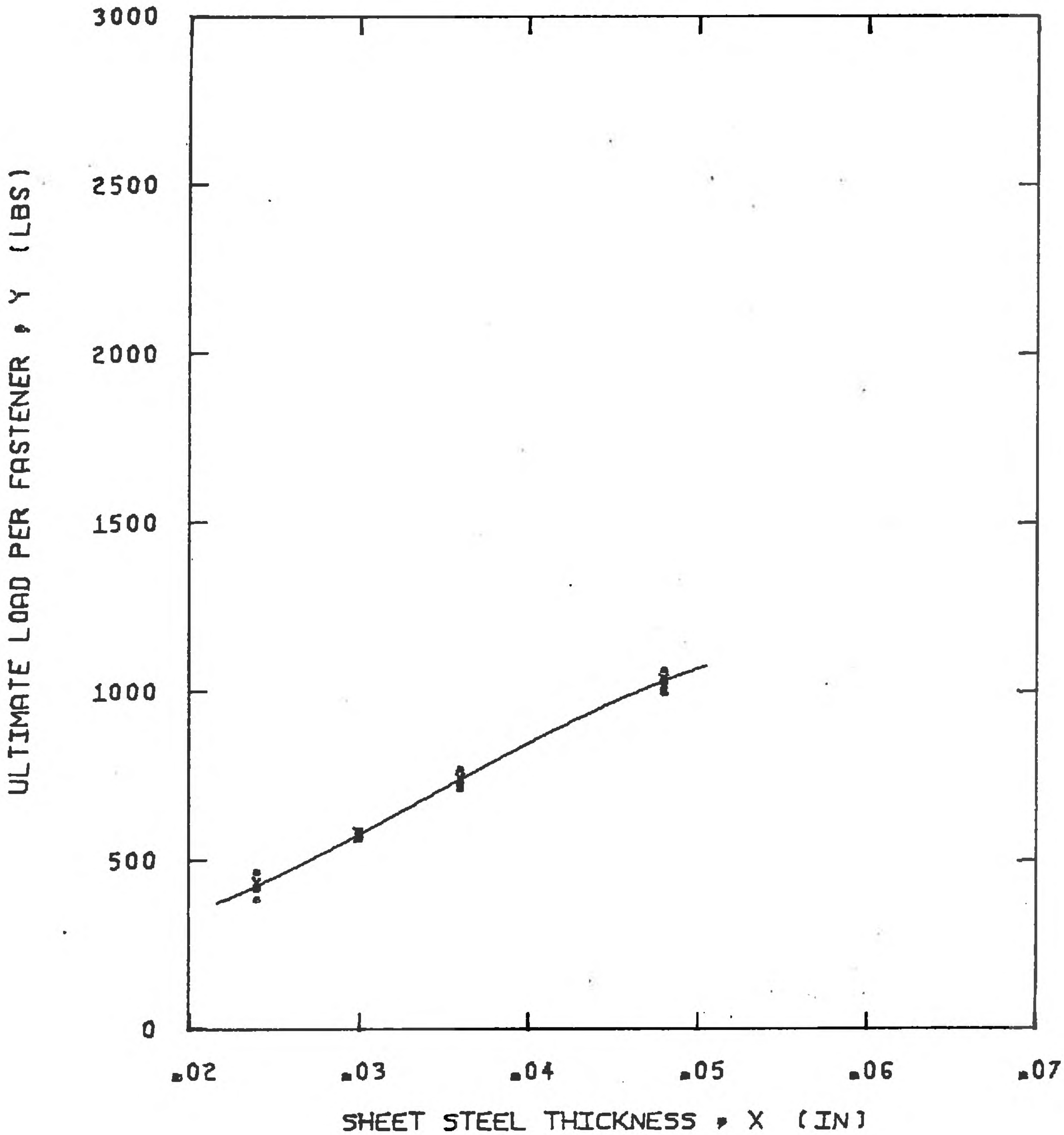
A = -.187E+04 B = .177E+06

C = -.429E+07 D = .406E+08



NUMBER 10 TYPE AB 16TPI
THREAD FORMING

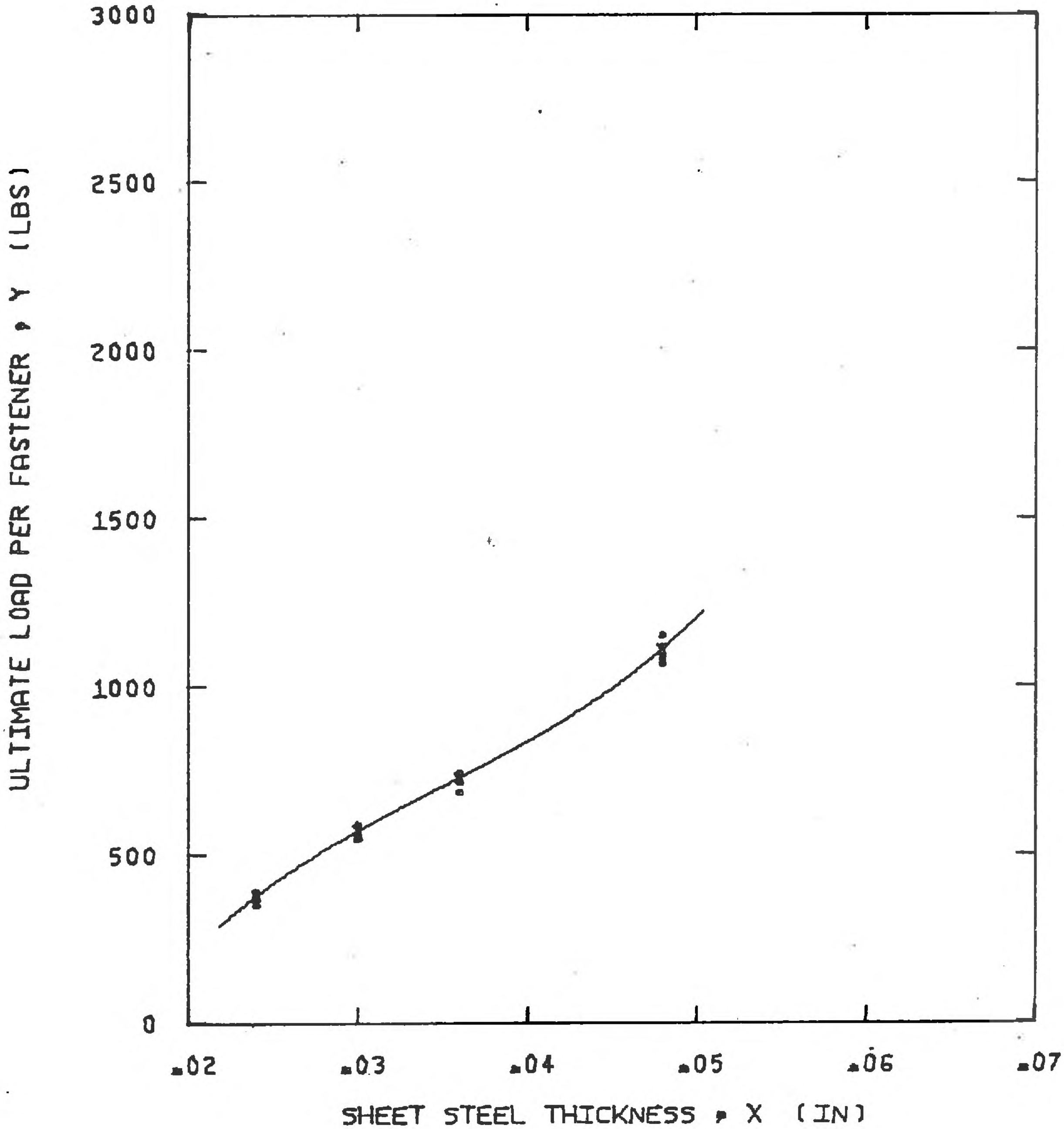
Y = A + B X + C (X**2) + D (X**3)



NUMBER 10 TYPE AB 16TPI
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .288E+03 B = -.192E+05
C = .137E+07 D = -.134E+08



NUMBER 10 TYPE AB 16TPI

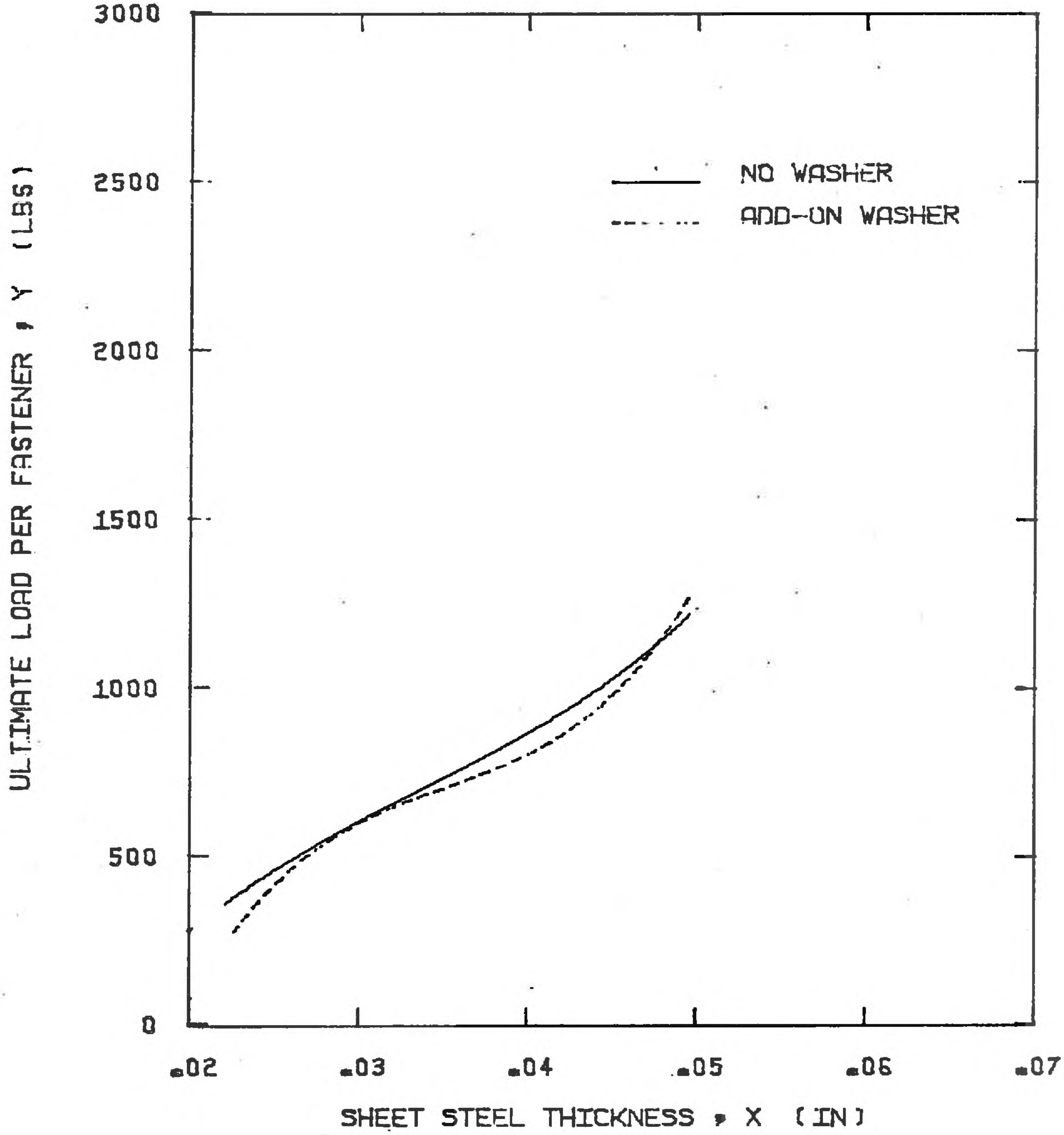
THREAD FORMING

FLAT METAL AND NEOPRENE WASHER

Y = A + B X + C (X**2) + D (X**3)

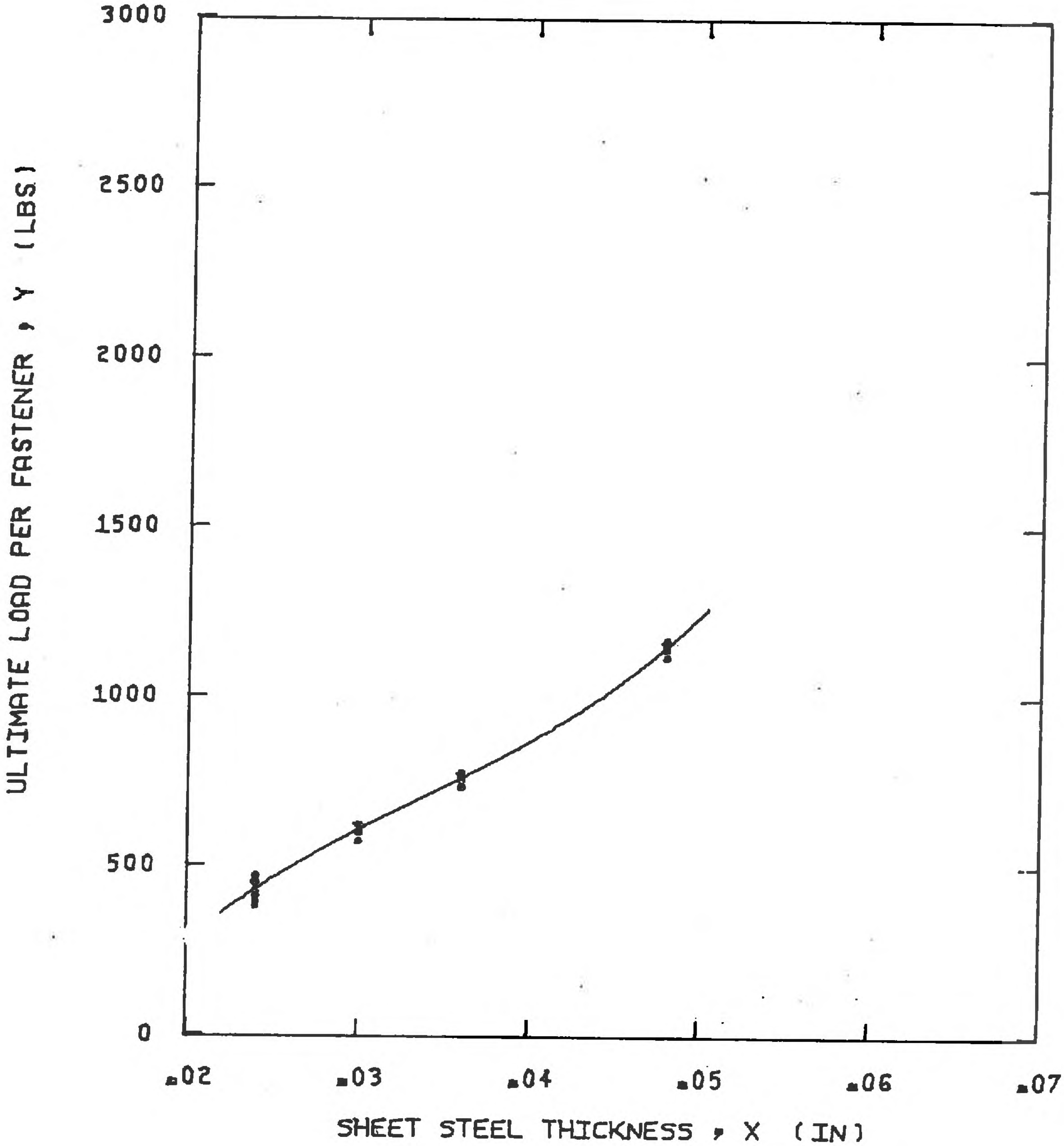
A = -.164E+04 B = .150E+06

C = -.354E+07 D = .337E+08



NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

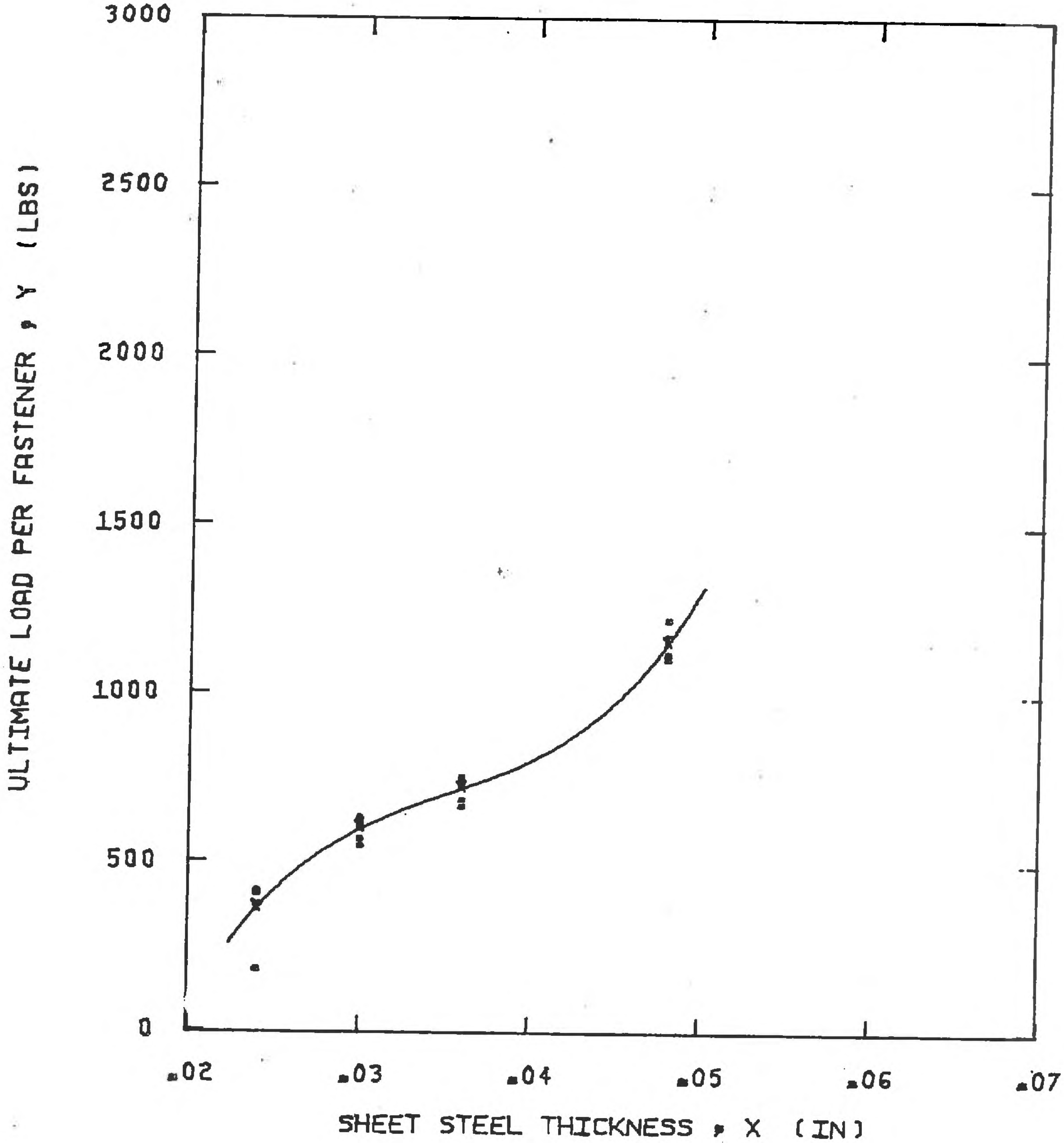


NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI
SELF DRILLING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.130E+04 B = .127E+06

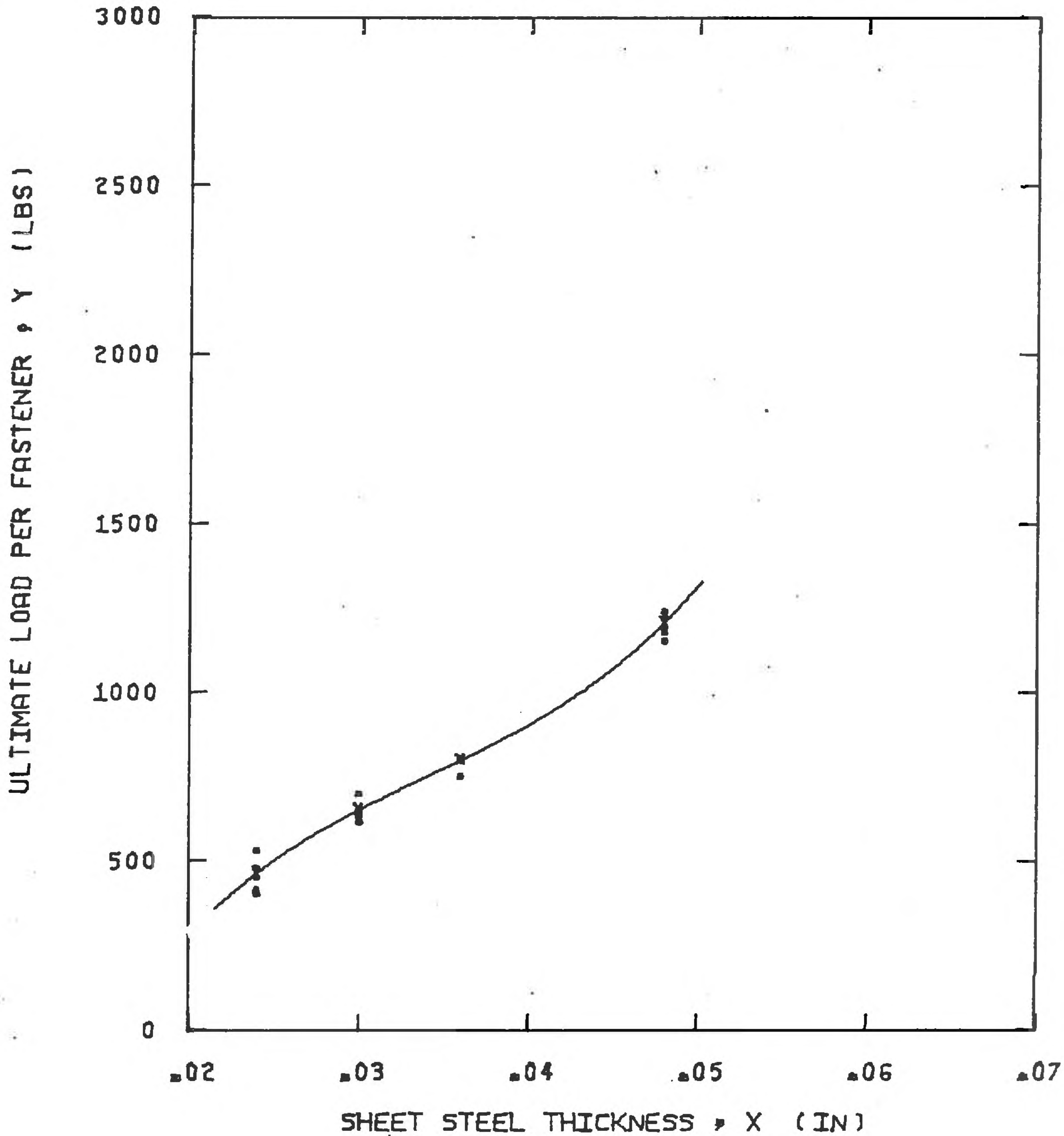
C = -.302E+07 D = .298E+08



NUMBER 10 TYPE TEKS/1≤STITCH≤ 16TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

A =	-.447E+04	B =	.407E+06
C =	-.111E+08	D =	.105E+09

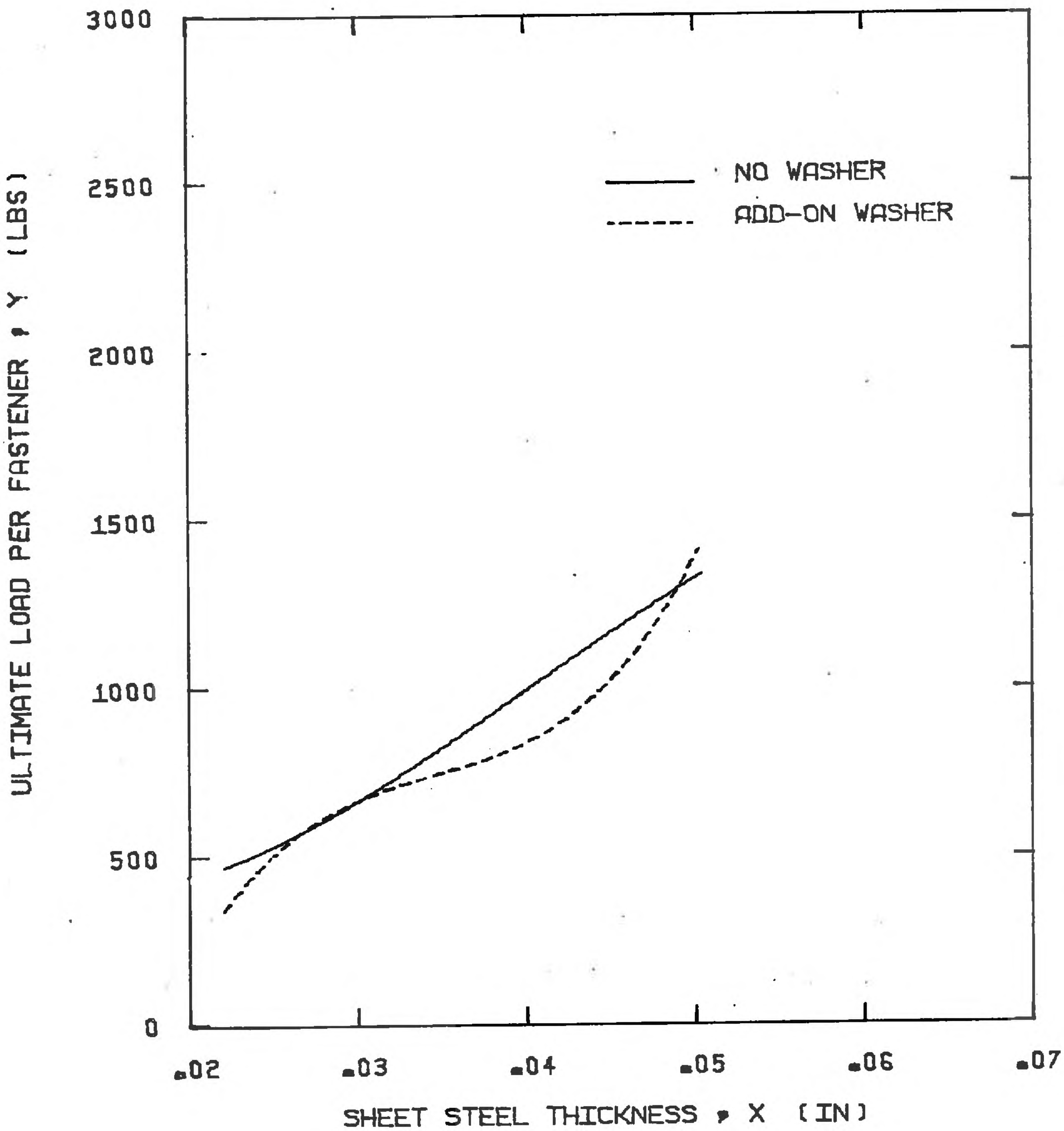


NUMBER 12 TYPE TEKS/2/MB/HT 14TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

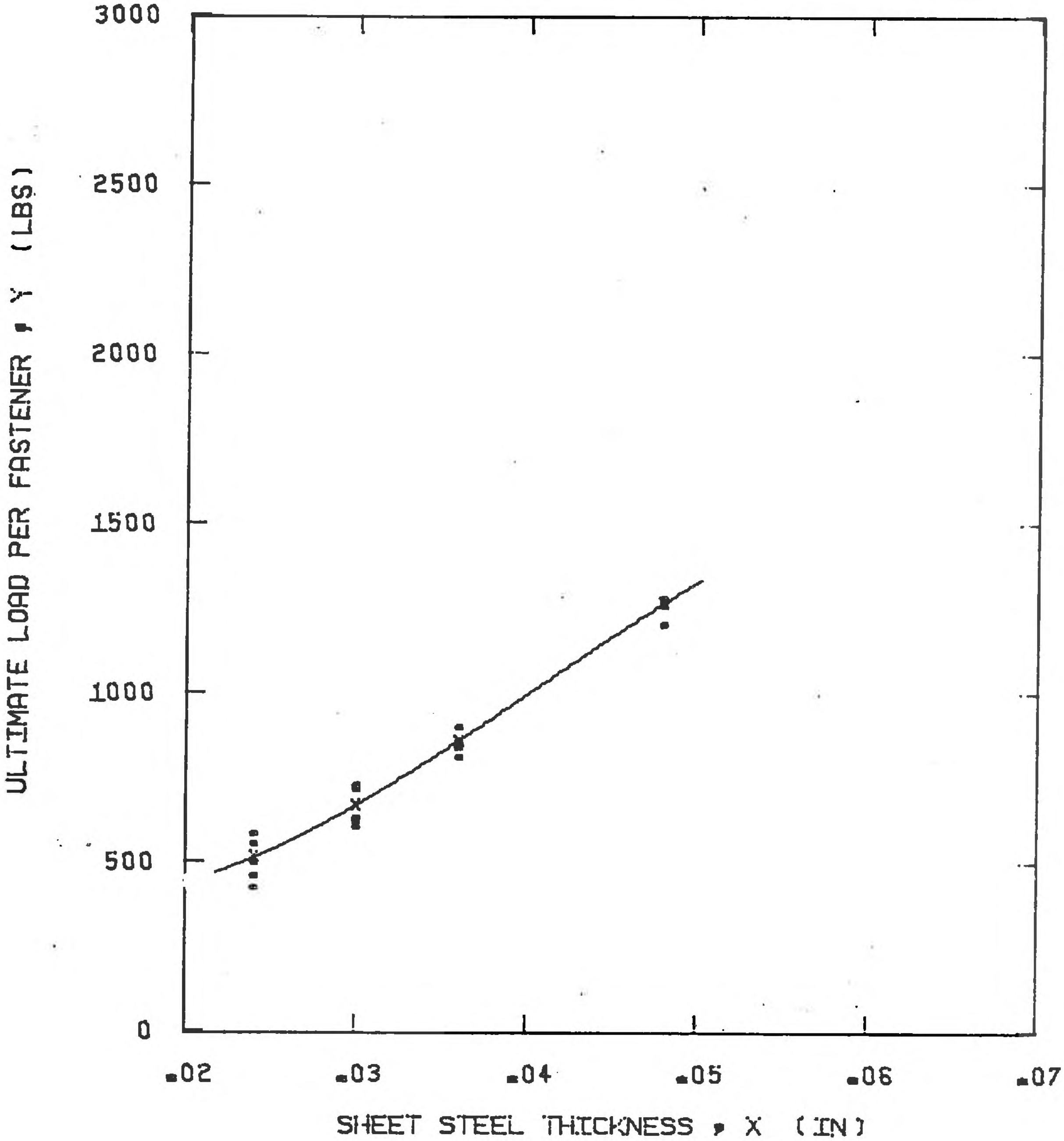
A = -.191E+04 B = .186E+06

C = -.474E+07 D = .461E+08



NUMBER 14 TYPE A 10TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)



NUMBER 14 TYPE A 10TPI

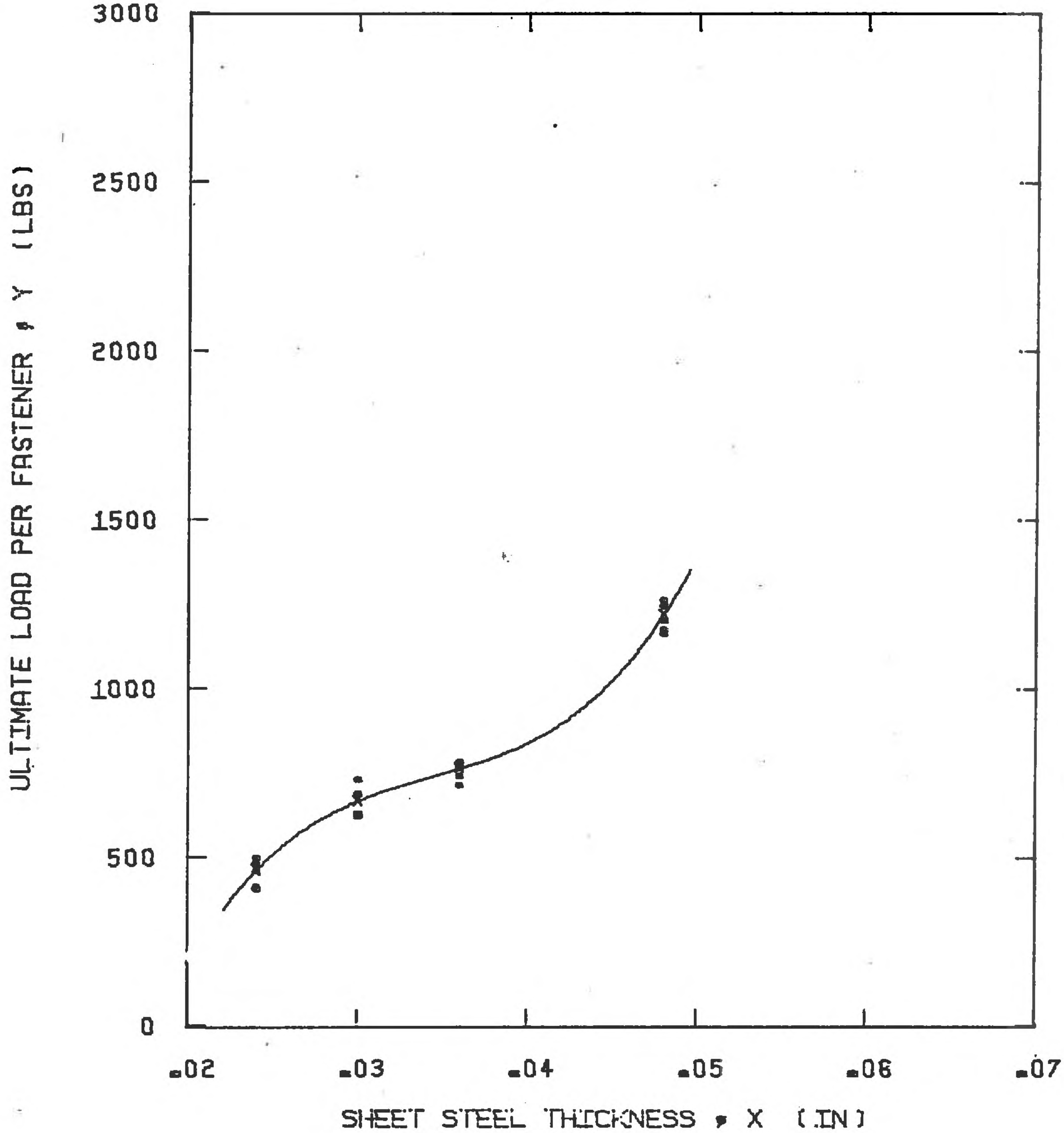
THREAD FORMING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .652E+03 B = -.422E+05

C = .189E+07 D = -.155E+08

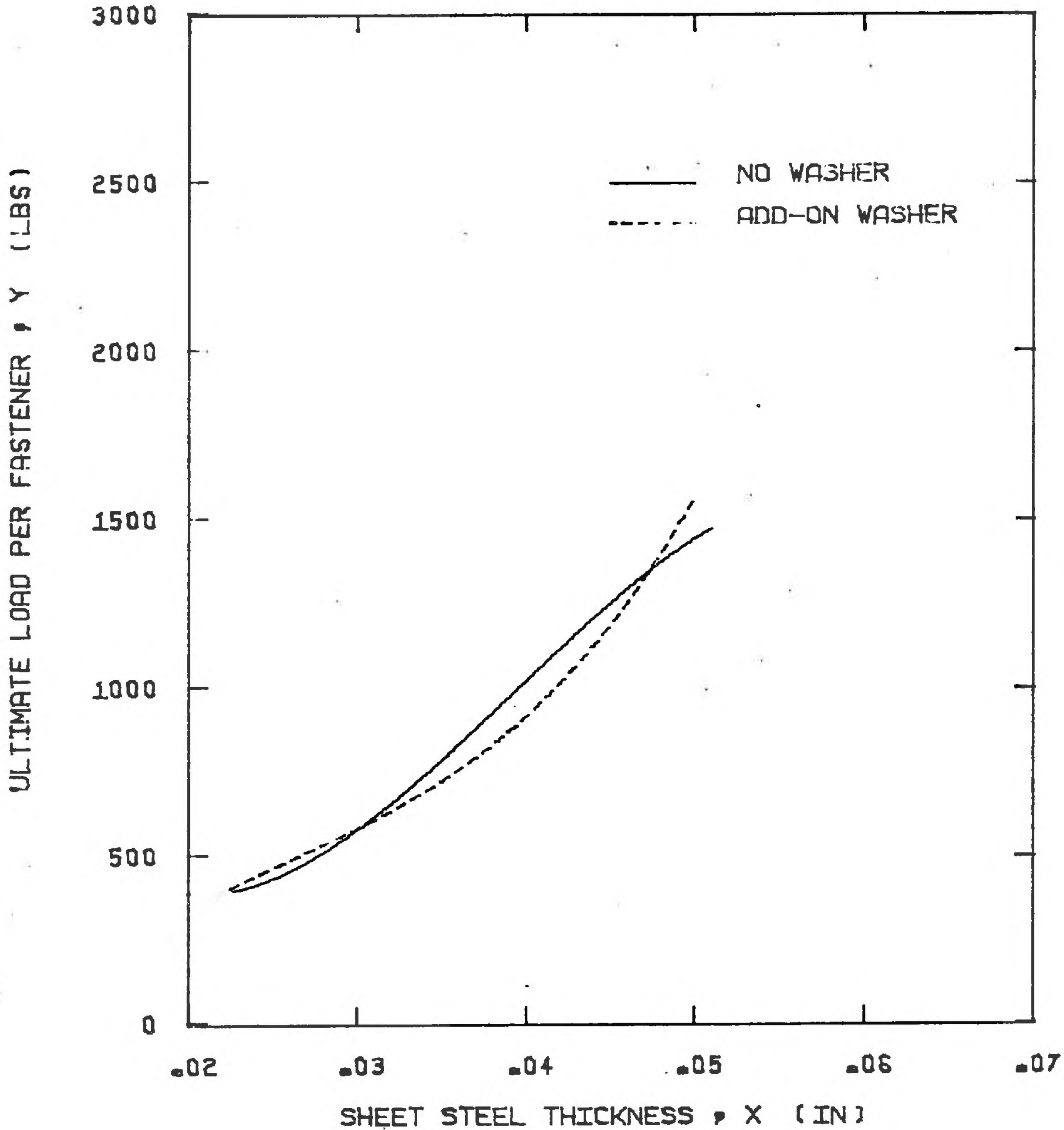


NUMBER 14 TYPE A 10TPI
THREAD FORMING
GALVANIZED AND RUBBER WASHER

Y = A + B X + C (X**2) + D (X**3)

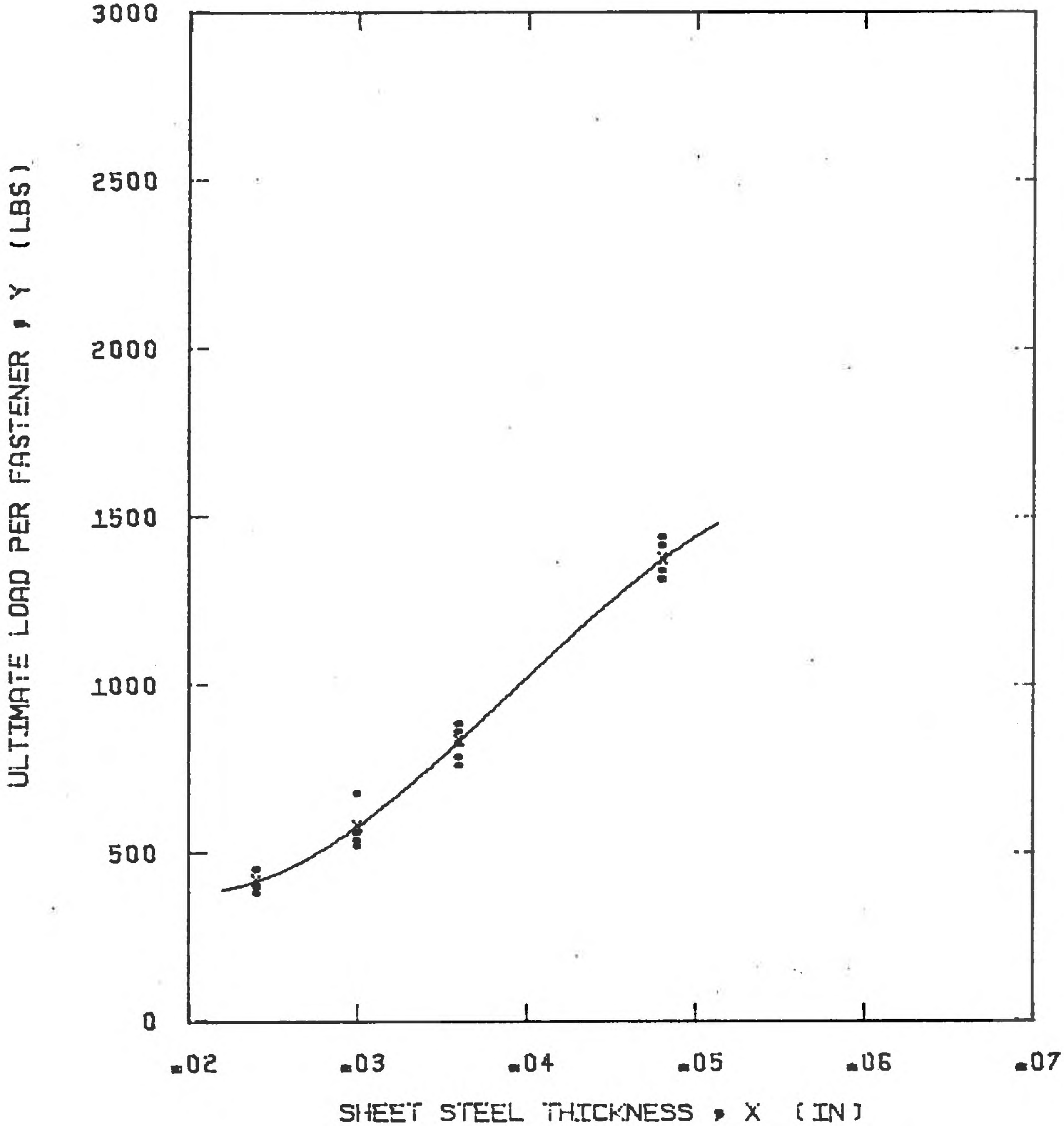
A = -.449E+04 B = .427E+06

C = -.120E+08 D = .116E+09



NUMBER 14 TYPE AB 14TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

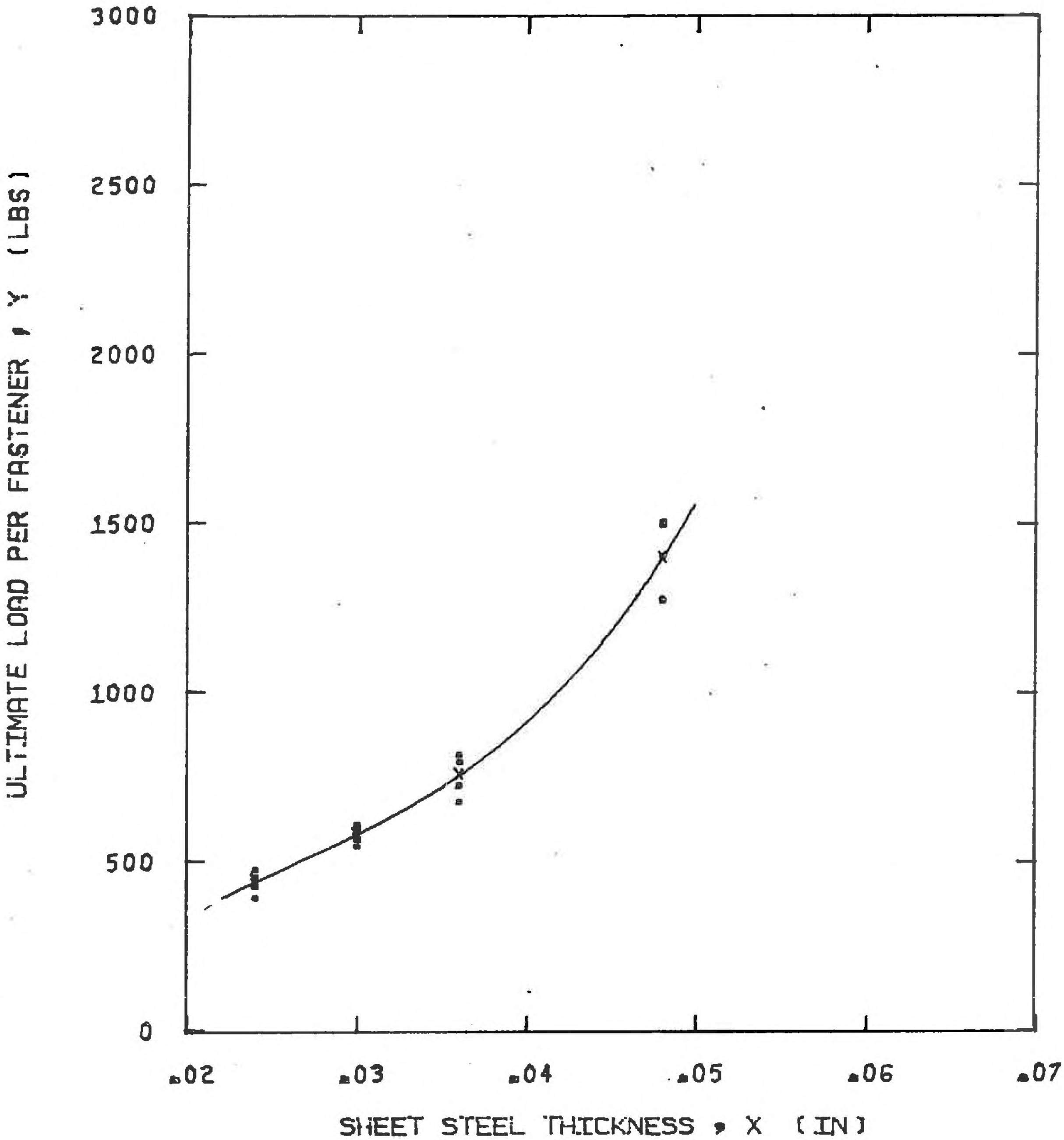


NUMBER 14 TYPE AB 14TPI H.H.
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .181E+04 B = -.158E+06

C = .526E+07 D = -.447E+08

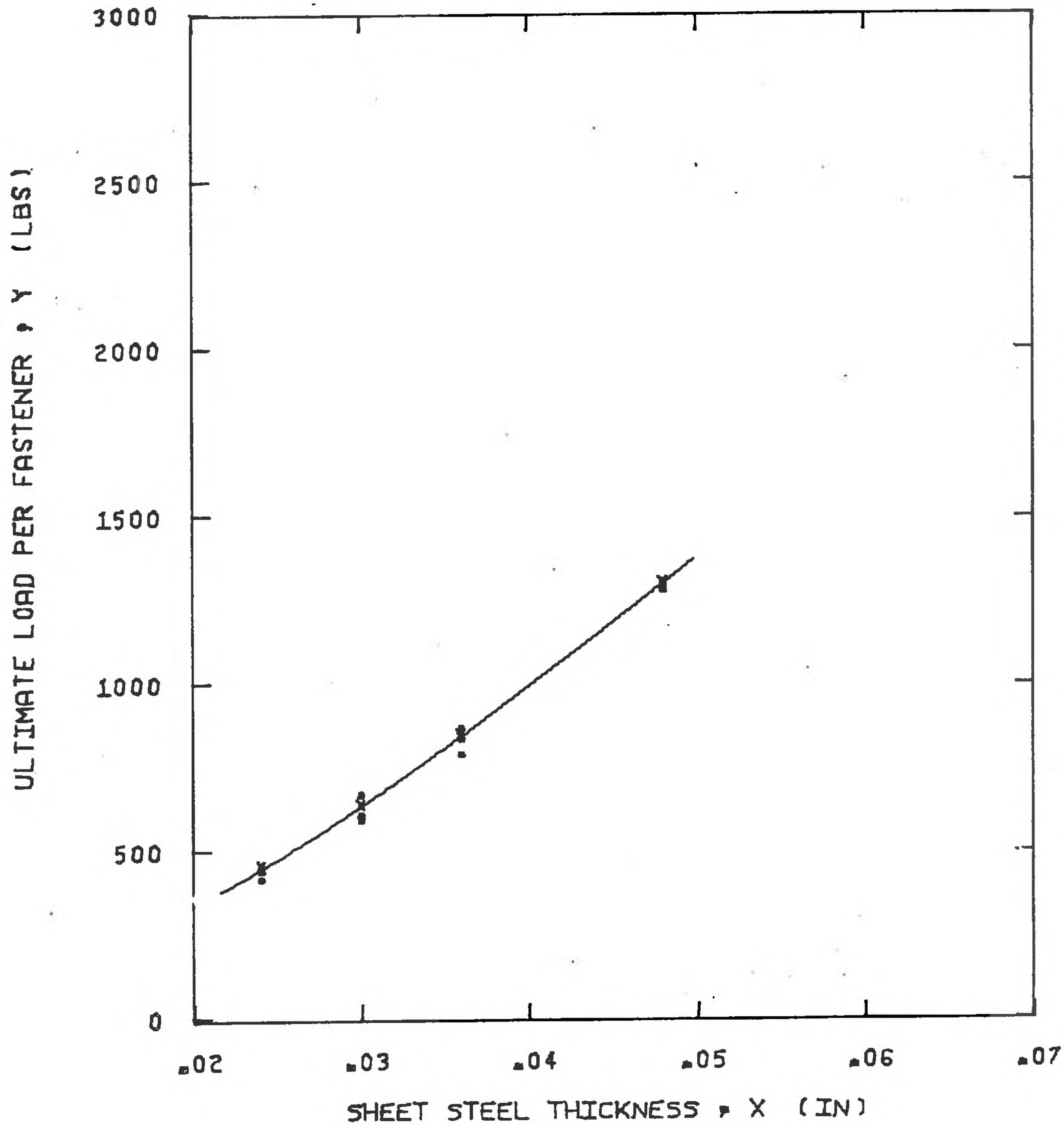


NUMBER 14 TYPE AB 14TPI H.H.
THREAD FORMING
GALVANIZED AND RUBBER WASHER

Y = A + B X + C (X**2) + D (X**3)

A = -.760E+03 B = .986E+05

C = -.292E+07 D = .375E+08

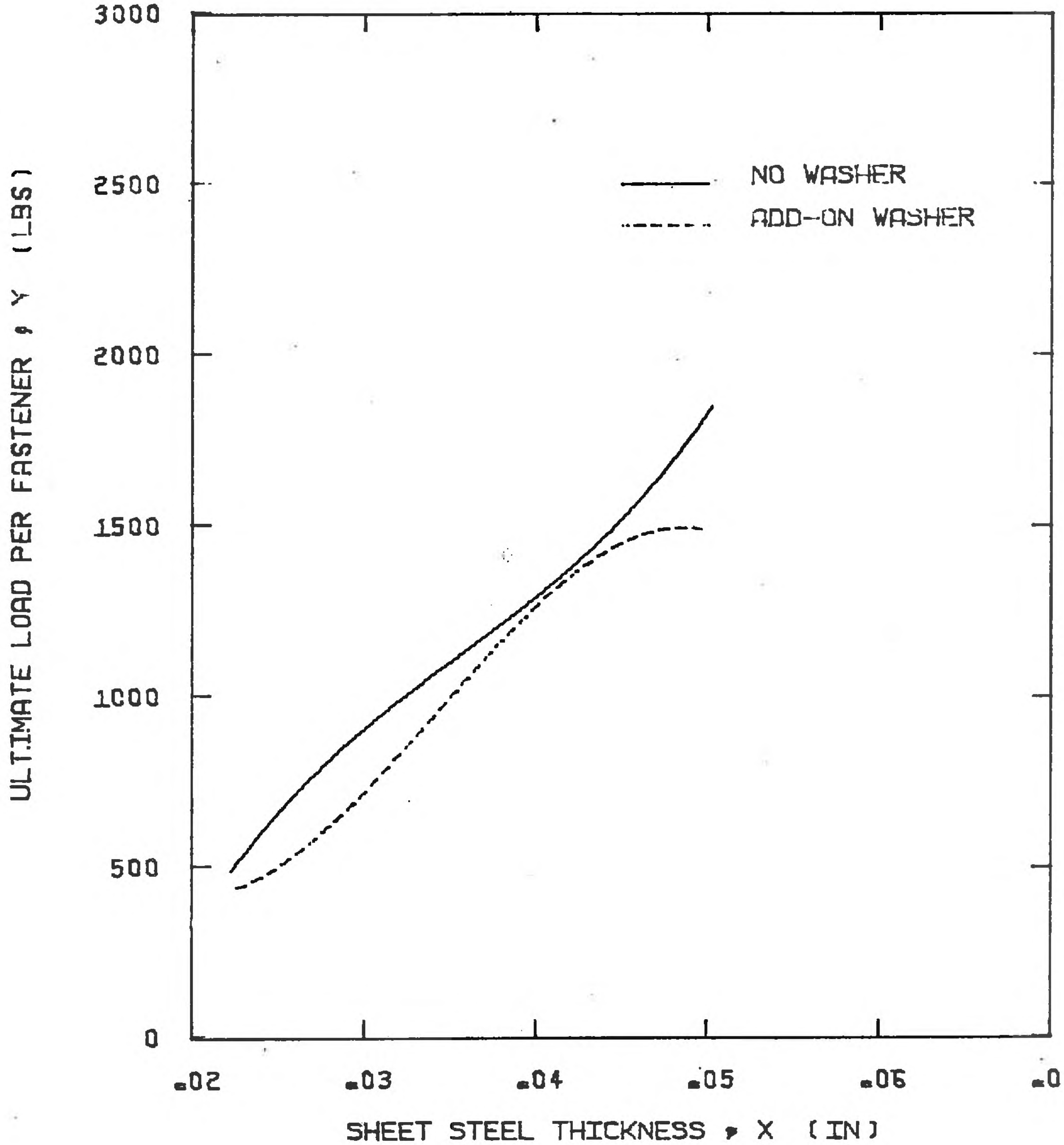


NUMBER 14 TYPE AB 14TPI H.W.H.
THREAD FORMING
NO WASHER

Y = A + B X + C (X**2) + D (X**3)

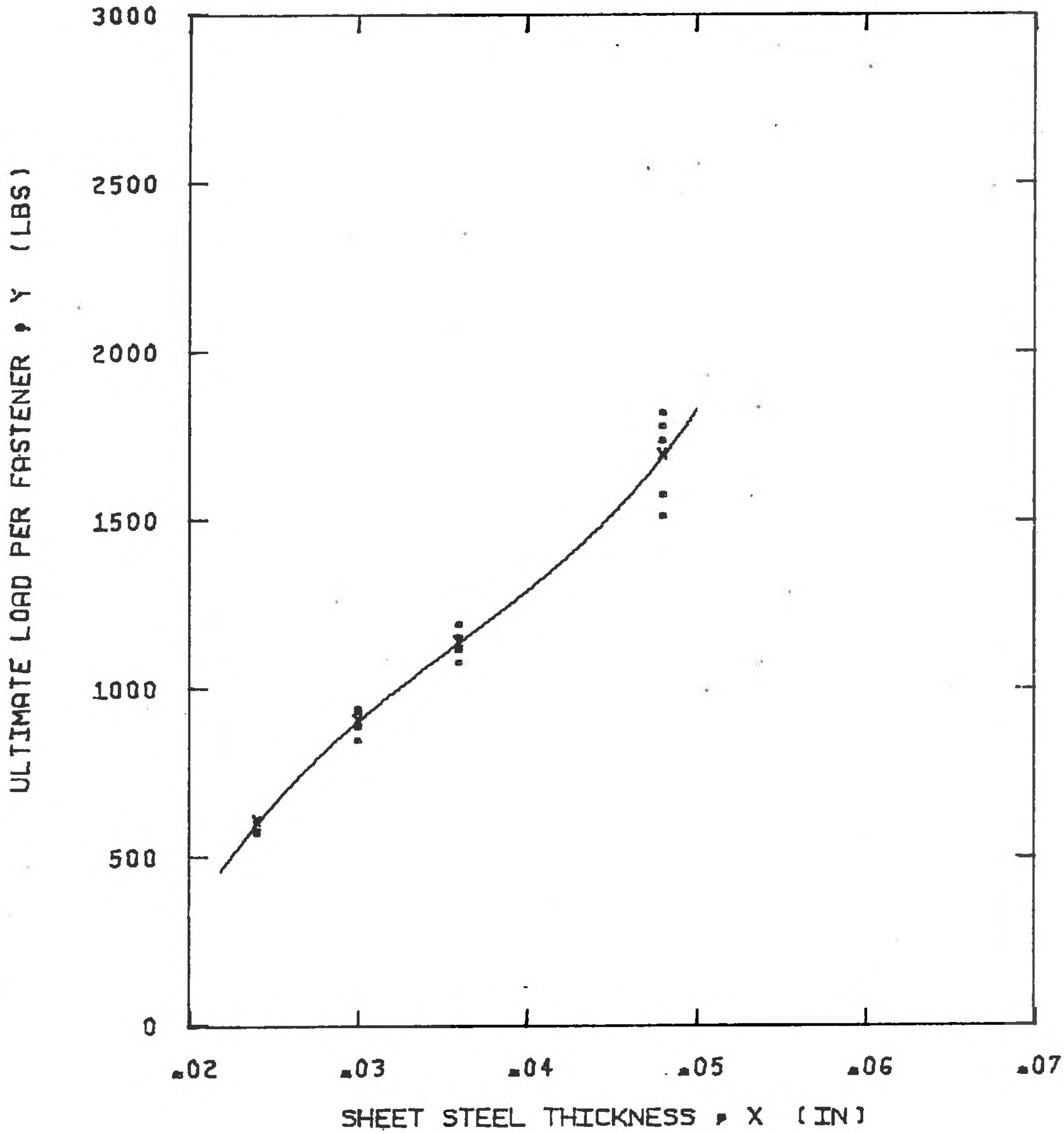
A = .548E+02 B = .139E+04

C = .759E+06 D = -.514E+07



NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)



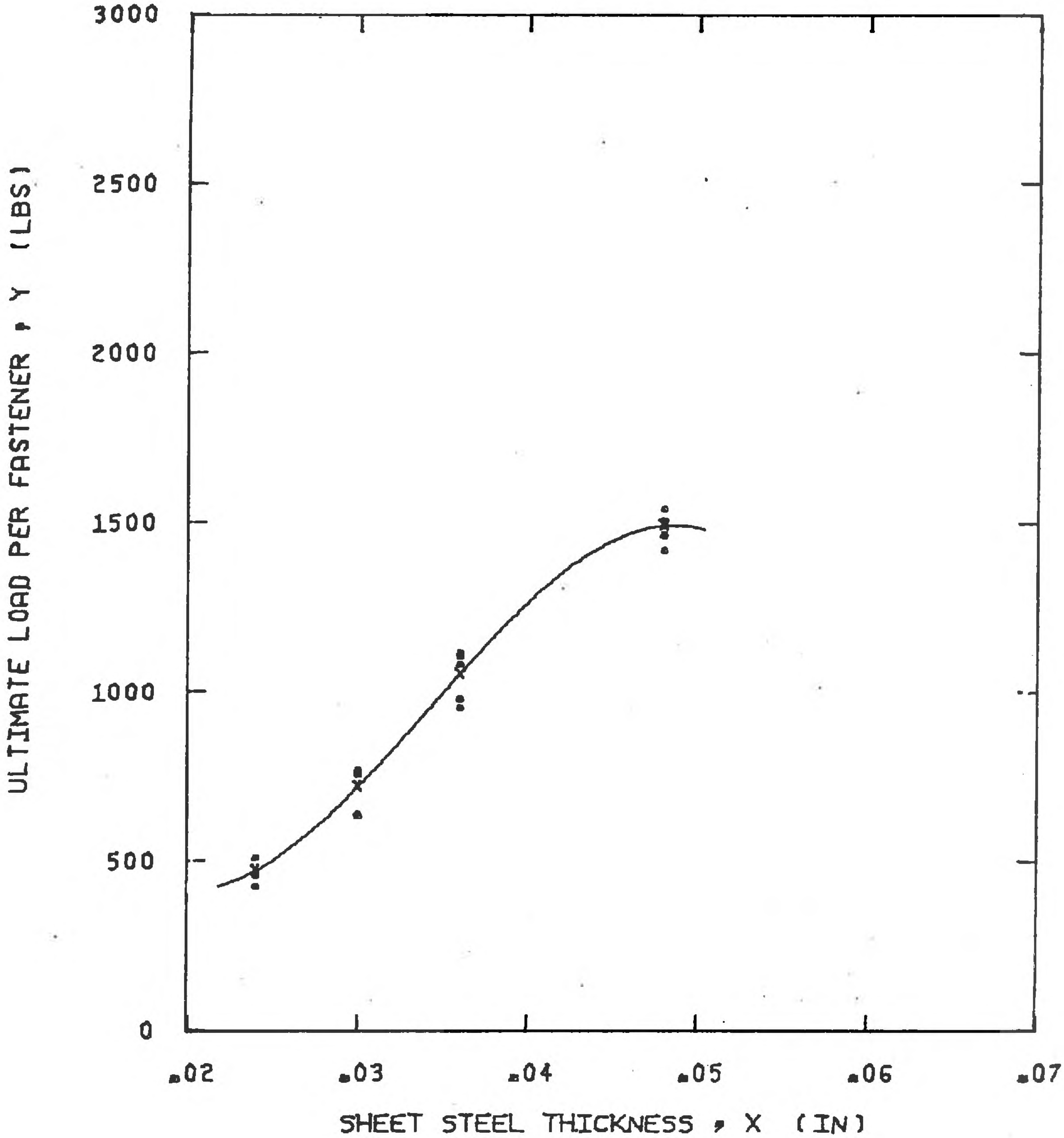
NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI

SELF DRILLING

NO WASHER

Y = A + B X + C (X**2) + D (X**3)

A =	-.283E+04	B =	.259E+06
C =	-.622E+07	D =	.581E+08

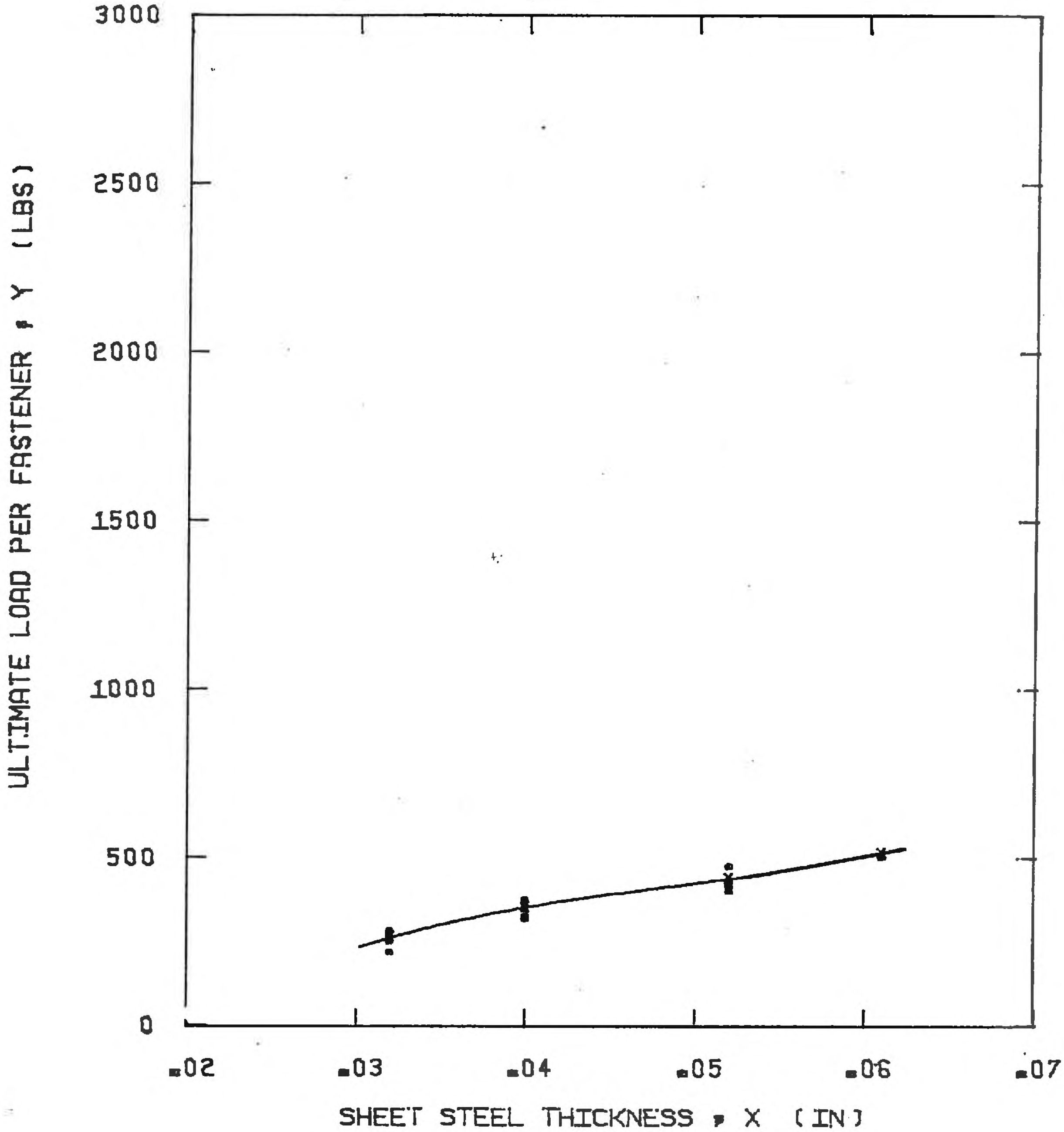


NUMBER 14 TYPE TEKS/1≤STITCH≤ 10TPI
SELF DRILLING
TWIN SEAL WASHER

Y = A + B X + C (X**2) + D (X**3)

A = .277E+04 B = -.273E+06

C = .963E+07 D = -.938E+08

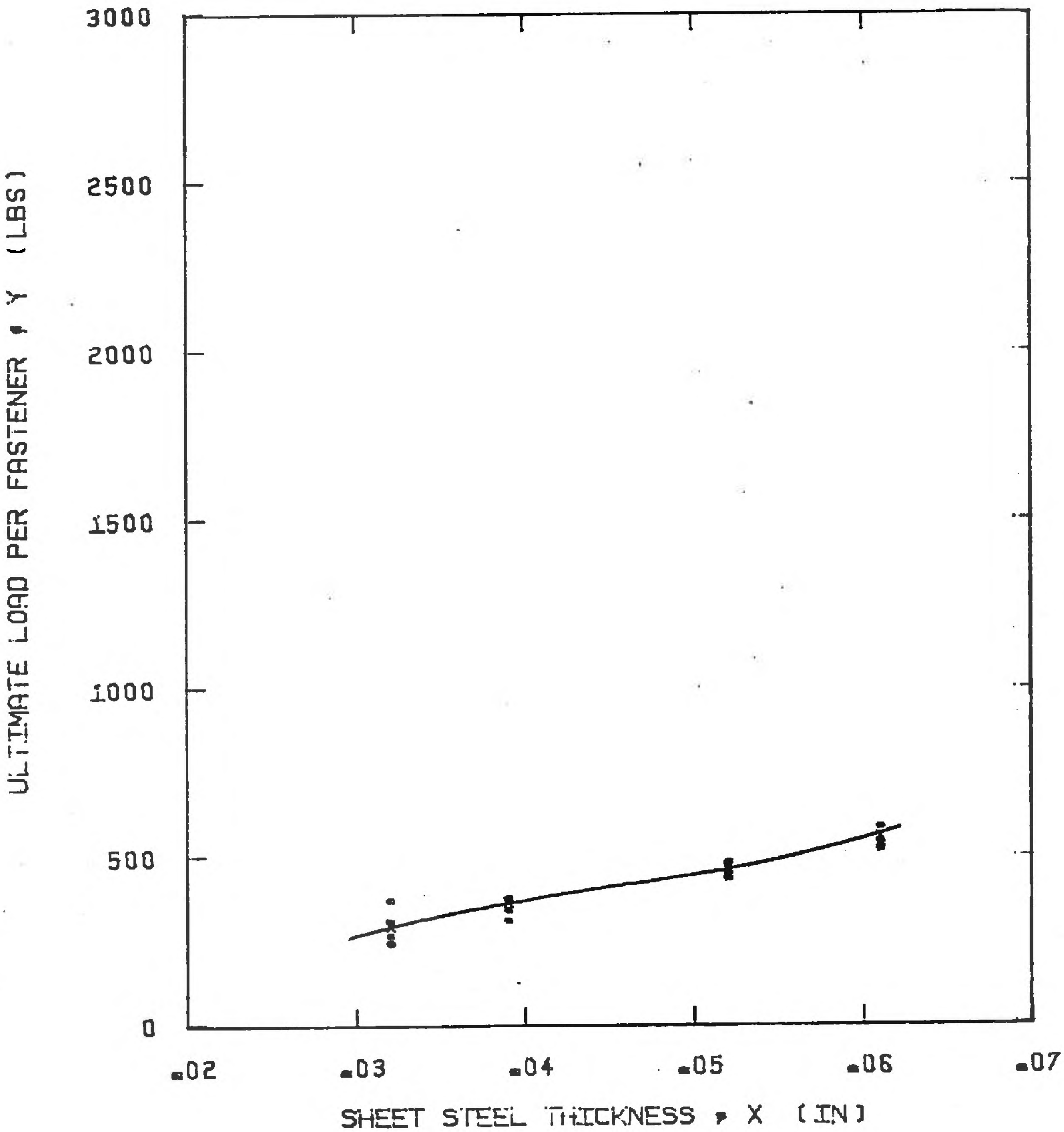


NUMBER 8 TYPE A 15TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A = -.961E+03 B = .714E+05

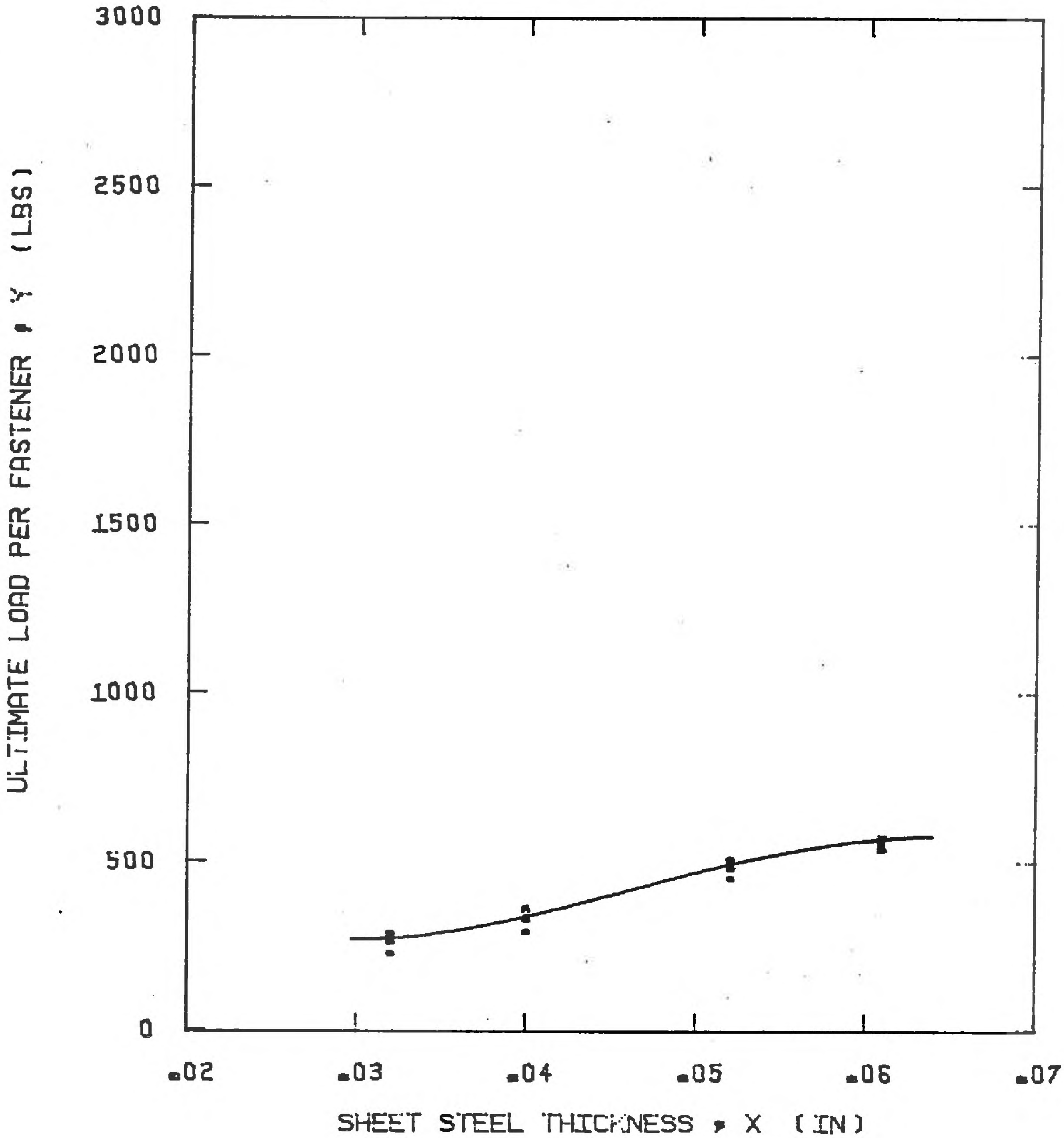
C = -.132E+07 D = .897E+07



NUMBER 8 TYPE AB 18 TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A =	-.684E+03	B =	.572E+05
C =	-.108E+07	D =	.777E+07

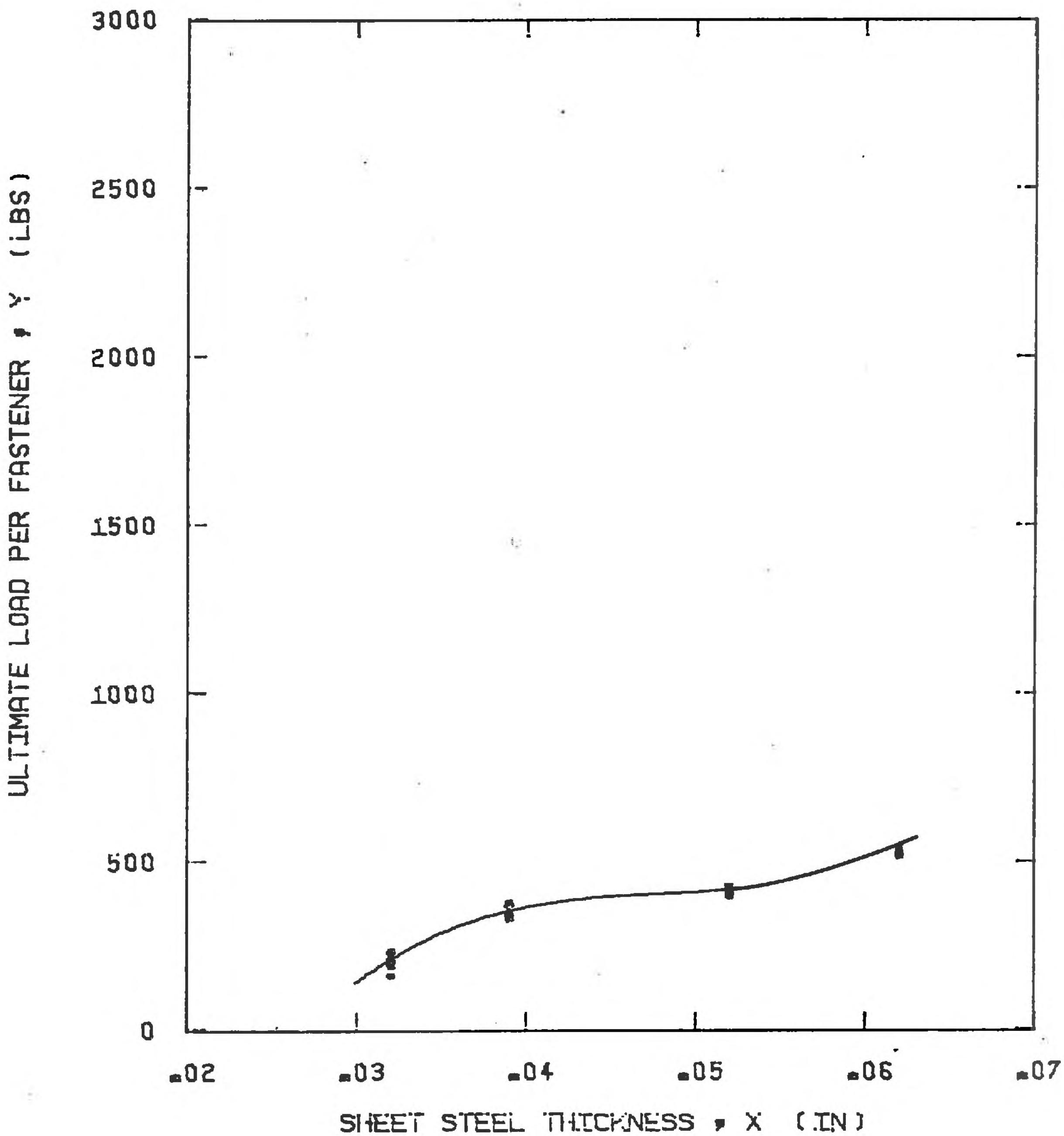


NUMBER 8 TYPE TEKS/2F 18TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A = .144E+04 B = -.943E+05

C = .235E+07 D = -.170E+08

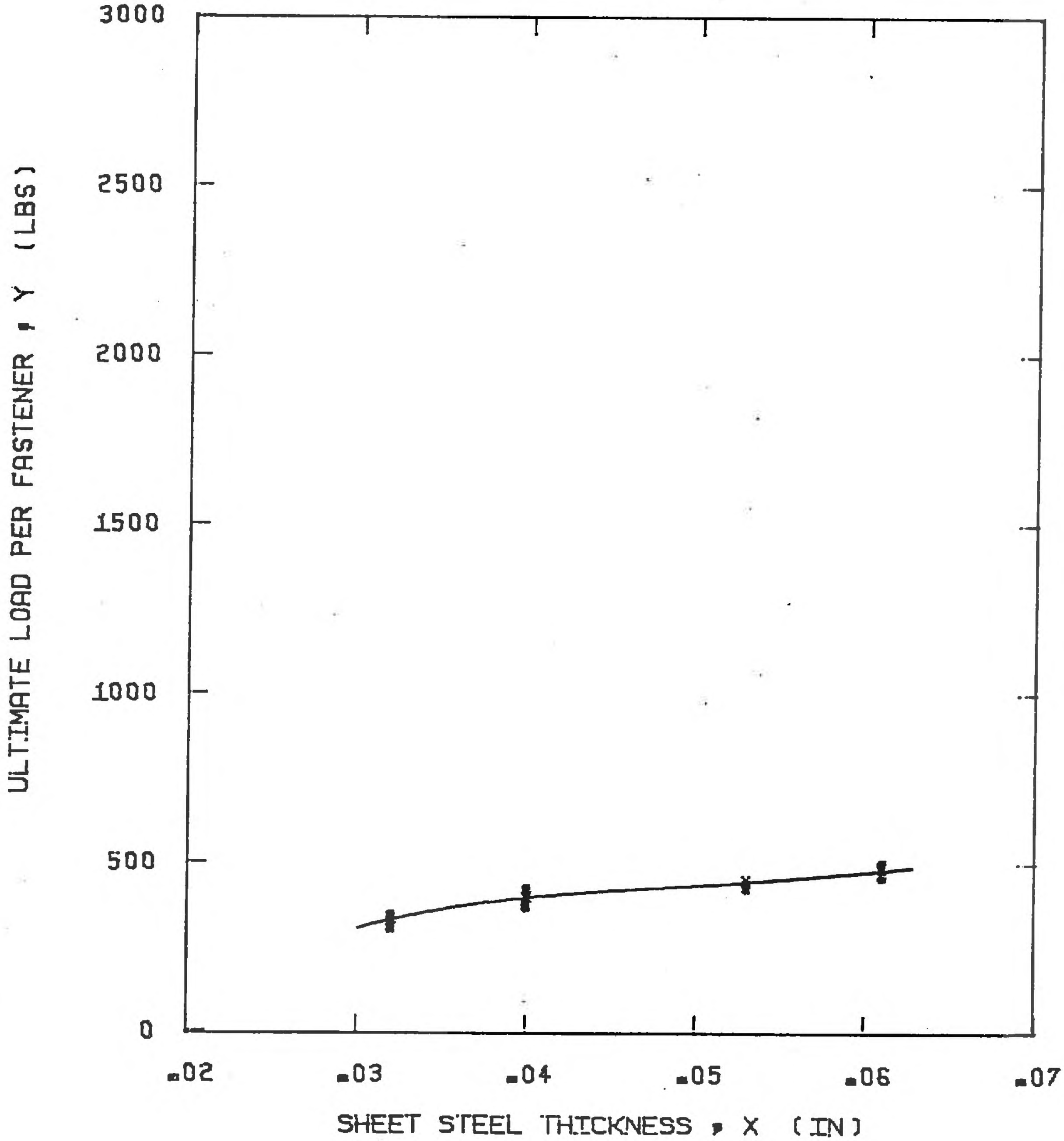


NUMBER 8 TYPE C 32TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A = -.376E+04 B = .254E+06

C = -.522E+07 D = .361E+08



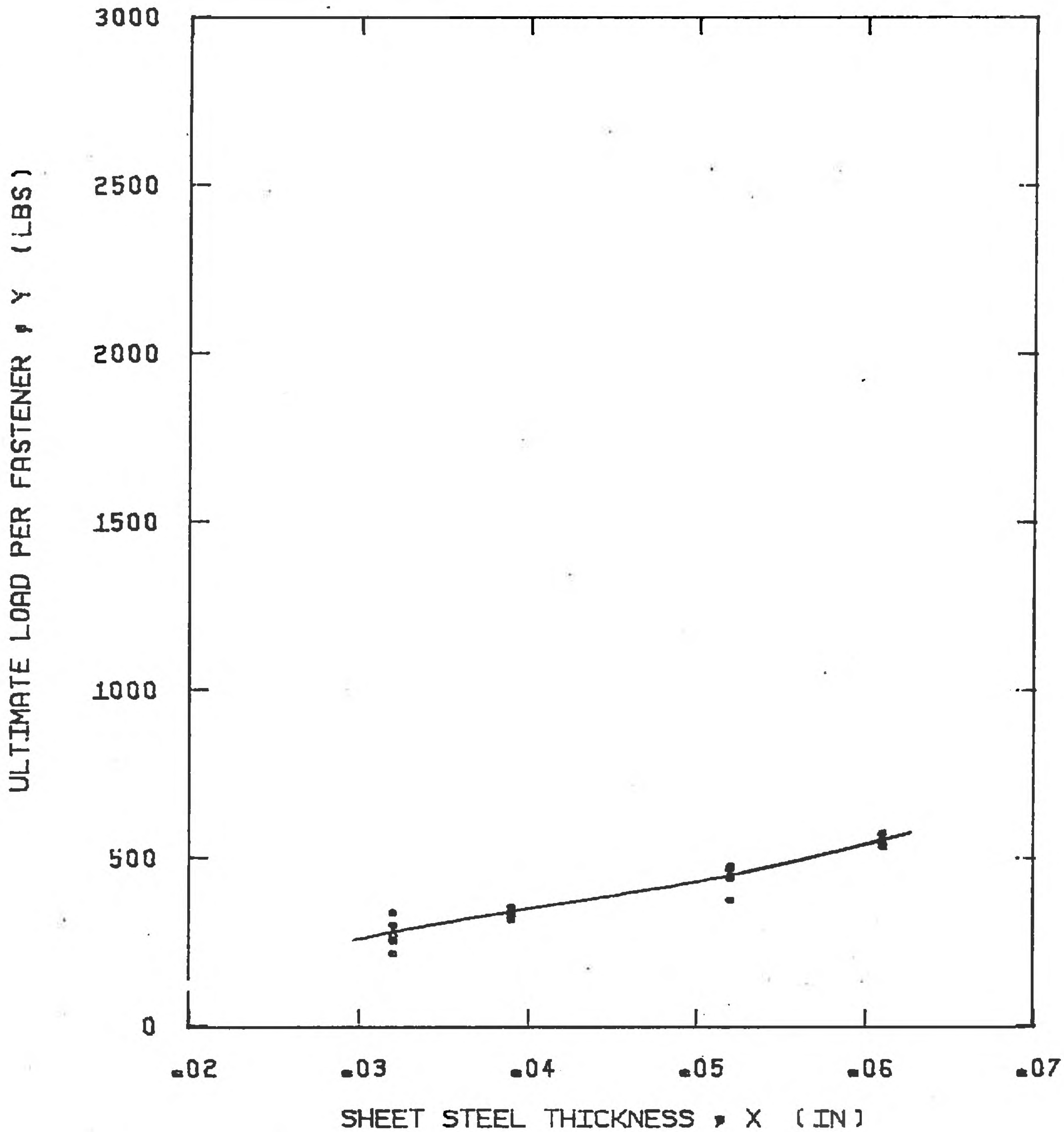
NUMBER 10 TYPE A 12TPI

THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A = -.885E+03 B = .752E+05

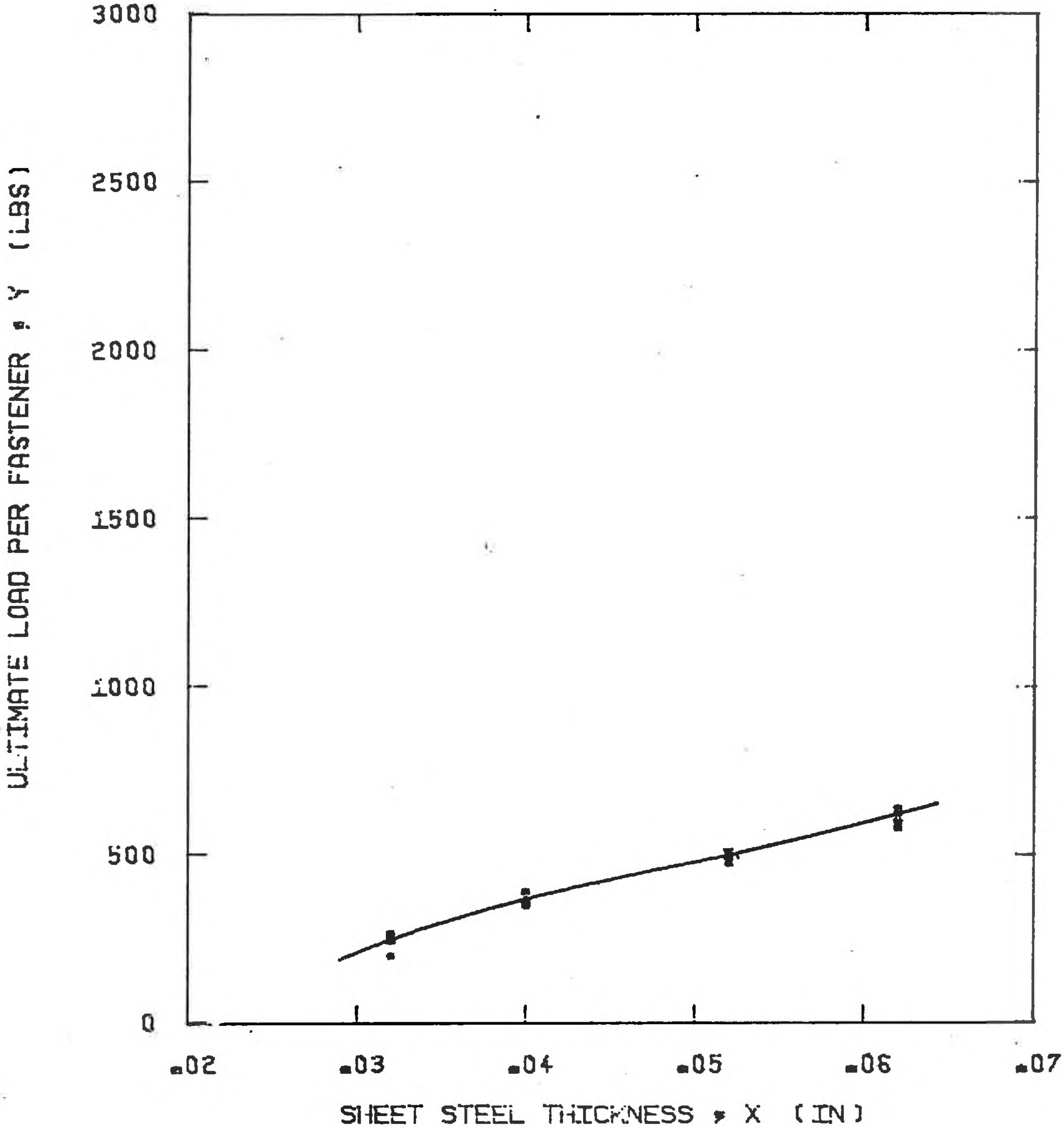
C = -.148E+07 D = .101E+08



NUMBER 10 TYPE AB 16TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A =	-.414E+03	B =	.401E+05
C =	-.768E+06	D =	.609E+07

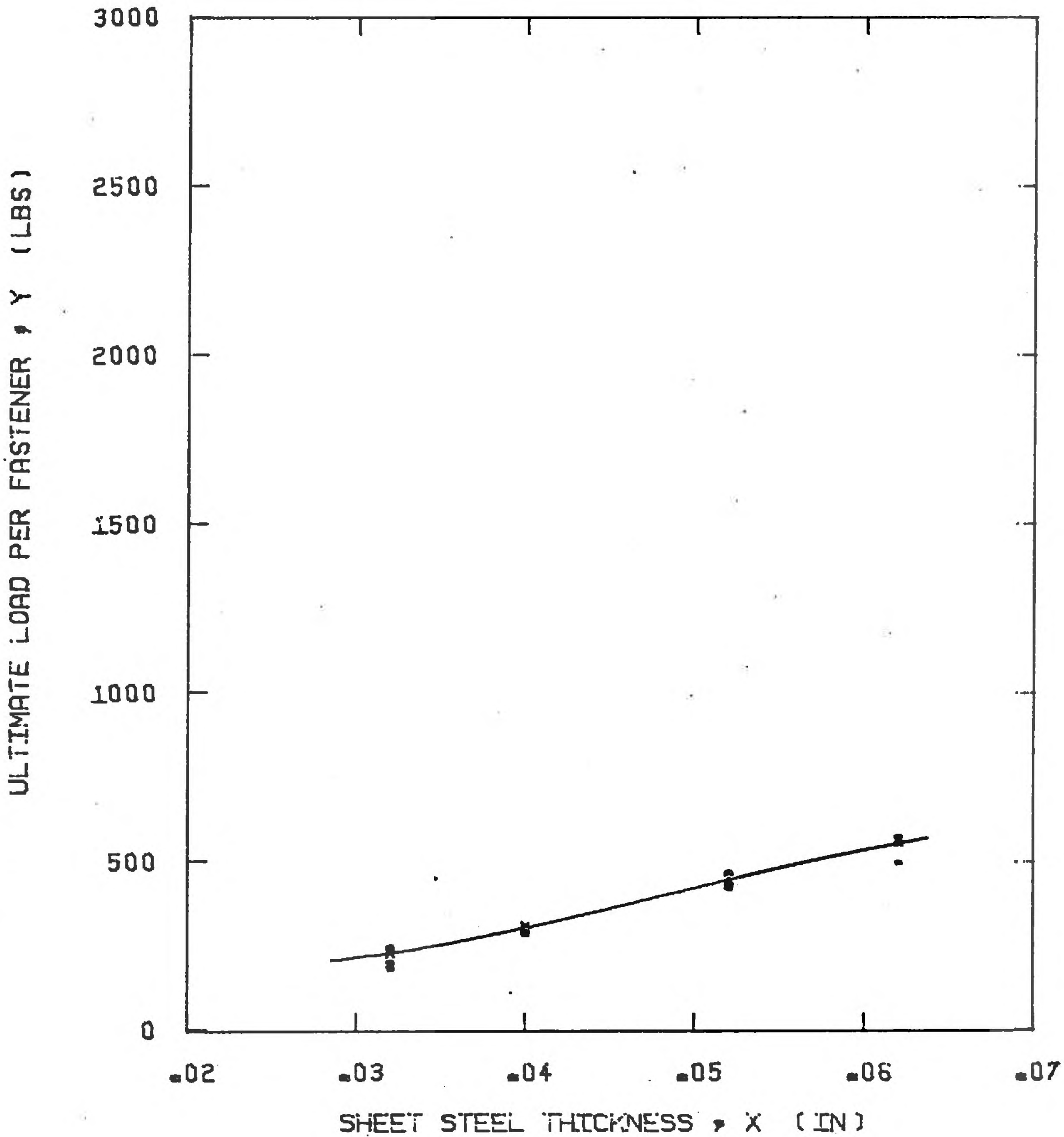


NUMBER 10 TYPE TEKS/2 16TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A = -.101E+04 B = .686E+05

C = -.116E+07 D = .762E+07

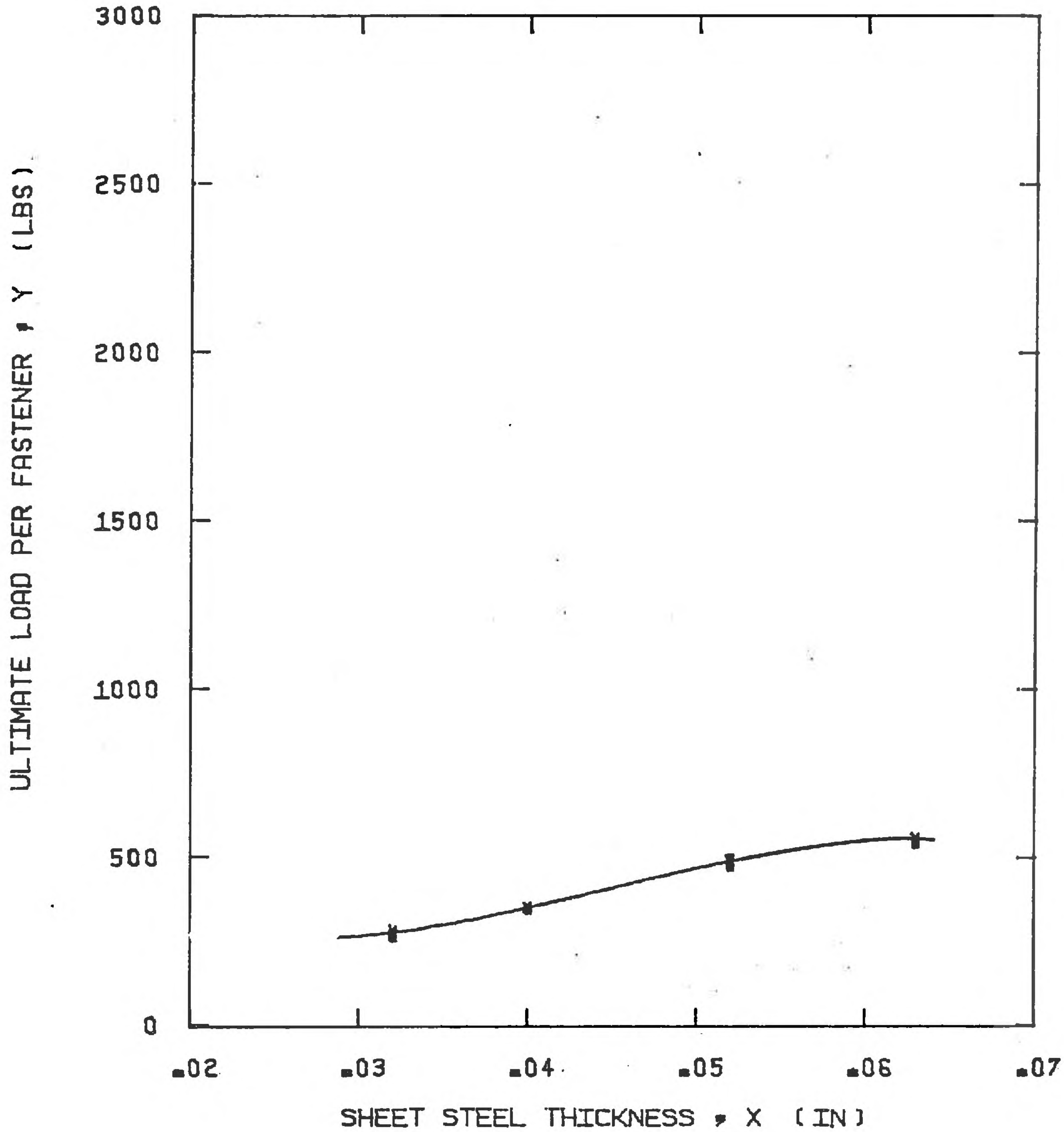


NUMBER 10 TYPE TEKS/3 16TPI

SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A =	.469E+03	B =	-.279E+05
C =	.818E+06	D =	-.555E+07



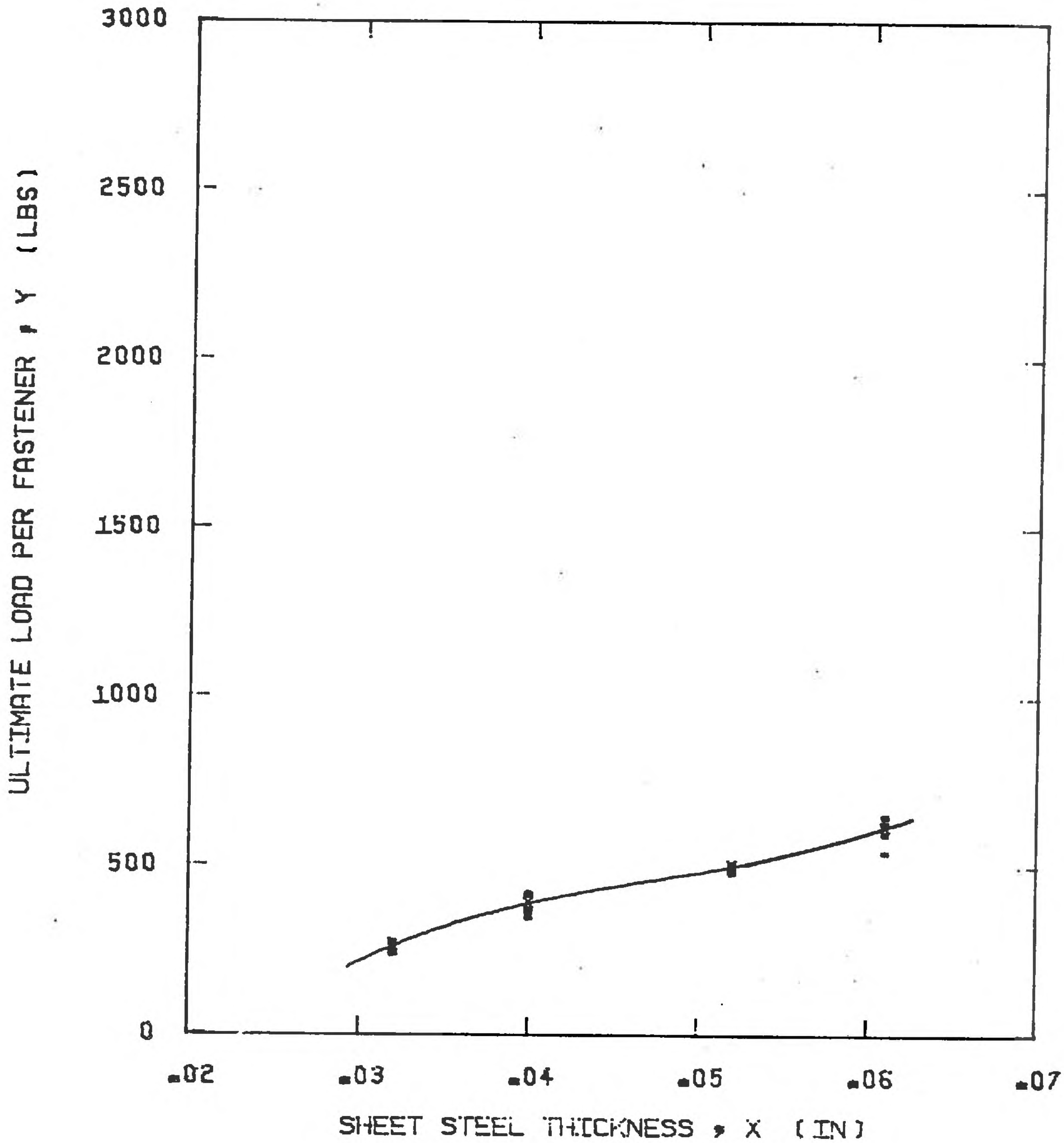
NUMBER 12 TYPE AB 14TPI

THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A = .919E+03 B = -.585E+05

C = .158E+07 D = -.118E+08

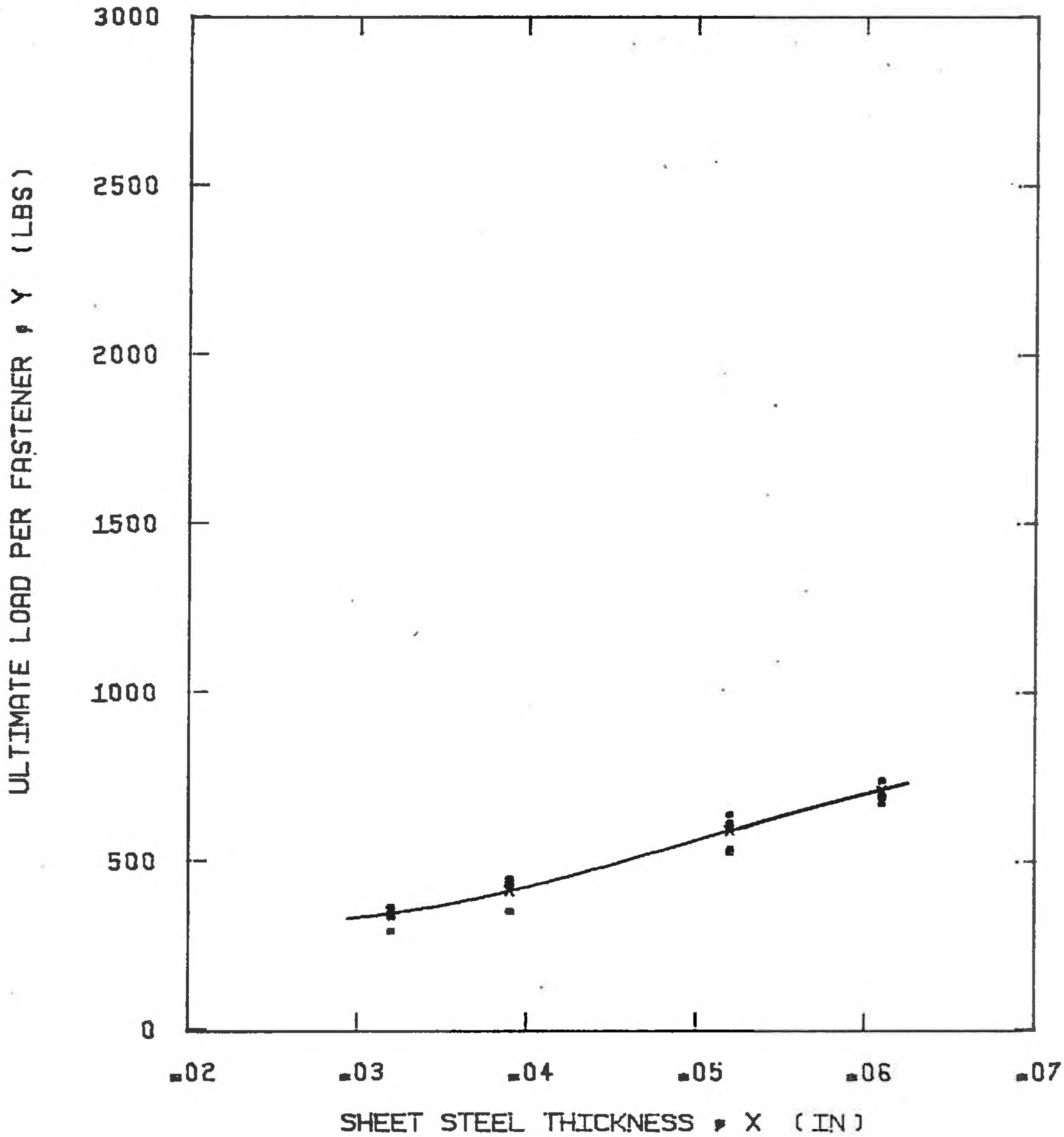


NUMBER 12 TYPE TEKS/2/MB/HT 14TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A = -.182E+04 B = .127E+06

C = -.248E+07 D = .174E+08



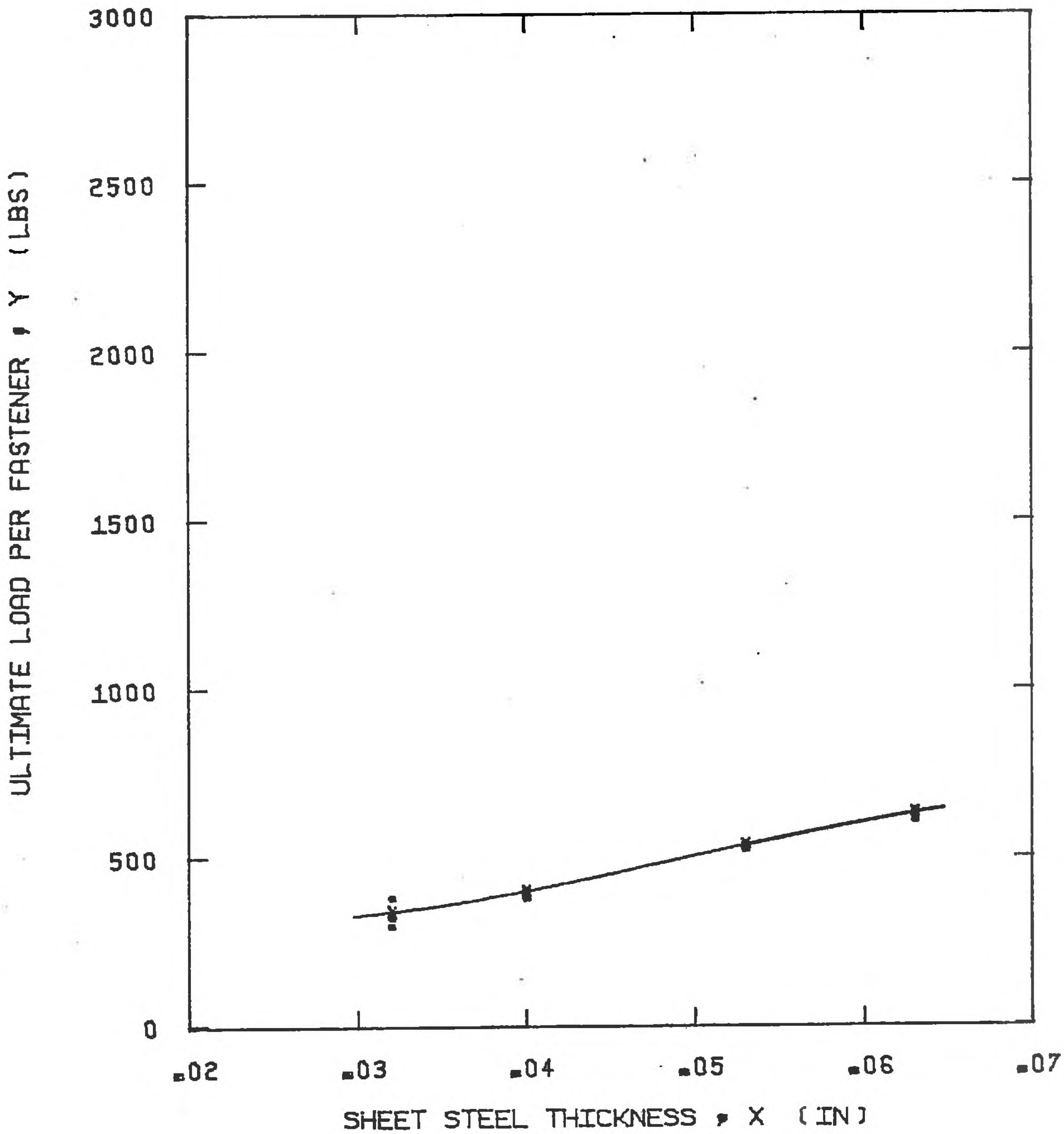
NUMBER 14 TYPE A 10TPI

THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A = .910E+03 B = -.515E+05

C = .136E+07 D = -.931E+07

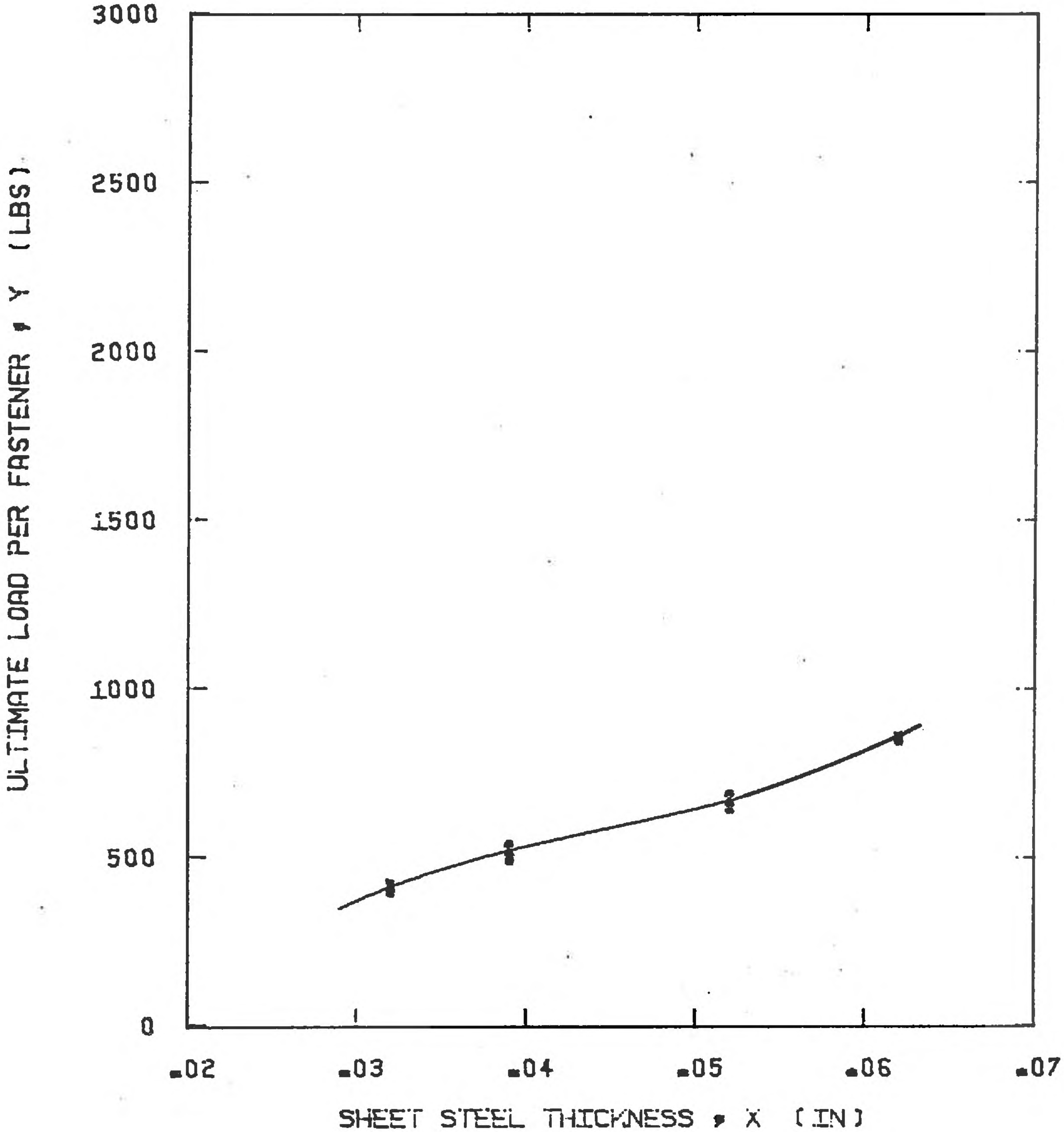


NUMBER 14 TYPE AB 14 TPI
THREAD FORMING

Y = A + B X + C (X**2) + D (X**3)

A = .672E+03 B = -.323E+05

C = .875E+06 D = -.592E+07

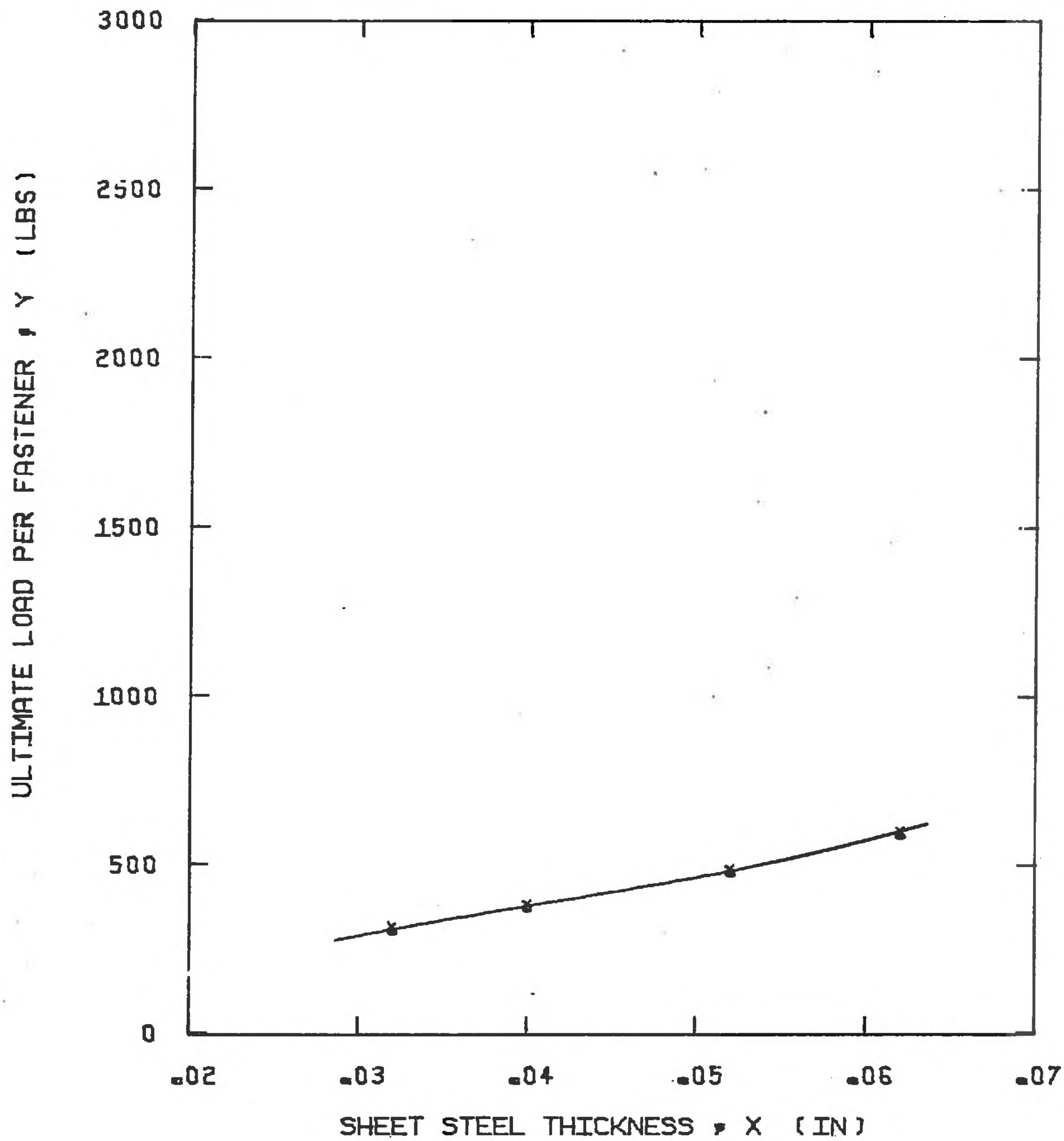


NUMBER 14 TYPE TEKS/2/MB 14TPI
SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A = -.144E+04 B = .114E+06

C = -.231E+07 D = .171E+08



NUMBER 14 TEKS/3 14TPI

SELF DRILLING

Y = A + B X + C (X**2) + D (X**3)

A =		B =	
C =	-.222E+03	D =	.282E+05
	-.484E+06		.392E+07