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Explosive Tests For the Evaluation of the Glass Fragment Mitigation Characteristic of MSC Specialty Films Inc. Security Window Films

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PREFACE

Applied Research Associates, Inc. (ARA) conducted high-explosive tests on February 15-March 3, 2000, in order to evaluate the response of security window film to blast loads. Five high explosive tests were conducted and four windows were evaluated in each test for a total of 20 window samples. This report documents the findings of these tests.

The tests were performed at the Chestnut Test Site on Kirtland Air Force Base in New Mexico. This test site is owned and operated by the Defense Threat Reduction Agency (DTRA), which is the US Government's lead agency for force protection. A special thanks is extended to DTRA for allowing ARA use of the test site. This work was sponsored by MSC Specialty Films Inc. The support and efforts of MSC Specialty Films Inc. are acknowledged and greatly appreciated

NAME	TITLE	PROJECT ASSIGNMENT
James T. Brokaw	Senior Engineer	Principal investigator, field test engineer
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Larry M. Bryant	Senior Engineer	Analysis
Charles Ellison	Staff Engineer	Analysis
Paul Gay	Engineering Aide	Analysis
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EXECUTIVE SUMMARY

In response to the heightened concern about terrorism, the US Government and private industry are developing and testing new technologies to mitigate hazards to people in the vicinity of a terrorist bombing. In cooperation with the Defense Threat Reduction Agency, Applied Research Associates conducted tests to assess the capability of security window film to reduce the hazards of flying glass shards during an explosion. Propelled by the forces of a terrorist bomb, glass fragments cause large numbers of serious injuries.

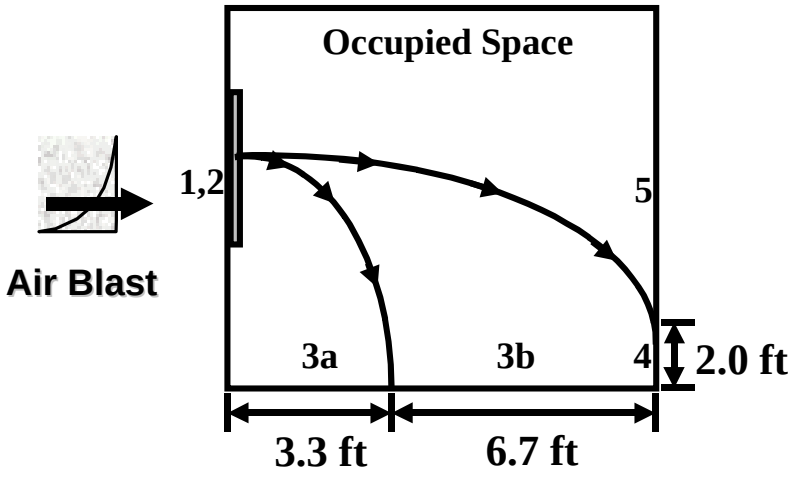
The US General Services Administration (GSA) developed criteria for evaluation of acceptable levels of protection from the glass fragment hazards in a terrorist bombing. These criteria are part of the comprehensive security criteria (GSA Security Criteria, Final Working Version, January 1997) developed by the GSA, which includes physical security, electronic security, and many other criteria for blast considerations. The GSA has indicated that manufacturers must test their window products against the criteria to evaluate the performance of these products in blast if they want to be considered for use in GSA buildings. The current GSA Test Procedure is included in Appendix A.

MSC Specialty Films Inc. commissioned ARA to perform a series of five open-air high explosive tests in order to evaluate the performance of security window film products. The tests

The test charge was 600 lb of Ammonium Nitrate and Fuel Oil (ANFO), which is equivalent to 500 lb of TNT. The standoff distance to the structures was varied to affect specific peak pressures on the test specimens.

A thorough test matrix was developed to explore the effect of film thickness and attachment method on window response. The nominal window size for the tests was 4 ft by 5-1/2 ft. One-fourth inch thick annealed glass was used during testing. The windows were tested in commercially available aluminum storefront window frames. The glass type and film attachment method for each window is given in the summary and test description for each test.

The GSA glass fragment hazard rating scheme is presented graphically and is described in the table which follows. The approach compares potential hazards based on the type and location of glass fragments interior and exterior to the test cubicle. These criteria indirectly reflect the velocity (hence hazard level) of fragments based on their distance from the original window position.



RESULT SUMMARIES AND CONCLUSIONS

The GSA Security Criteria requires that windows meet a certain level of performance for a particular blast design threat. This is true for GSA buildings with security classifications of Levels C and D. Level A and Level B buildings, which are lower in security classification than C and D buildings, require no specific blast performance criteria though the use of certain window types in Level A and B buildings is prohibited. Level E buildings are very high security buildings and the generalized criteria do not give guidance for these buildings.

The airblast loading that is used in the window design for GSA Level C and Level D buildings is based on a particular threat size at the worst-case threat scenario location given the available perimeter standoff. Realistic limits are placed on the maximum design loads with the

Interagency Security Committee (ISC) Security Criteria are similar with minor modifications.

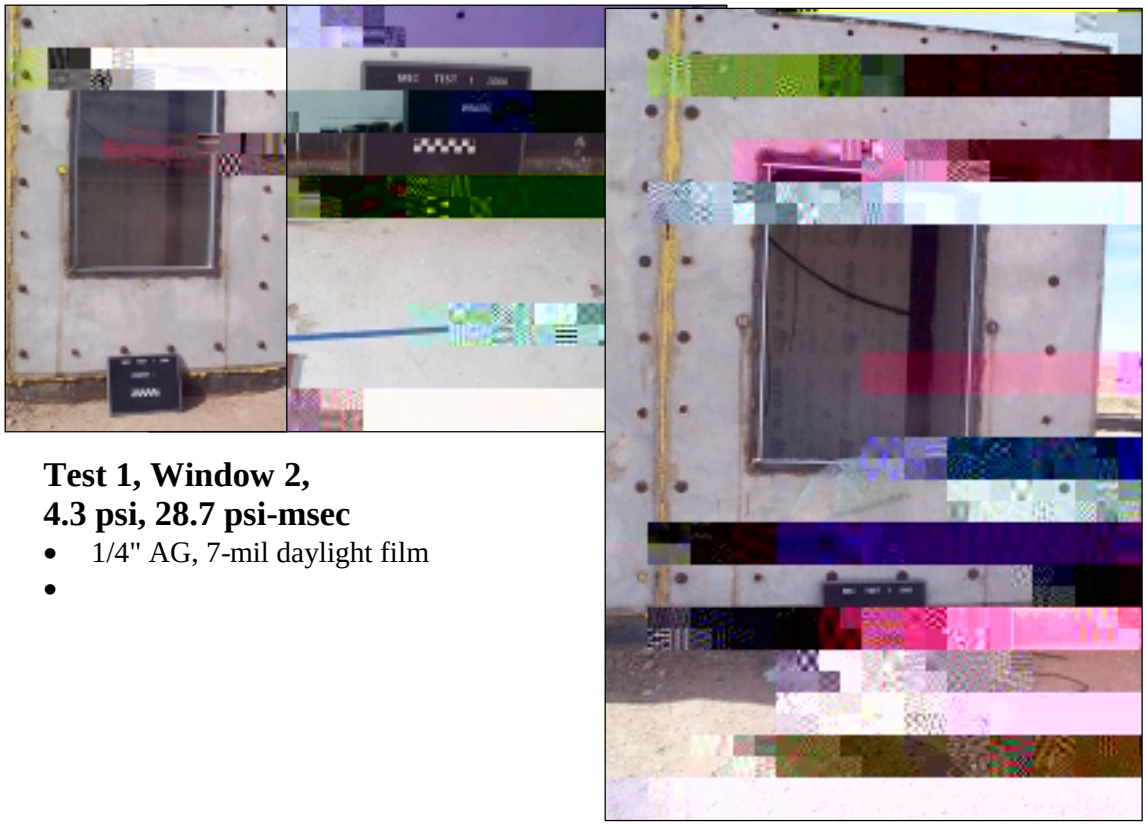
Result Summaries

Test windows were constructed with standard commercial aluminum frames and ¼ inch annealed glass. The windows were tested under conditions consistent with the "US General Services Administration (GSA) Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loading" (Appendix A). Twelve test articles were tested at GSA Performance Criteria for Level C buildings 4 psi (28 psi-msec). Eight test articles were tested at a higher pressure loading of 10 psi. The results for the test articles at 4 psi (28 psi-msec) are summarized in Table 4.1 through Table 4.3. The articles tested at 10 psi (48 psi-msec) are summarized in Table 4.4.

Table 4.1 presents results of test articles using daylight application of film when subject to airblast loading of 4 psi (28 psi-msec). Film was installed in a daylight application with a 1/16 inch or smaller gap between the edge of the window film and the window frame. Each of the following test articles with daylight application surpassed the GSA Performance Criteria requirements for Level C buildings (performance conditions 1 through 4 are acceptable).

Peak Pressure (PSI)	Test Article	Film	Application Method	GSA Performance Condition
4.3	MSC-1-1	No film	---	5
4.3	MSC-1-3	4-mil	daylight	3b
4.3	MSC-1-2	7-mil	daylight	3b
4.3	MSC-1-4	8-mil, 2 ply	daylight	3b

Table 4.1 Summary of results for daylight installed film at 4-psi (28 psi-msec) pressure on ¼ inch annealed glass (46 × 64 inch window panes).



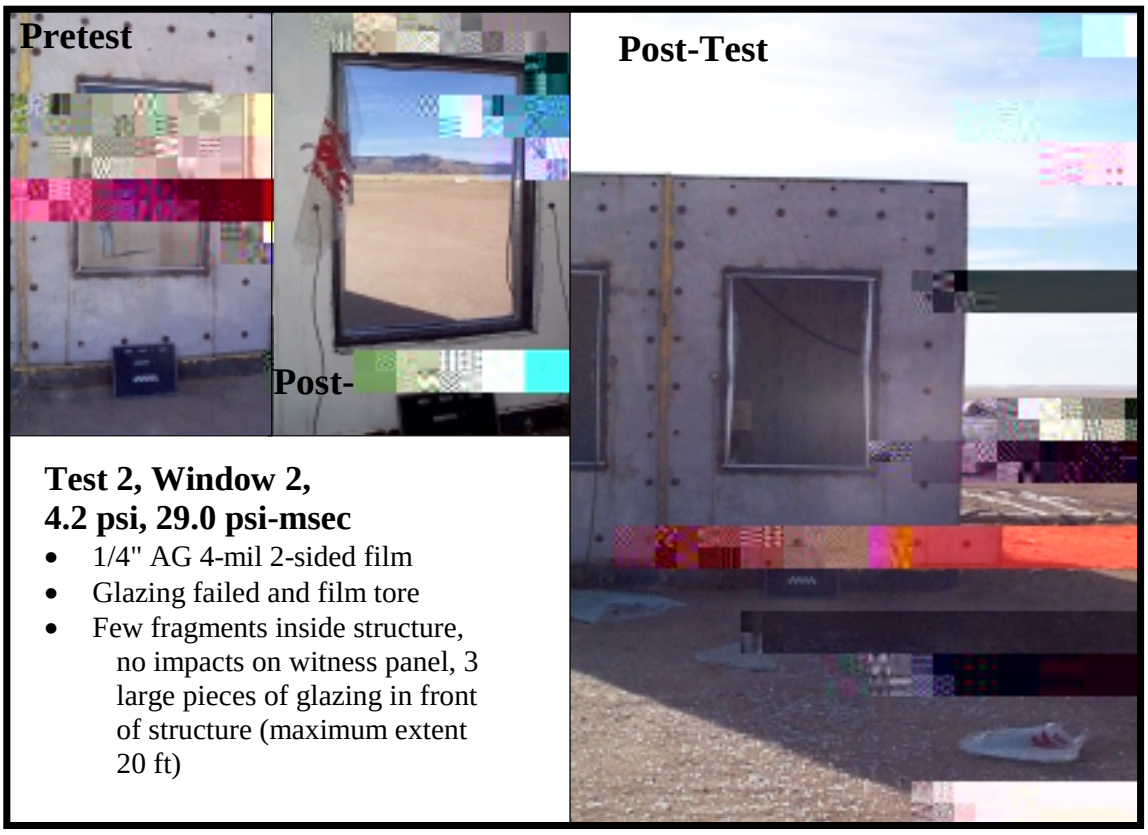
Test 1, Window 2,
4.3 psi, 28.7 psi-msec

- 1/4" AG, 7-mil daylight film
-

Table 4.2 presents results of test articles using two-sided mechanical attachment of film when subject to airblast loading of 4 psi (28 psi-msec). Film was installed with the right and left side of the film anchored by a mechanical attachment. The film extended under the attachment and was secured to the frame by a metal batten and self tapping screws. Each of the following test articles passed the GSA Performance Criteria for Level C buildings (performance conditions 1 through 4 are acceptable).

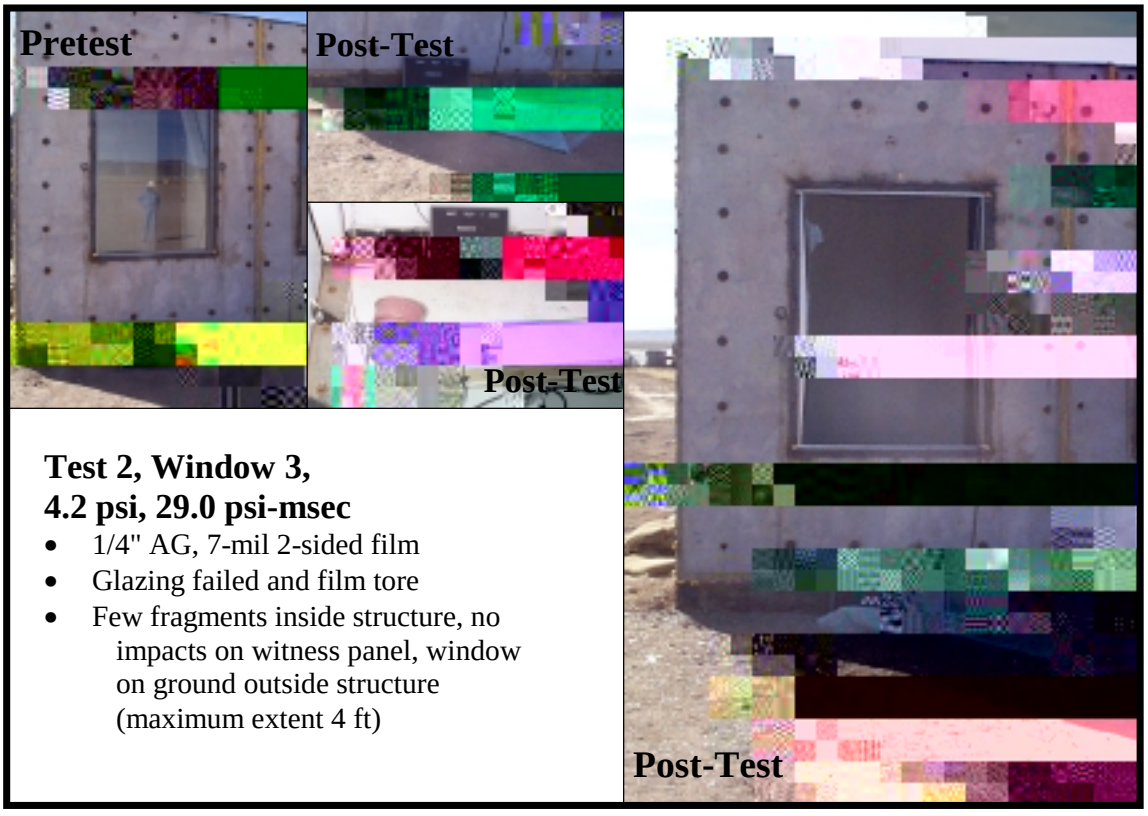
Peak Pressure (PSI)	Test Article	Film	Attachment Method	GSA Performance Condition
4.2	MSC-2-2	4-mil	2-sided mechanical	3b
4.2	MSC-2-3	7-mil	2-sided mechanical	3b
4.2	MSC-2-1	8-mil, 2 ply	2-sided mechanical	3b
4.2	MSC-2-4	14-mil, 3 ply	2-sided mechanical	3b

Table 4.2 Summary results for film with 2-sided mechanical attachment at 4 psi, 28 psi-msec pressure on ¼ inch annealed glass (46 × 64 inch window panes).



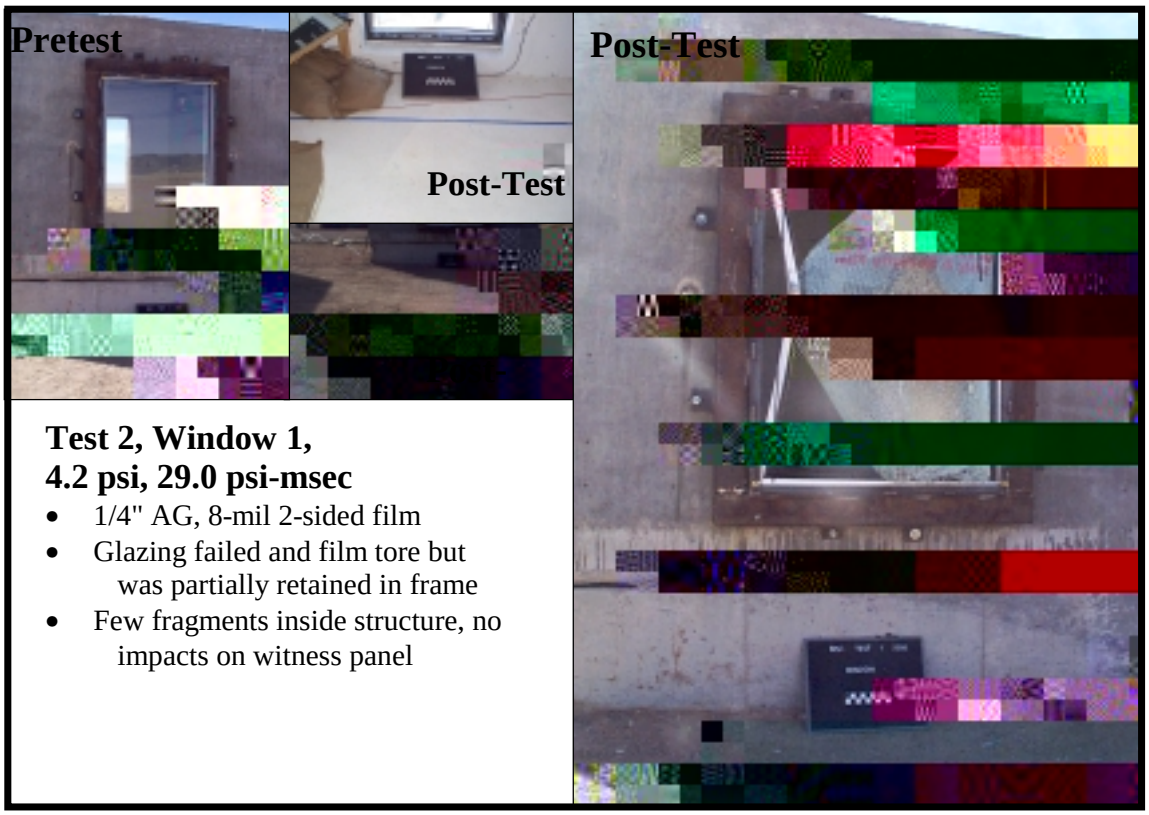
Test 2, Window 2,
4.2 psi, 29.0 psi-msec

- 1/4" AG 4-mil 2-sided film
- Glazing failed and film tore
- Few fragments inside structure, no impacts on witness panel, 3 large pieces of glazing in front of structure (maximum extent 20 ft)



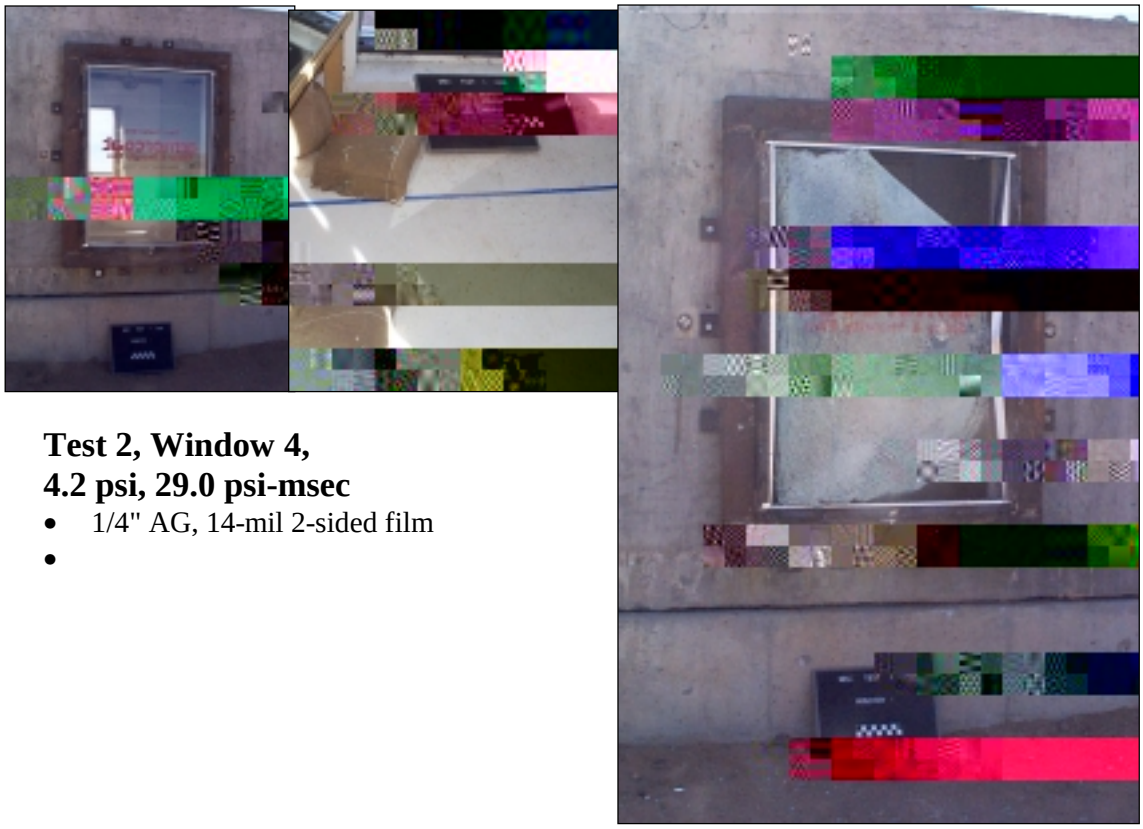
Test 2, Window 3,
4.2 psi, 29.0 psi-msec

- 1/4" AG, 7-mil 2-sided film
- Glazing failed and film tore
- Few fragments inside structure, no impacts on witness panel, window on ground outside structure (maximum extent 4 ft)



Test 2, Window 1,
4.2 psi, 29.0 psi-msec

- 1/4" AG, 8-mil 2-sided film
- Glazing failed and film tore but was partially retained in frame
- Few fragments inside structure, no impacts on witness panel



Test 2, Window 4,
4.2 psi, 29.0 psi-msec

- 1/4" AG, 14-mil 2-sided film
-


armorcoat

Test 5, Window 4, bution 5bution2ents enter08 0 T.00ure, no8n8n8n8.81 0 0 12 324.28 0 17

Conclusions

Of the window frame, film and attachment sy

History and Need for GSA Testing

When an explosion is detonated in an urban environment, window breakage is typically widespread and can occur over several city blocks. The window glass fragments generated by

entities, both domestic and foreign, that are responsible for security planning of building facilities.

The explosive tests were conducted at the Defense Threat Reduction Agency's Chestnut Test Site on Kirtland Air Force Base in New Mexico during the period of February 15-March 3, 2000. The test procedure was designed in accordance with the procedure adopted by the GSA. The GSA test procedure is included in Appendix A. Each test used 600 lb of ANFO (500 lb of TNT). The window sizes were nominally 4 ft by 5-1/2 ft. The windows were mounted in enclosed concrete reaction structures for testing. The standoff distance to the charge was varied to affect particular blast pressure levels on the windows.

APPENDIX C

Conversion Factors

(Non-SI to SI Units of Measurement)

CONVERSION FACTORS
(NON-SI TO SI UNITS OF MEASUREMENT)

Non-SI units of measurement used in the report can be converted to SI units as follows:

Multiply:	**By:**	**To Obtain:**
degrees (deg)	0.01745329	radians (rad)
miles (U.S. statute)	1.609347	kilometers (km)
feet (ft)	0.3048	meters (m)
inches (in)	25.4	millimeters (mm)
mil	0.0254	millimeters (mm)
pounds (lb)	4.448222	newtons (N)
pounds (lb)	0.4535924	kilogram (kg)
kips per square inch (ksi)	6.894757	megapascals (mPa)
pounds per square inch (psi)	6894.757	pascals (N/m^2 or Pa)
pounds per square inch (psi)	6.894757	kilopascals (kPa)
pounds per square inch (psi)	0.006894757	megapascals (mPa)