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19 mm BALLISTIC RANGE
A POTPOURRI OF TECHNIQUES AND RECIPES

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ABSTRACT

The expansion of ballistic gun range facilities at LLL has introduced state-of-the-art diagnostic techniques to glovebox-enclosed ballistic guns systems. These enclosed ballistic ranges are designed for the study of one-dimensional shock phenomena in extremely toxic materials, such as plutonium. The extension of state-of-the-art photographic and interferometric diagnostic systems to glovebox-enclosed gun systems introduces new design boundaries and performance criteria on optical and mechanical components. A technique for experimentally evaluating design proposals is illustrated, and several specific examples (such as, target alignment, collateral shrapnel damage, and soft recovery) are discussed.

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INTRODUCTION

Research in one-dimensional shock wave phenomena has been steadily expanding in scope at the Lawrence Livermore Laboratory with the addition of several new range facilities to our existing complement. These facilities now include: Small calibre systems (.110 smooth to 50 calibre rifled), 20 mm (non-toxic materials), 20 mm (toxic materials), a 4" gun (60' long with gas/powder breech) and a two-stage gun with a maximum projectile velocity of 8 mm/μs.[1] In addition, a 19 mm smoothbore gun (powder) and a 40 mm gun (gas/powder breech) have recently been added.[2]

Coincident with the growth of range facilities, we have expanded our diagnostics capability from the original electronic pin and high-speed rotating turbine cameras to include: Axi-symmetric magnetic (ASM) probes, Manganin gauges, flash x-radiography, capacitor gauges, split-field strobe light photography, long-path velocity interferometry and, recently, the VISAR[3] type of diffuse surface velocity interferometry. As we have applied more sophisticated diagnostics to our more-or-less standard gun ranges, we have also begun to adapt these techniques to the more difficult problem of instrumenting a 40 mm gun, completely enclosed in a glovebox environment.[2] The adjustment to a glovebox environment has introduced some novel problems -- particularly for our photographic and interferometer diagnostics. I have included several of these problems and our approach to their solution in the following discussion.

*This work was performed under the auspices of the U.S. Energy Research & Development Administration.

19 mm BALLISTIC RANGE

From its inception, the 19 mm gun system (Figs. 1a, 1b, 2) has been designed for the twofold purpose of providing materials study data on toxic materials (i.e., in a glovebox installation) and secondly, to aid in the development of diagnostics systems. The 19 mm gun has become so useful for the latter purpose that we have not yet used it as a glovebox installation. Meanwhile, we have a 40 mm gun system almost completed and intended to replace the 19 mm system for plutonium studies. Thus, the 19 mm gun range has become a valuable tool for checking out hardware designs and techniques prior to trying to implement them in an unwieldy glovebox environment with the associated personnel hazards.

To date we have applied the 19 mm gun to solve a series of problems associated with the 40 mm gun design that might be loosely classified as:

a. target alignment
b. collateral shrapnel damage
c. soft recovery methods
d. optical beam and image relay methods.

TARGET ALIGNMENT CONTROL AND MEASUREMENT

A glovebox gun installation such as our proposed 40 mm gun design indicated a need for a remote viewing autocollimator assembly, adapted to fit into the breech bore (Fig. 3) and coupled to a remotely operated electromechanical target mounting. A rugged gimbal-type-design target-mounting, with its axes coupled to remotely driven stepping motors, was constructed and tested on the 19 mm gun (Figs. 4, 5, 6).

TARGET HOLDER GIMBAL SUPPORT

Construction of the gimbal consists of 2"-thick gimbal rings (S/S-304), supported on a 1-1/2"-diameter vertical shaft captured in a tapered roller bearing. The horizontal axis is captured in oilite bushings with an axial clearance hole to permit the travel of a threaded locking rod from the outer gimbal through the inner gimbal to a target-holder insert body (Figs. 4, 5, 6).

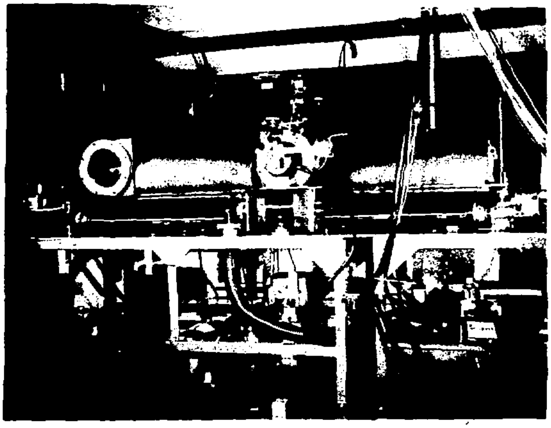

Fig. 1a. 19 mm gun showing vacuum tank lid in firing position, and split-field strobe camera and strobe at center of chamber.

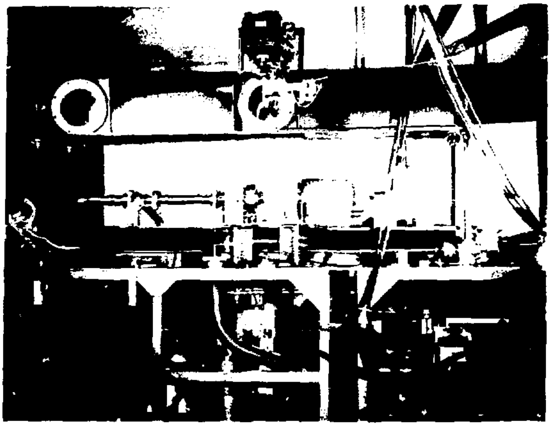

Fig. 1b. 19 mm gun with vacuum tank lid shown in its extended or "loading" position. Note that the strobe camera travels with the vacuum lid; refocussing is not necessary.

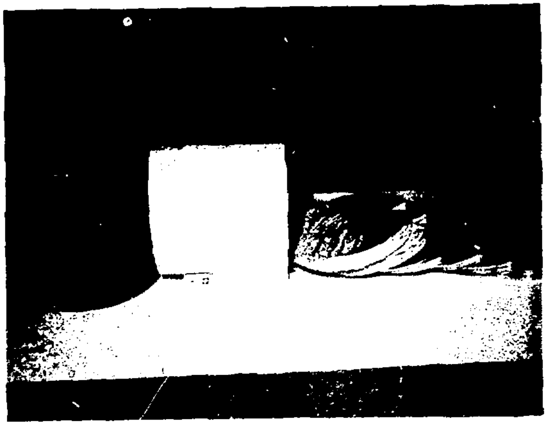

Fig. 2. 19 mm gun catcher tank showing several soft recovery materials used: 0.2 density foam, plywood and aluminum discs.

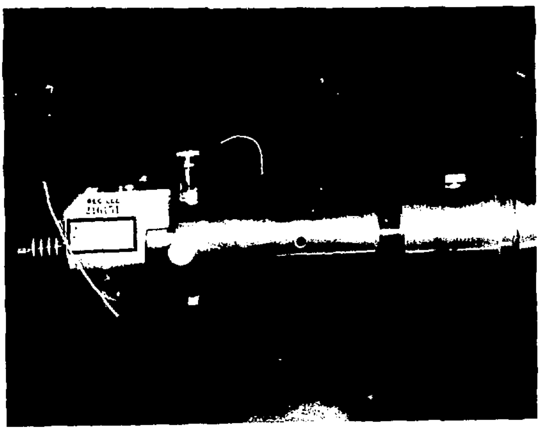

Fig. 3. Alignment autocollimator shown mounted in 19 mm gun breech adapter.

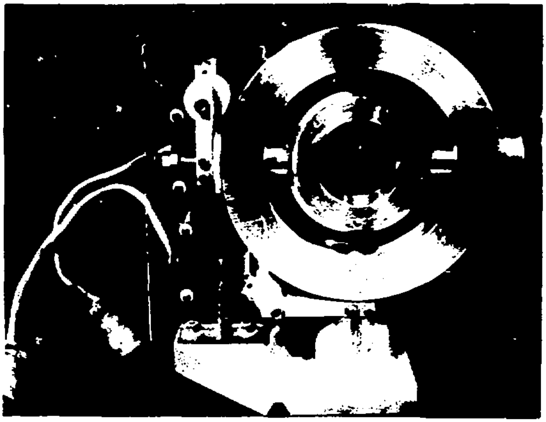

Fig. 4. Gimbal target-holder mount -- catcher side.

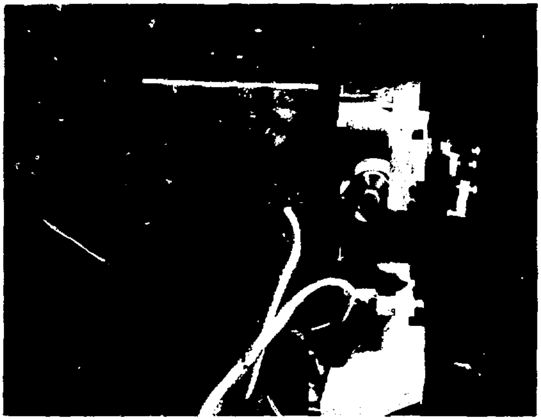

Fig. 5. Gimbal target-holder mount -- profile view showing target-holder insert.

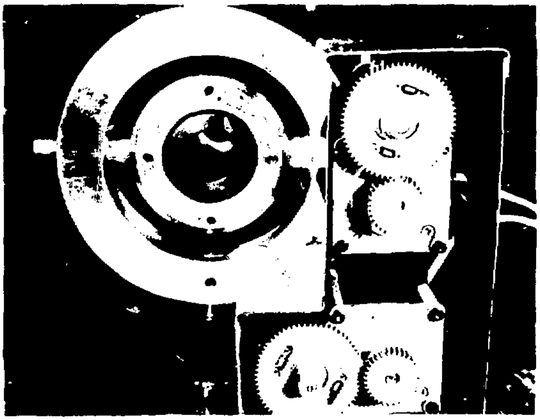

Fig. 6. Gimbal target-holder mount -- muzzle side showing gimbal stepping motor drive with anti-backlash gears.

A separate target-holder insert fits snugly into the inner gimbal ring, and is retained by two independent options:

(1) a threaded rod-stock, passing through the inner tilt axis and compressing the target-insert cylinder wall;

(2) two necked down breakaway mounting screws, passing through the target-holder insert and the inner gimbal ring, and secured to the rear of the inner gimbal ring with locknuts.

Although the target-holder is firmly retained, it is designed to release on impact; first, at the Delrin retainer nut and, secondly, at the inner gimbal interface before any damage occurs.

TARGET-HOLDER INSERT

The target-holder (Figs. 7 and 8) is made of 6061-T6 aluminum with a Delrin retaining nut for target retention. The Delrin nut, with its three adjustable mounting fingers, press the target against a 0.5 mm-deep shoulder bored into the target-holder insert. The design of this target-holder provides:

1. A rigid coupling of target position to the gimbal ring.
2. A method to rigidly locate pin-placement for tilt and pre-impact pins.
3. A low-strength target-retaining nut for soft recovery.
4. A rapid, uncomplicated method of mounting the target in a glovebox with no need for tools or intricate hardware components. A couple of turns on a large-diameter Delrin nut spring loads the target to the target-holder without any need for deft finger-manipulation in the unwieldy gloves.
5. A method to hold the target in position with a maximum of the free surface of the target kept available for photography, and with ample accessibility of the free surface for shadowgraphs with target thicknesses down to 0.5 mm (Fig. 8).

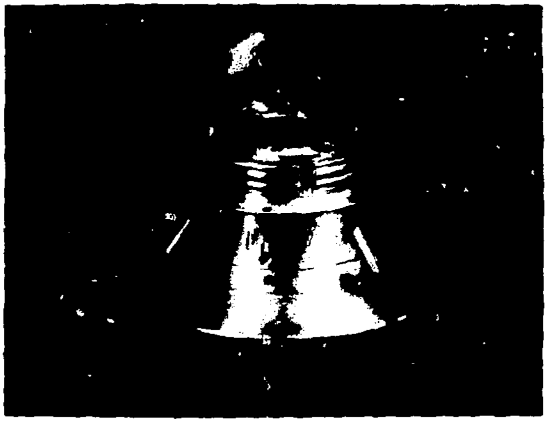

Fig. 7. Target-holder insert (aluminum) showing radial tilt pins and pre-impact pins.

Fig. 8. Target-holder insert showing target mounted and secured with Delrin retainer nut.

The present target-holder insert design is reusable after each firing, with the large Delrin retaining nut as the only expended hardware item. This design has the simplicity and ease of assembly that could warrant its application to any gun installation -- not just those requiring gloveboxes, or soft recovery techniques.

TARGET ALIGNMENT AND DRIVE CONTROLS

The target-holder insert mounted rigidly in the gimbal mount is remotely-controlled by a hand-held controller. The controller is capable of tilt and rotation, slewing of the target gimbal, or single-pulse control of the gimbal stepping motors. The gimbal stepping motors and gear train (Fig. 6) permit a rotation and tilt control sensitivity of about six (6) arc-seconds. Alignment of the target while slewing the gimbal is performed while viewing the polished target through a precision autocollimator (Fig. 9) adapted to fit into the gun breech (Fig. 10).

Initial zeroing of the autocollimator is accomplished through the use of a precision alignment sabot (Fig. 11), provided with a mirror-polished rear surface and inserted at the muzzle end. Nulling of the autocollimator to the reflection from the alignment sabot at the muzzle is accomplished by means of adjustment screws in the breech adapter (Fig. 3). The alignment sabot is then removed. At this point, the target-holder insert, together with a mounted target or an alignment mirror, is inserted into the gimbal (Fig. 9), and the gimbal is slewed into position as the autocollimator return-image from the target is superimposed over the autocollimator crosshair (Fig. 10). As indicated above, the target impact surface need not be polished to a specular mirrored surface. An alignment mirror with the same diameter as the target can be inserted in place of the target. After the gimbal alignment is completed, the alignment mirror can be replaced easily with the actual target without disturbing the target-holder alignment. This gimbal-alignment technique and target-holder design has been thoroughly tested for use on the 40 mm gun, using the 19 mm system.

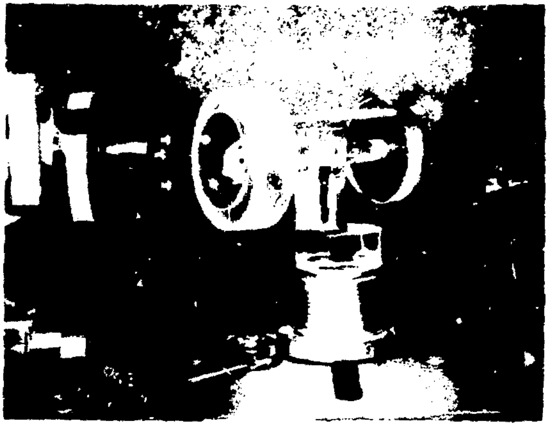

Fig. 9. Remote-controlled target-holder gimbal-mount, showing target-holder insert, target, and breakaway lucite turning-mirror mount -- view shown from velocity interferometer.

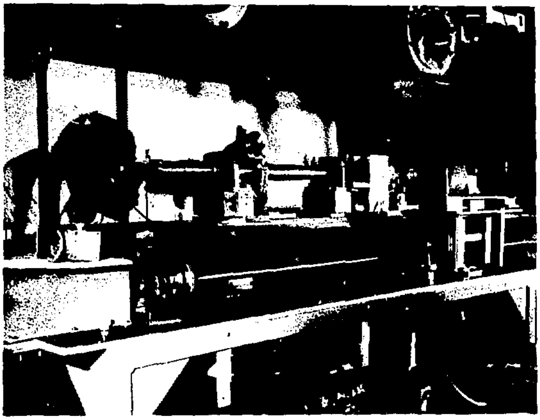

Fig. 10. View of 19 mm gun target-holder gimbal-mount adjustment using breech-mounted autocollimator and stepping-motor slew control.

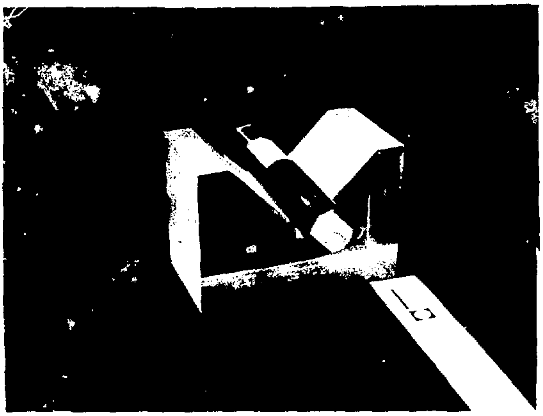

Fig. 11. Mirror-faced alignment sabot for 19 mm gun.

The addition of hardware into the projectile path, such as turning mirrors for use with high-speed photography, or velocity interferometer diagnostics, gave us concern over collateral shrapnel damage that might occur to the existing porthole glass, vacuum seals, gimbal drive motors or to the target/flyer combination.

In order to observe the collateral shrapnel damage and its angular distribution, a split-field strobe camera system was added to the 19 mm gun (Figs. 1, 12). This technique has provided useful data on the performance of optical hardware designs, soft recovery target damage and collateral damage caused by impacts of the sabot with down-range hardware (Figs. 13-17).

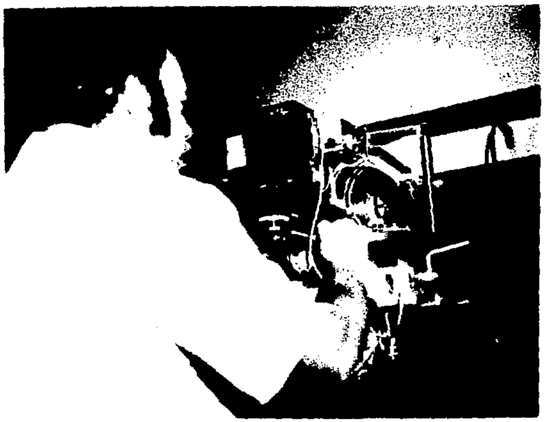

Fig. 12. Split-field strobe camera

Fig. 13. Set-up picture of zone 1 (t_1) of split-field strobe camera view. Zone barrier is located at plane of 45° turning-mirror under test. Strobe light is located out of field at upper edge of photo.

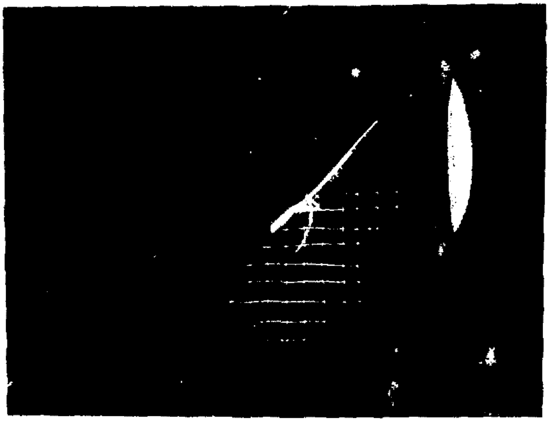

Fig. 14. Set-up picture of zone 2 (t_1 + 400 μs) of split-field strobe camera. Catcher tank is just visible at right edge of field. Strobe light is located out of field, at bottom edge of photo.

Evaluation of the breakaway performance of the soft recovery target-holder insert retaining nut was also made with this split-field strobe system (Fig. 16).

Fig. 15. Composite set-up picture of zones 1 and 2, comprising full field of split-field strobe camera.

Fig. 16. Split-field strobe view showing breakaway characteristics of Delrin target retaining-nut fingers (zone 1) and collateral shrapnel patterns 400 μs later (zone 2) after impacting 45° turning mirror.
V_f = 0.5 mm/μs; grid spacing ∿ 0.5".

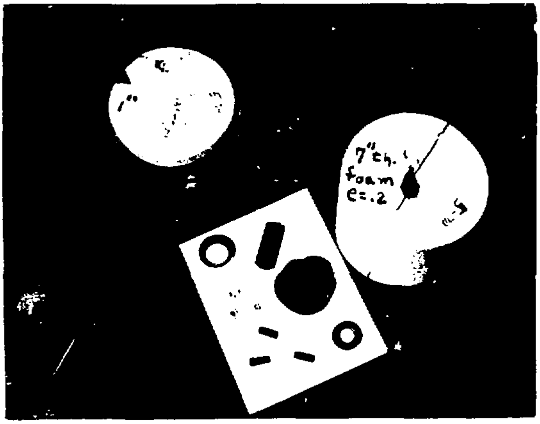

Fig. 17. Recovered target holder debris showing shear points on Delrin target retainer nut and recovery package -- 7" foam and 1" plywood.

OPTICAL BEAM AND IMAGE RELAY HARDWARE

The soft recovery lucite turning-mirror assembly, shown in Figs. 9 and 18, was developed and tested by the split-field strobe method described above. This 2"-diameter mirror-mount, like other diagnostic hardware to be used in the glovebox environment of the 40 mm gun, was designed and developed to simplify adjustment with gloves on. No tools are needed to adjust this mirror assembly, yet two degrees of translation and three degrees of rotational freedom are available, along with its built-in breakaway features.

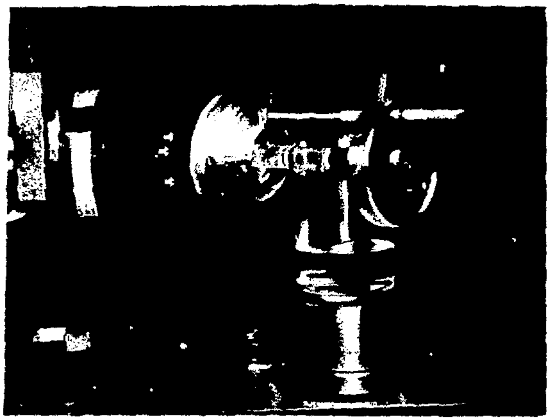

Fig. 18. Breakaway lucite turning-mirror-mount -- rear view, showing control options and shear points.

CURRENT INSTRUMENTATION DEVELOPMENT

We have added long-path velocity interferometry (Fig. 19) to our 19 mm gun system, and we are conducting ringdown tests on a VISAR-type[3] velocity interferometer (Fig. 20). Upon completion of the VISAR checkout, we will adapt it as necessary for use in the one-dimensional shock wave studies of plutonium planned for the 40 mm gun mentioned previously.[2]

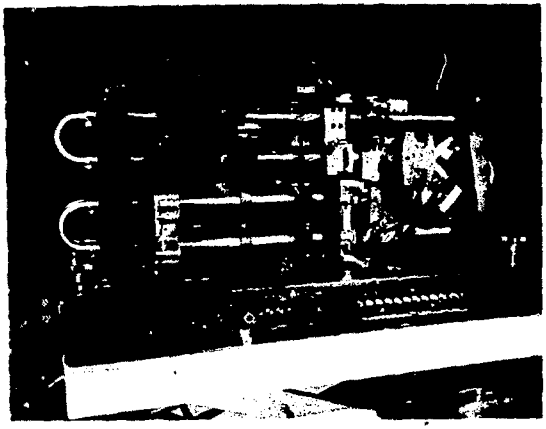

Fig. 19. Long-path velocity interferometer used for free-surface velocity measurement of impacted specular targets.

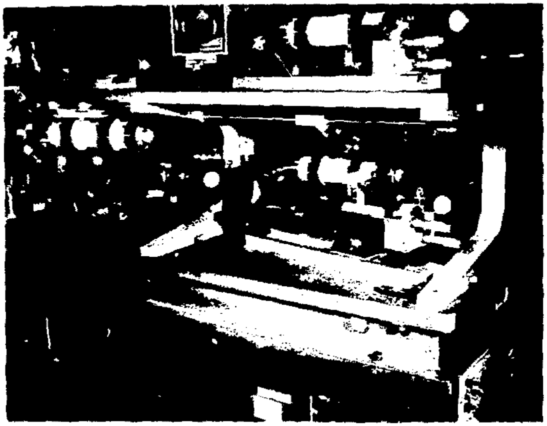

Fig. 20. VISAR -- Velocity Interferometer System for Any Reflectivity.

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2. C. A. Honodel, "A Glovebox-Contained 40 mm Gun System for the Study of One-Dimensional Shock Waves in Plutonium," --to be presented at the 26th ARA Meeting, October 1, 1975.

3. L. M. Barker and R. E. Hollenbach, "Laser Interferometer for Measuring High Velocities of Any Reflecting Surface," J. Appl. Phys. 43, 4669 (1974).

ACKNOWLEDGMENTS

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