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BLASTING DETONATORS INCORPORATING SEMICONDUCTOR BRIDGE TECHNOLOGY

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(PRESENTATION ABSTRACT)

The enormity of the coal mine and extraction industries in Russia and the obvious need in both Russia and the U.S. for cost savings and enhanced safety in those industries suggests that joint studies and research would be of mutual benefit. I suggest that mine sites and well platforms in Russia offer an excellent opportunity for the testing of Sandia's precise time-delay semiconductor bridge detonators, with the potential for commercialization of the detonators for Russian and other world markets by both U.S. and Russian companies.

Sandia's semiconductor bridge is generating interest among the blasting, mining and perforation industries. This interest is because of the enhanced safety and cost savings projected from using semiconductor bridge detonators in which timing and safing circuitry are incorporated directly into the bridge.

The semiconductor bridge is approximately 100 microns long, 380 microns wide and 2 microns thick. The bridge may be formed from doped polysilicon, doped silicon, or tungsten implanted silicon, on silicon or sapphire substrates. The chip containing the bridge is approximately 2 mm square and 0.5 mm thick. A short current pulse of approximately 10 microseconds duration melts and vaporizes the bridge producing a plasma discharge that quickly heats the powder pressed against the bridge to ignition. A typical semiconductor bridge firing set consists of a 20 microfarad capacitor charged to 28 V and a solid state switch that discharges the capacitor through the bridge.

The input energy required for semiconductor bridge ignition is one-tenth the energy required for conventional bridgewire devices. With an input energy of only 3 mJ, explosive outputs are obtained in less than 100 microseconds. But because of the excellent thermal conductivities of the substrates supporting the bridge, semiconductor bridge no-fire currents are excellent and higher than bridgewires. A typical Sandia semiconductor bridge device

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has a no-fire current of 1.3 A; no-fire current is defined as the dc current that can be applied to the device for 5 minutes without causing the unit to fire.

Semiconductor bridge devices also meet electrostatic discharge requirements. And with the addition of two circuit elements (either as discrete components or directly integrated onto the chip with the bridge) the devices can withstand harsh RF and enhanced electrostatic discharge safety requirements. In fact, Sandia recently tested devices that met the Hazards to Electromagnetic Environments to Ordnance (HERO) requirements of the U.S. military.

Because semiconductor bridge processing is compatible with other microcircuit processing, timing and logic circuits can be incorporated onto the chip with the bridge. These circuits can provide for the precise timing demanded for cost effecting blasting. Indeed tests by Martin Marietta and computer studies by Sandia have shown that such precise timing provides for more uniform rock fragmentation, less fly rock, reduced ground shock, fewer ground contaminants and less dust. Cost studies have revealed that the use of precisely timed semiconductor bridges can provide a savings of $200,000 per site per year.

In addition to Russia's vast mineral resources, the Russian Mining Institute outside Moscow has had significant programs in rock fragmentation for many years. I anticipate that collaborative studies by the Institute and Sandia's modellers would be a valuable resource for field studies.

The SCB program offers unique advantages for partnering with Russia. Detonators are presently being developed by Sandia and American industry (SCB Technologies, Inc., Thiokol Inc., TPL Inc. and Blasting Analysis Inc.). This work is supplemented by the involvement of two universities — the University of New Mexico and New Mexico Tech (the NM Tech program is headed by Prof. Per-Anders Person, an expert in blasting technology who has visited Russia many times in the past). Prospective American users includes Western Atlas, Haliburton, Schlumberger and IRECO (the latter company has established Russian contacts).

I suggest that a research program encompassing Sandia organizations (1300, 1500, 2600 and 6200), American private industries and universities collaborating with Russian universities and industries would allow the demonstration of the advantages of precise timing in blasting, provide the Russians with the opportunity to use the detonators for more economical recovery of their mineral resources as well as provide a market for the development of both Russian and American business interests in producing semiconductor detonators for world wide usage.

Blasting Detonators Incorporating Semiconductor Bridge Technology

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Extraction Industry Demands

- Safety
  - Handling
  - Environments
- Cost Savings
  - Unit costs
  - Operational savings

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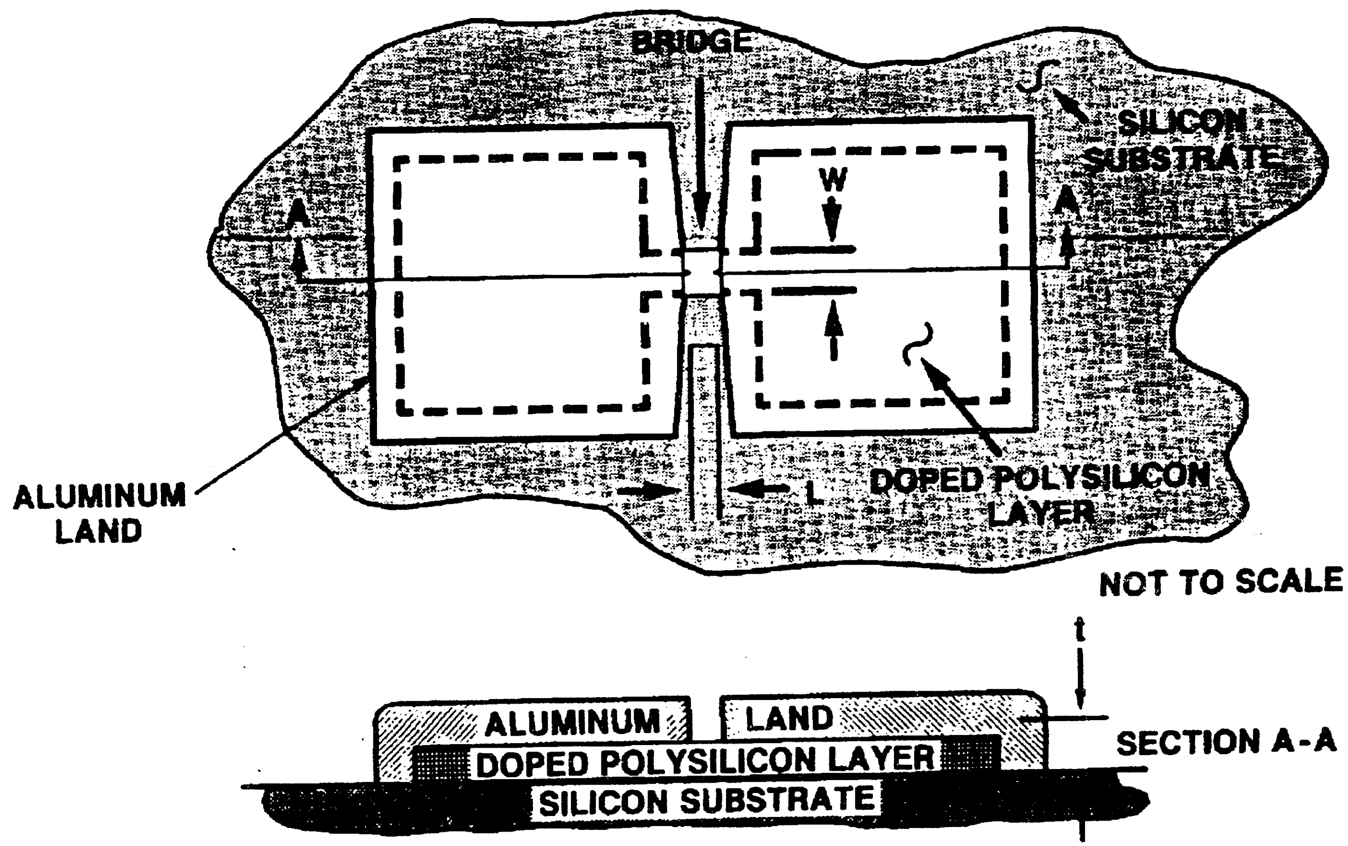
SKETCH OF AN SCB

An SCB is the Doped Volume between the Lands



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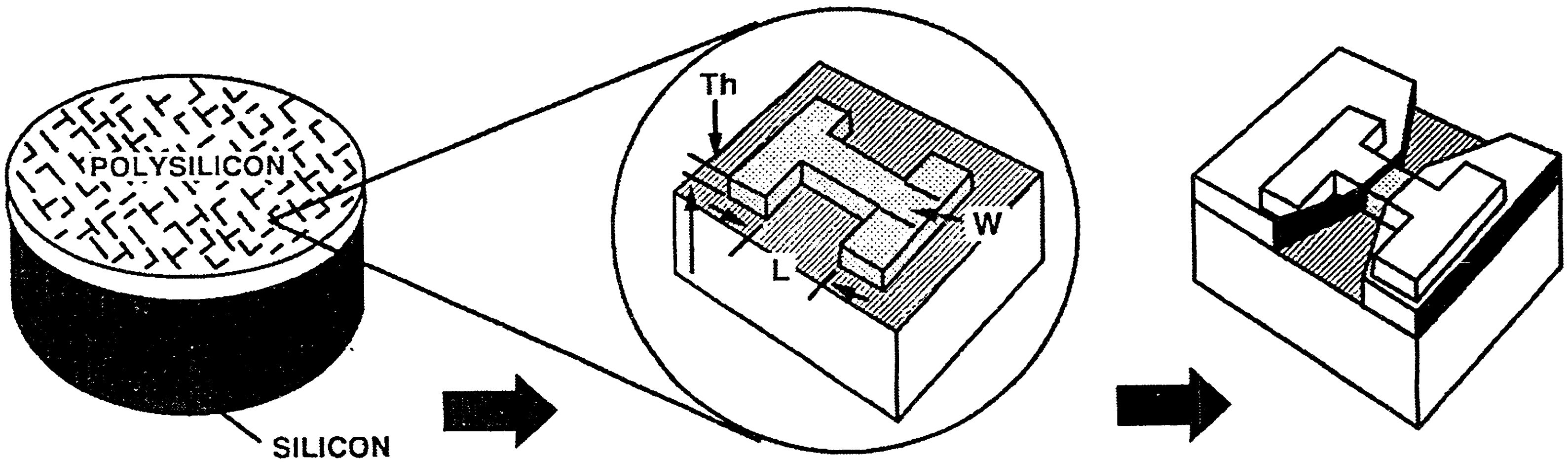
SCB PROCESSING

A 2 Mask Procedure

PHOSPHOROUS DOPING
OXIDE LAYER GROWTH
PHOTORESIST & MASK
WASH & ETCH

PVD ALUMINUM LAYER
PHOTORESIST & MASK
WASH & ETCH



POLYSILICON-ON-SILICON WAFER
1-4 MICRON POLYSILICON LAYER
0.022" SILICON
SUBSTRATE

DOPED POLYSILICON
LAYER DEFINED

METAL LANDS
DEFINE SCB
(FINISHED BRIDGE)

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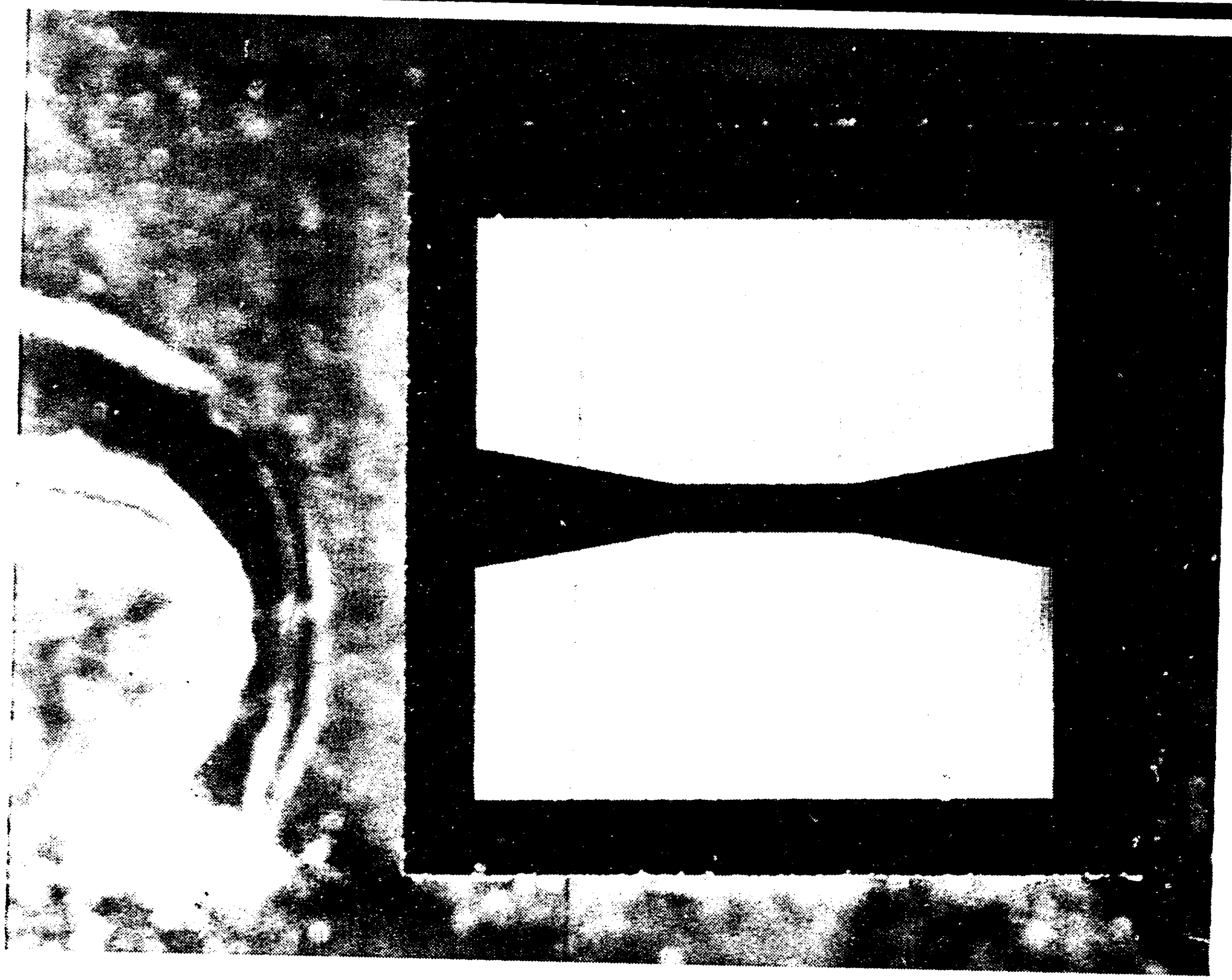
SCB CHIP



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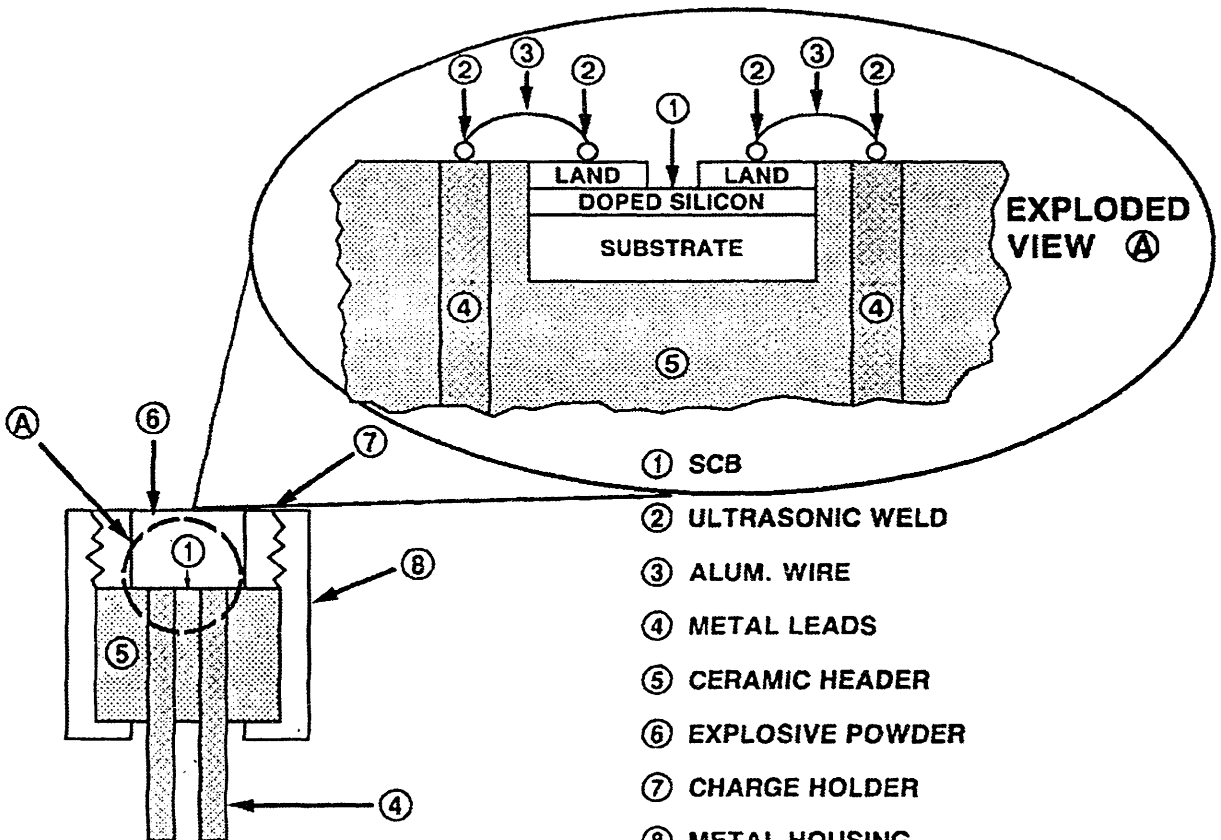
SCB TEST ASSEMBLY

A Prototype SCB Device



① SCB
② ULTRASONIC WELD
③ ALUM. WIRE
④ METAL LEADS
⑤ CERAMIC HEADER
⑥ EXPLOSIVE POWDER
⑦ CHARGE HOLDER
⑧ METAL HOUSING

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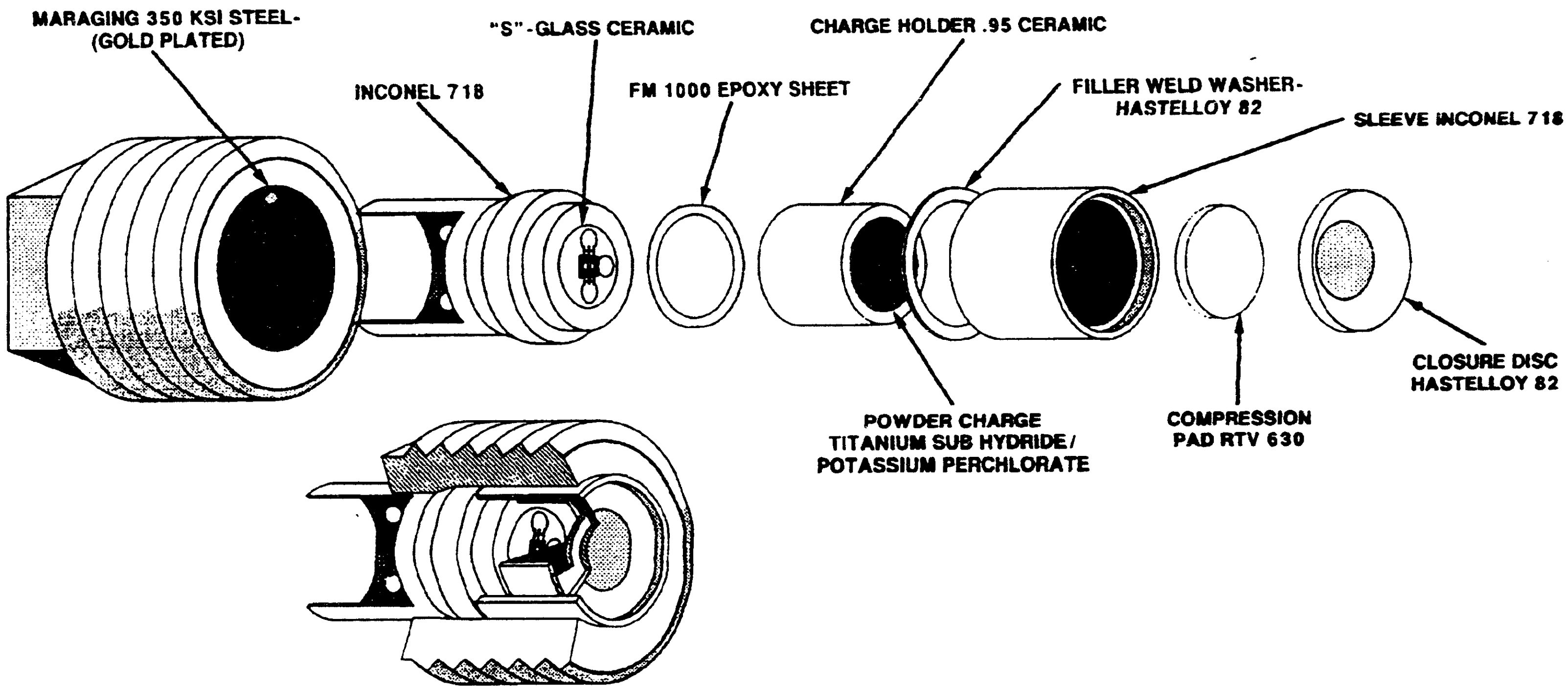
SCB RETROFIT

SCB Substituted for Hot Wire



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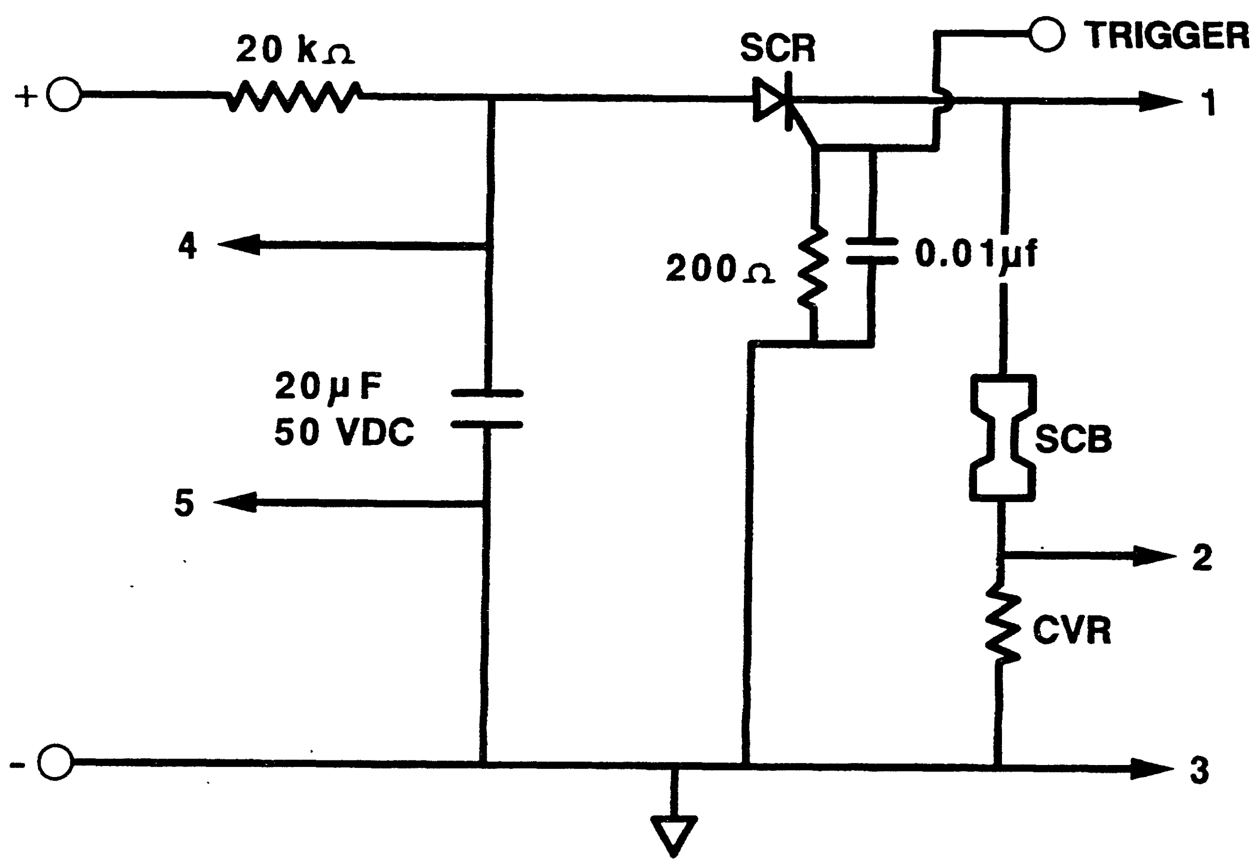
CDU FIRING SET

Small & Lightweight Energy Source



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HOT WIRE vs. SCB

Based on Hot-Wire Devices
Retrofitted with an SCB

- SCB's require one-tenth the energy
- SCB's function in microseconds vs. milliseconds
- Better no-fire levels
- In addition
  - less sensitive materials needed
  - enhanced ESD & HERO protection can be obtained

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LOW INPUT ENERGIES

Lower Energy Provides Many Advantages

- Cost savings
- Size reduction in systems & subassemblies
- Weight savings

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FAST FUNCTION TIMES

SCB Devices Function in Microseconds versus Milliseconds for Hot Wires

- Precise timing now available
- Better simultaneity
- Demanded by new systems
  - air bags & restraints
  - rock blasting

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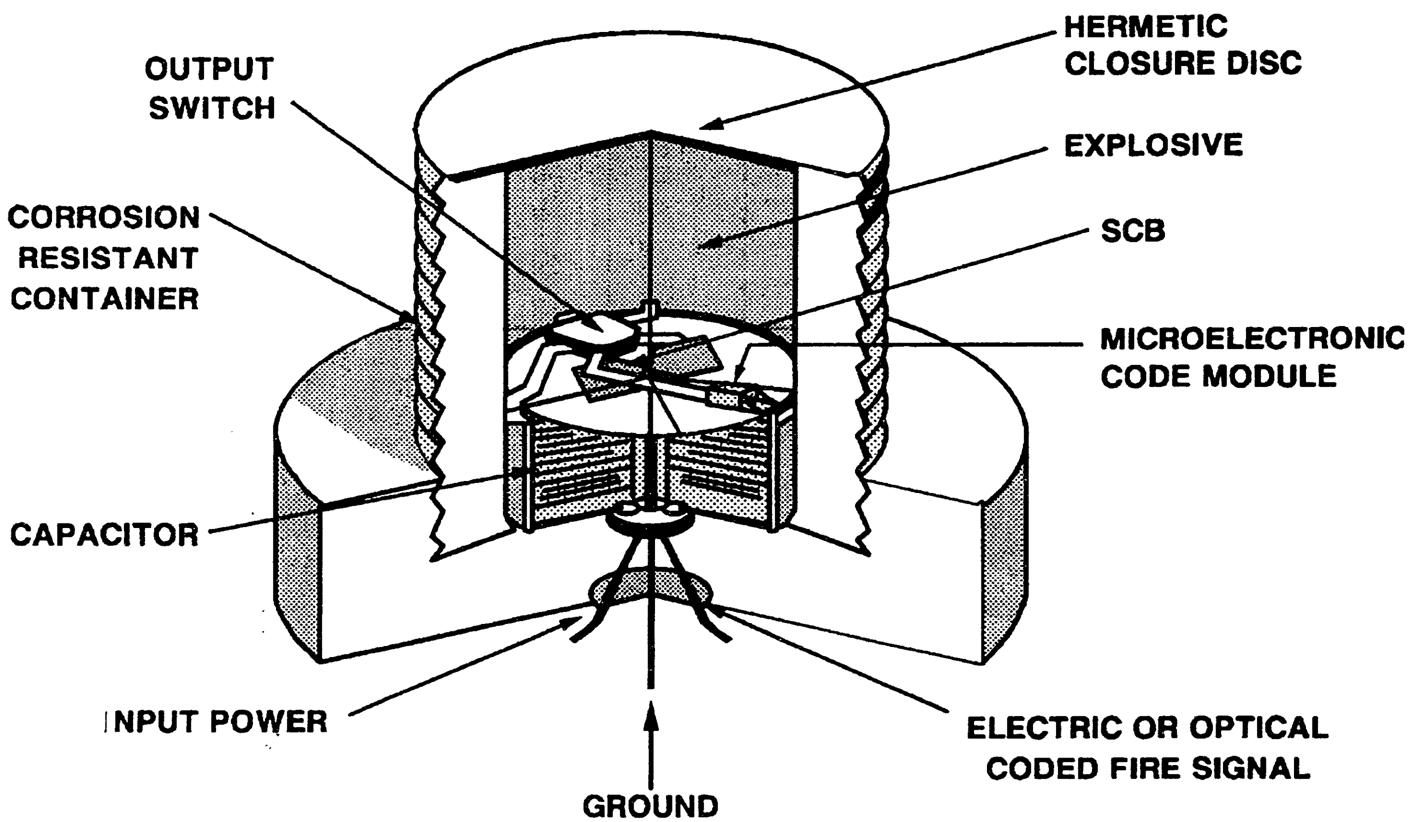
SMART SCB COMPONENT

An Integrated Firing System in a Single Housing



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SAFETY & TIMING

Circuitry can be integrated onto the SCB to provide:

- Enhanced RF and ESD safety
- Programmable time delays

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COST SAVINGS

- Blasting Analysis International cost analysis showed a potential cost savings of $200,000 per year per site.

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PROGRAM BENEFITS

- Demonstrate advantages of precise timing
- More economical recovery of resources
- Vast worldwide market

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END