A Semiconductor Bridge Ignited Hot Gas Piston Ejector

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Outline

- Concept
- Performance
- Development
- Application

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SEMICONDUCTOR BRIDGE TECHNOLOGY

OBJECTIVE:	Development of Very Low Energy Explosive Devices
BENEFITS:	Low Energy (Cost, Size, Weight Savings), Fast Function, Enhanced Explosive Safety, Digital Compatibility and Circuit Integration (Smart Device), Automated Manufacture
APPLICATIONS:	Valve Actuators, Rocket Igniters, Miniature Thrusters, DoD & DOE Devices, Air Bags, Delayed Detonators
PROGRESS TO DATE:	Low Energy, Safety, Digital Compatibility, and Integration Demonstrated
FUTURE:	Focal Point, Satellite Systems, Actuator Controlled Missiles, Anti-Tank Weapons, Phalanx, Universal Water Activated Recovery Systems, Multiple Air Bag Systems, Rock Blasting and Mining, Photo-Optic SCB Devices

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9/17/91

SCB Philosophy

- **SYSTEM DEVELOPMENT**
  - **Sensors**
  - **Smart Firing Sets**
  - **Digital Coupling (Wire and Optical)**
  - **Explosive Component**
  - **Smart SCB**
- **SCB INTEGRATION**
  - **Discrete**
  - **In-situ**
- **PARTNERING**
  - **Government Facilities**
  - **Private Industry**
  - **Universities**

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Technology Transfer

SANDIA – R&D

Technology Transfer

Commercialization, Production and Sales

	License
Government Applications	Private Enterprise
SCB Technologies	SCB Technologies
Thiokol	Thiokol
Bulova	BAI
Hercules	

Products

Attitude Control Motors	Air Bags
RAP	Blasting
UWARS	

CRADA
WFO
MIPR

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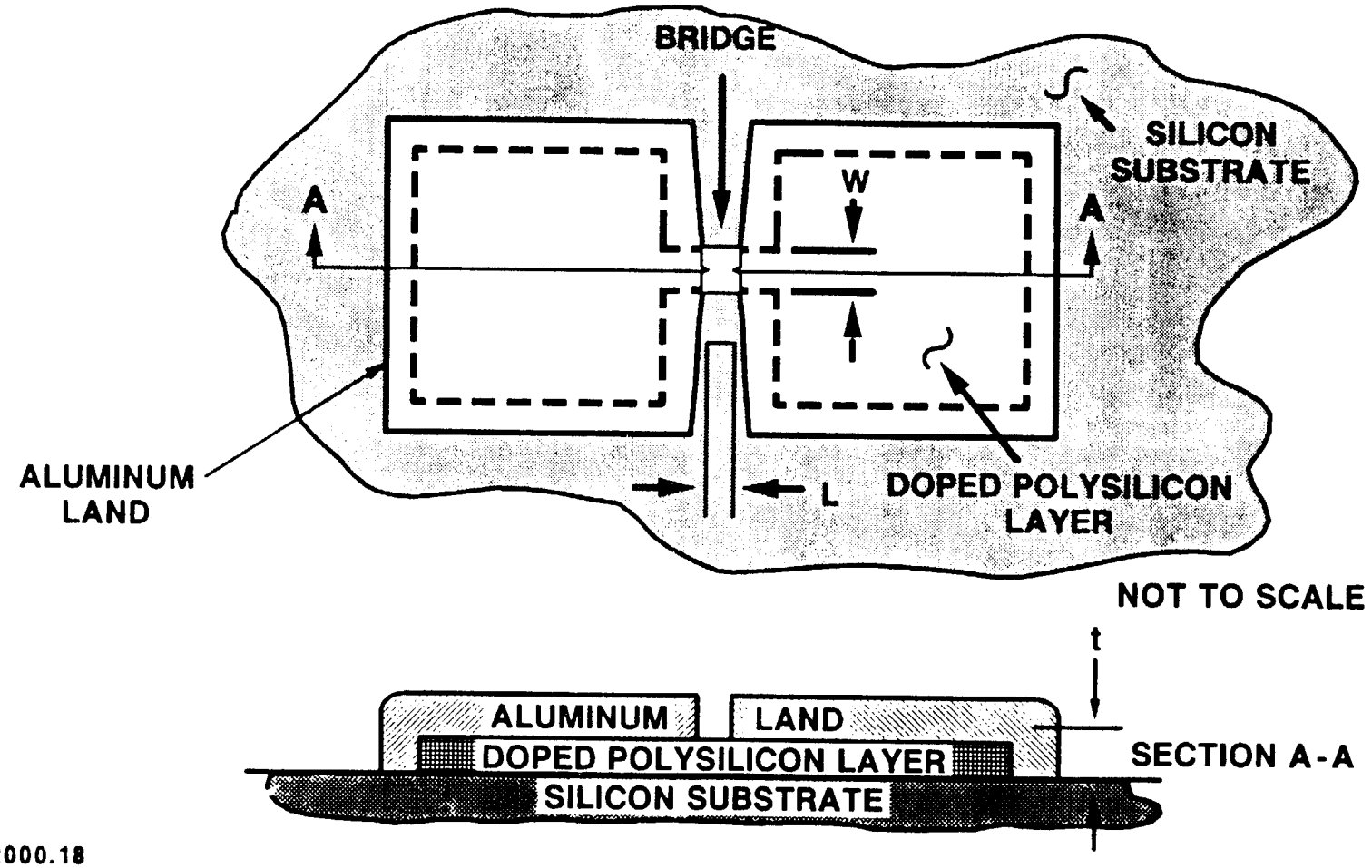
SIMPLIFIED SKETCH OF SEMICONDUCTOR BRIDGE (SCB)



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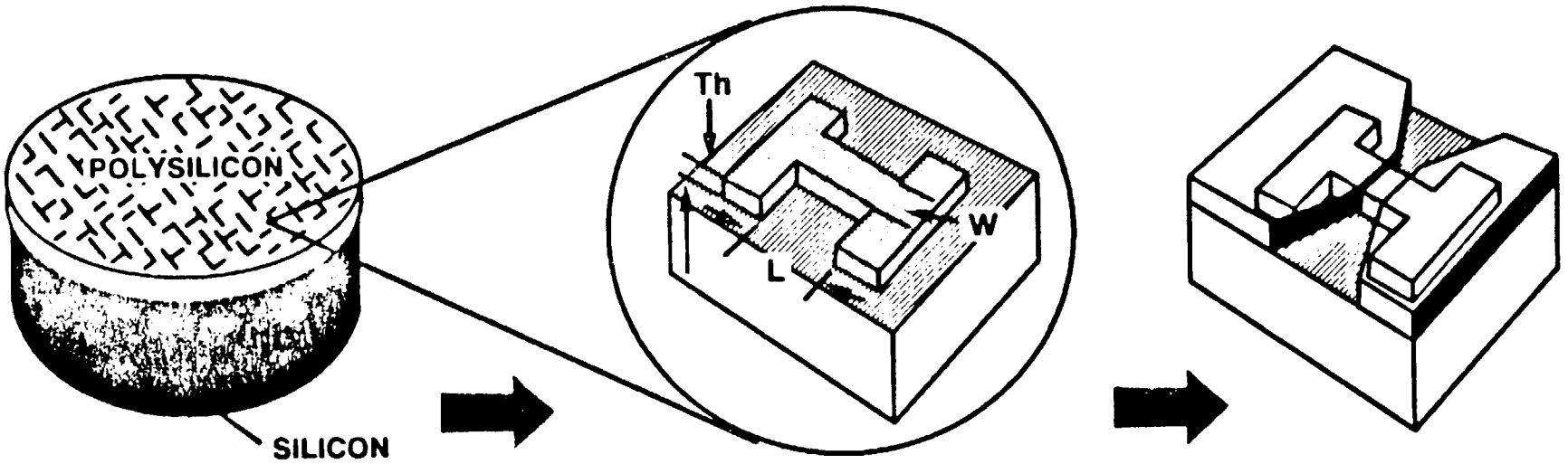
SCB PROCESSING

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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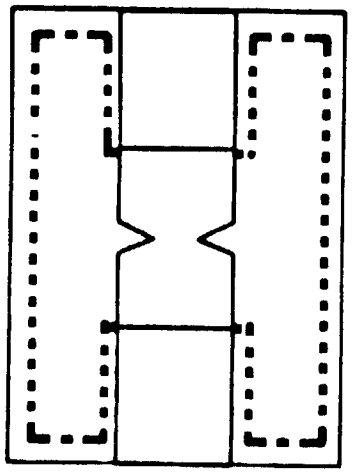
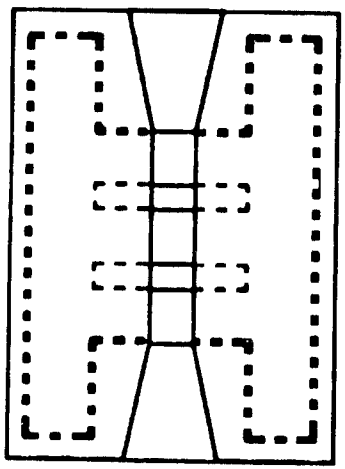
SCB DESIGNS



TYPE 12



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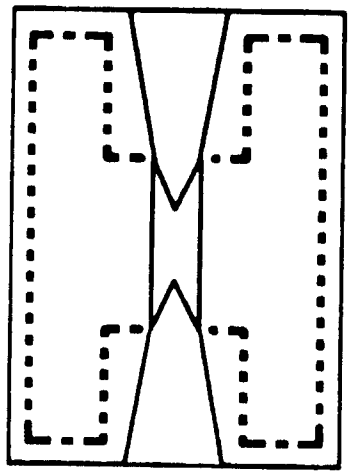

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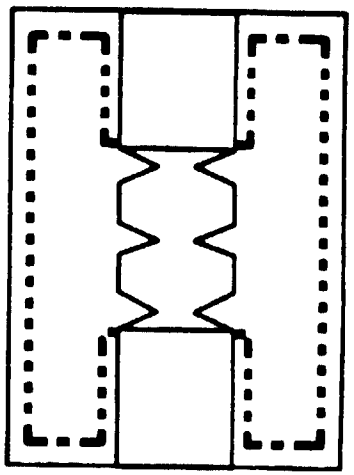

TYPE 13

100

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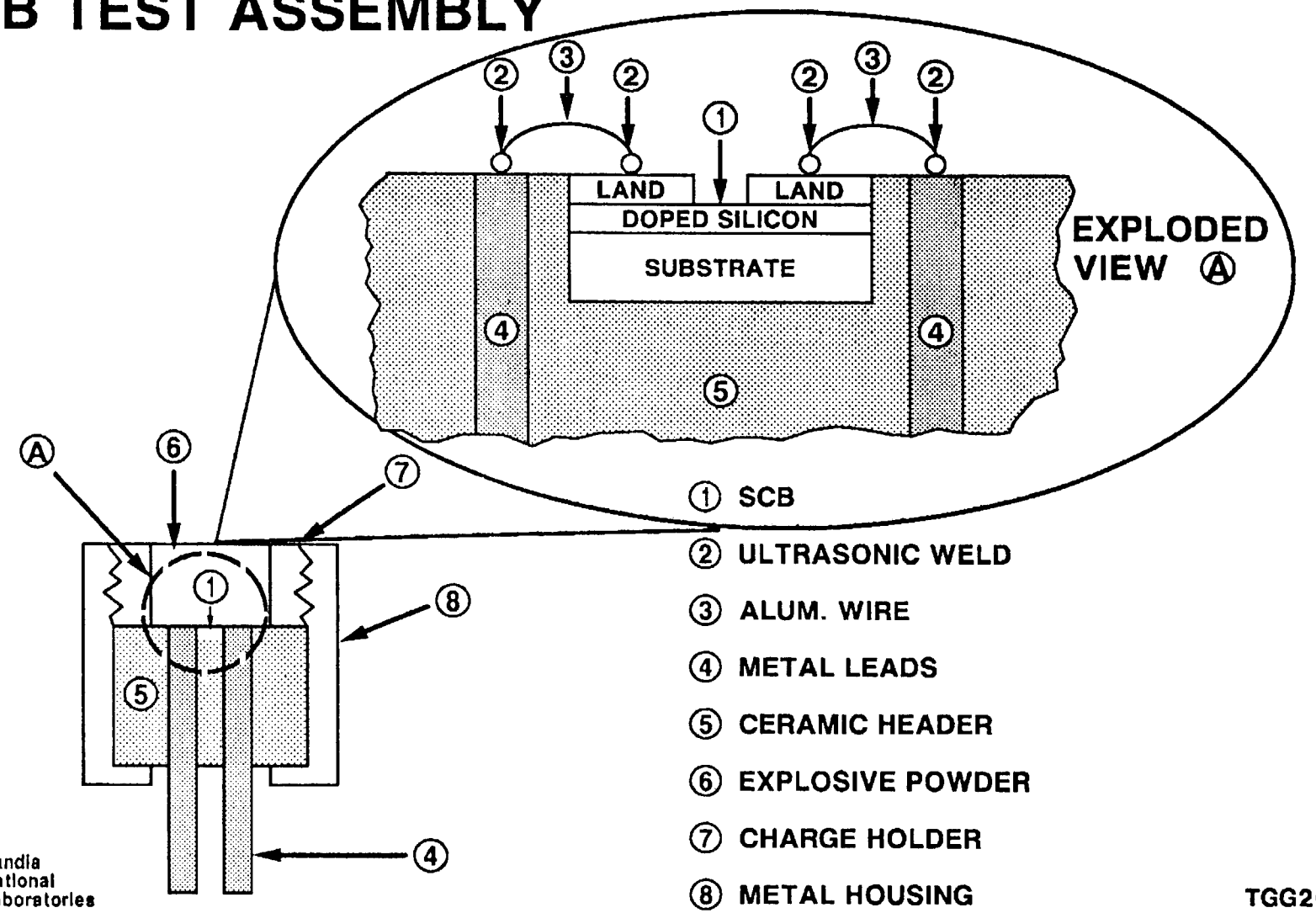
SCB TEST ASSEMBLY



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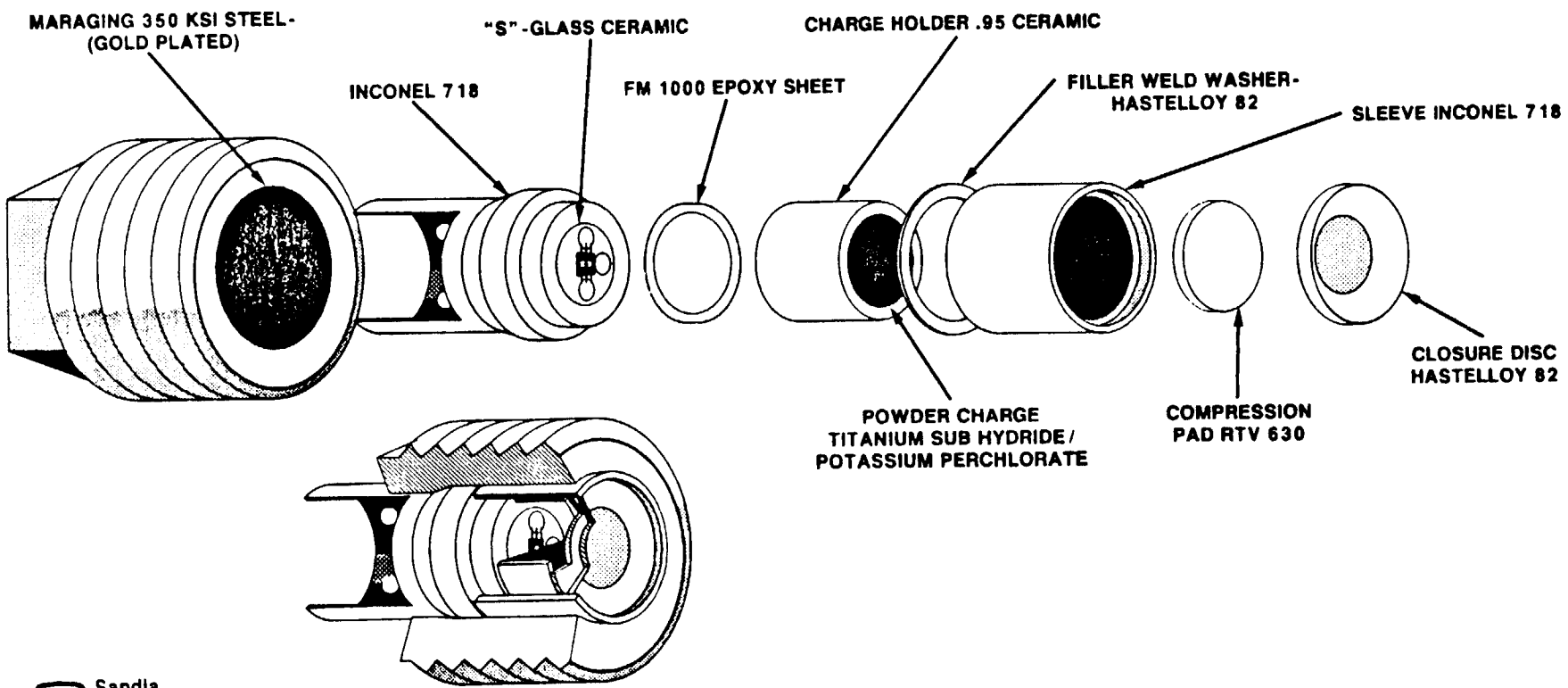

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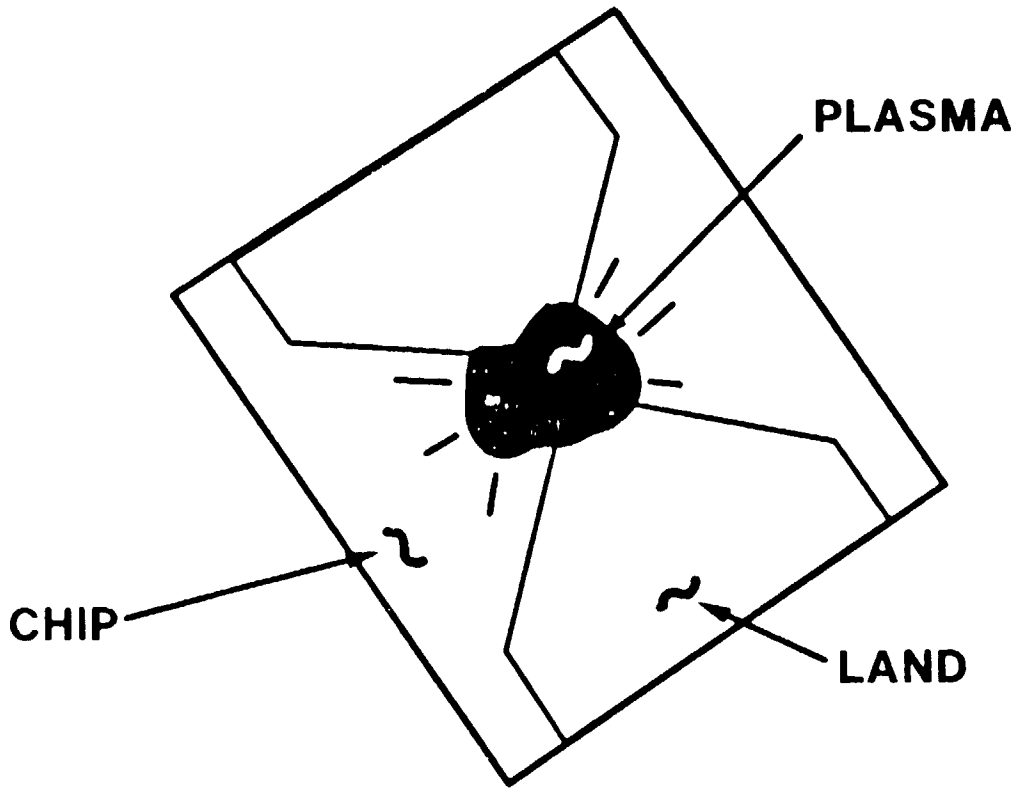
5 mJ SCB BURST
BASED ON A POLAROID PHOTOGRAPH



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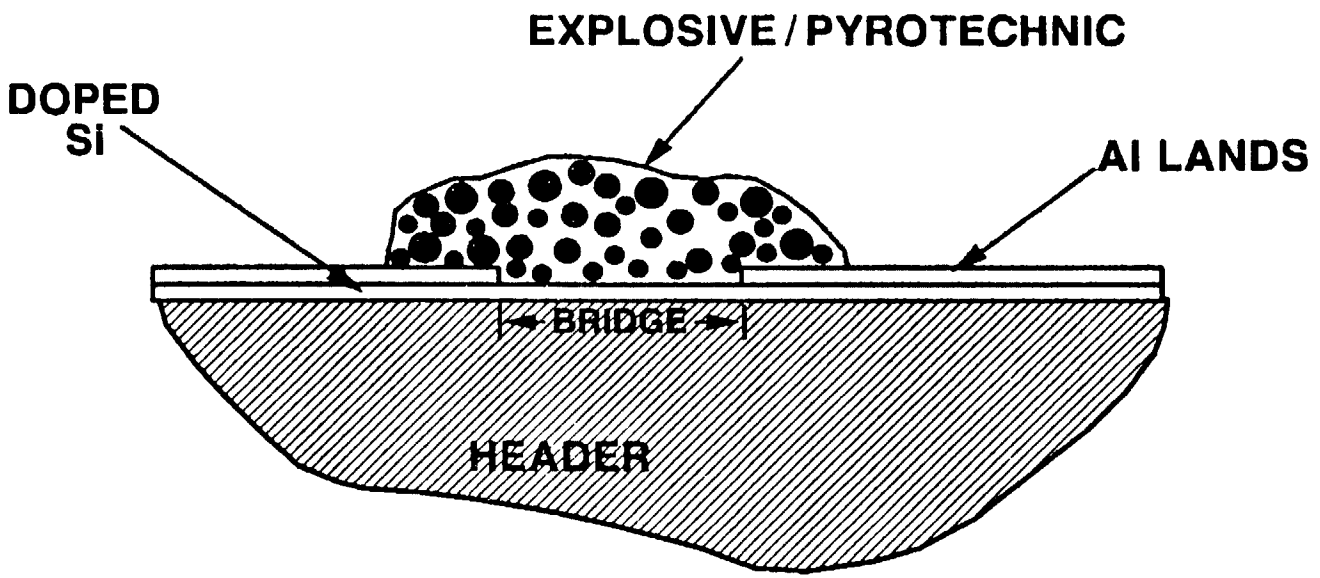
MICRO-CONVECTIVE HEAT TRANSFER HYPOTHESIS

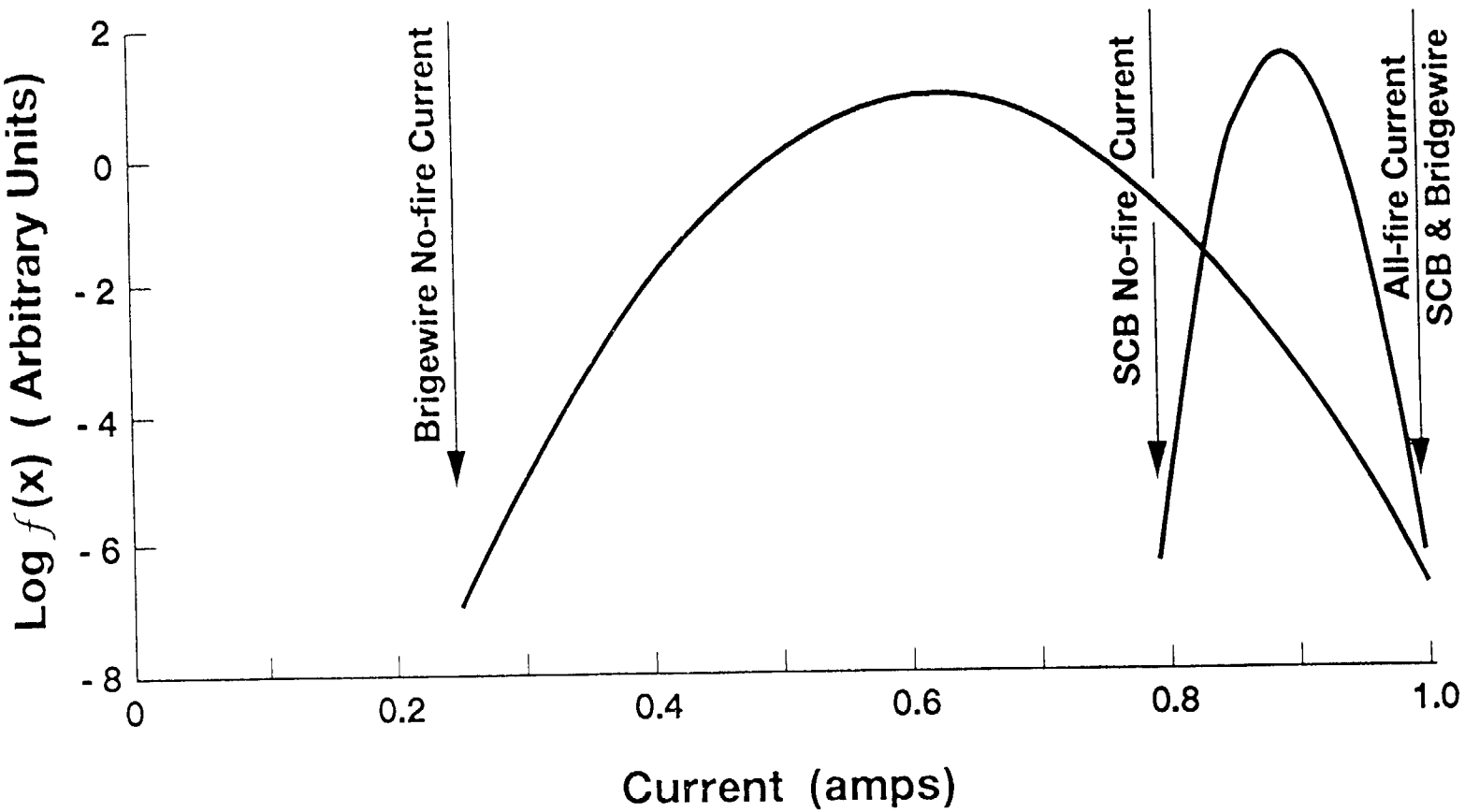


- THE BRIDGE IS VAPORIZED
- Si VAPOR IS ELECTRICALLY HEATED
- Si VAPOR PERMEATES THE ADJACENT EXPLOSIVE / PYROTECHNIC
- LOCAL CONVECTION AND CONDENSATION EFFICIENTLY HEATS THE PARTICLES

LOG OF NORMAL DISTRIBUTION

$$f(x) = \frac{1}{2\pi\sigma} e^{-(x-\bar{x})^2/2\sigma^2}$$

AS A FUNCTION OF FIRING CURRENT



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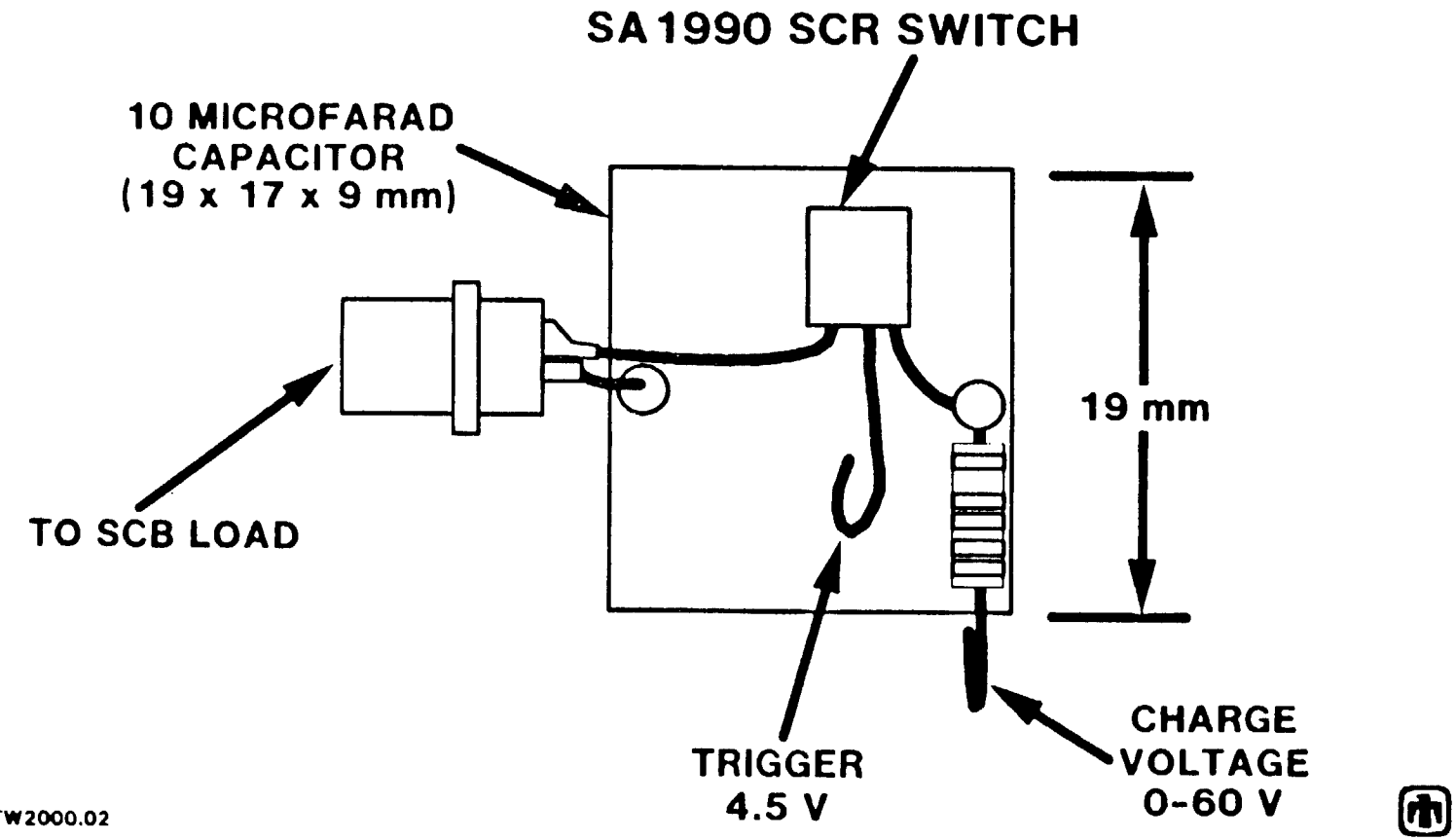
SCB FIRE SET



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COMPARISON OF SCB AND HOT-WIRE ACTUATORS

	HOT WIRE	TYPE 3-2	TYPE 15
ALL-FIRE ENERGY (mJ)	32.6 ± 1.02 (AMBIENT)	2.72 ± .48 (-65 °F)	1.33 ± .03 (-65 °F)
NO-FIRE CURRENT (A)	1.1 (AMBIENT)	1.39 ± .03 (165 °F)	1.30 ± .12 (165 °F)
ESD TEST	PASSED	PASSED	PASSED
FUNCTION TIME (μs)	3400 (AMB.)	60 (AMB.)	60 (AMB.)

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HERO STUDIES

- Direct RF Injection
  - 10 MHz - 20 W
  - 200 MHz - 3 W
  - 8.9 GHz - 20 W
  - 10 Second Injection Times
  - Franklin Institue: "Grossly Insensitive"
- NSWC Ground Plane Facility
  - High Level RF Environments
    - HF Communications Bands
    - Radar Frequencies
  - Only One Unit Fired (Arc Conditions)

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SATELLITE FIRING SETS

- **Multiple Fire**
  - **2200 micro-Farads**
  - **Charge = 27.4 V**
  - **Four Parallel Outputs**
  - **Bridge Burst Delta t = 5 microseconds**
- **Single Fire**
  - **300 micro-Farads**
  - **Charge 16 V**
  - **Series Resistance 0.4 Ohms**
  - **2.5 mJ**
  - **Function Time = 81 microseconds**

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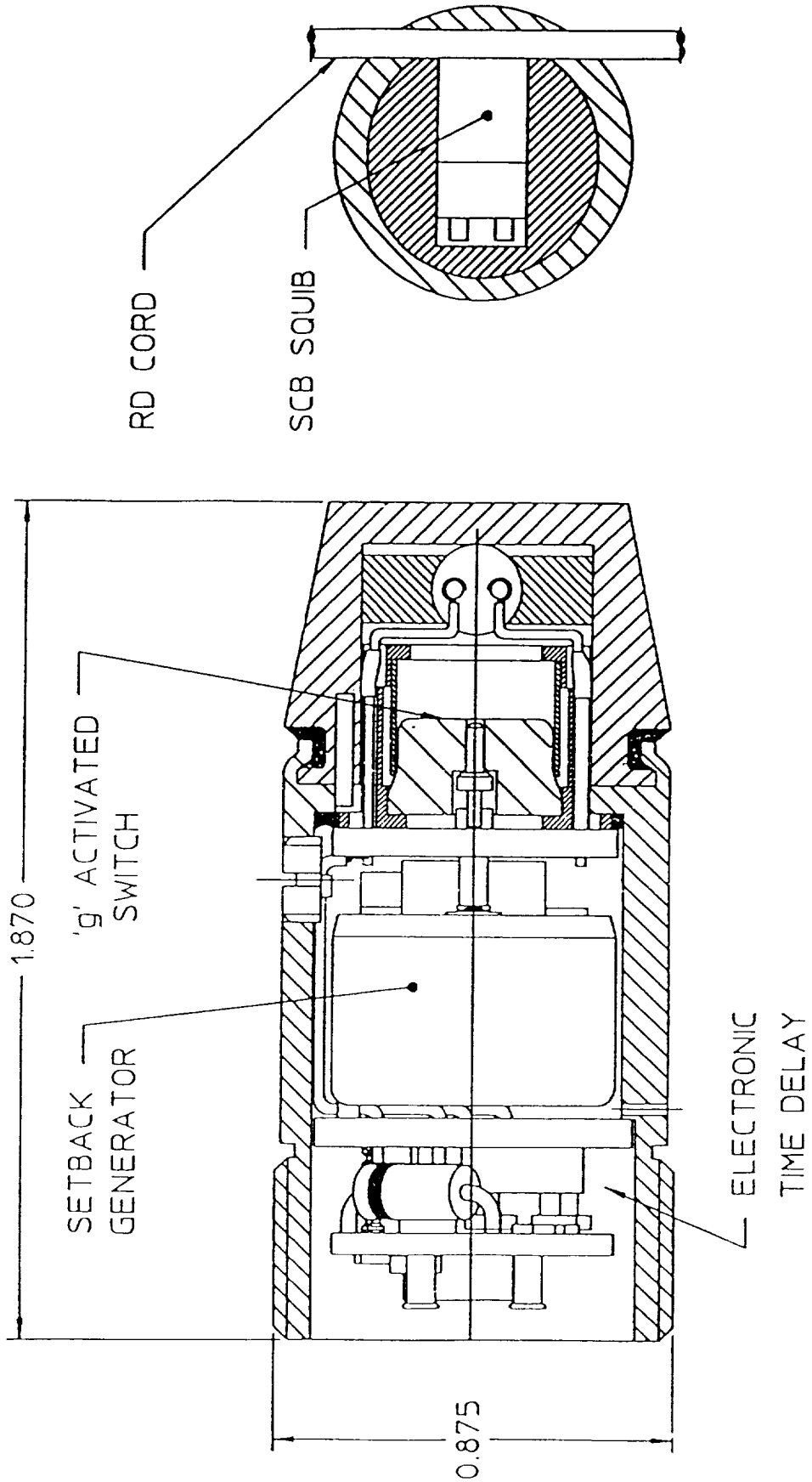
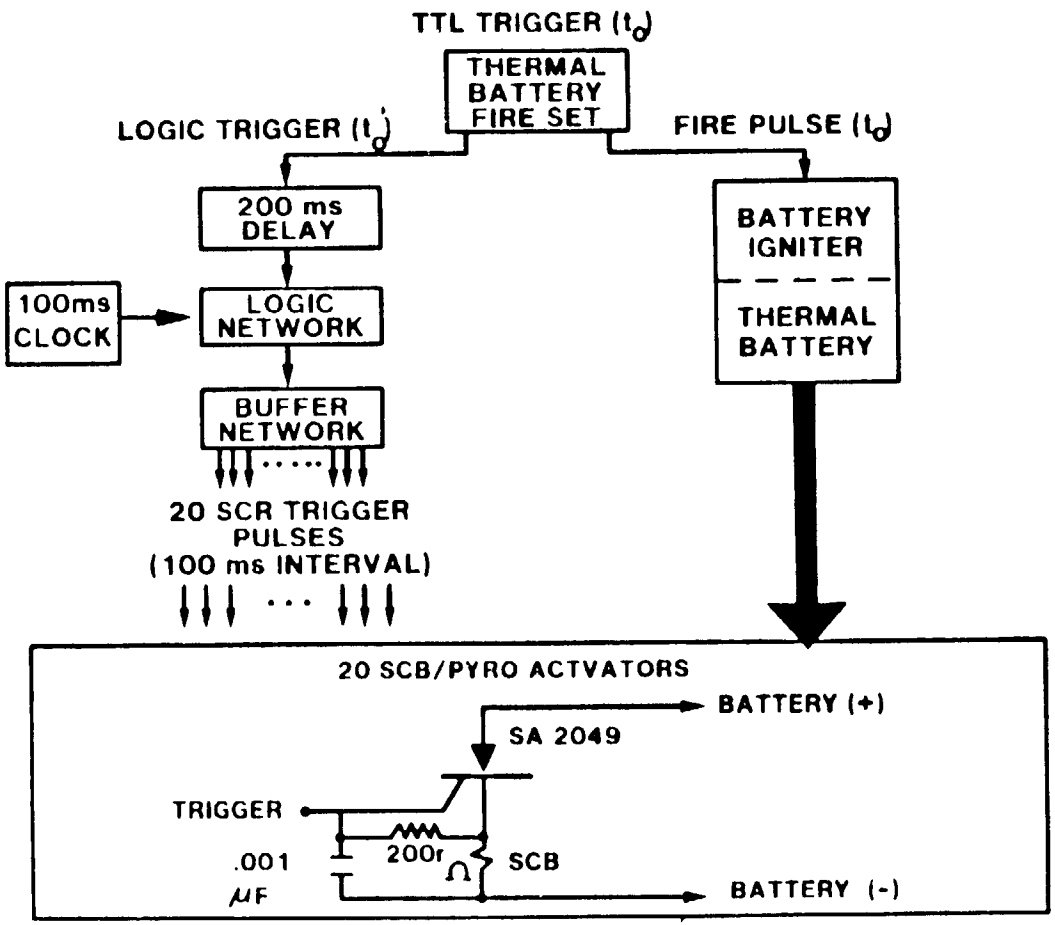

RD CORD
SCB SQUIB
1.870
'g' ACTIVATED SWITCH
SETBACK GENERATOR
ELECTRONIC TIME DELAY
0.875

LOGIC FIRE SET



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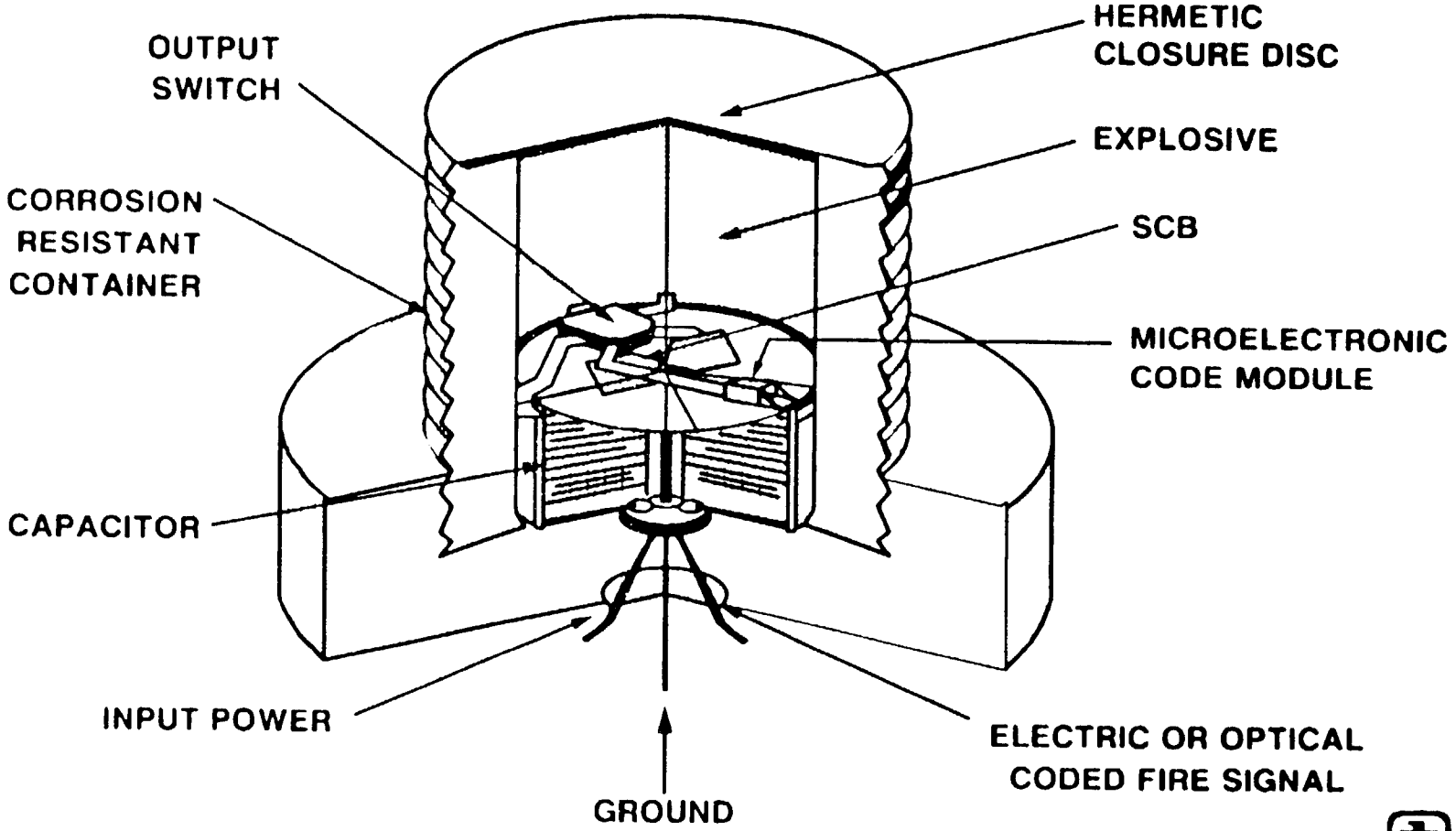
SCB SMART COMPONENT



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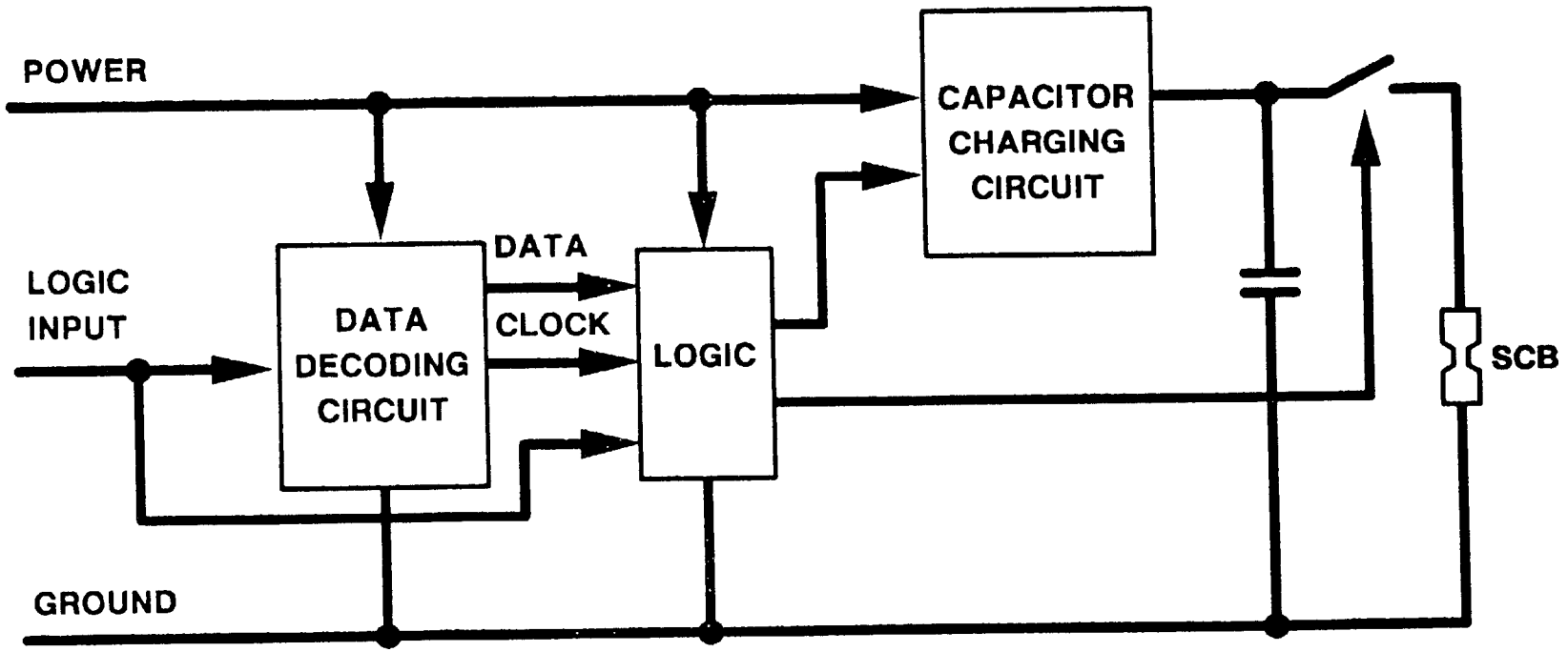
SCB SMART FIRING SET



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SCB CONCEPT
SEMICONDUCTOR DESIGN CONSIDERATIONS

- THE SCB IS A RESISTOR NOT AN ACTIVE ELEMENT
  - Allows separation of SCB design and existing semiconductor design technology

- ULTIMATE DESIGN FLEXIBILITY
  - Resistor size and doping and integrated components can be independently varied to suit application

- ALLOWS USE OF EXISTING SCB INITIATING AND PYROTECHNIC DATA BASE

- LEAST INTRUSIVE TO STANDARD SEMICONDUCTOR DESIGN AND FOUNDRY PROCESS FLOWS

Motivation

- Develop a Low Firing Energy Ejector
- Control Acceleration Profile
- Control Ejection Velocity
- Use a Single Pyro Device for All Applications

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Why Use Pyro Actuators?

- **ENERGY DENSITY**
- **FUNCTION TIME**

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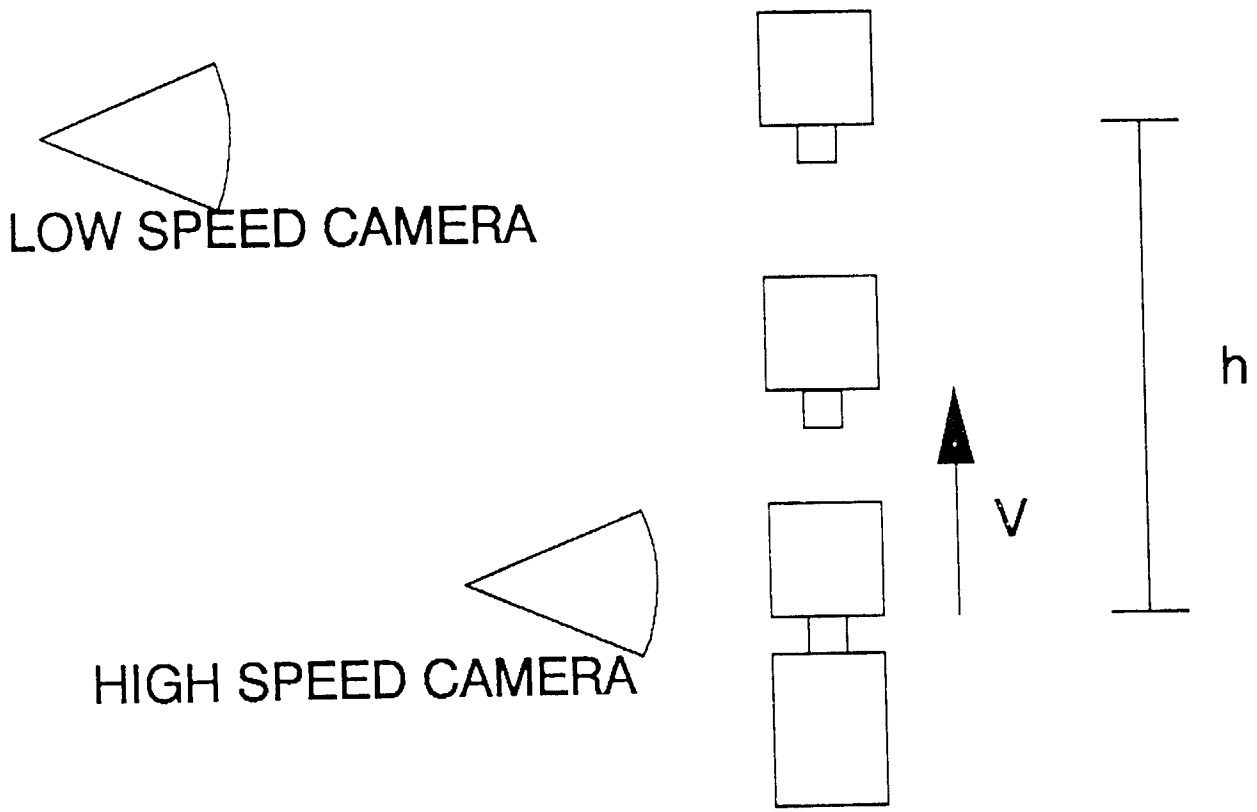
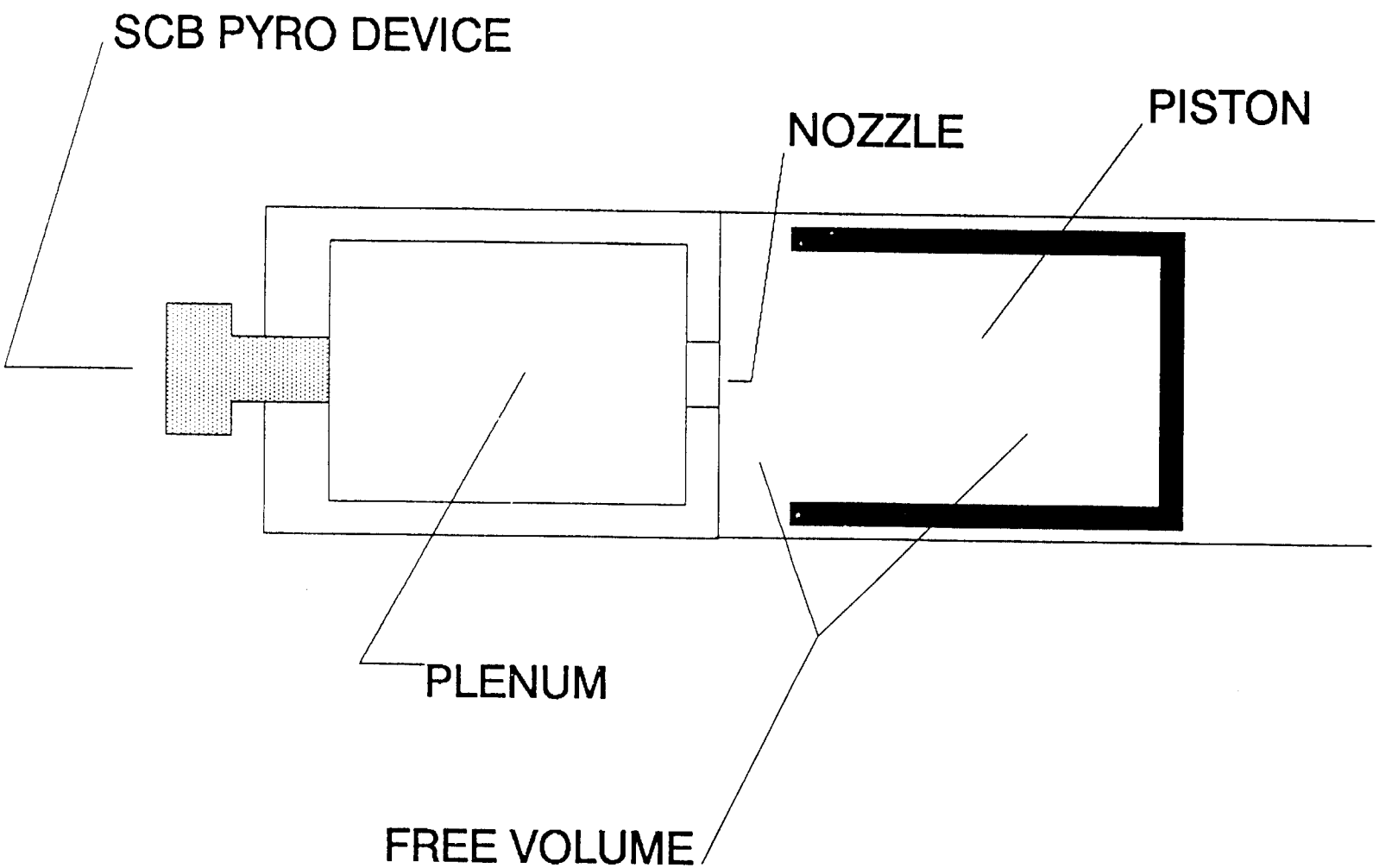
TEST

AVAILABLE PV ENERGY = $mgh = 1/2mv^2$



"ADJUSTABLE" ACTUATOR SYSTEM



Results for THKP

- Recover 20% of Total Energy Available
- Losses - Condensed Species, Heat Transfer

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Summary

- SCB – Safe Low Energy Igniter
- Ignite THKP with an SCB
- Use THKP to Pressurize Small Volume
- Vent Pressurized Volume to Eject Mass
- Control Velocity and Acceleration
- Simple Method to Determine Available Energy

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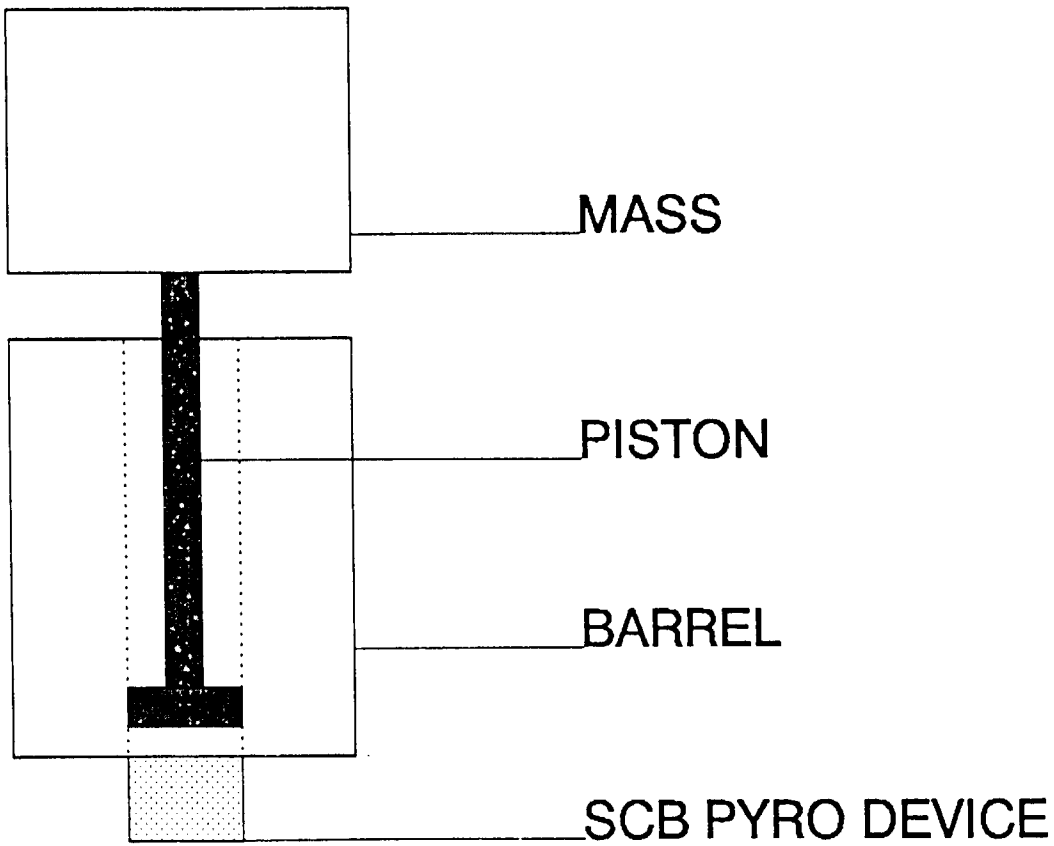
TEST FIXTURE



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