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(54) Title: INTERNAL COMBUSTION (IC) ENGINE HEAD ASSEMBLY COMBUSTION CHAMBER MULTIPLE SPARK IGNITION (MSI) FUEL SAVINGS DEVICE AND METHODS OF FABRICATION THEREOF

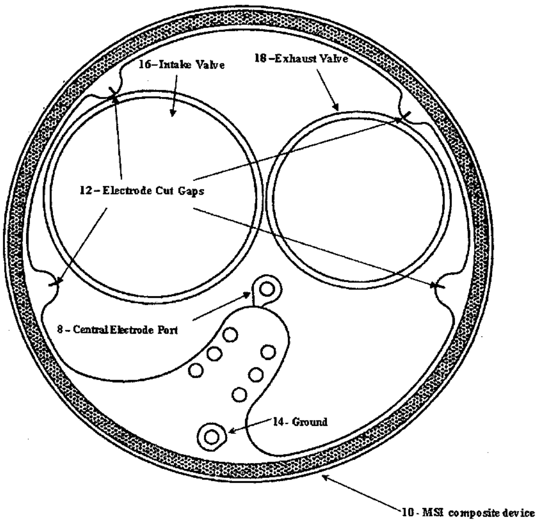

Figure 1a

Flexible Ceramic Multiple Spark Ignition device shown as ring structure with four electrodes and spark plug circular gap in relation to the intake and exhaust valves of the combustion chamber.

(57) Abstract: This invention describes how a blend of silicon polymers, mixed with the right combination of fillers applied to fiber reinforcement laminated with an embedded circuit and laser cut into vacuum formable preforms enables the production of "red heat" durable flexible ceramic multiple spark ignition devices which are vacuum formed into the head combustion chamber of IC engines for realizing fuel savings from up to 33% increased combustion efficiency. The MSI device also comprises a spark plug which is made with the steel adjustable grounding gap section removed. The spark plug electrode alignment for the fuel injectors is also used to align the spark plug electrode to insert during assembly into the MSI device (see Figure 1) circuit port. This electrode insertion enables the electrode to arc within the 360° gap of the circuit port setting off the "in series" arcing of the two other electrodes within the surround combustion circuit completing the drop in potential at the ground attachment (see Figure 1). This innovation allows the plugs to be inspected and changed as is common to current engine maintenance schedules. Since only three electrodes are needed to provide the fuel savings, only two electrodes beyond the central plug are needed to realize the fuel savings. The Figure 1 drawing provides 4 separate electrodes which may be fired in any combination with the central spark plug. The two extra electrodes are designed with a keeper that prevents the gap from firing until it is cut; this leaves the two electrode gaps in reserve for future use if needed. The MSI device attachment is designed for maximum contact with the head combustion chamber's intake valve zone while avoiding the exhaust valve port area using optional laser cut lightener holes and cut away zones which are ceramically sealed by the laser cutting at 16,500℃. These MSI devices can be retrofit on "after-market" trucks and automobiles also providing these existing vehicles an affordable increase in combustion efficiency fuel savings.

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Internal Combustion (IC) Engine Head Assembly Combustion Chamber Multiple Spark Ignition (MSI) Fuel Savings Device and Methods of Fabrication Thereof

Related Application Data

The present application claims benefit from commonly owned, co-pending United States Application for Provisional Patent, Application No. 60/936,472, filed June 19, 2007. The present application is related to commonly owned co-pending applications, Silicone Resin Composites for High Temperature Durable Elastic Composite Applications and Methods for Fabricating Same, Application No. ________ ("Clarke patent 1"), and "Red Heat" Exhaust System Silicone Composite O-Ring Gaskets and Method for Fabricating Same, Application No. ________("Clarke patent 1"), each filed on even day herewith.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Multiple spark ignition capability has been incorporated into IC engines by Toyota, Mazda and Clarke & Associates and presented in their technical briefs (References 1, 2 and 3) where the engines equipped with MSI systems consistently performed at three electrodes with a 33% increased fuel efficiency realized. Glass fabric reinforced polysiloxane composite head gaskets have been successfully made with embedded electric circuits (Reference 3) that realized up to 33% fuel savings. Since these earlier efforts new high temperature flexible ceramic composite materials have been developed (see Clarke Patent 1) that have performed over 350,000 miles cab fleet durability testing (under confidentiality agreement) as exhaust manifold hot-gas composite gaskets (see Clarke Patent 2). The MSI fuel savings device is fabricated with embedded circuits within the high temperature durable flexible ceramic materials. The methods of fabricating the devices comprises innovations in efficiently fabricating affordable composite ignition devices that can be assembled within IC engine head assembles providing up to 33% fuel savings

2. Description of the Previously Published Art

Plaksin, et.al. German Patent, WO 94/09271 is the earliest recorded patent filed relating to providing multiple spark ignition using head gaskets with embedded electrodes. The Clarke

MSI composite device is not a head gasket. The patent was filed in Germany as DE 3530997 September 4, 1986. The patent is specific to teach the use of parallel circuits with diode devices which are necessary for keeping the multiple spark ignition electrodes sparking in balance.

The Clarke composite device is assembled into the top of the head combustion chamber as a vacuum formed in place MSI composite structure with embedded electrodes connected by an "in series" electrical circuit. The Clarke composite device is not directly attached to the ignition source, but uses an arc from the central spark plug electrode to initiate the multiple spark ignition series which is grounded after the last electrode position.

Lipski, U.S. 5,046,466 patent is superseded by the German Plaksin patent in 1986, 1987 and 1988 filings and is specific to teach the use of a head gasket (Clarke MSI composite device is not a head gasket) with embedded electrodes within a head gasket made with organic substrate materials (e.g., FR 4 fire retardant polymer) that cannot withstand the combustion temperatures of IC engines 850 to 950°C. The circuits as illustrated cannot sustain ignition as suggested. The invention does not use spark plug advantages for avoiding costly electrical attachment requirements. The invention depends on a head gasket to provide the electrodes to the firing locations. The Clarke MSI composite device is not a head gasket.

The Clarke patent, US 6,161,520 is specific to teach the use of a head gasket to provide the multiple spark ignition (MSI). The Clarke MSI composite device is not a head gasket. The Clarke composite device retains the central spark plug, using its electrode to make an arc attachment with the in series circuit eliminating the costly high voltage 520' patent attachment requirement. The Clarke 520' patent is specific to teach that the gasket materials derived from Clarke's copending US patent applications Ser. Nos. 08/962,782; 08/962,783 and 09/185,282, all teach the required use of boron nitride as the catalyst for condensation polymerization of the resin blend needed to produce the gaskets. Clarke has verified that boron nitride is *not a catalyst* as incorrectly claimed. Clarke verified the certainty that boron nitride is not a catalyst by attempting to repeat the 873 patent's *Figure 1* "gel" curve at 177°C using the preferred CERAC, Inc. item #B-1084- 99.5% pure boron nitride.

The Clarke SAE 2002-01-0332 paper (Reference 3) refers to the use of a head gasket to provide the multiple spark ignition (MSI). The Clarke MSI composite device is not a head gasket. The Clarke composite device retains the central spark plug, using its electrode to make an arc attachment with the in series circuit eliminating the costly high voltage 520' patent attachment requirement. Additionally, the methods of producing "flexible-ceramic" laminates capable of high-temperature elastic recovery (Figure 2) are not addressed. The flexible-ceramic "self extinguishing" property when heat is removed is an essential requirement to prevent combustion pre-ignition in the MSI fuel saving flexible ceramic composite ignition devices.

References Cited

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3. Clarke, W.A.; Azzazy, M and West, R., *Reinventing the Internal Combustion Engine Head and Exhaust Gaskets,* Clarke & Associates, SAE PAPER, 2002-01-0332, (March 4, 2002)
4. Thompson, Raymond, *The Chemistry of Metal Borides and Related Compounds*, reprinted from *PROGRESS IN BORON CHEMISTRY*, Vol. 2, Pergamon Press, (1969) p.200
5. Sparking Gasket System (SGS), Exhibited by Aura Systems, Inc. at February 1996 SAE Exposition in Detroit, Michigan where a fully operational 2.3-liter Ford Ranger, with 100% MSI gasket driven IC engine capability was demonstrated. Ford Engineers and Scientific Laboratory personnel drove the SGS truck using the SGS

multiple sparking gasket ignition or single spark plug or both ignition systems simultaneously as options.

SUMMARY OF THE INVENTION

Objectives of the Invention

It is the objective of this invention to eliminate the need for a physical electrical high voltage attachment by providing an open circular portal for inserting the central spark plug electrode enabling it to initiate the in series ignition by arcing within the 360° gap. The grounding gap portion of the spark is removed so as to not interfere with the assembly.

It is the further objective of this invention to retain the central spark plug for the above advantage and to allow for servicing or replacing the plugs as engine tune up or maintenance schedules may require.

It is the further objective of this invention to provide an ignition device made from preceramic elastic composite material that will be heat cured by the combustion heat to a flexible ceramic MSI composite device where the intake valve zone will remain elastic while the exhaust valve area will have a ceramic surface backed up by elastic layers closer to the head cavities metal surface.

It is the futher objective of this invention to provide two additional electrodes more than the three combustion spark ignition electrodes which are redundant as spares with "keepers" that only need to be cut to engage in spark ignition.

It is the further objective of this invention to provide an insulated wire which can be selectively stripped, machine flattened and die cut to form end ports and four spark electrodes (Figure 1). This stamped wire innovation eliminates the need to weld the electrodes to copper wire.

It is the further objective of this invention to selectively provide the above stamped wire from a nickel-copper alloy which is platinum coated for durable spark ignition erosion resistance.

It is the further objective of the invention to eliminate the use of head gaskets when incorporating embedded electrodes into composite materials to achieve multiple spark fuel savings advantages.

It is the further objective of the MSI composite device to provide sufficient combustion efficiency to realize up to 33% fuel savings for IC engines and to enable retrofitting of standard engines to allow the fuel savings to be also realized in the after market vehicles.

It is the further objective of the invention to provide the optional use of silk screened high electrically conductive carbon circuits in addition to the metallic elements within the laminates for computer chip and reduction in electric circuit advantages.

The invention comprises a “flexible ceramic” multiple spark ignition (MSI) device that fits inside an IC engine combustion chamber increasing its fuel combustion efficiency by up to 33% and methods of fabrication thereof. Composite combustion devices using electric circuits embedded in fabric reinforced polysiloxane (Reference 3) have achieved 33% superior fuel savings using three spark ignition gap electrodes greater than conventional single spark plug ignition. The cured laminates and laser cutting innovations produces affordable superior three sparks IC engine ignition devices installed inside the combustion chamber of the IC engine head assembly. The key elements of the devices are:

(1) The device comprises a flexible ceramic composite embedded with an surround multiple ignition circuit located inside the top surface area of the IC engine head closed piston combustion chamber (Figure 1b). The discovered high-temperature Figure 2 compression recovery property of flexible-ceramic material enables the outer ring structure of Figure 1a to extend into the piston bore compression ring zone of the head gasket assembly.

(2) The device also comprises four spark ignition gaps (or combination of such gaps) connected in series from the spark plug gap to the ground. Each gap is connected to the next by an insulated nickel/copper wire (or optionally copper wire) embedded in the flexible ceramic composite device. The shape of the embedded circuit (Figure 1b) is a ring of optional spark ignition gaps starting with the spark plug’s centrally located

"circular gap" extending out into the ring circuit ending at the ground circular gap and "compression spacer". The edge ends at the cylinder bore combustion compression ring

(3) The device comprises a wire (optional foil) circuit wrapped in up to 25% boron nitride filled polyimide sealed with extruded Teflon® coating and embedded between the laminate plies closer to the metal surface and optionally from 0.10 up to 0.25 inches thickness. The composite laminate is processed to a cure ply thickness of 0.0105 (or other Table 1a or b thicknesses), with preferably Table 1a S-glass prepreg and laminate composition. The ignition device comprises an assembly method of vacuum molding the device inside the combustion chamber against the metallic (e.g., aluminum) metal surfaces allowing for attachments at the spark plug threads and head gasket joint locations where the ground wire is clamped during the head assembly.

(4) The device also comprises a simple less costly modified spark plug where the spark plug's stainless steel grounding gap for the spark is eliminated (for prototype work these are simply cut off at the end of the spark electrode gap). This enables the central electrode to be threaded into the first circular gap of the in-series multiple gap circuit. This unobvious design assures the firing of the circuit through an unobvious circular gap opening discovery. The circular opening provides a 360° gap opening for initiating the ignition and to make arc contact without the need for direct attachment. This allows plugs to be replaced, inspected and serviced as needed. Also, the combustion chamber fuel injector optimal location is not affected at the first spark plug gap location which is always a concern of combustion engineers.

(5) The device fabrication methods comprises laser cutting the majority of openings and edges of the composite device forming ceramic sealed edges. The fired surfaces of the composite device are self extinguishing and the preferred nickel gaps are alloyed to sufficient copper to prevent pre-ignition (Reference 1). Interior combustion surfaces of the ignition device are optionally YAG (yttrium, alumina, garnet) laser milled forming optional ceramic edge morphology.

(6) The method of circuit fabrication is shown in Figures 3 to 6. The circuit starts with an insulation wrapped wire of nickel-copper alloy which is stipped at the ends and between the ends for allowing for the MSI electrodes. All stripped wire sections are stamped into circular flat sections which are die cut with holes. The electrode circular sections are cut with elliptical holes, then folded over to form the sparking electrodes. The end circular sections are die cut with holes, one of which is the spark plug arcing

port and the other is the grounding port. The use of a single wire to form the electrodes and port holes as well as accommodate the wire wrapped insulation is a significant economical method eliminating welding the electrodes to copper wire, and forming the port attachments and grounding without welding.

(7) The methods of fabricating the device also comprises an optional silk screening of vapor grown carbon fiber circuits applied within the composite laminate layers instead of wire or foil circuits or in addition to these circuits.

Table 1a

Laminate and Prepreg Material Composition of S-Glass, 6781 8HS Fabric Reinforced Polysiloxane Composites

Fabric and Filler Properties		Resin Properties		
Properties	**Data**	**Resin Blend**	**Parts by Weight**	**Density (g/cm^3)**
Fabric Areal Weight (g/m^2)	300.07	SR 355	65	1
Fiber Density (g/cm^3)	2.48	TPR 178	25	0.98
Cured Resin & Filler Density (g/cm^3)	1.33	TPR 179	10	0.95
Fabric Thickness inches (mm)	0.0090 (0.229)	BN	20	2.25
Laminate Porosity	1%	SiO_2	6	2.4

Nomenclature

t_L	Cure Ply Thickness	W_F	Fiber Weight
V_F	Fiber Volume	W_{R+f}	Resin + Filler Weight
V_{F+f}	Fiber + Filler Volume	W_p	Prepreg Fabric Weight of 4" x 4" = $16in^2$ ($103.23cm^2$) Test Sample
V_{R+f}	Resin + Filler Volume		

Laminate Properties				Prepreg Properties		
t_L	V_F	V_{R+f}	V_{F+f}	W_F	W_{R+f}	W_p
Inches (mm)	%	%	%	%	%	gm
0.0080 (0.203)	59.55	39.45	64.64	74.11	25.89	4.18
0.0085 (0.216)	56.04	42.96	61.58	71.23	28.77	4.35
0.0090 (0.229)	52.93	46.07	58.87	68.58	31.42	4.52
0.0095	50.14	48.86	56.44	66.12	33.88	4.68

(0.241)						
0.0100 (0.254)	47.64	51.36	54.27	63.85	36.15	4.85
0.0105 (0.267)	45.37	53.63	52.29	61.72	38.28	5.01
0.0011 (0.279)	43.31	55.69	50.49	59.74	40.26	5.18
0.0115 (0.292)	41.42	57.58	48.85	57.87	42.13	5.35
0.0120 (0.305)	39.70	59.30	47.35	56.14	43.86	5.52

Table 1b

Laminate and Prepreg Material Composition of E-Glass, 1583 8 HS Fabric Reinforced Polysiloxane Composites

Fabric and Filler Properties		Resin Properties		
Properties	**Data**	**Resin Blend**	**Parts by Weight**	**Density (g/cm^3)**
Fabric Areal Wt. (g/m^2)	560.80	Dow Corning 249	35	1.07
Fiber Density (g/cm^3)	2.585	Dow Corning 233	30	1.32
Resin & Filler Density (g/cm^3)	1.27	Dow Corning 3037	25	1.07
Fabric Thickness inches(mm)	0.0179 (0.455)	Dow Corning MR2404	10	1.11
Laminate Porosity	1%	BN	20	2.25
		SiO_2	6	2.4

For Nomenclature, please see Table 1a.

Laminate Properties				Density of Prepreg Resin and Additives		
t_L	V_F	V_{R+f}	V_{F+f}	W_F	W_{R+f}	W_p
In.(mm)	%	%	%	%	%	gm
0.0140 (0.356)	61.00	38.0	66.36	76.86	23.14	7.53
0.0145 (0.368)	58.90	40.10	64.51	75.25	24.75	7.69
0.0150 (0.381)	56.93	42.07	62.76	73.7	26.3	7.85
0.0155 (0.394)	55.10	43.90	61.14	72.2	27.8	8.02
0.0160	55.38	45.62	59.62	70.8	29.2	8.18

(0.406)						
0.0165 (0.419)	51.76	47.24	58.19	69.4	30.6	8.34
0.0170 (0.432)	50.24	48.76	56.84	68.2	31.9	8.49
0.0175 (0.445)	48.80	50.20	55.56	66.9	33.1	8.65
0.0180 (0.457)	47.44	51.56	54.36	65.7	34.3	8.81
0.0185 (0.470)	46.16	52.84	53.23	64.5	35.5	8.98
0.0190 (0.483)	44.95	54.05	52.16	63.4	36.6	9.13

Table 2

Volume and Mass Calculations Forecasting Table 2 Press Cured Laminate Properties from Prepreg Formulations

Nomenclature

t_F	Cure ply thickness of fabric	W_R	Weight of resin
t_L	Cure ply thickness of laminate	W_f	Weight of filler
A_W	Areal weight of fabric	W_{BN}	Weight of boron nitride
A_F	Area of fabric	W_{SiO2}	Weight of silicon dioxide
A_L	Area of laminate	W_L	Weight of laminate
A_p	Area of prepreg	W_F	Weight of fiber
V_F	Volume of fibers	W_p	Weight of prepreg
V_{R+f}	Volume of resin + filler	W_{F+f}	Weight of fiber + filler
V_f	Volume of filler	ρ_{BN}	Density of boron nitride
V_o	Volume of voids	ρ_{SiO2}	Density of silicon dioxide
V_L	Volume of laminate	ρ_{R+f}	Density of resin + filler
V_{F+f}	Volume of fiber + filler	ρ_F	Density of fiber

Procedure and Calculations:

(1) $t_F = A_W/\rho_F$

(2) $V_F\% = (t_F/t_L)\bullet 100\%$, where $V_L\% = 100\%$ for $V_F = (t_F/t_L)\bullet V_L$ from $A_F = A_L$ (premise)

(3) $V_{R+f}\% = (V_L - V_F - V_o)\bullet 100\%$, where $V_L\% = 100\%$ and $V_o\% = 1\%$

(4) $V_{F+f}\% = [(V_F + V_f)/V_L]\bullet 100\%$, where $V_{R+f} = (W_R + W_f)/\rho_{R+f}$, then

$\mathbf{V_L} = V_{R+f}/(V_{R+f}\%/100\%)$, $\mathbf{V_F} = V_L - V_{R+f}$ and $\mathbf{V_f} = W_{BN}/\rho_{BN} + W_{SiO2}/\rho_{SiO2}$

(5) $W_F\% = (\mathbf{W_F}/\mathbf{W_L}) \cdot 100\%$, where $\mathbf{W_F} = V_F \cdot \rho_F$ and $\mathbf{W_L} = W_F + W_f + W_R$

(6) $W_{F+f}\% = [(W_F + W_f)/W_L)] \cdot 100\%$, where $W_f = W_{BN} + W_{SiO2}$

(7) $W_p = W_F/(W_F\%/100\%)$, where $W_F = A_W \cdot A_p$

BRIEF DESCRIPTION OF DRAWING

Figure **1**A is a top surface view drawing of the multiple spark ignition (MSI) flexible ceramic device installed in the upper combustion chamber of the IC engine head showing 4 in series electrodes surrounding the central spark plug electrode port in a circuit that ends with the ground.

Figure **1**B is a cut away central view drawing of each of the head combustion chambers containing MSI composite devices revealing embedded four ignition electrodes in series per cylinder with central spark plug circular arc-gap electrode for GM 3500 V6 Engine Cylinder Head Combustion Chamber.

Figure **3** is a fragmentary, cut away, perspective view of a wrapped wire constructed according to the principles of the present invention

Figure **4** is a selectively stripped circuit wrapped wire exposing the metallic elements

Figure **5** is the metallic elements stamped and with die cut holes for electrode, spark ignition electrodes and ground compression port.

Figure **6** is the circuit with die cut electrodes before assembly within the laminate as a circular structure as shown in Figure 1B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The MSI composite device **10** of the present invention is illustrated in Figure 1A from the inside head cavity view revealing four thermally insulated electrodes fabricated with high temperature boron nitride loaded composite insulation laser cut with ceramic sealed cut edges including electrode cut spark ignition gaps **12**. The internal electrical circuit starts with a central spark plug electrode port **8** which eliminates the need for a high voltage connector for initiating the multiple spark ignition by providing an open port **8** in which the spark plug electrode is inserted enabling the spark plug electrode to arc to the MSI circuit which consists of sparking electrode gaps 12 and a ground **14** which is compressed against the metal head and cylinder block during assembly.

The invention also compresses a unique spark plug with the ground removed so as to assure the arc connection advantage. Invention provides for spark plug replacement and servicing during engine maintenance and tune up operations. The MSI composite device is selectively laser cut to provide valve **16** and **18** clearance holes sealed with a ceramic edge and central spark plug port supporting composite structure with lightener holes allowing for exhaust gas flow during combustion cycles.

Figure 1b illustrates a cut away view of three individual MSI devices assembled in a GM 3500 V6 engine cylinder head **28** combustion chambers. The exposed circuit **20** starts with the spark plug arcing port **8** and continues in series forming a circular set of four sparking electrodes **12** which ends at the grounding port **14**. Each sparking electrode **24** in the circuit series is positioned to overlap into the head cavity combustion chamber **22** which prevents the initial flame front initiating from the sparking gap from being inhibited by head cavity restrictions. The composite device methods of fabrication comprises the laser cutting of the device to assure no restriction of the combustion cavities **22** illustrated in Figure 1B. The device comprises composite laminate non-conductive fabric and ceramic additive reinforced elastic composite laminate material such as described in the above referenced copending patent applications. Such patent applications should be consulted for a detailed understanding of the formulations, compositions and processing steps proposed for the manufacturing of the MSI composite devices.

The method of fabricating the wire circuit **20** of the MSI composite device starts with insulation wrapping the wire of Figure **3** between the insulating layers of 25% boron nitride filled polyimide tape wrapped insulation and Teflon ®layers. These insulation layers are selectively stripped (as shown in Figure **4**) to allow for the metal forming of the ports and electrodes as shown in Figure **5** for the stamping and die cutting of holes method of metal forming. Figure **6** illustrates the completed circuit when the electrode elliptical die cut holes are folded over to form the sparking electrodes.

The completed MSI composite device provides a surround combustion spark-ignition system **20** is depicted in Figure 1 comprising the ignition elements of spark electrodes, ground connectors and spark plug electrode insertion port **8.**

Central to the present invention, is the invention of the wire circuit metal formed from a nickel-copper alloy composite layered wire metal formed by brinnelling and die cutting with holes used to form the electrodes as depicted in Figures **5** and **6**. As depicted in Figures **1A** and **1B**, the insulated wire (Figure **3**) is embedded and bonded between the fabric reinforced elastic composite laminate layers forming the composite device **10**.

While a preferred embodiment has been described in detail herein above, it should be appreciated that changes may be made in the illustrated embodiment without departing from the spirit of the present invention. Therefore, the present invention is to be limited in scope only by the terms of the following claims.

The Claims

WHAT IS CLAIMED:

1. The composite device comprises an methyl and phenylselsesquioxane silicone resin and boron nitride, silica and boron oxide additives resin blend formulation and methods of processing that enables the economic manufacture of high temperature flexible ceramic composite materials suitable for durable high temperatures ranging from 100 to 500°C (see Figure 2) and 500 to 1000°C for red heat temperatures. The elastic silicone polymer used to produce Figure 2 high temperature durable "flexible ceramic" laminates must be properly resin formulation processed, fabric reinforcement impregnated, laminated and heat cured including laser processing.

2. The composite device methods of fabrication comprises the use of the resin blend to produce the prepreg of reinforcement fibers. Table 1a and & 1b provide preferred fibers and their corresponding prepreg and laminated compositions, but the claim 1 composite device also comprises all textile refractory, ceramic and preceramic (e.g., silicone carbide, silicon nitride and mixtures of these fibers) and Nextel fibers, where the laminate and prepreg compositions are within the range shown within table 1 adjusted by each fiber's density, weave and yarn properties and sizing preference for high temperature applications.

3. The claim 1 composite device comprises a flexible elastic laminate superior in very high temperature elastic retention and compression/recovery fatigue reliability as demonstrated in Figure 2 revealing after 10,000,000 fatigue cycles 90% recovery from 15% compression for heat cured material at exhaust gas temperatures.

4. The claim 1 composite device also comprises a flexible ceramic laminate made from the preferred (see Table 1a) S-glass 8-Harness Satin fabric reinforced polysiloxane laminated from an impregnation of the elastic resin blend. Optionally, Table 1b provides an economical reinforcement (1583 8 HS E-glass fabric) for laminating polysiloxane laminates. The discovery is not limited by the example fabrics provided in Table 1a and 1b but applies to all textile refractory, ceramic fabrics where the laminate composition is calculated as given in Table 2 for each fabric's areal weight,

density and basic textile composition and additive composition necessary for high temperature performance advantage.

5. The claim 1 flexible ceramic device wherein the composite material has both high temperature elastic and high yield (>90%) ceramic properties. When the flexible materials are selectively heat treated at temperatures higher than 500°C, the regions heat treated become ceramic while the non-heat treated areas remain flexible. The pyrolyzed ceramic and preceramic region's porosity is filled (see Figure 2) with the resin blend impregnant and cured to the desired flexible ceramic performance temperature.

6. The claim 1 composite device wherein the flexible ceramic materials are made by laser cutting at temperatures up to 16,500°C. These laser cut flexible elastic sealing edges are produced with ceramic sealed edges and when tensile tested have up to 25% higher tensile strength than when die cut. This discovery enables different types of ceramic edges to be produced by using different ceramic fabric reinforcements when the flexible laminates are produced for example, each of the following fabrics will have different important ceramic edges; Nextel 610 (alumina). S-glass (alumina, silica, magnesium oxide) or zirconium oxide fabric.

7. The methods of making the composite devices also comprises an unobvious nylon woven fabric that performs as a protective heat barrier for enabling multiple laminates to be laser cut without vaporization heat damage between the cut laminate surfaces. The unique woven polymer fabric performs as a tightly woven peel ply without removing resin and unobvious as a heat absorbing inhibitor when the laser is set up for stacked laminates cutting. This enables multiple stacks of laminates to be cut in one mass production operation. The mechanism that allows this advantage is nylon's uncommon melting point property where it melts over a melting temperature range of 100°C giving time for the laser to cut through multiple laminate stacks without heat damaging the flammable top surfaces of the stacked laminates.

8. The discovery is an unobvious use of claim 7 heat barrier, nitrogen purge and the preferred power settings (described in the Embodiments) to enable a carbon dioxide laser to be capable of laser cutting multiple laminates for significant cost advantage:

(1) The claim 7 thermo-vaporization heat barrier fabric is initially placed between laminates molded together in "book stacks",

(2) the nitrogen purge is applied to cover the cutting focus point at a 1.5mm nozzle gap expelling nitrogen gas at 142 psi from a 2mm nozzle orifice, and

(3) the preferred carbon dioxide power settings (see Embodiments) are used to cut multiple stack laminates with up to 16,500°C focus point by thermo-vaporizing the laminate stack in cutting through the stack, but not the adjacent laminate interfaces protected by the heat absorbing protective nylon fabric separator peel plies. The power set up enables laser cutting book stacks of 10 to 20 laminates at a time with higher cutting capacity if needed.

9. The MSI composite device of claim 2, wherein the composite reinforcement's ply to ply architecture is an unobvious "triaxial" oriented architecture of fabric plies oriented in balanced 0°, +60°, -60 ° warp stacking orientations. These multi-layer triaxial fabric reinforcements enables the Figure 2 elastic laminate to have superior mechanically assisted elastic recovery from thickness compression and tensile elastic stretching performance modes. Additionally, tensile bars laser cut from the triaxial laminate have up to 25% higher tensile strength than shearing die cut bars. The laser cut fiber edges are ceramically sealed with the fiber's ceramic materials.

10. The MSI composite device of claim 9, wherein the composite triaxial architecture enables cost savings production of durable expansion joints by laser cutting a lightener holes within the composite structure separating hot from cooler regions of attachment requiring expansion joints. The balanced triaxial fabric reinforcement enables the laser cut lightener holes to stretch in the smaller cross sectional areas on both sides of the holes and to elastically buckle when compressed without breaking the fibers. This type expansion joint was tested (under confidentiality agreement) on 4.6 liter V8 Crown Victoria engine exhaust manifold gaskets that passed the 150,000 mile durability test requirements with no gasket problems with many of the gaskets continuing to perform up to and in excess of 350,000 miles after four years testing.

11. The composite device of claims 1, 2, 3 and 10, wherein the composite has been formulated, reinforced, laminated and heat cured to self-extinguish from applied "red heat" "thermal glow" proven by the lack of pre-ignition experienced when the MSI

composite device is tested in IC engine combustion chambers at common engine operating timing and combustion heat levels.

12. The composite device of claim 11, wherein an unobvious formulation of submicron boron nitride/silica in a parts by weight ratio of 10/3 to 30/9 for each 100 parts by weight of the claim 1 resin blend produces the superior "self-extinguishing" capability. The relatively high boron nitride composition of the claim 1 resin blend in combination silica and boron oxide within the cured silicone resin increases the composite's thermal conductivity and the opportunity to form a stable boron oxide oxidation protective film (Reference 4) at *red heat* temperatures which is also "self extinguishing". This capability enables superior composite combustion ignition devices to be economically manufactured for use in superior multiple spark fuel saving applications (Reference 5).

13. The composite device of claim 12, wherein the embedded electric circuit is produced from a mixture of the claim 1 resin blend high temperature resin formulation and electrically conductive carbon fibers in part or totally by highly efficient rapid silk screening processes to cost effectively create precise raised thickness electrically conductive composite coatings embedded within ceramic fiber reinforced silicone laminates formed into the composite device and co-cured together.

14. The composite device comprises a flexible ceramic composite embedded with a surround multiple ignition circuit located inside the top surface area of the IC engine head closed piston combustion chamber (Figure 1). The **(Clarke Patent 1)** discovered high-temperature Figure 2 compression recovery property of flexible-ceramic material enables the outer ring structure of Figure 1 to extend into the piston bore compression ring zone of the head gasket assembly.

15. The composite device (see Figure 1) comprises four (but is not limited the four) spark ignition gaps (or combination of such gaps) connected in series from the spark plug gap to the ground. Each gap is connected to the next by an insulated conductive material (wire, foil, continuous carbon fiber, or conductive coating) embedded in the flexible ceramic composite device. The shape of the embedded circuit (Figure 1b) is a ring of optional spark ignition gaps starting with the spark plug's centrally located

"circular gap" extending out into the ring circuit ending at the ground circular gap and "compression spacer" completing the cylinder bore combustion compression ring. Other options include using the intake valve combustion chamber surface for the embedded circuit while applying compression spacers in the head gasket combustion compression ring zone.

16. The composite device comprises a wire, foil, continuous fiber, and coated conductive circuit enclosed in up to 25% boron nitride filled polyimide sealed with Teflon® film and embedded between the laminate plies closer to the metal surface and optionally up to 0.25 inches thickness. The composite laminate is processed to a cure ply thickness of 0.0105 (or other Table 1 optimal thicknesses), with preferably Table 1a and 1b prepreg and laminate composition.

17. The composite ignition device comprises an assembly method of vacuum forming the device inside the combustion chamber against the metallic (e.g., aluminum or iron) metal surfaces allowing for attachments at the spark plug threads and head gasket joint locations where the ground circuit attachment (e.g., wire) is clamped during the head assembly to the engine block.

18. The composite device also comprises a simple less costly modified spark plug where the spark plug's stainless steel grounding gap for the spark is eliminated (for prototype work these are simply cut off at the end of the spark electrode gap). This enables the central electrode to be threaded into the first circular port of the in-series multiple gap circuit. This unobvious design assures the firing of the circuit through an unobvious circular gap opening discovery. The circular opening provides a 360° gap opening for initiating the ignition and to make arc contact without the need for direct attachment. This allows plugs to be replaced, inspected and serviced as needed. Also, the combustion chamber fuel injector optimal location is not affected at the first spark plug gap location which is always a concern of combustion engineers.

19. The composite device fabrication methods comprises laser cutting the majority of openings and edges of the composite device forming ceramic sealed edges. The fired surfaces of the composite device are self extinguishing and the preferred nickel gaps

are attached to sufficient copper to prevent pre-ignition (Reference 3). Interior combustion surfaces of the ignition device are optionally YAG (yttrium, alumina, garnet) laser milled forming an optional ceramic edge morphology.

20. The composite device methods of fabrication also comprises an optional silk screening of vapor grown carbon fiber circuits applied within the composite laminate layers instead of wire or foil circuits or in addition to these circuits.

21. The composite device methods of circuit fabrication is shown in Figures 3 to 6. The circuit starts with a insulation wrapped wire of nickel-copper alloy which is stripped at the ends and between the ends for allowing for the MSI electrodes. All stripped wire sections are stamped into circular flat sections which are die cut with holes. The electrode circular sections are cut with elliptical holes, then folded over to form the sparking electrodes. The end circular sections are die cut with holes, one of which is the spark plug arcing port and the other is the grounding port. The use of a single wire to form the electrodes and port holes as well as accommodate the wire wrapped insulation is a significant economical method eliminating welding the electrodes to copper wire, and forming the port attachments and grounding without welding.

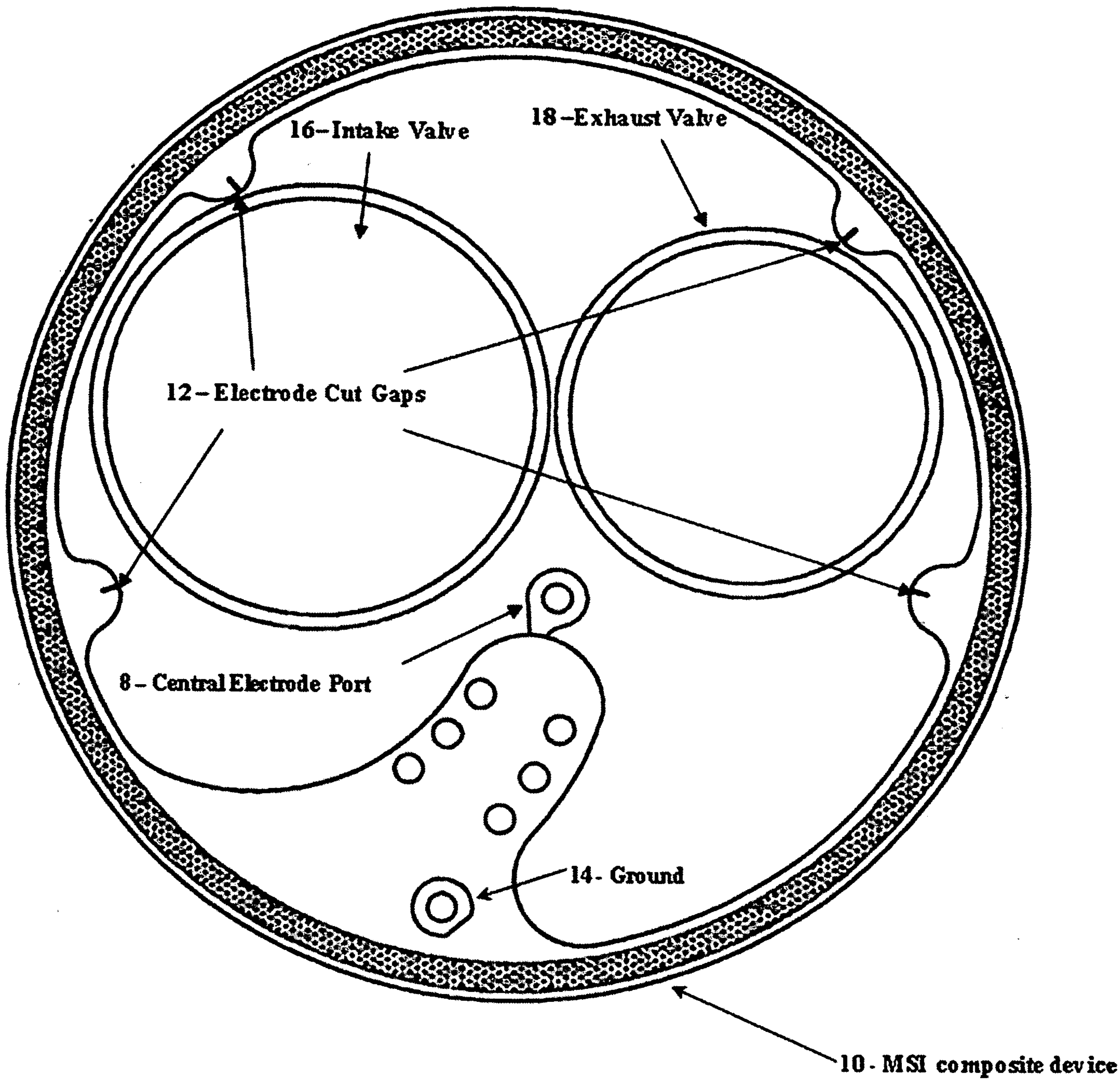

Figure 1a

Flexible Ceramic Multiple Spark Ignition device shown as ring structure with four electrodes and spark plug circular gap in relation to the intake and exhaust valves of the combustion chamber.

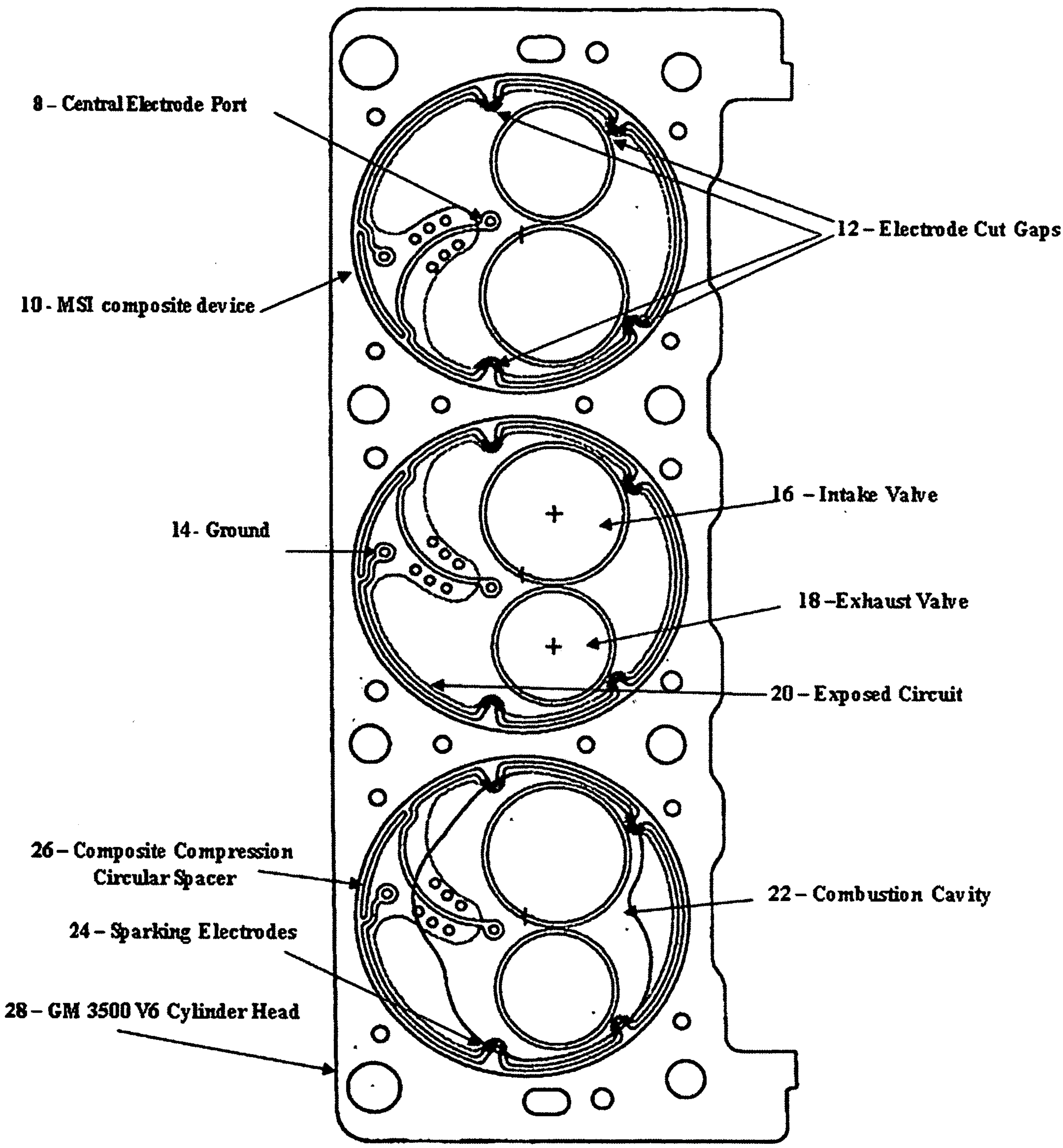

Figure 1b

Flexible Ceramic Multiple Spark Ignition device revealing embedded four ignition electrodes in series per cylinder with central spark plug circular arc-gap electrode for GM 3500 V6 Engine Cylinder Head Combustion Chamber.

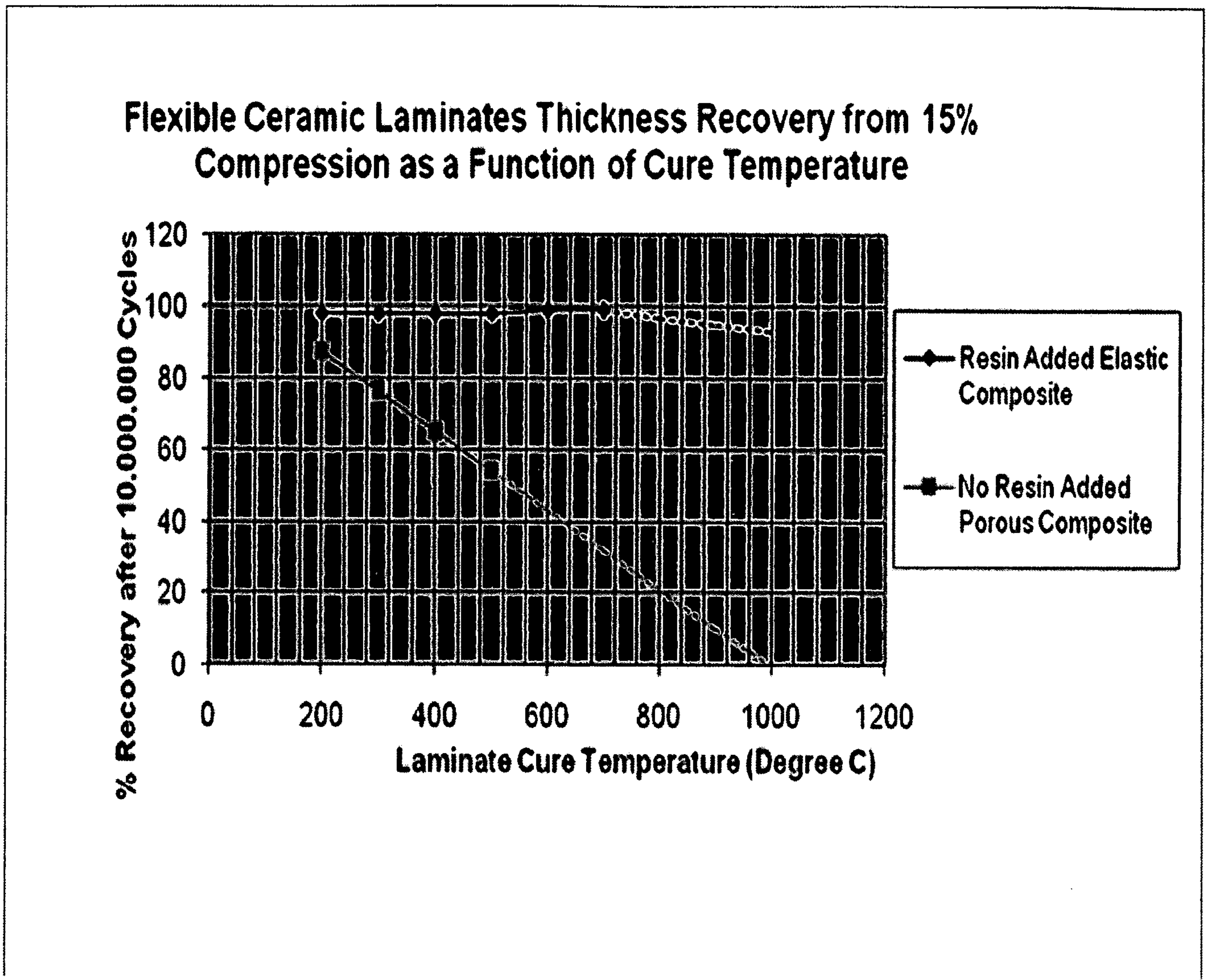

Figure 2

Insulation Wrapped Nickle/Copper Alloy Wire

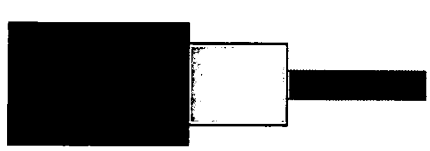

Figure 3

Stripped Wire in Sections for Forming the Electrodes, End Spark and Ground Ports

Figure 4

Stamped Circular Metal Sections With die cut holes

Figure 5

Completed Circuit Revealing the Folded Over MSI Spark Electrodes

Figure 6