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(54) Title: COATED CUTTING TOOL

(57) Abstract

A coated cutting tool, e.g., a razor blade is covered with a coating comprising a material selected from the group consisting of: titanium carbonitride; tungsten carbide; zirconium nitride; titanium aluminum nitride; mixtures of chromium, boron carbide and silicon carbide; mixtures of titanium diboride and chromium; mixtures of titanium diboride and titanium carbonitride; and mixtures thereof. The coating is then covered with a film that is preferably a fluorocarbon polymer and more preferably Vydax®.

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COATED CUTTING TOOL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to coatings for shaving razor blades and for cutting tools generally, and to processes for preparing such coated shaving razors or cutting tools.

2. Description of Related Art

As referred to in this disclosure, a "razor" is defined as a self-contained shaving unit having at least one blade, a blade support, a guard surface attached to the blade support and extending outwardly from the support below the blade or blades, and a cap covering and protecting the blade or blades. The support and cap combine to maintain the blade or blades in a predetermined shaving position. The razor can include an attached disposable handle to provide a disposable razor per se or it may be in the form of a disposable cartridge for use with an interchangeable handle. In both instances the disposable cartridge and the razor head of the disposable razor are substantially identical. The term "razor" may also refer to injector mechanisms of other single or double edge shaving mechanisms as well.

The blades utilized in modern shaving razors incorporate a plurality of features that interact to provide efficient and comfortable shaving action. A shaving razor blade is far sharper than an ordinary industrial razor blade or knife. This sharpness can be expressed and measured in terms of the "ultimate tip radius". Shaving razor blades ordinarily have ultimate tip radii of about 500-600 Angstroms or less, whereas industrial razor blades, cutting knives and the like ordinarily have ultimate tip radii of several thousand Angstroms. Moreover, modern shaving razor blades have lubricant coatings, such as coatings of fluorocarbon

polymers on their cutting edges. The lubricant decreases the frictional forces created by engagement of the blade with the individual whiskers, and hence materially reduces the drag or "pull" experienced by the user upon shaving. Because the requirements for a shaving razor are specialized when compared to other types of cutting tools, it is not always easy to predict properties of a shaving razor based on a cutting tool having similar features.

To be considered satisfactory by modern standards, a shaving razor blade should remain usable for many shaves. The blade should retain a keen edge and should retain its lubricant during these repeated shaves, despite exposure to the physical effects of contact with the beard and skin, and despite exposure to the chemical effects of water, soaps and the like encountered in the shaving environment. The shaving razor blade must be adapted for efficient and economical mass production. It must withstand shipment, storage and handling under ordinary conditions without special care. All of these factors together create a formidable technical challenge.

Typically, razor blade cutting edges are coated with a thin metal coating that provides enhanced durability and corrosion resistance to the underlying stainless steel substrate. This coating, usually chromium or a chromium/platinum alloy, is deposited at a thickness of only a few hundred angstroms, keeping the ultimate tip radius of curvature to about 500 angstroms in order to maintain blade sharpness. After the metal coating is applied, a fluoropolymer film may be applied to the blade edge to provide comfort while shaving. The bonding forces between the thin film and the substrate and between the thin coating and the polymer film should be greater than the mechanical forces experienced at the blade edge while shaving. If the mechanical forces exceed either of the bonding forces, the polymer film can delaminate from the thin film, or the thin coating can

delaminate from the substrate, taking the polymer film along with it. Both conditions lead to nicks, cuts and severe degradation of shaving comfort. Any potential coating material must therefore adhere well to the substrate and also demonstrate good adherence with the polymer overcoat. Chromium and chromium/platinum alloys demonstrate these favorable adhesive properties, but the search for other less expensive and more facile coatings continues.

Important parameters such as blade durability, comfort, and safety are affected by the type of thin film coating material and application technique used. Coatings of certain metallic, intermetallic, and ceramic compounds that are much harder than the chromium or chromium/platinum alloys, and which offer sufficient adherence to the substrate and polymer film, are capable of demonstrating improved shaving characteristics over the chromium or chromium/platinum coatings.

Typical modern shaving razor blades incorporate a substrate of stainless steel, such as an iron and chromium- containing martensitic stainless steel, together with a hard coating of chromium or chromium nitride overlying the stainless steel substrate at least along the cutting edge of the blade. The fluoropolymer lubricant, such as polytetrafluoroethylene, overlies the hard coating and adheres thereto. The hard coating may be on the order of a few hundred Angstroms thick.

The hard coating is applied by a process known as sputtering. As further discussed hereinbelow, sputtering ordinarily is conducted under a controlled atmosphere, typically a noble gas at extremely low pressures. Following the sputtering process, the semifinished blades, with the hard coating thereon, are removed from the controlled atmosphere. The blades are coated with the lubricant by applying a dispersion of the fluorocarbon polymer in a fugitive liquid solvent,

evaporating off the solvent and then fusing the remaining lubricant by heating. Although the fusing step typically is conducted in an inert atmosphere, the blades are exposed to ordinary room air during application of the lubricant dispersion, and during any storage period between application of the hard coating and application of the lubricant dispersion.

Razors incorporating blades according to this general construction have been regarded heretofore as superior in that they provide a good combination of shaving performance, durability and low cost. Nonetheless, still further improvements have been needed.

One avenue of research in the razor art has been directed toward the development of a hard coating that could be used as a substitute for chromium in the blade. Ordinary cutting tools become dull and unusable due to gradual abrasive wear of their cutting edges. Resistance to this type of wear typically is related directly to hardness and adhesion of the various layers to each adjacent layer. The brittleness of the blade also affects the durability of the blade. These characteristics are all part of the "wear resistance" of the blade. Chromium has been used as a coating to increase the overall hardness of the cutting tool, and this approach has been tried with razor blades. There are, however many materials harder than chromium. In theory, any such hard material might be a candidate for experimentation. However, shaving razor blade cutting edges normally do not become dull in the same manner as cutting tools. The very sharp, thin edges of shaving razor blades normally become dull due to microscopic fractures of the edge brought on by the extra thinness of blade. Therefore, hardness alone does not always correlate well with blade edge durability in a shaving razor blade.

A shaving razor blade coating must also be compatible with the lubricant film and with the processes

used to apply the lubricant. In particular, the lubricant must adhere to the hard coating to provide a durable lubricating effect in use. Adhesion between hard coating materials and lubricants is not predictable. Many otherwise suitable hard coating materials are incompatible with lubricants in that the lubricant will not adhere satisfactorily. Of course, the coating must also be compatible with the underlying substrate. For these and other reasons, the search for better hard coatings for use in shaving razor blades has not been fully successful heretofore.

Others have tried to bond the fluoropolymer film to the coating and the coating to the substrate using various techniques. For example, in U.S. Patent No. 4,102,046, issued July 25, 1978, bis-(chloroalkyl) vinyl phosphonates were added to a fluorocarbon to provide stronger adherence to coatings consisting of alumina, silica, tungsten, titanium or tantalum. While the modified polymer did apparently bond to the coatings, the adherence to tungsten and titanium proved to be the least satisfactory of those tested.

In U.S. Patent No. 4,208,471, issued June 17, 1980, hydroxy-functional, cyclic polysiloxane resins and compounds of the formula $CH_2CRCOOCH_2CHCH_2$, wherein R is H or CH_3, were used

O as coating agents over steel, aluminum alloy, aluminum sheeting, tin sheet, tin foil, brass, copper, silver, glass, and acrylic plastic sheets.

U.S. Patent No. 4,933,058, issued June 12, 1990, was directed to a steel blade having a coating of 2000-3000 angstroms of titanium nitride. The patent indicated that suitable coating materials included metal oxides, nitrides, carbides and borides, and mixtures of a metal and an oxide, nitride or carbide thereof. Specific examples of coating materials are alumina (sapphire), tungsten carbide, titanium nitride, boron nitride,

mixtures of boron and boron nitride, and diamond-like carbon. The patent also says that multilayer coatings are also acceptable coatings, such as a first coating of titanium nitride under a second coating of boron/boron nitride and a first coating of chromium or titanium under a seconding coating of diamond-like carbon.

Boron carbide, alone or in combination with silicon has been suggested as a coating material for a razor blade in commonly assigned U.S. Patent Application Serial No. 218,637 filed July 13, 1988. Boron carbide, however, can have various, unpredictable failure modes, so it is not fully appropriate for large-scale commercial development.

Surprisingly, it has been found that certain compounds and mixtures, set out below, have both good hardness and good adhesion properties.

SUMMARY OF THE INVENTION

The invention comprises a cutting tool, e.g., a razor blade, having a substrate. The substrate is covered with a coating comprising a material selected from the group consisting of: titanium carbonitride; tungsten carbide; zirconium nitride; titanium aluminum nitride; mixtures of chromium, boron carbide and silicon carbide; mixtures of titanium diboride and chromium; mixtures of titanium diboride and titanium carbonitride; and mixtures and combinations thereof. The invention also comprises ceramic compounds having a binder of up to 20%, by weight, of metallic compounds. The coating is then covered with a film, preferably a fluorocarbon polymer such as Vydax.

Another embodiment of the invention comprises a cutting tool having a substrate and a film, preferably a fluorocarbon polymer. Disposed between the substrate and the film is a coating having at least two mutually compatible materials, the first material compatible with

at least the substrate and the second material compatible with the film.

Another embodiment of the invention is a method for making a cutting tool comprising the steps of: (a) providing a substrate; (b) placing a coating on the substrate, wherein the coating comprises a material selected from the group consisting of: titanium carbonitride; tungsten carbide; zirconium nitride; titanium aluminum nitride; mixtures of chromium, boron carbide and silicon carbide; mixtures of titanium diboride and chromium; mixtures of titanium diboride and titanium carbonitride; and mixtures and combinations thereof or a ceramic material having up to 20% by weight of a binder; and (c) covering the coating with a film.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional diagram of a fully processed razor blade edge.

Figure 2 is a schematic of the sputtering apparatus used in the Example. Though the vacuum pumping system is not shown, it consists of mechanical roughing pump and cryogenic high vacuum pump.

Figures 3A and 3B show overall performance of blades coated with titanium carbonitride or chromium.

Figures 4A and 4B show comfort levels of blades coated with titanium carbonitride.

Figures 5A and 5B show the closeness level of blades coates with titanium carbonitride.

Figures 6A and 6B show the safety levels of blades coated with titanium carbonitride.

Figures 7A and 7B show the overall performance of blades coated with titanium carbonitride compared with blades coated with tungsten carbide.

Figures 8A and 8B show the comfort levels of blades coated with titanium carbonitride compared with blades coated with tungsten carbide.

Figures 9A and 9B show the closeness levels of blades coates with titanium carbonitride compared with blades coated with tungsten carbide.

Figures 10A and 10B show the safety levels of blades coated with titanium carbonitride compared with blades coated with tungsten coarbide.

Figures 11A and 11B show the overall comparison between blades coated with tungsten carbide and blades coated with chromium.

Figures 12A and 12B show the comfort levels of blades coated with tungsten carbide compared with blades coated with chromium.

Figures 13A and 13B show the closeness levels of blades coated with tungsten carbide compared with blades coated with chromium.

Figures 14A and 14B show the safety levels of blades coated with tungsten carbide compared with blades coated with chromium.

Figures 15A and 15B show the overall comparison of blades coated with zirconium nitride compared with blades coated with chromium.

Figures 16A and 16B show the comfort levels of blades coated with zirconium nitride and blades coated with chromium.

Figures 17A and 17B show the closeness levels of blades coated with zirconium nitride and blades coated with chromium.

Figures 18A and 18B show the safety levels of blades coated with zirconium nitride and blades coated with chromium.

Description of the Preferred Embodiments

As stated above, the invention comprises three components: (a) a substrate; (b) a coating; and (c) a film.

The film is preferably a lubricant desirably comprising a fluorinated polyolefin. Lubricants consisting essentially of polytetrafluoroethylene (PTFE) are particularly preferred. The substrate preferably includes a ferrous alloy, such as a stainless steel, including iron and chromium. Desirably, the hard coating directly overlies the ferrous alloy and adheres thereto.

A blade according to one embodiment of the present invention includes a flat, striplike substrate. The substrate may incorporate substantially any of the materials commonly utilized for conventional razor blades. Of those materials, ferrous metals, such as stainless steels, are preferred. Especially preferred are martensitic stainless steels of the type commonly referred to in the trade as "400-Series." These steels incorporate at least about 80% Fe and at least about 10% chromium. 440A stainless steel, consisting essentially of about 13 to 15% Cr, about 0.7% C and the remainder Fe is particularly preferred.

In the conventional manner, a first rough-honed or rear facet, a second ground facet, and a third fine-honed or forward facet are provided on at least one face of a substrate or at least on one cutting edge. A fine-honed

or forward facet, rough-honed or rear facet, and ground facet also provided on the opposite face of the cutting edge of the substrate. The forward facets and intersect one another at an extremity of the edge. The facets are formed by conventional processes such as grinding, honing and the like. The geometry of the facets may also be conventional, and may be the same as that employed for the facets of a conventional chromium-coated stainless steel razor blade. Typically, the intersecting forward facets of the substrate define an edge radius of no more than about 300 Angstroms. For a double-edge blade, the same arrangement of facets is provided on a second cutting edge opposite from the first-mentioned cutting edge.

After formation of the facets, the blades are cleaned by a conventional wet cleaning process, which may include washing in appropriate solvent solutions to remove debris and grease left as residues from the grinding or honing processes.

Following this preliminary cleaning step, the blade is subject to a sputter cleaning step. Preferably, the blade is arrranged as part of a stack of blades with the faceted or cutting edges and of all of the substrates in the stack aligned. The stack is placed within a chamber of the sputtering apparatus. A conventional vacuum pumping device is actuated to bring the chamber to a low, subatmospheric pressure, typically about 10^{-7} to 10^{-6} mmHg, whereupon a conventional gas supply apparatus is actuated to fill the chamber with a noble gas such as argon and to maintain the pressure in the chamber at about 10^{-3} to 10^{-2} mmHg. A sputtering power supply is then actuated to apply an alternating radio frequency ("RF") or direct current ("DC") potential between the stack of substrates and the chamber ground. Ordinarily, the power density applied may be about 0.1 watts cm^2 to about 1.0 watts/cm^2, based on the projected area of the long sides of the stack, i.e., the area of the stack

projected in the planes defined by the cutting edges. The alternating potential creates an electrical discharge within the low pressure gas inside the chamber, thus converting the gas to a plasma or mixture of positively charged ions and the electrons. Due to the well-known "diode effect" of the plasma, the stack of substrates assumes a negative potential with respect to the plasma. Under the influence of this potential, positively charged ions from the plasma bombard the exposed edges of the substrates. Alternatively, the power supply may be arranged to provide a negative DC potential to the substrates, with or without an alternating or RF potential. A DC potential will likewise cause an electrical discharge and will likewise cause bombardment of the substrates by ions from the plasma. With either DC or RF sputter cleaning, the bombarding ions dislodge unwanted material from the surfaces of facets.

The dislodged material, in the form of highly energetic neutral atoms, passes into the vapor state and passes from the chamber or is deposited on the walls of the chamber. This sputtering action removes trace contaminants from the surfaces of the substrates, particularly at the facets. It is important to continue this sputter cleaning of contaminants for some time. In particular, it is desirable to remove in the sputter cleaning step any traces of oxygen remaining at these surfaces. Although stainless steels are ordinarily considered oxidation resistant materials, it should be appreciated that the surface of a stainless steel substrate -- the first few atomic layers forming the boundary between the substrate and the surroundings -- may incorporate substantial adsorbed oxygen, iron oxides, such as chromium oxides or combinations of these if the substrates have been exposed to the ordinary room atmosphere. This sputter cleaning step removes these first few atomic layers and hence removes adsorbed oxygen, oxides and other contaminants. The time required to achieve an acceptable degree of surface cleanliness

will vary depending upon the gas pressure, the applied power and the physical configuration of the sputtering apparatus. Typically, at least about five minutes to about fifty minutes or more, and more typically about ten minutes to about thirty minutes will provide substrate facet surfaces essentially free of either uncombined or oxide-form oxygen and essentially free of other contaminants as well.

Following the sputter cleaning step, the substrates are subjected to a sputter coating step. The substrates are maintained in a non-oxidizing atmosphere such as a noble or reducing gas or a high vacuum between these steps. Typically, the sputter coating step is conducted in the same apparatus as employed for the sputter cleaning step, and the sputter coating step is conducted immediately after the sputter cleaning step.

The sputter coating step is also conducted utilizing a noble gas atmosphere such as argon or may use nitrogen or some other gas. Preferably, the sputter coating step is performed at between aobut 10^{-3} and 10^{-2} mmHg pressure, and more preferably at about 4×10^{-3} mmHg pressure. In the sputter coating step, the targets confront the edges of the stacked substrates. Each target incorporates the material to be deposited as a hard coating on the substrates. Preferrably, targets may contain a binder.

Binders are materials added to targets to increase the thermal conductivity of the target. In commercial applications, DC magnetron sputtering is preferred due to the high deposition rates obtained. This technique, however, causes thermal shock to the target, and binders, usually metals, fill in crystal voids between the molecules of ceramic to bind the system. Preferably, binders are selected from the following materials, _____, more preferrably from _____, and most preferrably from cobalt and nickel and mixtures thereof.

Preferrably binders are present in an amount of less than about 20% by weight of the target, more preferably about 5-15% by weight and most preferably about 10% by weight.

Each target is retained on a conventional target holder of the type commonly employed in a sputtering apparatus. During the sputter coating operation, the power supply is actuated to maintain the stack of blades at the ground potential and to apply an RF potential between the targets and the chamber wall. Once again, the applied RF potential creates an electrical discharge in the gas within the chamber so as to convert the gas to a plasma. Under the influence of the diode effect, the targets assume a negative potential with respect to the plasma, so that positively charged ions from the plasma bombard each target and dislodge material therefrom. DC potential may be applied instead of RF potential if the target is an electrical conductor or in conjunction therewith. Further, the sputtering apparatus and techniques may employ well-known sputtering expedients. For example, a magnetic field may be applied in the vicinity of the target to enhance the sputtering by the well-known magnetron effect. Also, the stack of substrates and/or targets may move relative to one another so as to enhance uniformity of sputtering conditions along the length of each cutting edge.

The material dislodged from the targets deposits on the substrates, and particularly upon the exposed cutting edges therof as a coating directly overlying the ferrous material of the substrates and adhering thereto. The material from the target deposits as a substantially homogeneous, amorphous coating. Because the substrates are arranged in a stack as shown during the sputter coating step, the sputtered atoms pass generally forwardly-to-rearwardly with respect to each cutting edge of substrate before impinging on the substrate. Each layer projects in a forward direction beyond the extremity of the blade, so that the two layers merge with one another. The merged layers define the ultimate tip

or extremity of the cutting edge. The hard coating on the second cutting edge of each blade is substantially the same.

As used herein with reference to a hard coating layer overlying a substrate surface, the term "thickness" refers to the dimension perpendicular to the plane of the underlying surface. The thickness of each hard coating layer decreases progressively in the rearward direction, away from the ultimate tip of the cutting edge. Preferably, the average thickness of each hard coating layer on the forward facets closest to the forward extremity of the substrate is betwen about 100 and about 400 Angstroms, more preferably between about 150 and about 300 Angstroms, and most preferably between about 200 and 250 Angstroms. The tip to tip dimension or forward to rearward dimension d between the forwardmost extremity of the substrate and the forwardmost extremity of the hard coating desirably is between about 200 and about 900 Angstroms, more preferably between about 300 and 700 Angstroms, and most preferably between aobut 500 and about 600 Angstroms. Both the average coating thickness and the tip to tip distance increase as the sputter coating process progresses.

The time required to deposit the hard coating material to the desired coating thickness and tip to tip distance will depend upon the geometry of the sputtering apparatus, the gas pressure and the power applied.

The factors governing the deposition rate of various materials in sputtering processes in general are well known to those skilled in the sputtering art, and the same factors apply in the present sputter coating step. Merely by way of example, higher sputtering power input tends to produce a higher deposition rate. Under typical conditions however, employing about 1 to about 30, and desirably about 6, watts/cm^2 RF sputtering power input based upon the sputtered area of the target, the

deposition process can be completed in between about 5 minutes and aobut 50 minutes, typically between about 20 minutes and about 40 minutes and most preferably in about 30 minutes. Sputtering processes which deposit coatings of the preferred thicknesses mentioned above within the preferred times generally do not cause overheating or other adverse effects on the substrates or the coatings.

Provided that the facet surfaces are scrupulously cleaned during the sputter cleaning step, the hard coating may adhere tenaciously to the facet surfaces. Ordinarily, no special sputtering techniques or steps, apart from the thorough sputter cleaning step, needs to be employed to provide good adhesion. As is well known in the sputtering art, adhesion between a coating and the substrates may be enhanced by techniques such as ion implantation, wherein some of the sputtered target material is ionized and accelerated towards the substrate across an applied electrical potential. Such known additional techniques, however, are generally unnecessary.

The semi-finished blades resulting from the sputter coating step, incorporating the substrates with the hard coatings thereon, are removed from the sputtering chamber. A polymeric lubricant is then deposited on the blades, for example by contacting the blades with a dispersion of the polymer in a fugitive liquid carrier.

The dispersion may be sprayed from a conventional spray nozzle onto the exposed cutting edges of the blades. Dipping or other conventional liquid application techniques may be employed as alternates to spraying. Where the polymer is in powder form, conventional powder application techniques can be used. The polymer deposition step and any storage and handling between hard coating and polymer deposition may be conducted in an ordinary air atmosphere. Following the polymer deposition step, the blades are subjected to heat

treatment in a conventional industrial oven arranged with a gas supply apparatus. The gas supply apparatus is operated to maintain a non-oxidizing atomosphere such as a reducing or inert atmosphere within the oven during the heat treatment. The heat treatment is conducted at or above the melting temperature of the polymer, and preferably at about the melting temperature of the polymer, for a period sufficient to fuse the lubricant into a coherent lubricant coating overlying the hard coating. The thickness of the lubricant coating will depend upon the amount of lubricant applied. Preferably, the amount of lubricant applied is the minimum amount required to form a coherent coating on those portions of the hard coating overlying the forwardmost facets. Although some lubricant may be applied on other areas of the blade, the same is not essential.

The lubricant preferably is a fluorinated polyolefin or a copolymer or blend including the fluorinated polyolefin. Most preferably, it is Vydax. Thus, the lubricant preferably includes polymers having a main chain or backbone composed principally of - CF_2- repeating units. The lubricant more preferably includes polytetrafluoroethylene ("PTFE"), and most desirably consists essentially of PTFE. The molecular weight of the PTFE desirably is from about 10,000 to about 50,000, and about 30,000, is especially preferred. One suitable dispersion of a 30,000 molecular weight PTFE in a volatile fluorocarbon solvent is commercially available under the registered trademark VIDAX 1000 from the DuPont Company of Wilmington, Delaware, USA. Other PTFE dispersions are available under the registerd trademark Fluron from ICI Chemical Industries of Great Britain. Higher molecular weight PTFE suitable for use in the present process is sold under the registered trademark Teflon by the Dupont Company.

As noted above, the deposited hard coating material defines the ultimate tip of 42 of the cutting edge of the

blade. The sharpness of the edge at this ultimate tip can be expressed in terms of the ultimate tip radius R, which is the radius of curvature of the hard coating surface at the tip. the ultimate tip radius R normally is measured by use of a scanning electron microsope. The lubricant, however, is not considered in measurement of the ultimate tip radius. As used in this disclosure with reference to a lubricant-coated blade, the term "ultimate tip radius" should be understood as referring to the radius exclusive of the lubricant.

Chromium or chromium/platinum alloy coatings have been the standard in the industry for many years. The coating has been successful due to the fact that not only does it adhere well to the stainless steel blade edge, but the fluoropolymer coating that is deposited on top of the chromium or chromium/platinum alloy razors adheres well to the chromium or chromium/platinum alloy. This fluoropolymer coating provides the extra comfort. Loss of this fluoropolymer coating during use results in a blade that "pulls" uncomfortably at the whiskers, rendering the blade less comfortable to use. Loss of the fluoropolymer coating can occur in two ways. First, the coating supporting the fluoropolymer can delaminate from the substrate. The fluoropolymer film is also then lost, since the fluoropolymer coating is on top of the hard coating. Second, the fluoropolymer can delaminate from the coating. Hence, for any hard coating to enhance shave characteristics, it must demonstrate high affinity for both the stainless steel substrate and the fluoropolymer film.

Many hard, refractory materials have been investigated by the industry for use as coatings on cutting tools. Many of these materials demonstrate poor adhesion with the substrate, which either eliminates them as candidates or necessitates the introduction of an intermediate coating layer to promote adhesion. Other materials demonstrate relatively high adherence with the

substrate, only to be eliminated as candidates for an acceptable coating when the fluoropolymer film fails to sufficiently adhere to the coating. This invention provides a single layer coating of a material much harder than chromium or chromium/platinum alloy, that adheres well to the substrate and also adheres well to the fluoropolymer coating.

One material of interest for the application is Titanium Carbide, an extremely hard refractory material. Titanium Carbide, when sputter deposited on blade edges demonstrates sufficient adherence with the substrate. However, due to insufficient adhesion with the fluoropolymer film, after two or three shaves a blade with a Titanium carbide coating has its shaving comfort degraded to an unacceptable level.

When sputter depositions were conducted using Titanium Carbide targets in the standard inert Argon atmosphere with the addition of a partial pressure of nitrogen gas in order to allow the formation of the Titanium Carbonitride phase however, better results were obtained. This film, while demonstrating similar hardness to that of the Titanium Carbide phase, showed enhanced adherence to the substrate, and, surprisingly, very good adherence with the fluoropolymer coating.

In shave testing, blades with this Titanium Carbonitride coating out-performed blades coated with a standard chromium coating.

There are four basic methods to structure the thin film to obtain optimum performance.

1. **Simple Single Layer Film** - as implied, a single layer of homogeneous element or compound is deposited on the blade edge, followed by the application of the polymer coating.

2. **Complex Single Layer Film** - a single layer is deposited on the substrate, but this single layer is made up of two or more compounds. This enables performance optimization of the components. Components of this complex layer can be deposited from a single source or two or more sources may be activated simultaneously to produce the film. This coating step is followed by the application of the polymer film.

3. **Discrete Multilayer Film** - two or more distinct and discrete layers, each made up of one or more elements or compounds, or mixtures of elements and compounds, are applied to the substrate. With this technique, different physical properties can be utilized at different levels of the coating system for optimum performance (ie: a layer "A", which displays superior adherence to the stainless steel substrate might be deposited, followed by the deposition of a layer "B", which demonstrates superior adherence to both layer "A" **and** the polymer film). This is followed by the application of the polymer coating. Of course, layer "A" must have good adherence to layer "B" for this technique to be significant.

4. **Gradient Multilayer Film** - a coating system similar to the above multilayer film, except that instead of well defined, "discrete" or abrupt layer changes, the interfaces are mixed or "graded", due to the brief, simultaneous deposition of the materials that form layer "A", and the materials that form layer "B". this gradient step is done between deposition of layer "A" and "B". This "interlocking" of layers provides a more mechanically sound thin film structure, especially when the adhesion between two particular discrete layers would be less than optimal. This is followed by the application of the polymer coating.

There are many well established deposition techniques understood by those skilled in the art. Those

discussed in detail by way of example, are so discussed for the purpose of example, and should not be construed as a preferred or technologically imposed method.

The various equipment for carrying out the deposition of thin film systems is well understood by those knowledgeable in the art and is available from a variety of vendors in complete, computer controlled, production capable form.

Deposition techniques suitable for use with the invention are, but are not limited to, the following:

Sputtering (RF, DC RF Magnetron, DC Magnetron);
Reactive Sputtering (RF, DC, RF Magnetron, DC Magnetron);
Ion Beam Sputtering;
Ion Plating;
Electron Beam Gun Evaporation or Sublimation;
Electron Beam Gun Reactive Evaporation or Sublimation;
Resistive Evaporation;
Resistive Reactive Evaporation;
Cathodic Arc Evaporation; and
Chemical Vapor Deposition.

The above deposition techniques can be supplemented by additional ion bombardment from an ion beam gun either in inert mode (to modify thin film mechanical structure via bombardment with inert gas ions, esp. Argon), or in reactive mode (to modify the stoichiometry of the thin film via bombardment with reactive gas species, esp. O_2, N_2, and hydrocarbons).

The following thin film systems are suitable hard coatings for razor blade edges in accordance with the invention:

Tungsten Carbide;
Titanium Carbonitride;
Zirconium Nitride;

Titanium Aluminum Nitride; and
Chromium/Boron Carbide - Silicon Carbide Multilayer.

Based on the foregoing, the following coatings are expected to work in accordance with the invention:

Chromium/Diamond-Like Carbon Multilayer;
Titanium Diboride/Chromium Multilayer;
Titanium Diboride/Titanium Carbonitride Composite; and
Cermaics Containing Binders.

The following experimental description is included to serve as an example only, and is not intended to impose limits on the process parameters or deposition technique.

Example 1 - Titanium Carbonitride

A stack of razor blades was placed in a vacuum sputtering apparatus, which was subsequently evacuated to a pressure of 1.0×10^{-6} Torr. After achieving this base pressure, Argon gas was admitted into the chamber until a dynamic pressure of 1.0×10^{-3} Torr was attained. At this point, with the razor blades connected to the electrical circuit in such a manner as to serve as the cathode, a 1000 watt, 13.56 mHz RF plasma was initiated, and the blades were bombarded with Argon ions. This surface decontamination step was continued for 10 minutes.

After this step the chamber was again evacuated to the original base pressure. Next, Argon was introduced to the system at a pressure of 15.0×10^{-3} Torr. Nitrogen gas flow was then introduced to bring the combined Ar and N2 pressure to a level of 15.2×10^{-3} Torr. At this point, with the razor blades now connected to electrical ground potential and an RF generator connected to a pair of Titanium Carbide sputtering targets, a 2000 watt, 13.56 mHz plasma was initiated. The sputter deposition process was continued for 30

minutes. The vacuum chamber was then vented to atmosphere and the blades removed.

The razor blades went through standard subsequent processing which included deposition of a fluoropolymer. These blades, when shave tested against standard chromium coated blades, demonstrated superior performance. Tables 3, 4, 5 and 6 (corresponding to Figures 3A, 3B, 4A, 4B, 5A, 5B, 6A and 6B) show the improved performance of the blades of the invention.

Table 3 -- Titanium Carbonitride against chromium -- overall

E = Titanium Carbonitride
C = Chromium

Shave #	1	2	3	4	5	6	7
Sample size	78	77	77	75	75	61	61
Average E	3.97	3.94	3.97	3.92	3.83	3.95	3.77
Average C	3.92	3.91	3.90	3.84	3.72	3.69	3.95
Average E-C	0.05	0.03	0.08	0.08	0.11	0.26	-0.18
Fitted E-C	0.08	0.08	0.07	0.06	0.05	0.04	0.04
Significance	par	par	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 4 -- Titanium Carbonitride against chromium -- comfort

E = Titanium Carbonitride
C = Chromium

Shave #	1	2	3	4	5	6	7
Sample size	78	77	77	75	75	61	61
Average E	3.90	3.86	3.86	3.89	3.80	3.80	3.49
Average C	3.74	3.79	3.79	3.69	3.49	3.61	3.70
Average E-C	0.15	0.06	0.06	0.20	0.31	0.20	-0.21
Fitted E-C	0.17	0.15	0.13	0.11	0.09	0.07	0.05
Significance	dir	dir	*	dir	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 5 -- Titanium Carbonitride against Chromium -- Closeness

E = Titanium Carbonitride
C = Chromium

Shave #	1	2	3	4	5	6	7
Sample size	78	77	77	75	75	61	61
Average E	3.90	3.88	3.97	3.81	3.65	3.87	3.70
Average C	3.86	3.88	3.88	3.81	3.60	3.72	3.85
Average E-C	0.04	0.00	0.09	0.00	0.05	0.15	-0.15
Fitted E-C	0.06	0.05	0.04	0.03	0.02	0.01	0.00
Significance	par	par	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 6 -- Titanium Carbonitride against Chromium -- Safety

E = Titanium Carbonitride
C = Chromium

Shave #	1	2	3	4	5	6	7
Sample size	78	77	77	75	75	61	61
Average E	3.83	3.90	3.99	3.97	3.85	3.98	3.90
Average C	3.91	3.90	3.82	3.92	3.80	3.75	3.92
Average E-C	-0.08	0.00	0.17	0.05	0.05	0.23	-0.02
Fitted E-C	0.00	0.02	0.03	0.05	0.07	0.08	0.10
Significance	par	par	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Example 2 - Tungsten Carbide

A stack of blades was placed in the apparatus of Example I, and subjected to the same pre-deposition ion decontamination treatment. After this treatment a flow of Argon gas was admitted into the chamber and adjusted to provide a chamber pressure of 15 x 10^{-3} Torr. Next, with the RF power leads connected to a pair of Tungsten Carbide targets, a 2000 watt, 13.56 mHz plasma was initiated. The deposition was continued for 30 minutes.

After this hard coating application of Tungsten Carbide, the blades were processed as usual through the subsequent production steps. Physical property tests and shave tests found these blades to exhibit better safety than similar blades coated with chromium. The results are shown in Tables 7-10 (comparing tungsten carbide to Titanium carbonitride) and Tables 11-14 (comparing tungsten carbide to chromium). The results are also shown in Figures 7-14.

Table 7 -- Titanium Carbonitride against Tungsten Carbide -- Overall

E = Titanium Carbonitride
C = Tungsten Carbide

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.97	3.94	3.97	3.92	3.81
Average C	3.72	3.83	3.91	3.72	3.57
Average E-C	0.26	0.10	0.06	0.20	0.24
Fitted E-C	0.18	0.17	0.17	0.17	0.16
Significance	par	**	**	*	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 8 -- Titanium Carbonitride against Tungsten Carbide -- Comfort

E = Titanium Carbonitride
C = Tungsten Carbide

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.90	3.86	3.86	3.89	3.75
Average C	3.42	3.68	3.68	3.55	3.40
Average E-C	0.47	0.18	0.18	0.35	0.35
Fitted E-C	0.34	0.32	0.31	0.29	0.27
Significance	**	**	**	**	*

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 9 -- Titanium Carbonitride against Tungsten Carbide -- Closeness

E = Titanium Carbonitride
C = Tungsten Carbide

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.90	3.88	3.97	3.81	3.67
Average C	3.62	3.68	3.81	3.65	3.44
Average E-C	0.28	0.21	0.17	0.16	0.22
Fitted E-C	0.24	0.22	0.21	0.19	0.18
Significance	*	**	**	**	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 10 -- Titanium Carbonitride against Tungsten Carbide -- Safety

E = Titanium Carbonitride
C = Tungsten Carbide

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.83	3.90	3.99	3.97	3.82
Average C	3.79	3.83	3.91	3.79	3.64
Average E-C	0.04	0.06	0.08	0.19	0.18
Fitted E-C	0.05	0.08	0.11	0.14	0.17
Significance	par	par	dir	dir	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 11 -- Tungsten Carbide against Chromium -- Overall

E = Tungsten Carbide
C = Chromium

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.72	3.83	3.91	3.72	3.57
Average C	3.92	3.91	3.90	3.84	3.74
Average E-C	-0.21	-0.08	0.01	-0.12	-0.17
Fitted E-C	-0.12	-0.12	-0.11	-0.11	-0.10
Significance	par	par	dir	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 12 -- Tungsten Carbide against Chromium -- Comfort

E = Tungsten Carbide
C = Chromium

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.42	3.68	3.68	3.55	3.40
Average C	3.74	3.79	3.79	3.69	3.53
Average E-C	-0.32	-0.12	-0.12	-0.15	-0.13
Fitted E-C	-0.24	-0.20	-0.16	-0.13	-0.09
Significance	*	**	**	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 13 -- Tungsten Carbide against Chromium -- Closeness

E = Tungsten Carbide
C = Chromium

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.62	3.68	3.81	3.65	3.44
Average C	3.86	3.88	3.88	3.81	3.64
Average E-C	-0.24	-0.21	-0.08	-0.16	-0.19
Fitted E-C	-0.21	-0.19	-0.18	-0.16	-0.15
Significance	dir	**	**	dir	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 14 -- Tungsten Carbide against Chromium -- Safety

E = Tungsten Carbide
C = Chromium

Shave #	1	2	3	4	5
Sample size	78	77	77	75	72
Average E	3.79	3.83	3.91	3.79	3.64
Average C	3.91	3.90	3.82	3.92	3.82
Average E-C	-0.12	-0.06	-0.09	-0.13	-0.18
Fitted E-C	-0.05	-0.07	-0.09	-0.11	-0.13
Significance	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Comparative Example 3 - Titanium Carbide

The stack of blades coated with Titanium Carbide were also subjected to a blind two-day shave test on male volunteers. On a scale of 0-6, with 6 being the best rating, the blades were compared for comfort, closeness, safety, and overall evaluation to chromium coated blades. The average results were as follows:

TABLE 14A

	Comfort	Closeness	Safety	Overall
Day 1 TiC	4.08	4.31	4.31	4.23
Day 1 Cr	4.31	4.00	4.38	4.15
Day 2 TiC	3.92	4.15	4.31	4.15
Day 2 Cr	4.31	4.15	4.00	4.23

It is clear that titanium carbide coated blades are less comfortable than chromium coated blades.

Example 4 - Tungsten Carbide

The stack of blades of Example 2 were also subjected to a blind two-day shave test on thirteen male volunteers. On a scale of 0-6, with 6 being the best rating, the coverage scores for the tungsten carbide coated blades and chromium coated blades are as follows:

TABLE 14B

	Comfort	Closeness	Safety	Overall
Day 1 WC	4.08	4.00	4.77	4.15
Day 1 Cr	4.15	3.77	4.00	4.08
Day 2 WC	4.15	4.00	4.62	4.15
Day 2 Cr	4.23	4.15	4.31	4.23

Example 5 - Zirconium Nitride

A stack of razor blades was admitted into the etch chamber of an in-line DC Magnetron sputtering apparatus. This chamber was evacuated to a pressure of 1.0 x 10-6 torr. Argon gas was then introduced to the chamber to a dynamic pressure level of 6 x 10^{-3} torr. A 400 watt RF plasma was then initiated. This blade cleaning process was continued for 5 minutes. Upon completion of the etch process, the sputtering chamber of the in-line system was activated. Nitrogen gas was admitted into the evacuated chamber until a dynamic pressure of 1.6 x 10^{-3} torr was acheived. Argon gas was admitted next until the total pressure of the nitrogen plus the Argon was equal to 12. x 10^{-3} torr. A DC discharge was initiated, and two opposing zirconium magnetron targets were exposed to a power density of approximately 6 watts/cm^3. The blades were moved past the targets on a velocity controlled track and were coated with zirconium nitride. The track speed was adjusted to provide the same film thickness as standard chromium coated blades receive. These blades subsequently went through standard processing to completion. Physical property tests and shave tests revealed that the zirconium nitride coated blades exhibited qualities equal to or superior to the standard chromium coated product. The results are shown in Table 15-18, corresponding to Figures 15-18.

Table 15 -- Zirconium Nitride against Chromium -- Overall

E = Zirconium Nitride
C = Chromium

Shave #	1	2	3	4	5
Sample size	93	92	89	88	87
Average E	4.16	3.96	3.80	3.63	3.40
Average C	4.02	3.97	3.72	3.52	3.44
Average E-C	0.14	-0.01	0.08	0.10	-0.03
Fitted E-C	0.10	0.08	0.05	0.03	0.01
Significance	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 16 -- Zirconium Nitride against Chromium -- Comfort

E = Zirconium Nitride
C = Chromium

Shave #	1	2	3	4	5
Sample size	93	92	89	88	87
Average E	4.18	3.73	3.69	3.56	3.29
Average C	4.03	3.97	3.73	3.45	3.25
Average E-C	0.15	-0.24	-0.04	0.10	-0.03
Fitted E-C	-0.02	-0.01	0.00	0.01	0.02
Significance	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 17 -- Zirconium Nitride against Chromium -- Closeness

E = Zirconium Nitride
C = Chromium

Shave #	1	2	3	4	5
Sample size	93	92	89	88	87
Average E	4.08	3.80	3.60	3.44	3.18
Average C	4.06	3.82	3.69	3.40	3.23
Average E-C	0.01	-0.01	-0.09	0.05	-0.05
Fitted E-C	-0.01	-0.01	0.02	0.02	0.03
Significance	par	par	par	par	par

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Table 18 -- Zirconium Nitride against Chromium -- Safety

E = Zirconium Nitride
C = Chromium

Shave #	1	2	3	4	5
Sample size	93	92	89	88	87
Average E	4.15	3.84	3.82	3.70	3.47
Average C	3.97	3.92	3.71	3.48	3.36
Average E-C	0.18	-0.09	0.11	0.23	0.11
Fitted E-C	0.07	0.09	0.11	0.13	0.14
Significance	par	par	*	*	dir

Key: ** = 95% * = 90% dir = directional (80%)
par=parity

Example 6 - Edge Indentation Analysis

An edge indentation analysis was performed on blades coated with chromium, Tungsten carbide, titanium carbonitride, and zirconium nitride, respectively. An edge indentation analysis is performed by lowering a diamond tipped wedge onto the very edge of a blade and adding a small, known force to the wedge. In this example, the force was 5 grams.

The applied force results in an indentation in the edge of the blade. Multiple indentations were made across a blade to determine an average value. A microscope is then used to measure the length of the indentation in arbitrary units. Stronger edges will result in shorter indentations.

The results are shown in Tables 19 and 20. Smaller numbers indicate better performance.

Table 19 - TiCN, WC and Cr blades

Blade No.	Type	Indentation Number						Average value
		1	2	3	4	5	6	
1	TiCN	2.5	2.7	2.5	2.3	2.3	2.7	2.75
2	TiCN	2.8	2.5	2.4	2.5	2.3	2.4	2.48
3	TiCN	2.4	2.0	2.4	2.4	2.6	2.3	2.35
4	TiCN	2.2	2.0	2.1	2.3	2.3	2.4	2.22
5	Cr	2.5	2.5	2.6	2.6	2.5	2.6	2.55
6	Cr	2.5	2.7	2.8	2.6	2.5	2.6	2.62
7	Cr	2.7	2.7	2.7	2.5	2.5	2.6	2.62
8	Cr	2.7	2.8	2.5	2.6	2.7	2.6	2.65
9	WC	2.3	2.3	2.3	2.3	2.4	2.5	2.35
10	WC	2.3	2.3	2.2	2.1	2.8	2.3	2.33
11	WC	2.2	2.4	2.3	2.4	2.3	2.5	2.35
12	WC	2.2	2.0	2.3	2.2	2.2	2.3	2.20

Table 20 - Cr and ZrN Blades

Blade No.	Type	Indentation No.							Avg. Value
		1	2	3	4	5	6	7	8	
13	Cr	3.1	2.6	2.6	2.7	2.8	2.7	2.7	2.8	2.75

14	Cr	2.9	2.6	2.8	2.6	2.6	3.1	3.0	2.8
2.80									
15	Cr	3.1	3.0	2.6	2.9	2.7	2.8	2.8	3.0
2.86									
16	Cr	3.0	2.8	3.0	2.2	2.8	3.1	3.1	2.6
2.83									
17	Cr	2.8	3.0	2.7	3.0	3.0	2.5	2.6	3.0
2.83									
18	ZrN	2.5	2.9	2.8	2.8	2.6	2.6	2.6	2.5
2.66									
19	ZrN	2.8	2.6	2.9	2.5	2.6	2.6	3.4	2.4
2.73									
20	ZrN	2.4	2.6	2.6	2.8	2.7	2.6	2.9	2.3
2.61									
21	ZrN	2.8	2.5	2.7	2.8	2.4	2.8	2.7	2.5
2.65									
22	ZrN	2.6	2.9	2.6	2.6	2.7	2.6	2.8	2.5
2.66									

Example 7 Felt Cutting Test

Felt cutting is a test used to quantify how strong the edge of a blade is. A blade is used to cut through felt twenty times. Measurements of the force required to cut the felt are made. For food, strong blades, the force required to cut the felt should not increase greatly.

Four sets of 6 blades each coated with chronium were compared with four sets of 6 blades coated with titanium carbonitride. The results are shown on Table 21.

Table 21 - Felt Cutting Test Results (Force in Arbitrary Units)

Cut #	1	2	3	4	5	10	15	20
Cr	28.3	29.4	31.5	34.1	35.7	43.7	52.9	58.9
TiCN	24.0	22.8	23.7	24.3	24.1	26.0	27.1	29.3
Cr	22.0	22.1	21.5	22.0	22.7	23.4	23.7	25.6
TiCN	22.1	21.1	20.7	20.8	20.9	20.8	21.8	22.0
Cr	24.3	23.8	23.0	23.2	24.3	25.2	26.3	27.0
TiCN	19.5	18.8	18.8	19.0	19.4	20.1	21.0	22.6
Cr	26.8	23.9	23.9	24.1	23.6	24.1	25.9	25.3
TiCN	20.7	21.2	21.2	21.1	20.4	21.4	21.5	22.2

Prophetic Example 8

A stack of blades is introduced into a vacuum chamber, which is subsequently evacuated to a pressure of $< 1.0 \times 10^{-6}$ Torr. Argon gas is then admitted and is adjusted to provide a chamber pressure of 1.0×10^{-3} Torr. With the blade stack serving as the cathode in the circuit, a 900 watt, 13.56 mHz plasma is initiated. This pre-deposition ion surface cleaning process is continued for 2 minutes. The blades are then automatically loaded into the next evacuated processing chamber of the sputtering apparatus. Argon gas is then admitted into the process chamber and is adjusted to provide a pressure of 2.0×10^{-3} Torr. At this point, with the blades allowed to float with respect to the electric circuit, and DC high voltage leads connected to chromium magnetron sputtering targets, a 3000 watt plasma is initiated. A chromium deposit of ≈ 200 angstroms thickness is carried out. Next, the DC high voltage is removed from the chromium targets, and is applied instead to composite Boron Carbide - Silicon Carbide magnetron targets. A 3000 watt plasma is initiated. A Boron Carbide - Silicon Carbide film of ≈ 200 angstroms thickness is deposited on top of the chromium.

After this hard coating application of chromium/Boron Carbide - Silicon Carbide, the blades may be processed as usual through the subsequent production steps.

It will be apparent to those skilled in the art that various modifications may be made in the examples set out above without departing from the scope or spirit of the invention.

What is Claimed is:

1. A razor blade comprising:
   (a) a substrate;
   (b) an adherent coating on said substrate, selected from the group consisting of: titanium carbonitride; tungsten carbide; zirconium nitride; titanium aluminum nitride; mixtures of chromium, boron carbide and silicon carbide; mixtures of titanium diboride and chromium; and mixtures thereof; and
   (c) a compatible film on said substrate.

2. The razor blade of Claim 1, wherein said substrate is metallic.

3. The razor blade of Claim 1, wherein the thickness of said adherent coating is less than about 500 angstroms.

4. The razor blade of Claim 1, wherein said adherent coating is substantially uniform in cross-section.

5. The razor blade of Claim 1, wherein said adherent coating is selected from the group consisting of: titanium carbonitride, tungsten carbide, zirconium nitride, titanium aluminum nitride, and mixtures thereof.

6. The razor blade of Claim 1, wherein said adherent coating comprises titanium carbonitride.

7. The razor blade of Claim 1, wherein said adherent coating comprises tungsten carbide.

8. The razor blade of Claim 1, wherein said adherent coating comprises zirconium nitride.

9. The razor blade of Claim 1, wherein said adherent coating comprises titanium aluminum nitride.

10. The razor blade of Claim 1, wherein said adherent coating is selected from the group consisting of: mixtures of chromium, boron carbide and silicon carbide; mixtures of titanium diboride and chromium; and mixtures thereof.

11. The razor blade of Claim 1, wherein said adherent coating comprises a mixture of chromium, boron carbide and silicon carbide.

12. The razor blade of Claim 1, wherein said adherent coating comprises a mixture of titanium diboride and chromium.

13. The razor blade of Claim 1, wherein said compatible film comprises an organic polymer.

14. The razor blade of Claim 1, wherein said compatible film comprises a fluoropolymer.

15. The razor blade of Claim 1, wherein said compatible film comprises Vydax.

16. A method for making a razor blade comprising the steps of:

(a) providing a substrate;

(b) placing a coating on said substrate, wherein said coating comprises a material selected from the group consisting of: titanium carbonitride; tungsten carbide; zirconium nitride; titanium aluminum nitride; mixtures of chromium, boron carbide and silicon carbide; mixture of titanium diboride and chromium; mixtures of titanium diboride and titanium carbonitride; and mixtures thereof; and

(c) covering said coating with a film.

17. The method of Claim 16, wherein said substrate is metallic.

18. The method of Claim 16, wherein the thickness of said coating is less than about 500 angstroms.

19. The method of Claim 16, wherein said coating is substantially uniform in cross section.

20. The method of Claim 16, wherein said coating is not substantially uniform in cross section.

21. The method of Claim 16, wherein said film is an organic polymer.

22. The method of Claim 16, wherein said film comprises a fluorpolymer.

23. The method of Claim 16, wherein said film comprises Vydax.

24. A razor blade comprising

(a) a metallic substrate;

(b) a coating comprising a ceramic and a binder; and

(c) an organic polymer film.

25. The razor blade of Claim 24, wherein said ceramic is a metallic ceramic.

26. The razor blade of Claim 24, wherein said binder is slected from the group consisting of _____.

27. The razor blade of Claim 26, wherein said binder is selected from the group consisting of _____.

28. The razor blade of Claim 24, wherein said binder comprises less than about 20% by weight of said coating.

29. The razor blade of Claim 28, wherein said binder comprises between about 5% and about 15% by weight of said coating.

30. The razor blade of Claim 29, wherein said binder comprises about 10% by weight of said coating.

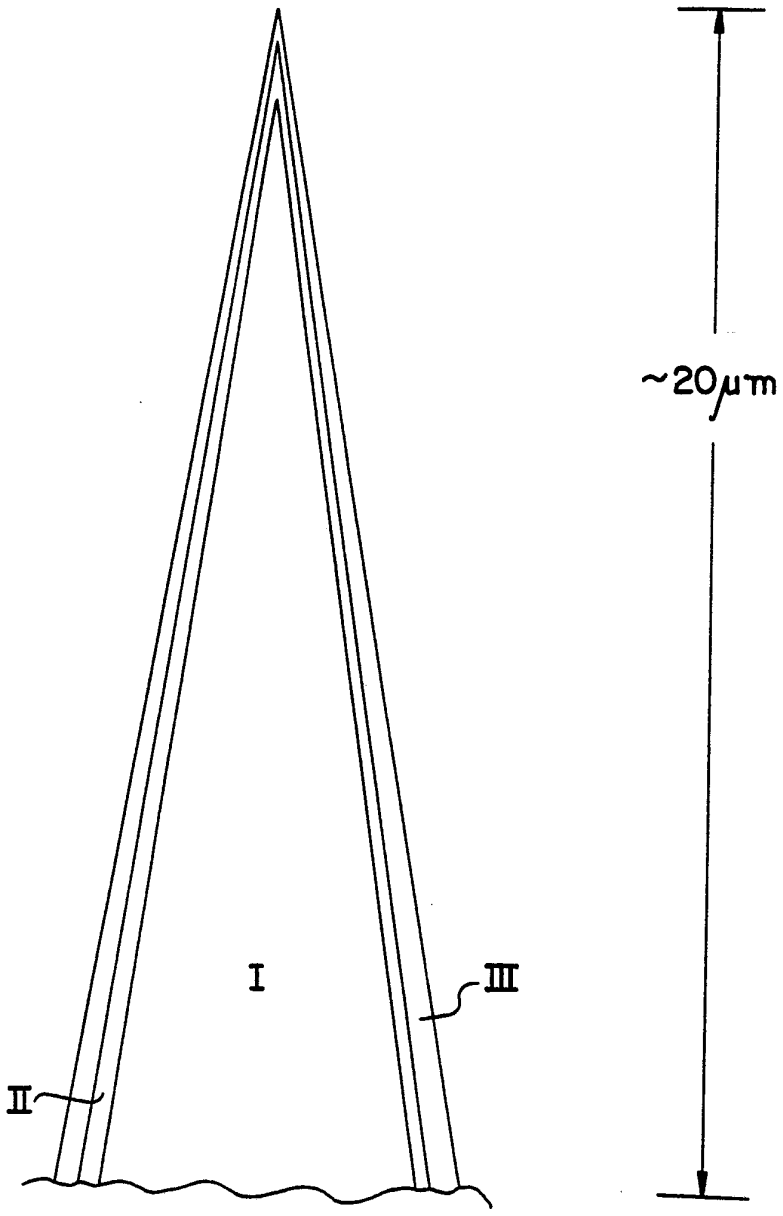


FIG. 1

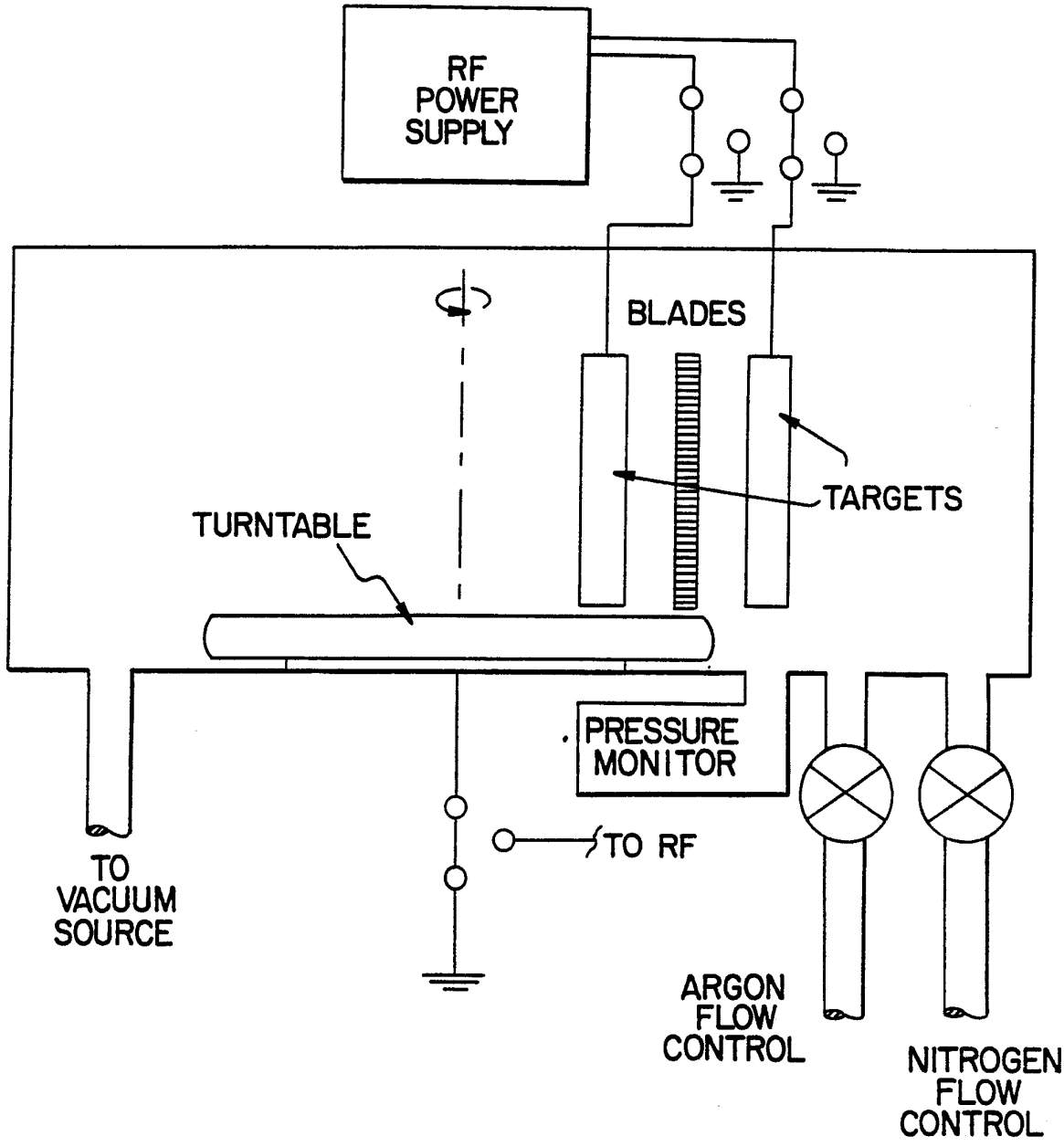

RF
POWER
SUPPLY
BLADES
TARGETS
TURNTABLE
PRESSURE
MONITOR
TO RF
TO
VACUUM
SOURCE
ARGON
FLOW
CONTROL
NITROGEN
FLOW
CONTROL

FIG. 2

FIG. 3A

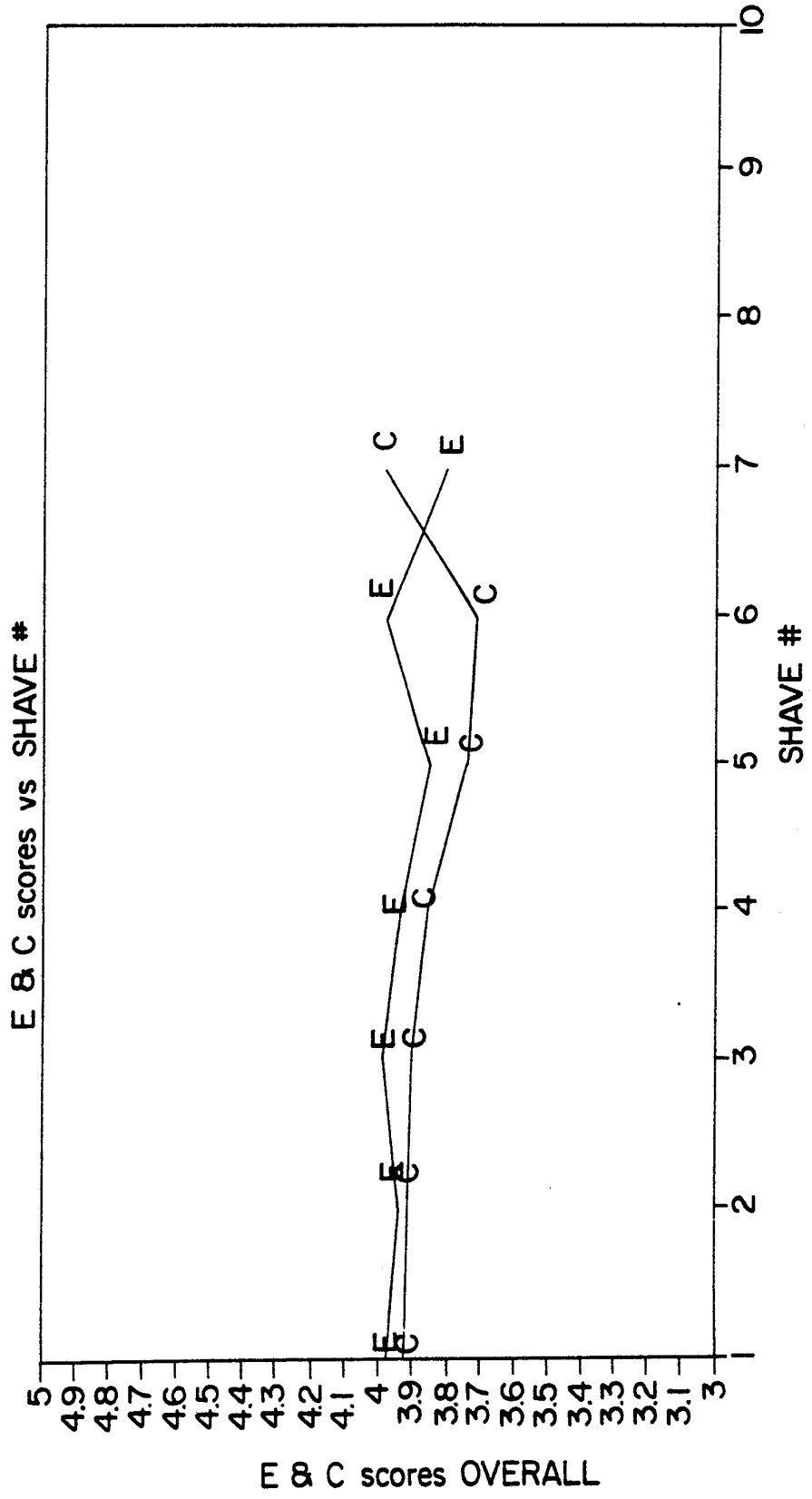

E & C scores vs SHAVE #
E & C scores OVERALL
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
E
C

FIG. 3B

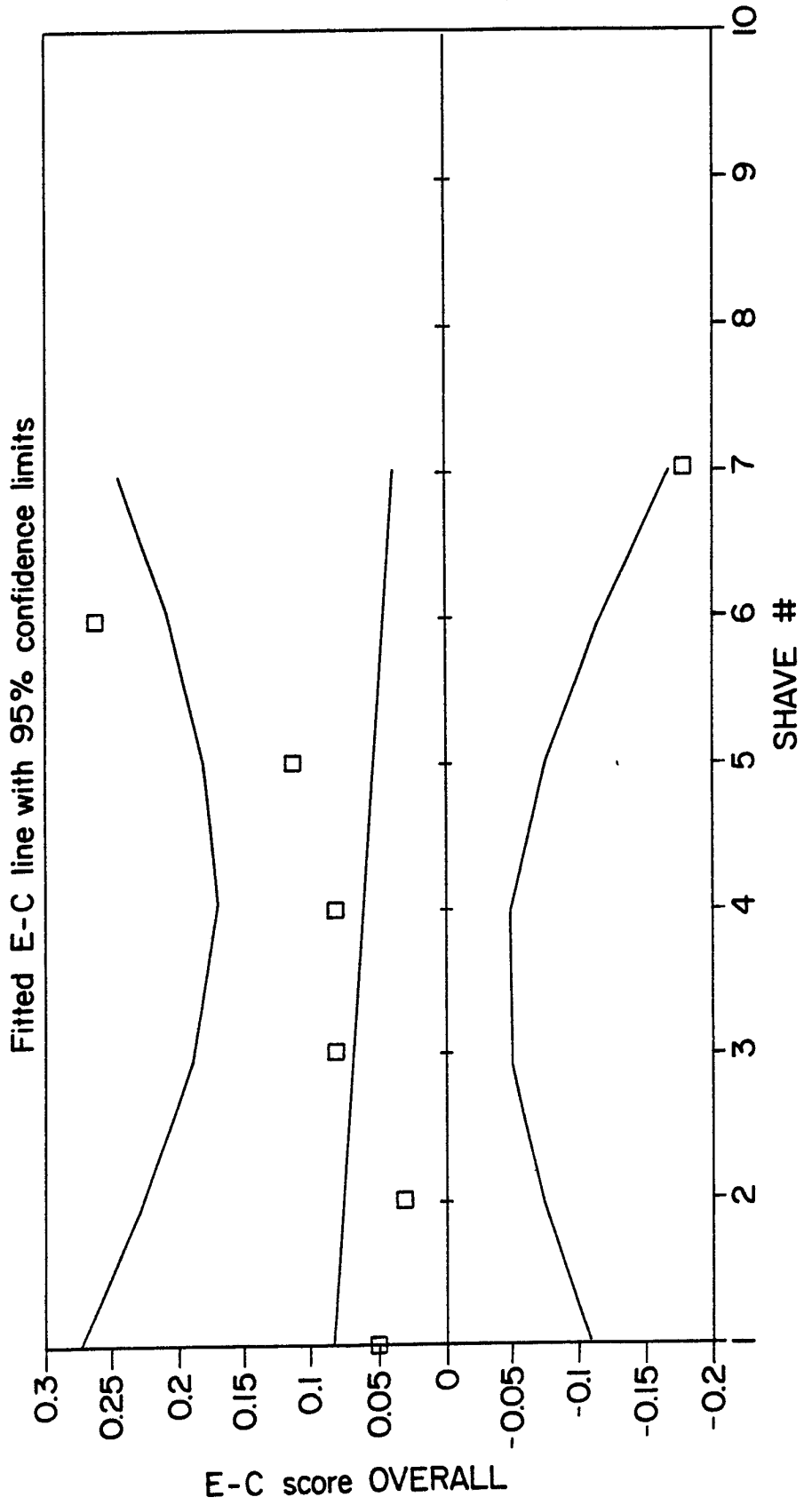

Fitted E-C line with 95% confidence limits
E-C score OVERALL
SHAVE #
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1
2
3
4
5
6
7
8
9
10

FIG. 4A

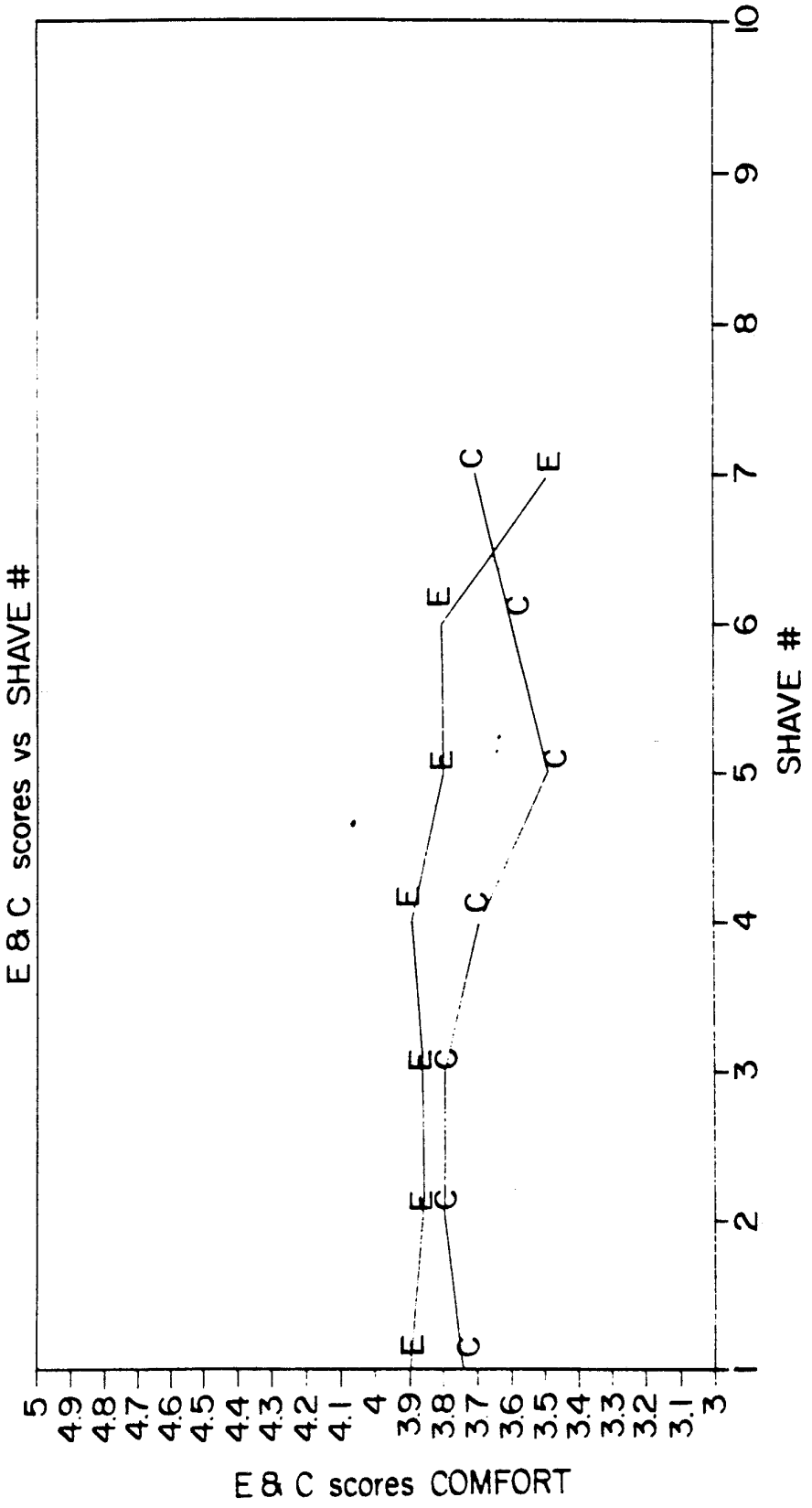

E & C scores vs SHAVE #
E & C scores COMFORT
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
E
C

FIG. 4B

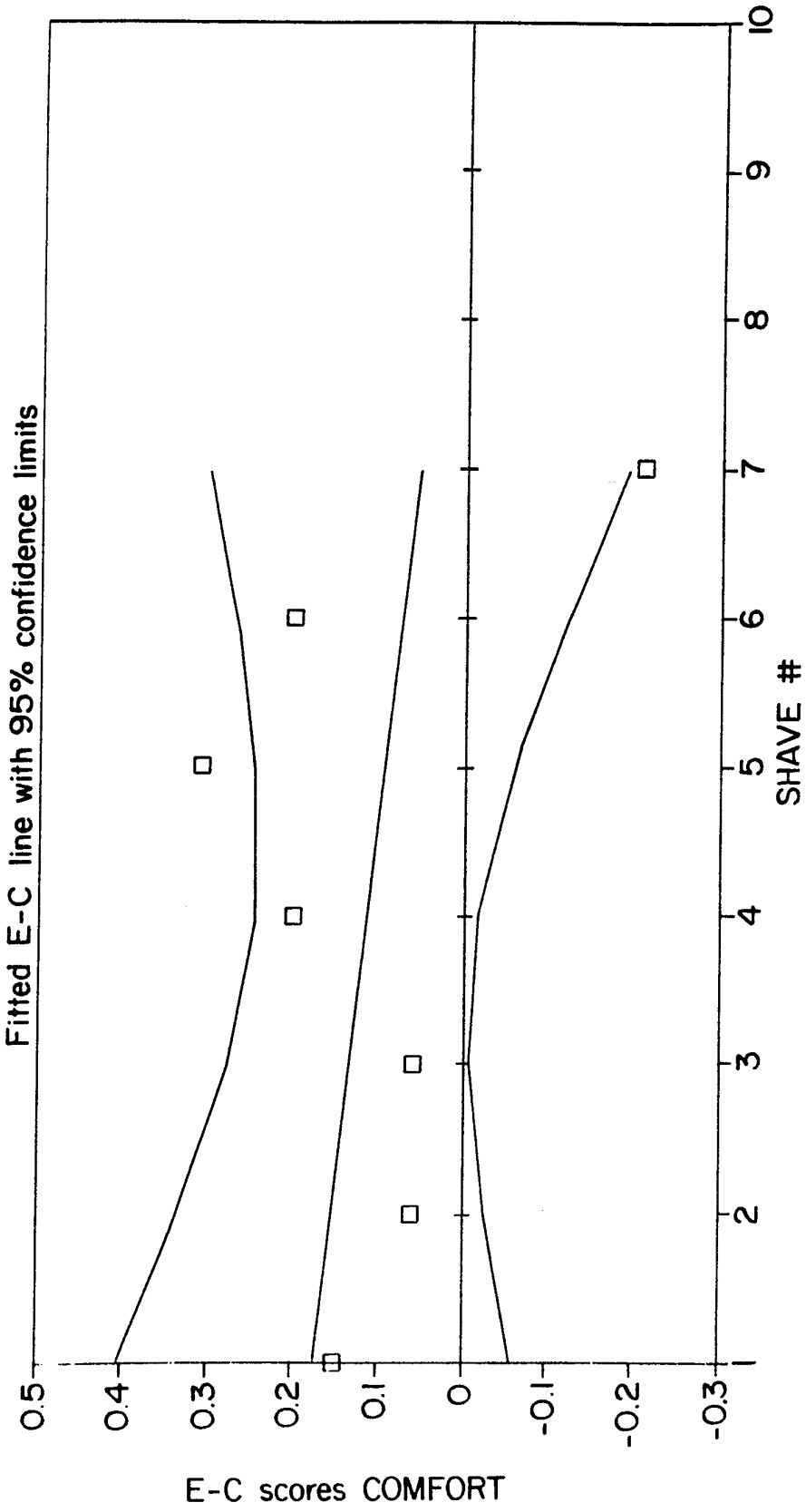

Fitted E-C line with 95% confidence limits
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
E-C scores COMFORT
1
2
3
4
5
6
7
8
9
10
SHAVE #

FIG. 5A

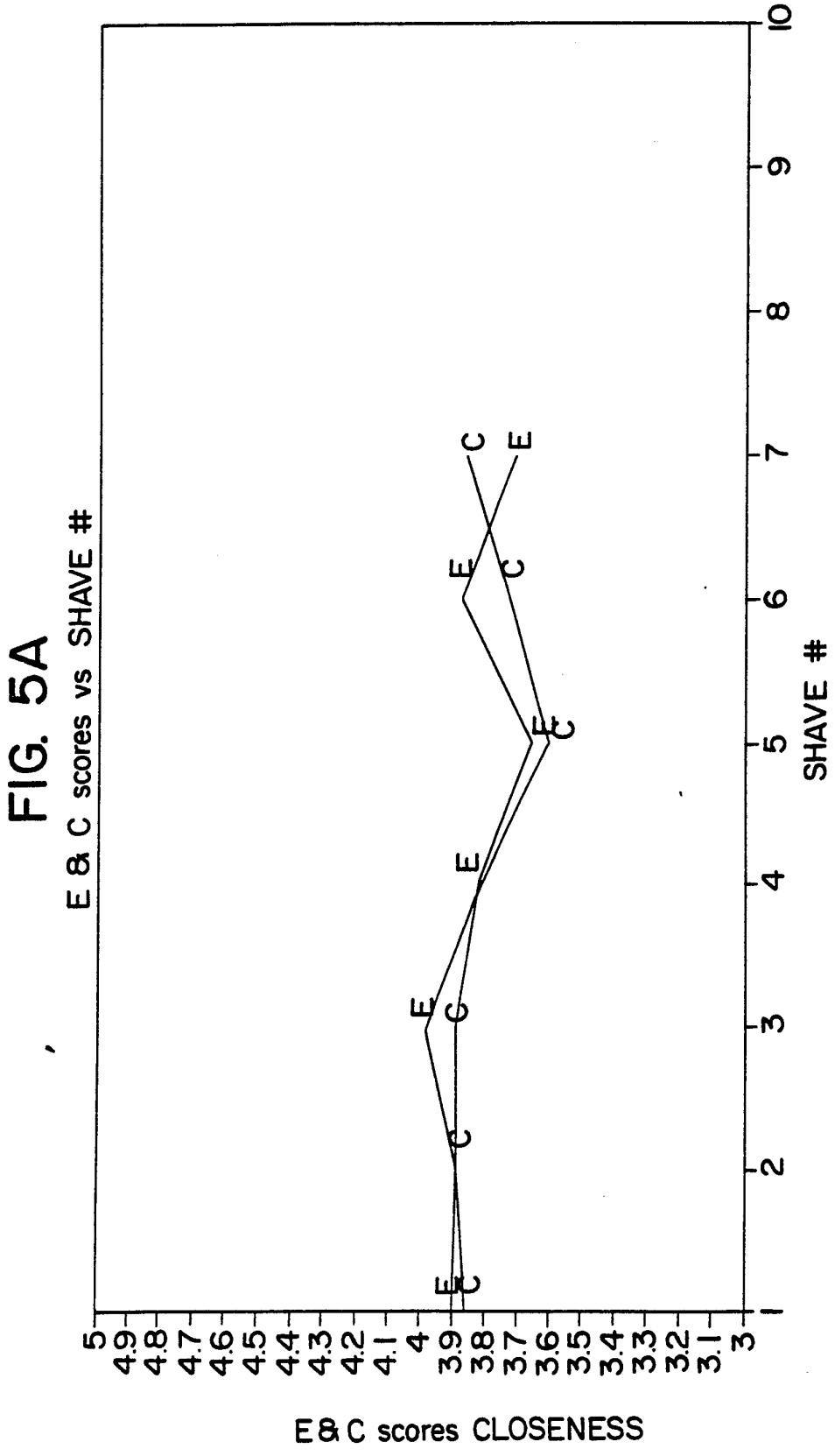

E & C scores vs SHAVE #
SHAVE #
E & C scores CLOSENESS
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E
C

FIG. 5B

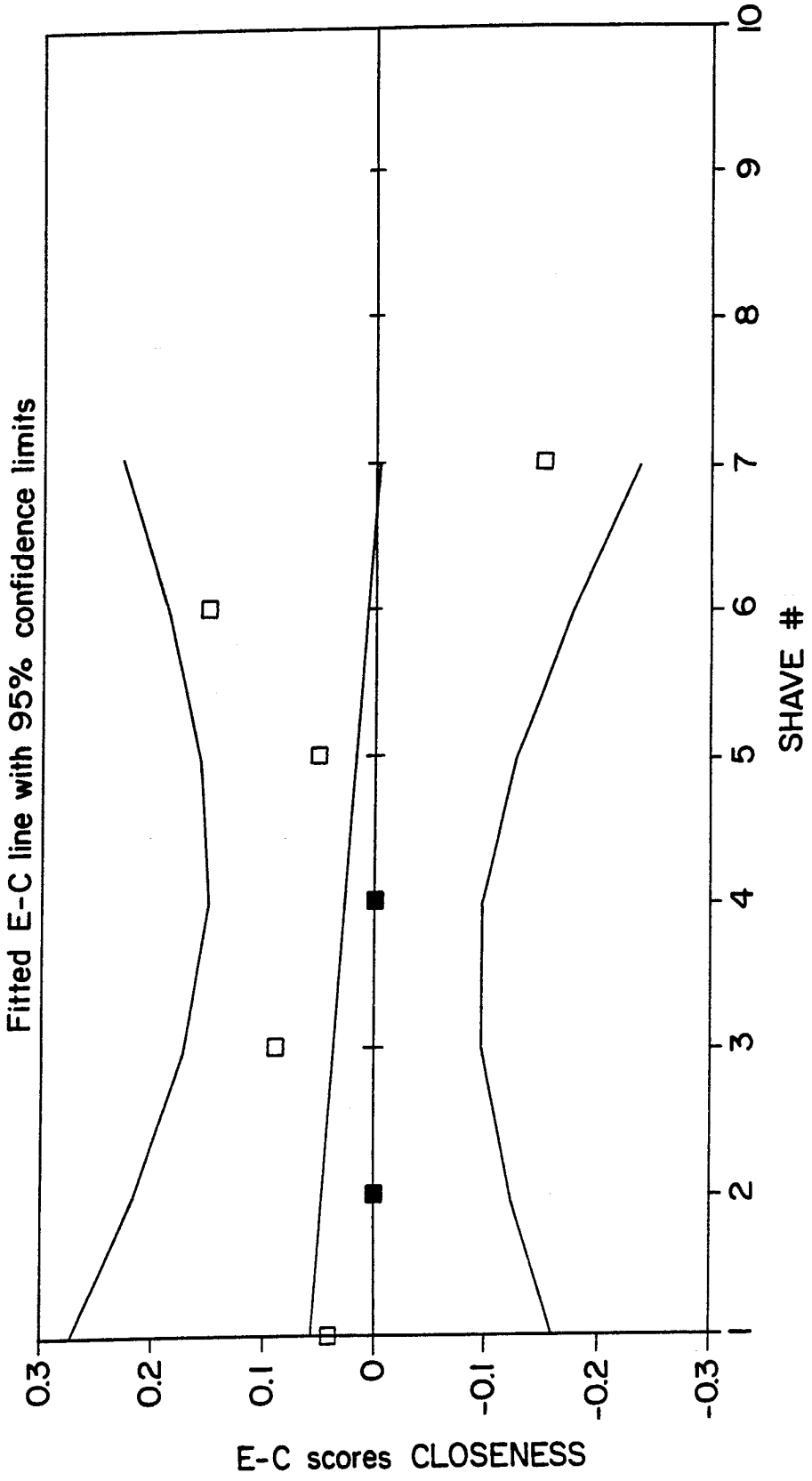

Fitted E-C line with 95% confidence limits
SHAVE #
1
2
3
4
5
6
7
8
9
10
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
E-C scores CLOSENESS

FIG. 6A

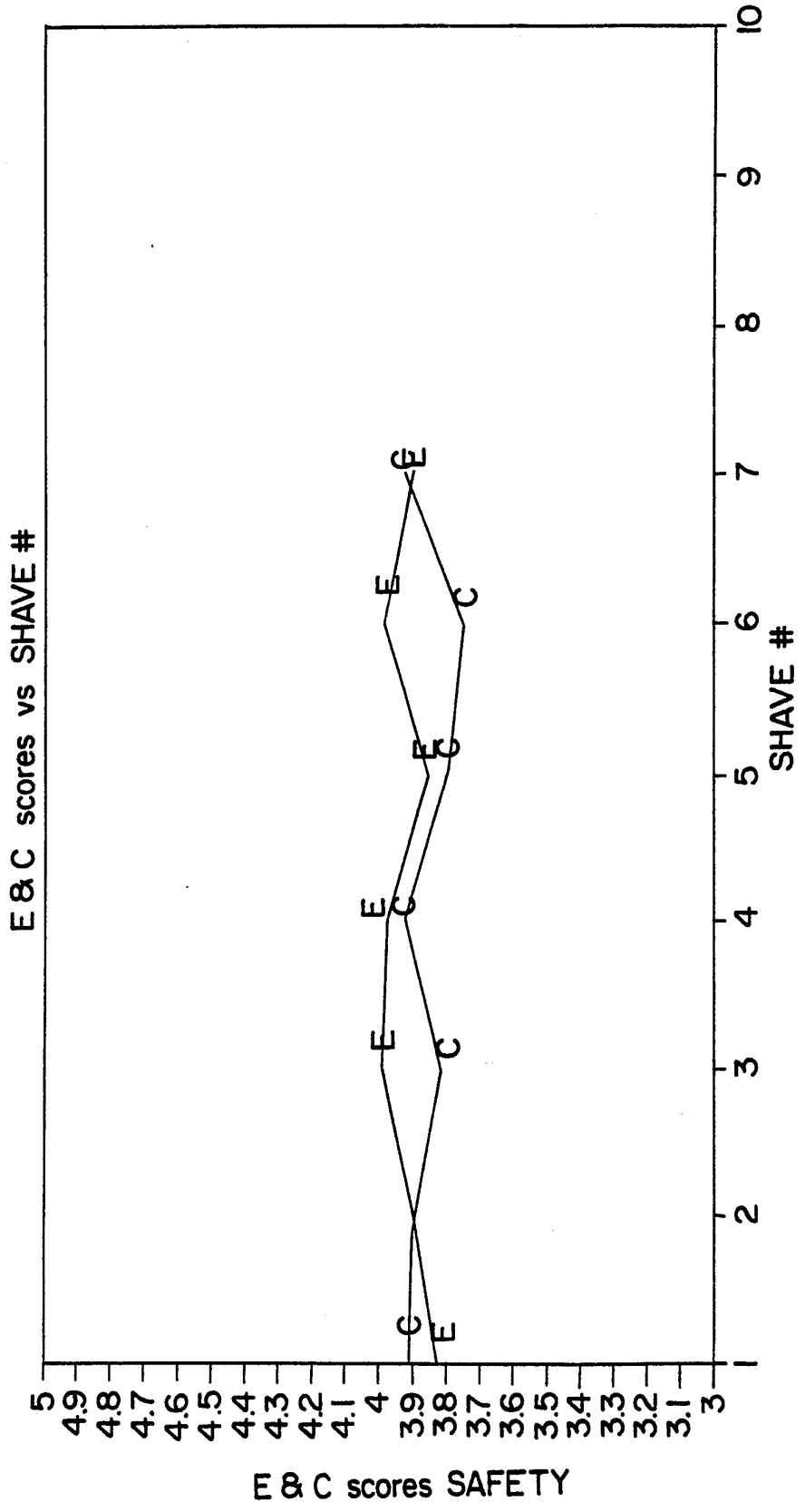

E&C scores vs SHAVE #
SHAVE #
E & C scores SAFETY
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E
C

FIG. 6B

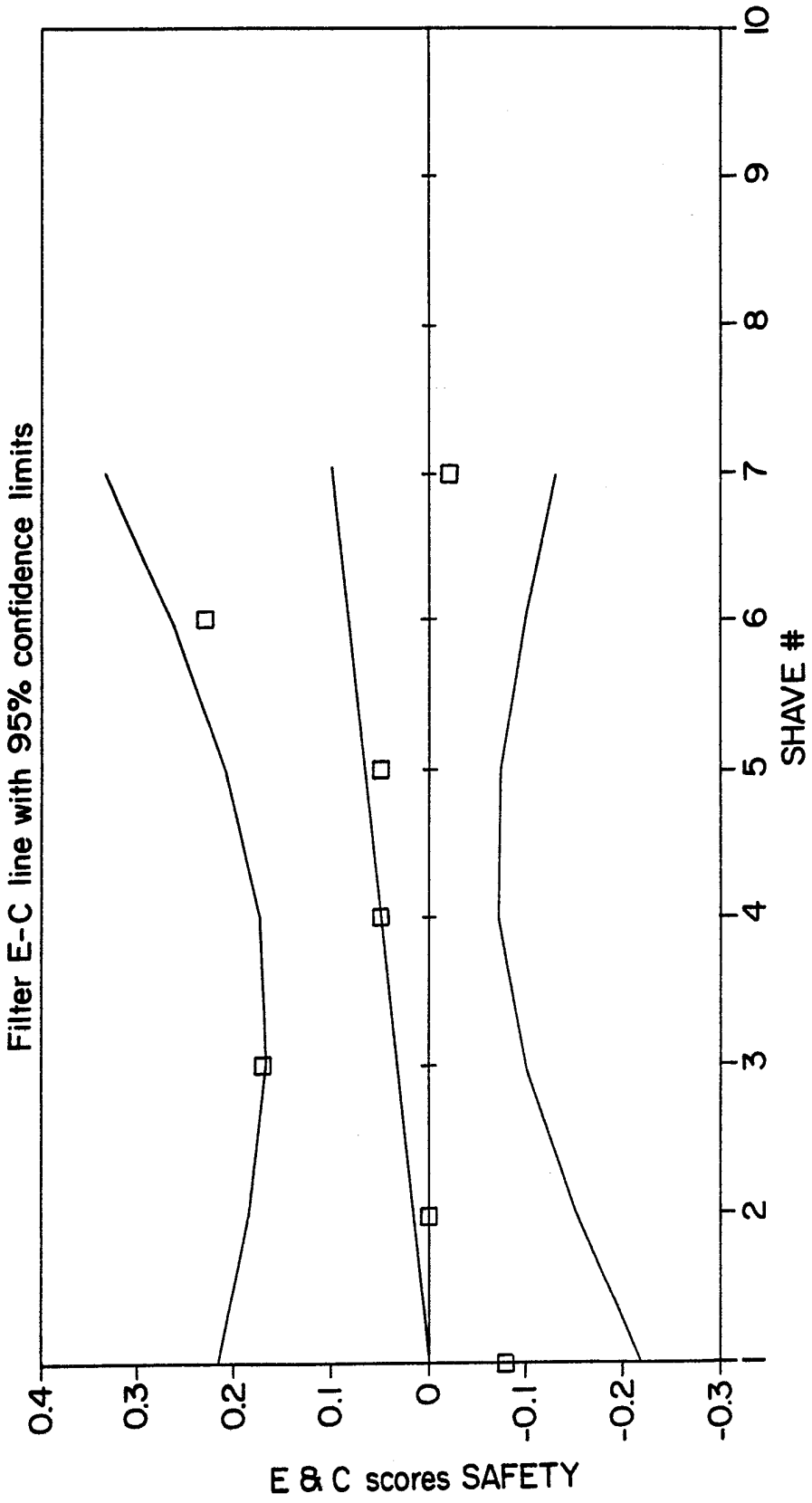

Filter E-C line with 95% confidence limits
E & C scores SAFETY
SHAVE #
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
1
2
3
4
5
6
7
8
9
10

FIG. 7A

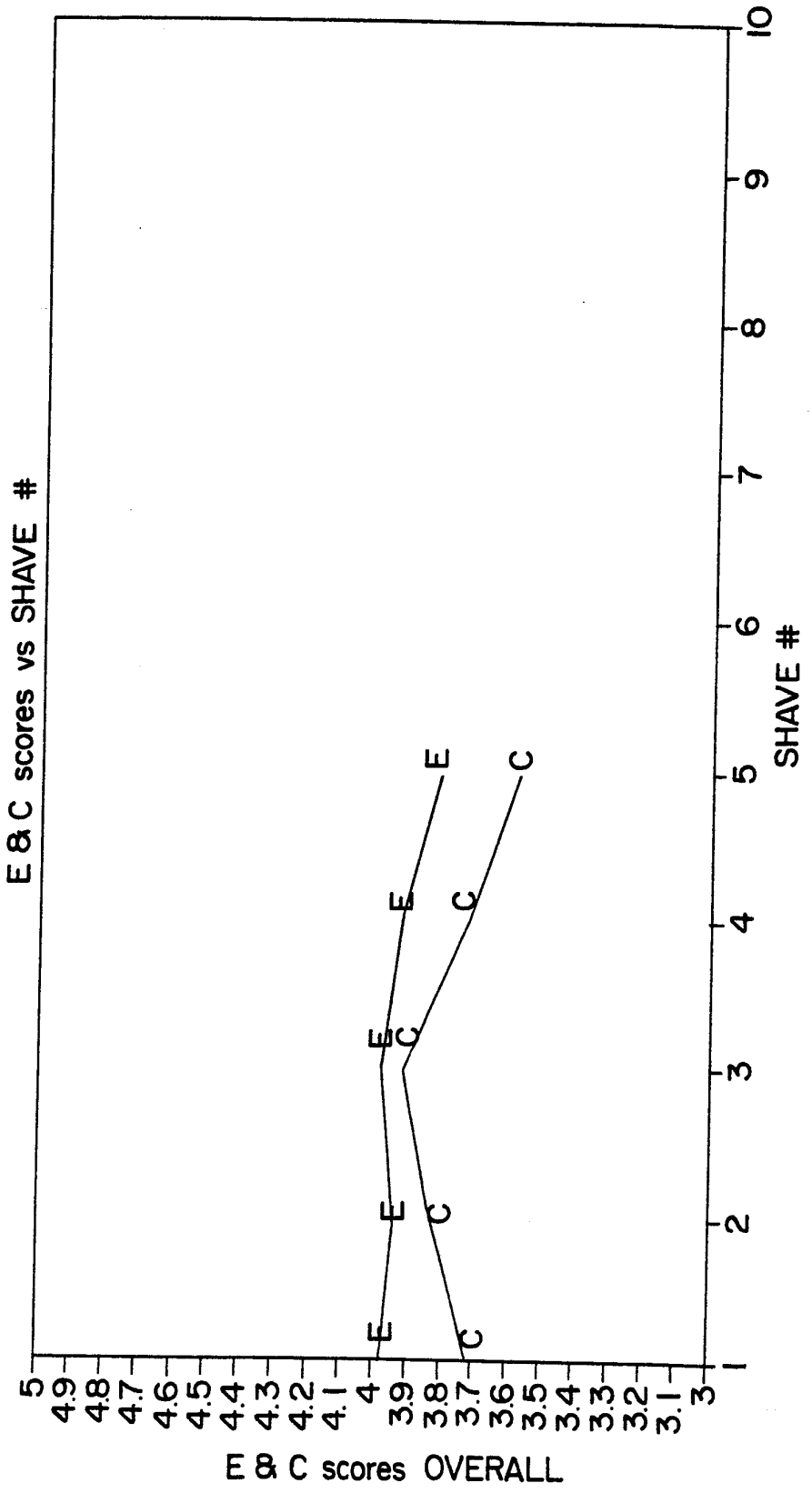

E & C scores vs SHAVE #
E & C scores OVERALL
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
E
C

FIG. 7B

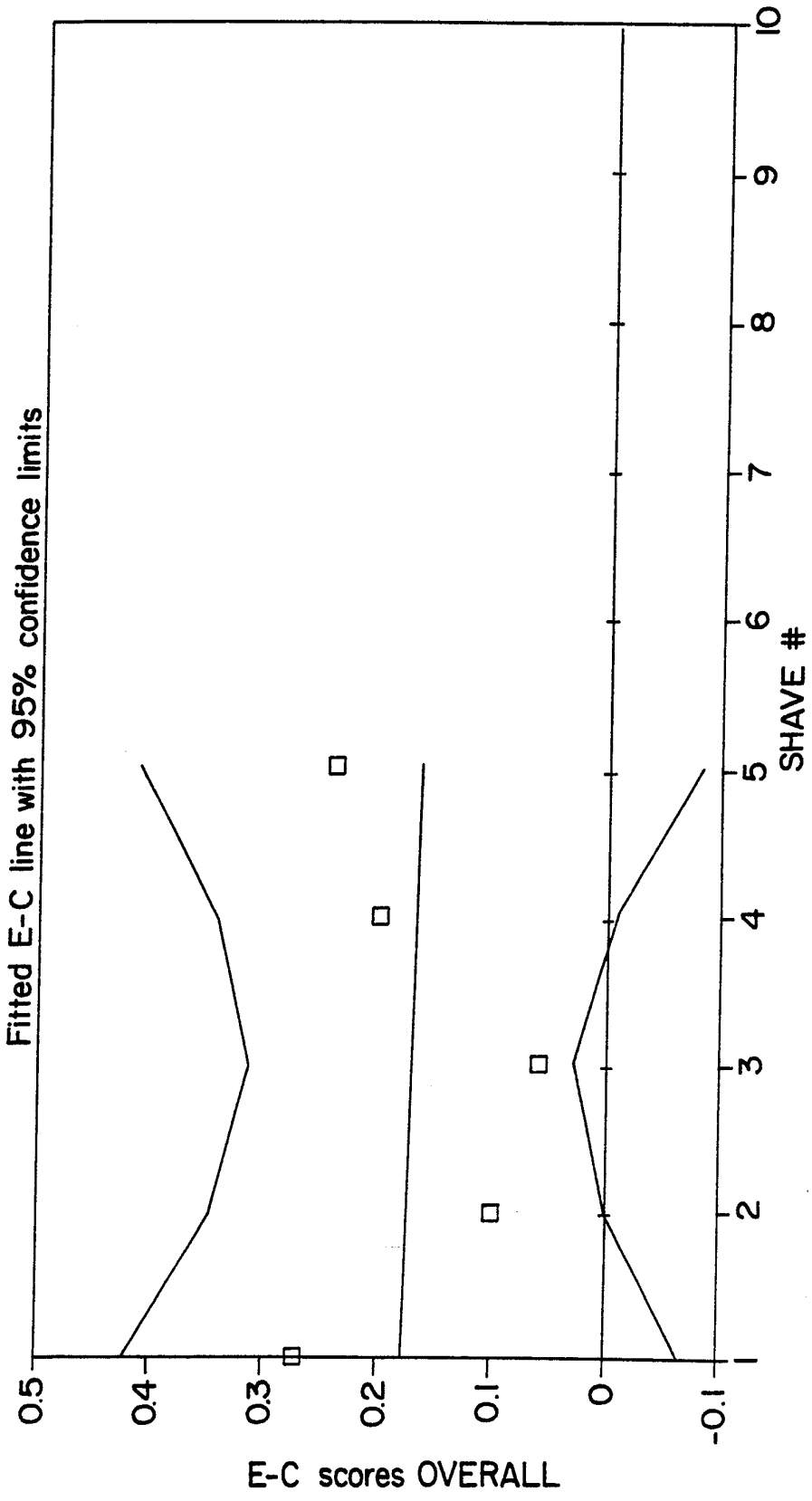

Fitted E-C line with 95% confidence limits
E-C scores OVERALL
SHAVE #
0.5
0.4
0.3
0.2
0.1
0
-0.1
1
2
3
4
5
6
7
8
9
10

FIG. 8A

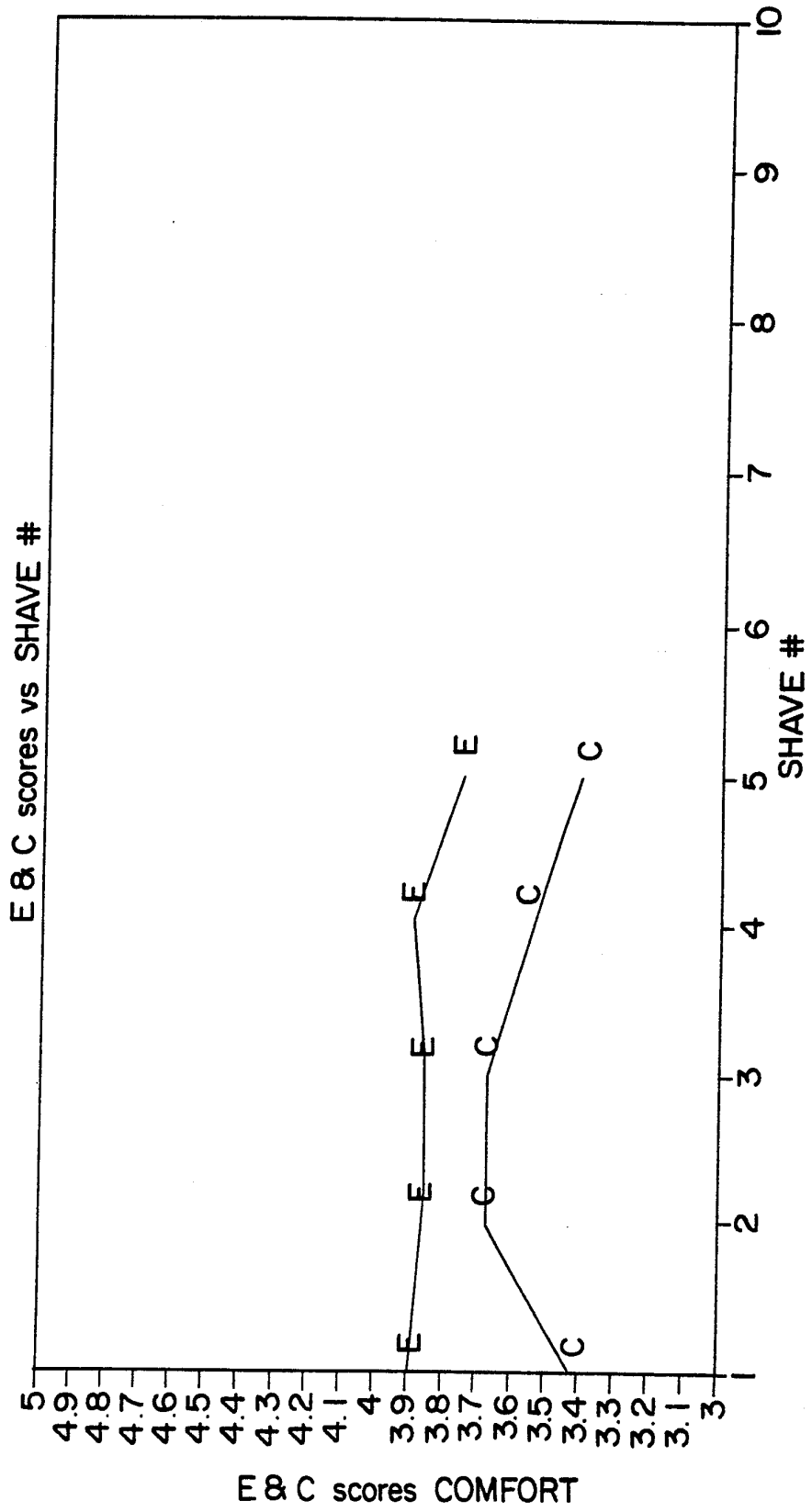

E & C scores vs SHAVE #
E & C scores COMFORT
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
E
E
E
E
E
C
C
C
C
C

FIG. 8B

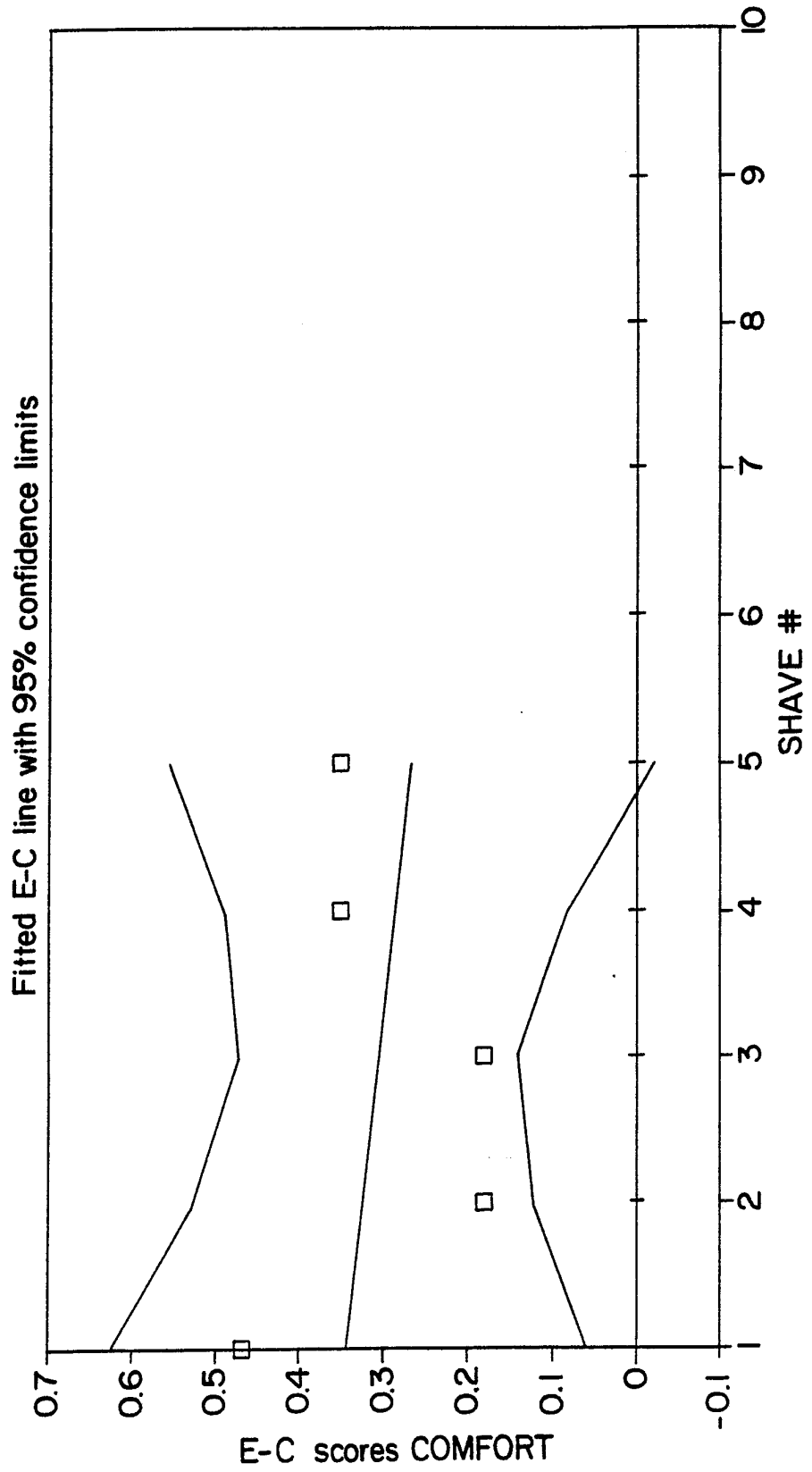

Fitted E-C line with 95% confidence limits
E-C scores COMFORT
SHAVE #
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
1
2
3
4
5
6
7
8
9
10

FIG. 9A

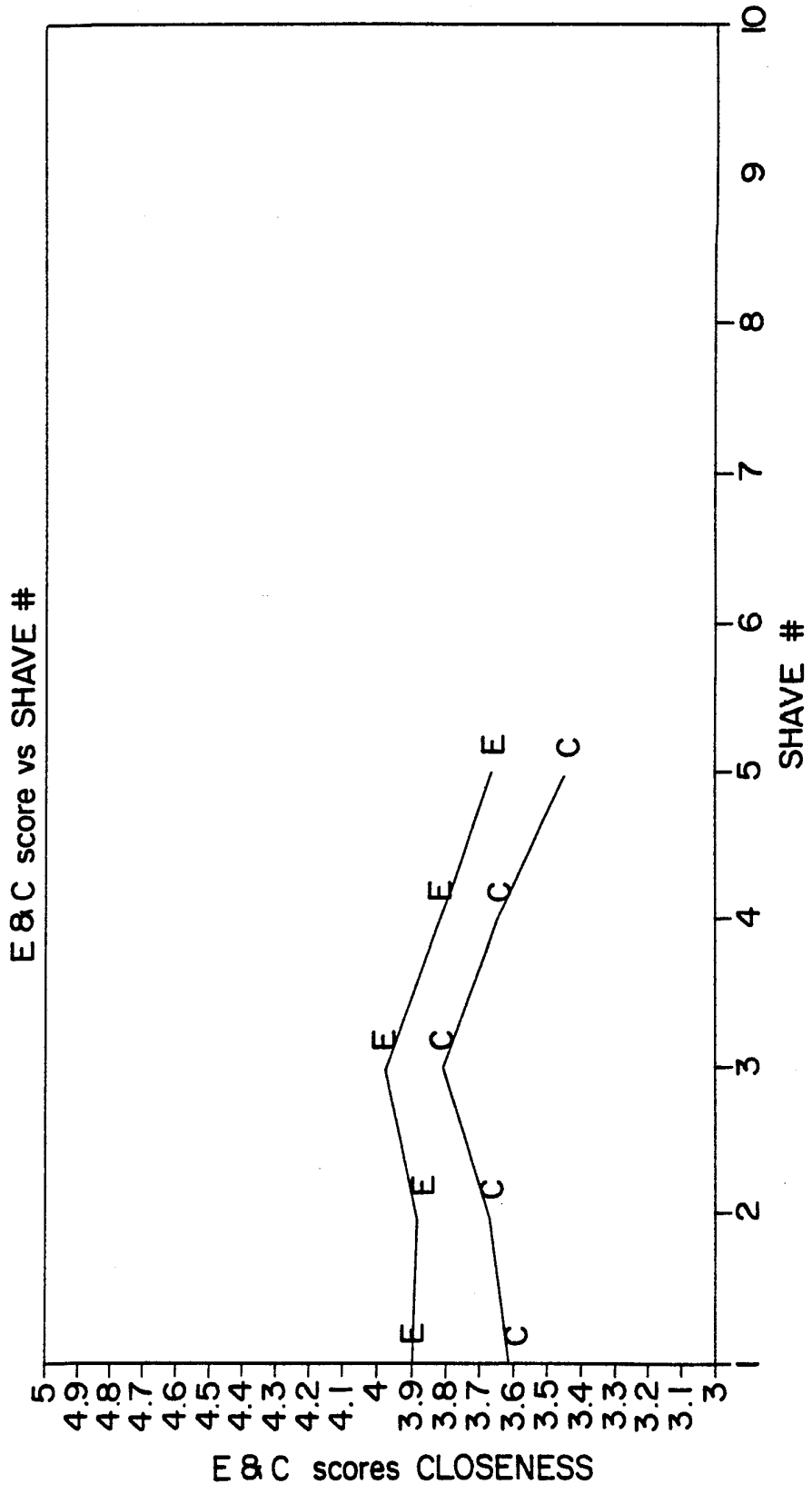

E & C score vs SHAVE #
E & C scores CLOSENESS
SHAVE #
5 4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6 3.5 3.4 3.3 3.2 3.1 3
1 2 3 4 5 6 7 8 9 10
E E E E E
C C C C C

FIG. 9B

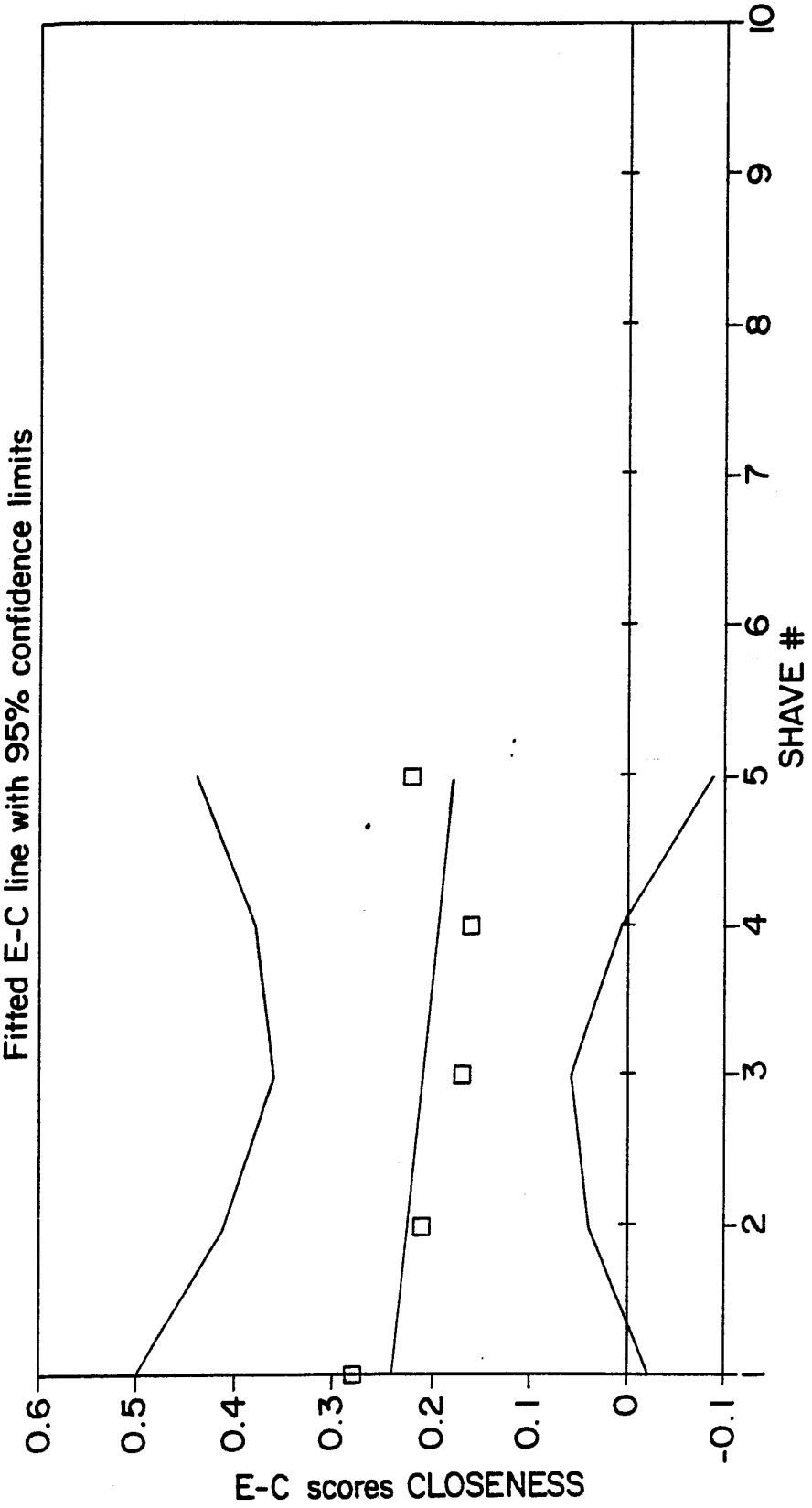

Fitted E-C line with 95% confidence limits
E-C scores CLOSENESS
SHAVE #
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
1
2
3
4
5
6
7
8
9
10

FIG. 10A

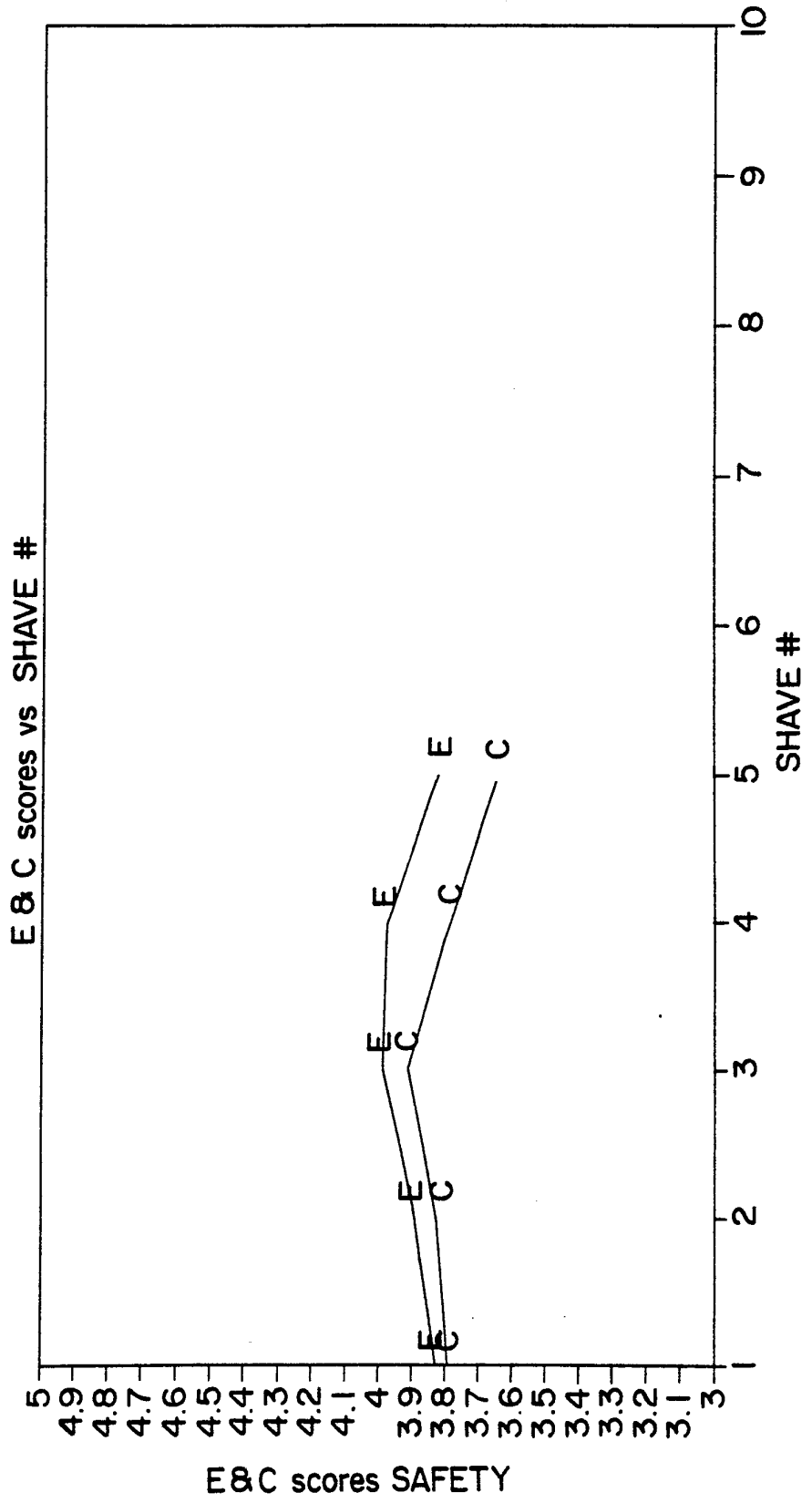

E & C scores vs SHAVE #
E&C scores SAFETY
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
E
C

FIG. 10B

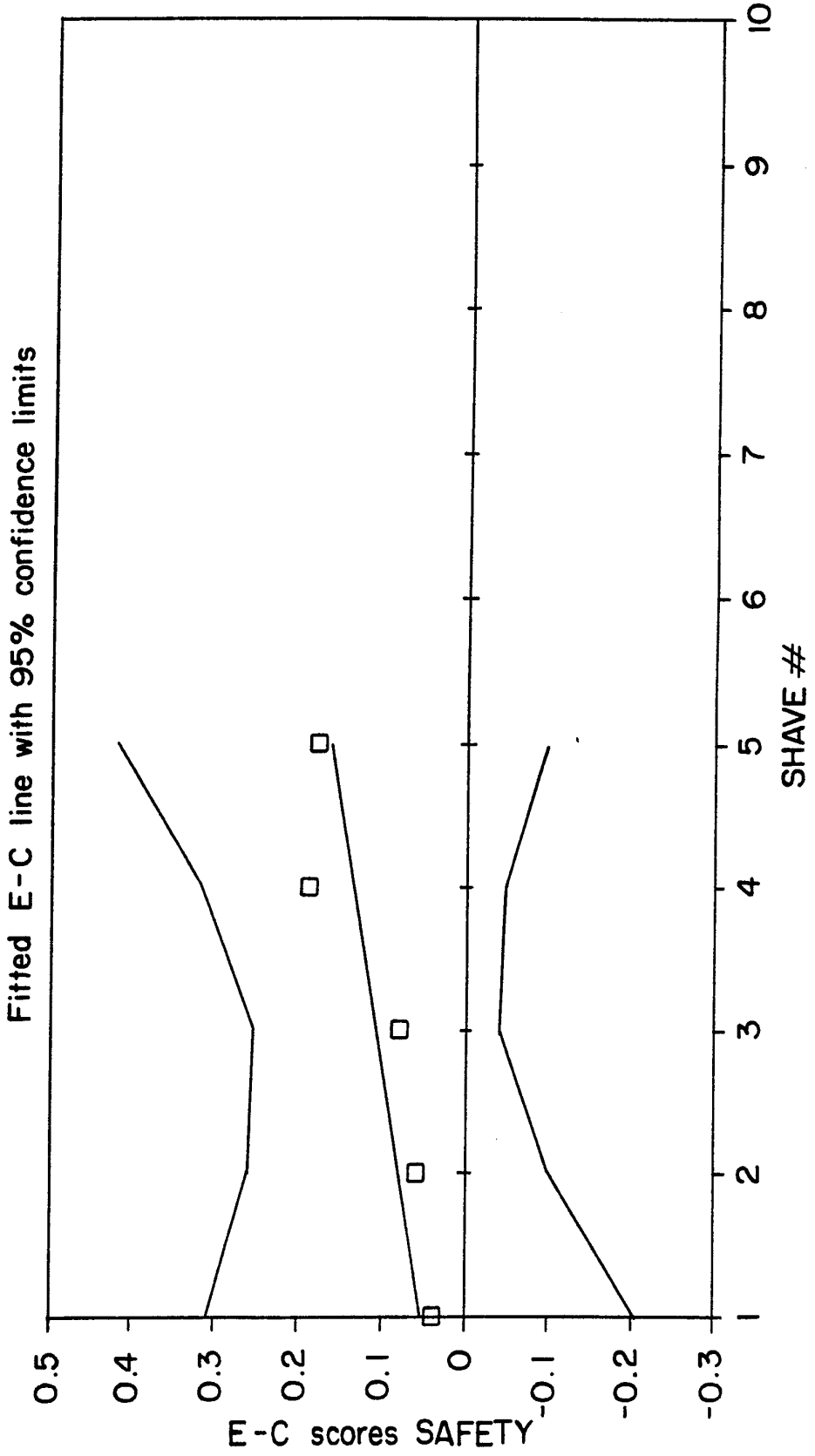

Fitted E-C line with 95% confidence limits
E-C scores SAFETY
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
SHAVE #
1
2
3
4
5
6
7
8
9
10

FIG. IIA

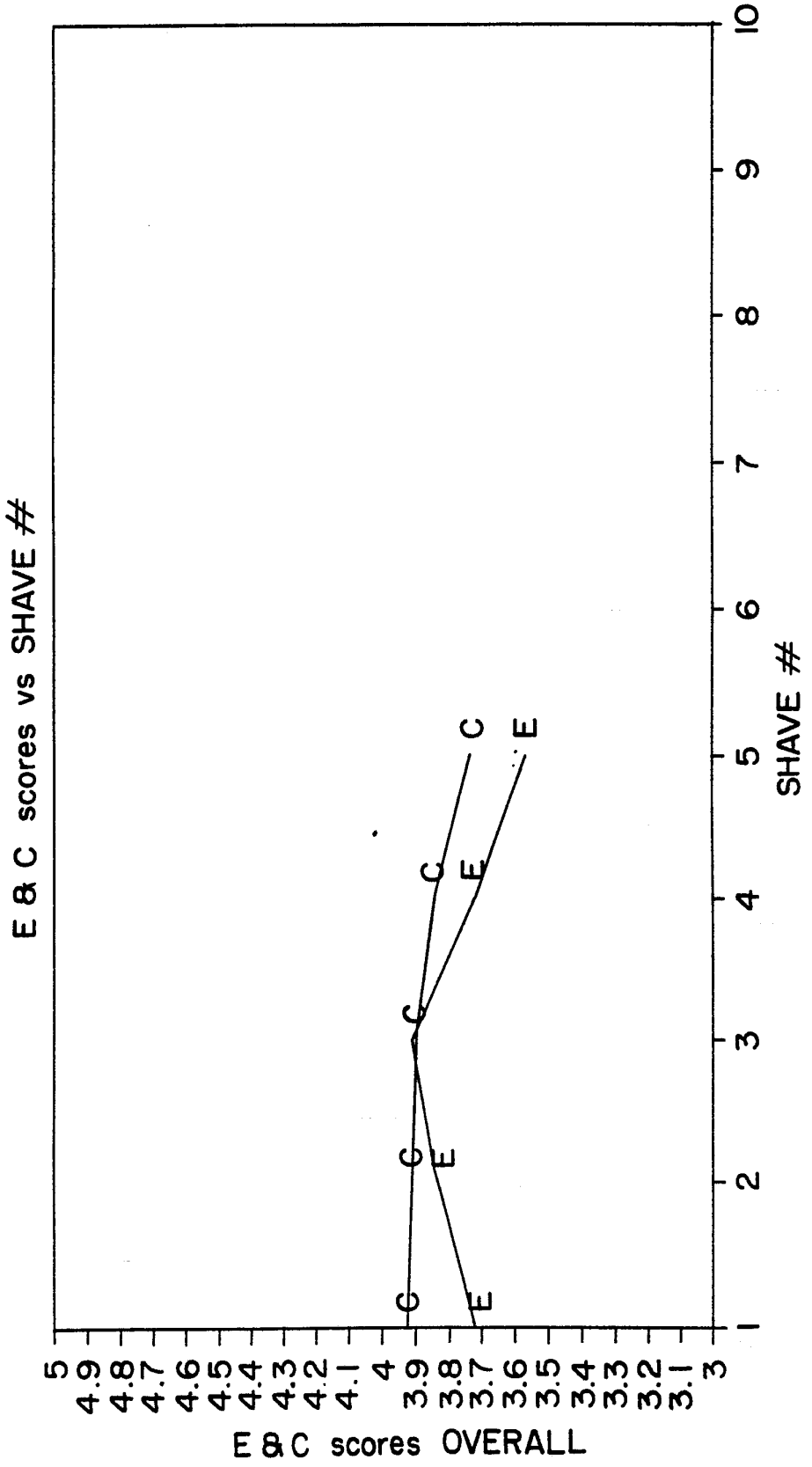

E & C scores vs SHAVE #
SHAVE #
1
2
3
4
5
6
7
8
9
10
C
E
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E & C scores OVERALL

FIG. 11B

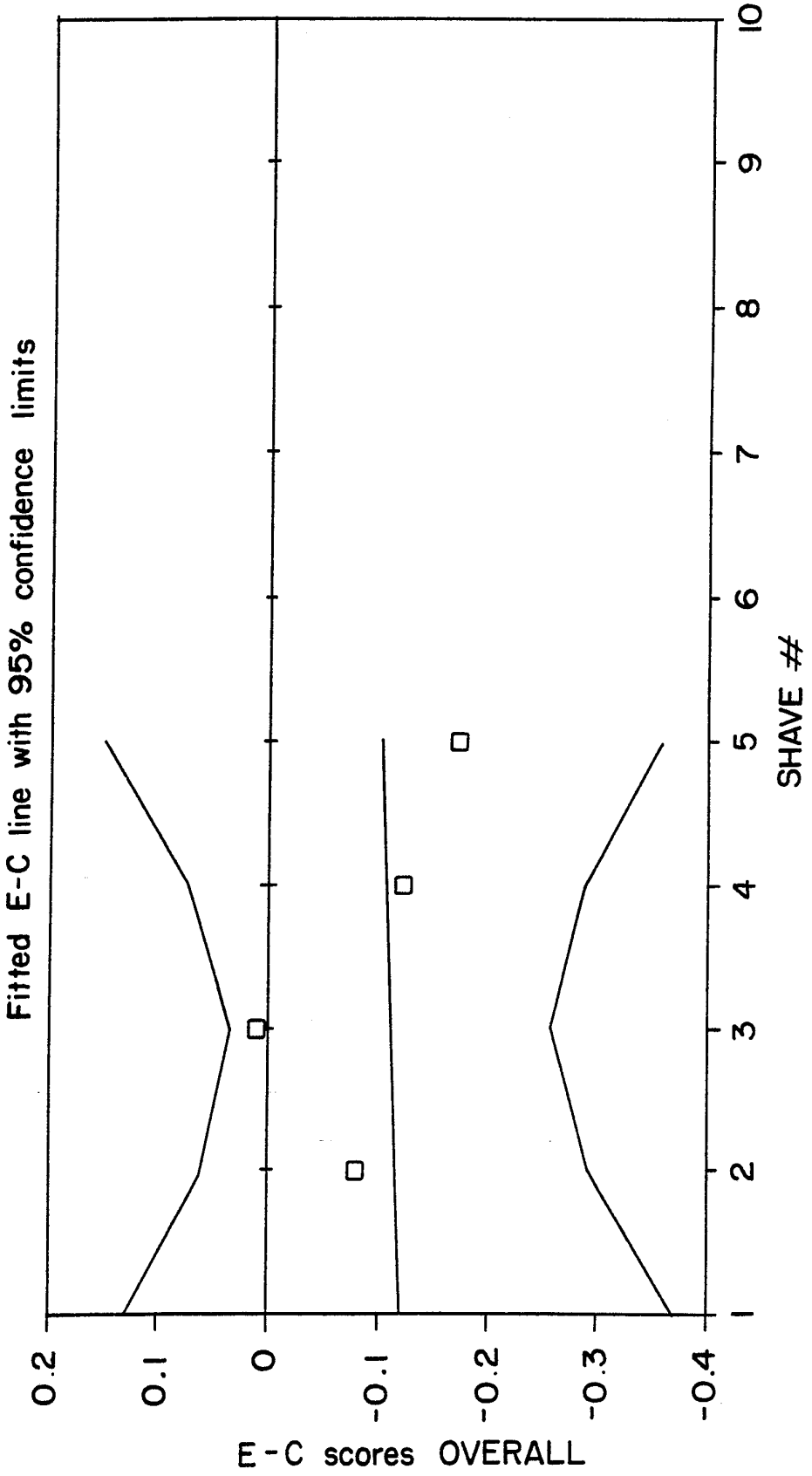

Fitted E-C line with 95% confidence limits
E-C scores OVERALL
SHAVE #
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1
2
3
4
5
6
7
8
9
10

FIG. 12A

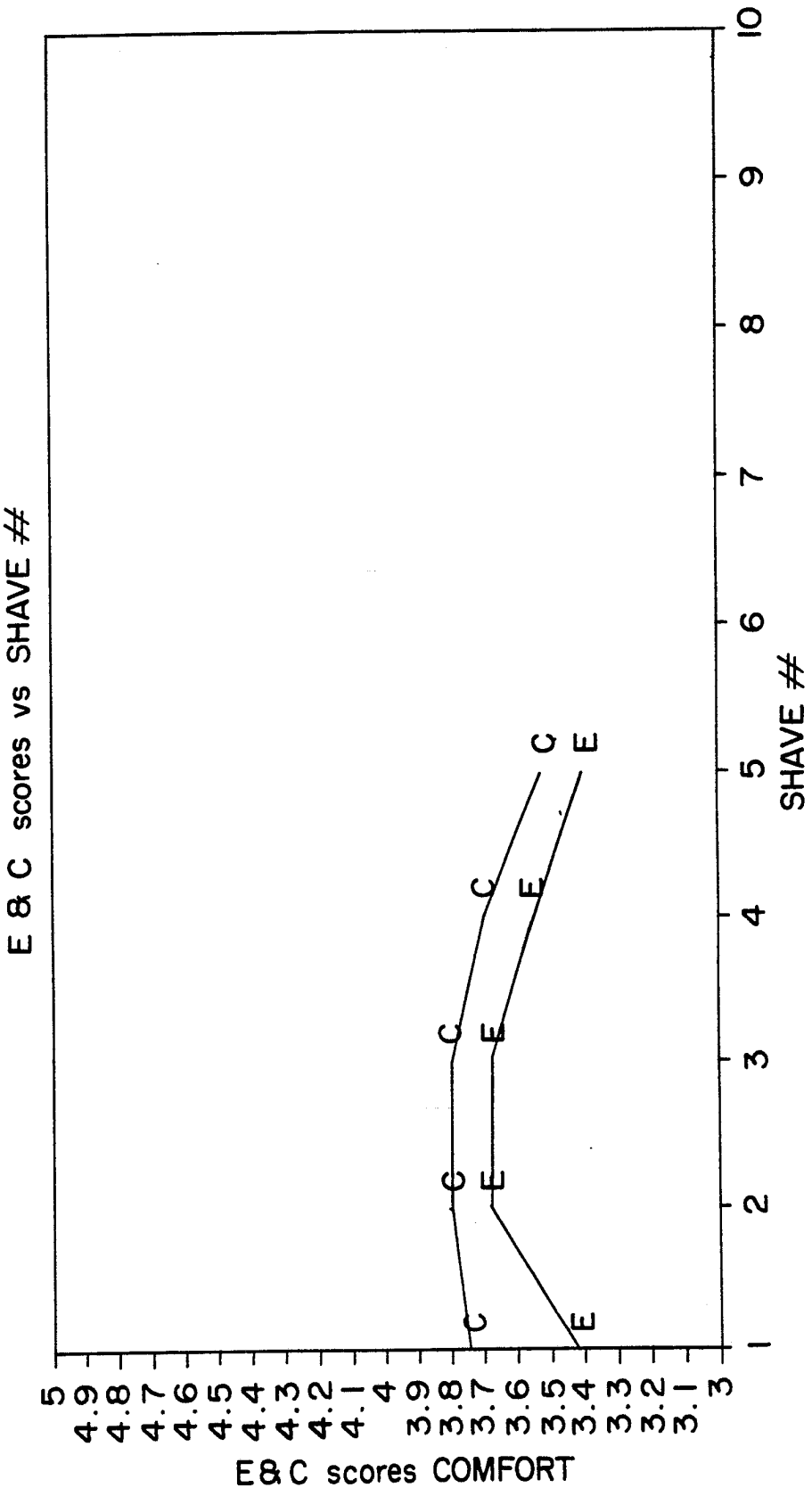

E & C scores vs SHAVE #
E&C scores COMFORT
SHAVE #
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
1
2
3
4
5
6
7
8
9
10
C
E

FIG. 12B

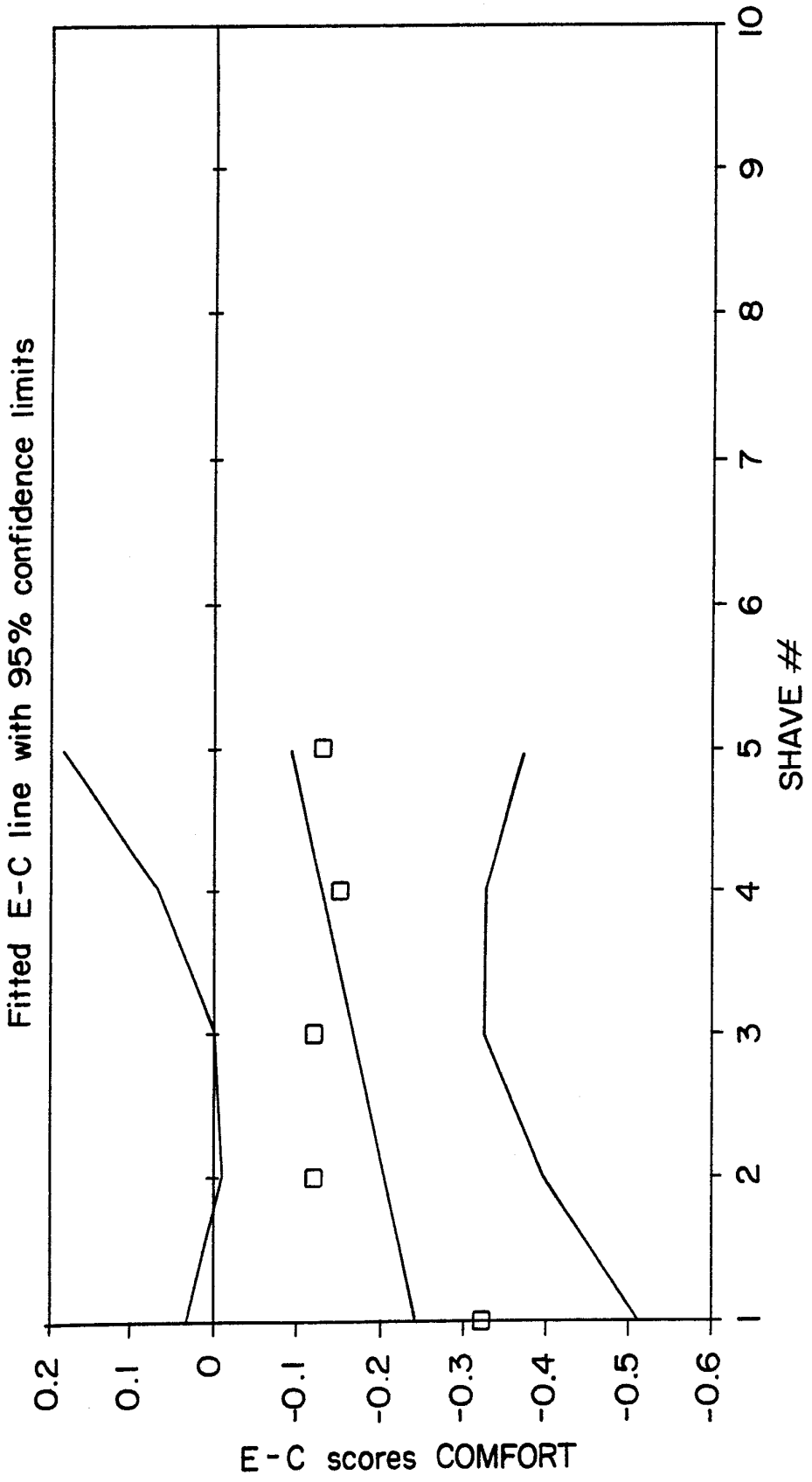

Fitted E-C line with 95% confidence limits
E-C scores COMFORT
SHAVE #
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1
2
3
4
5
6
7
8
9
10

FIG. 13A

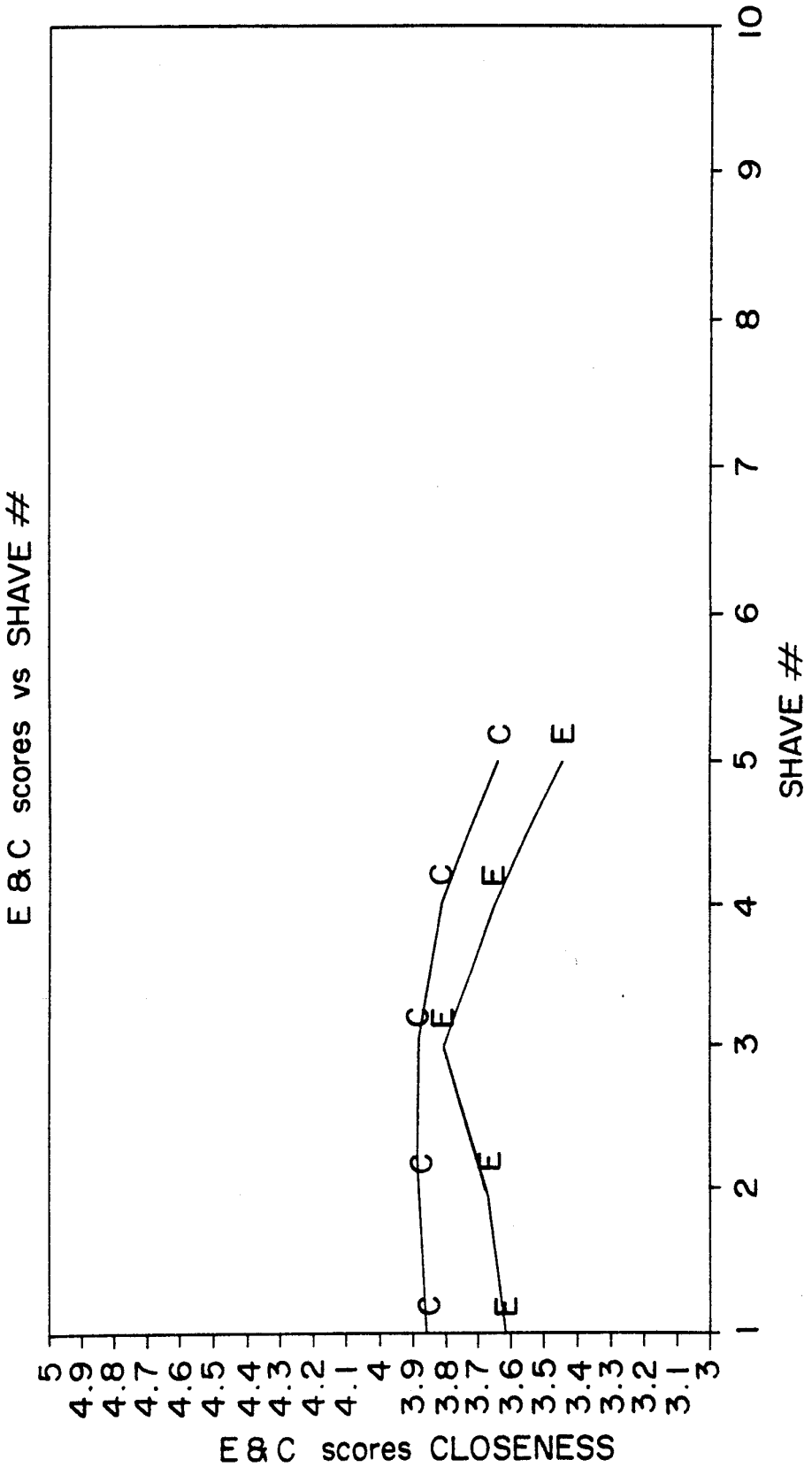

E & C scores vs SHAVE #
SHAVE #
E & C scores CLOSENESS
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
C
E

FIG. 13B

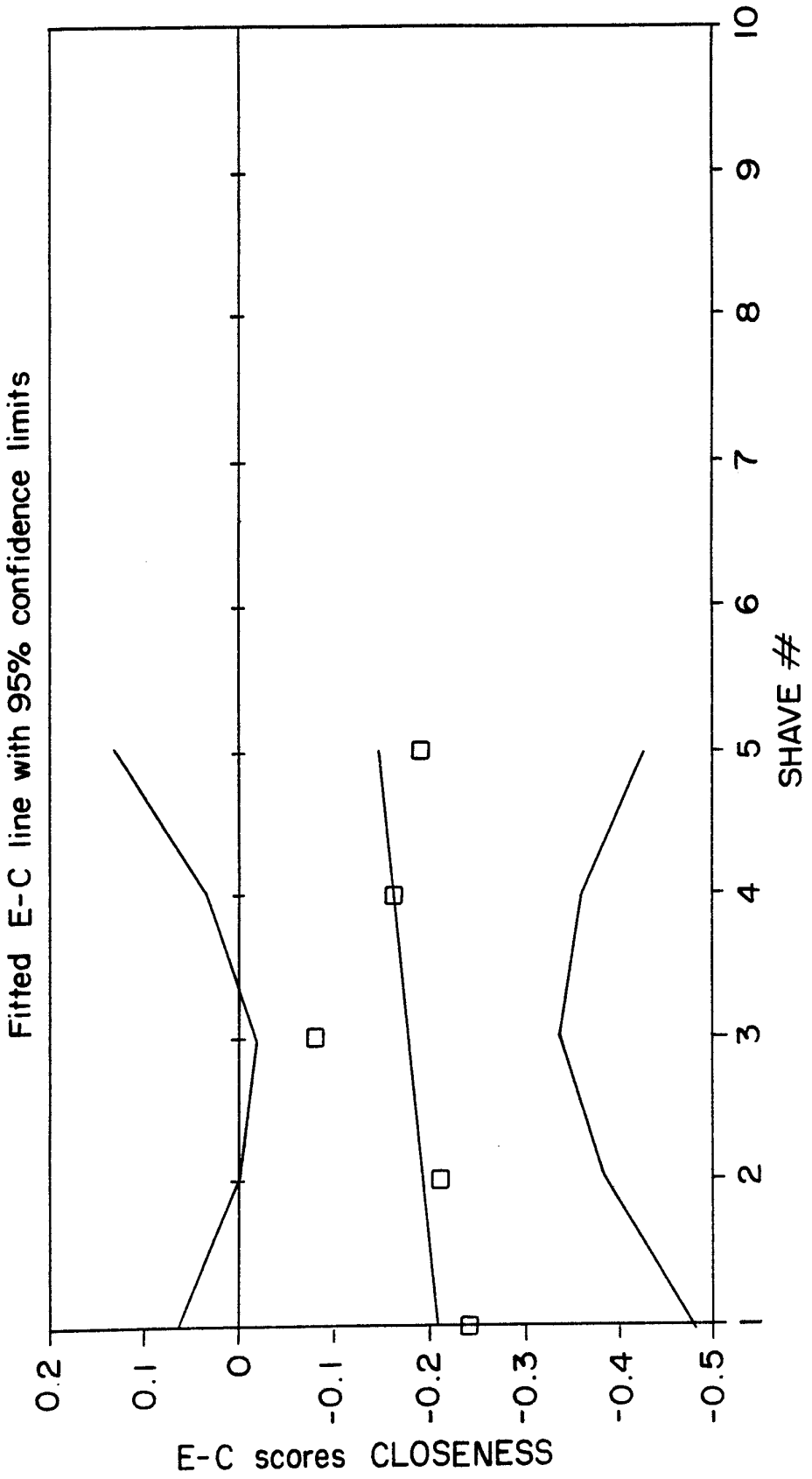

Fitted E-C line with 95% confidence limits
E-C scores CLOSENESS
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
2
3
4
5
6
7
8
9
10
SHAVE #

FIG. 14A

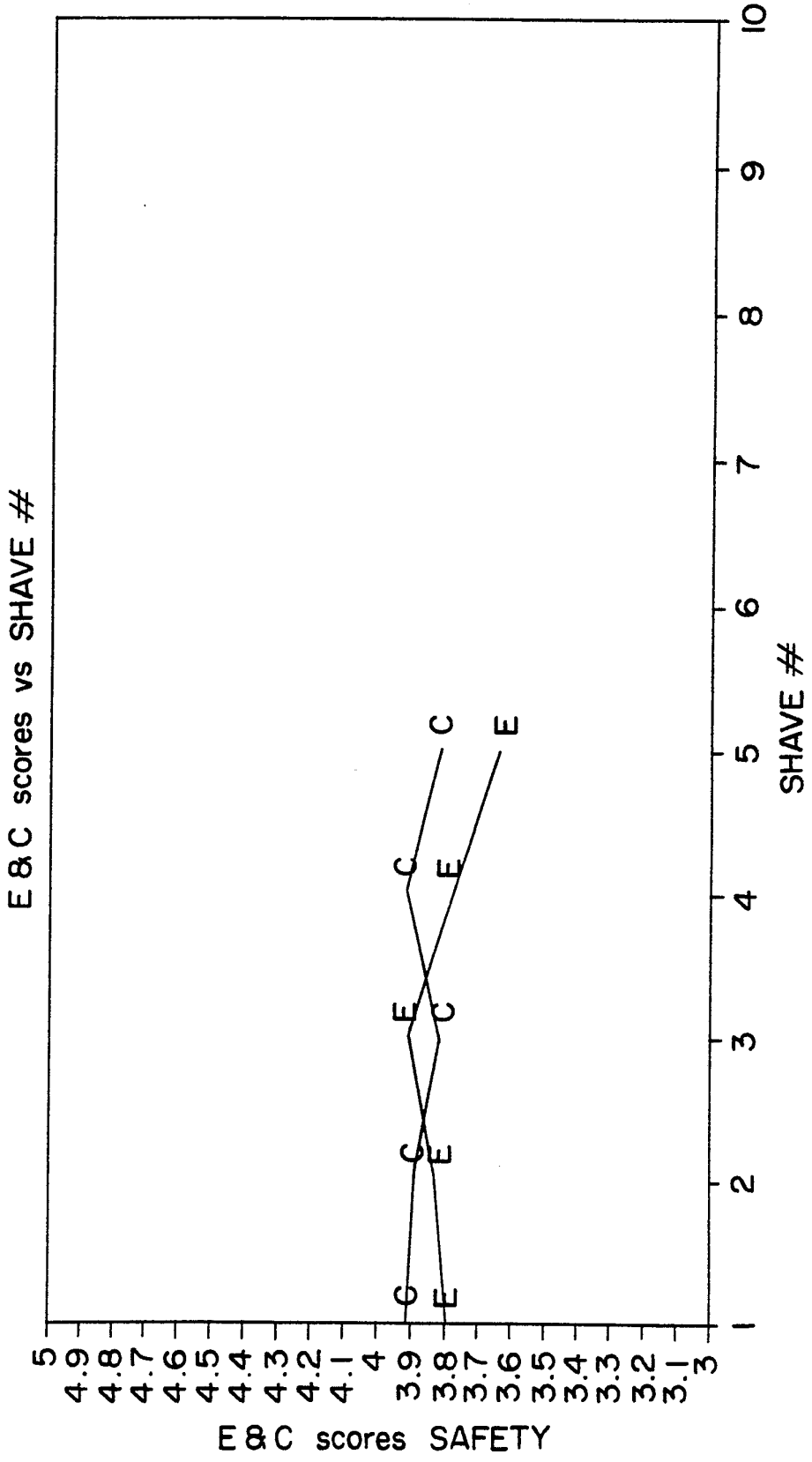

E&C scores vs SHAVE #
SHAVE #
E&C scores SAFETY
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
C
E

FIG. 14B

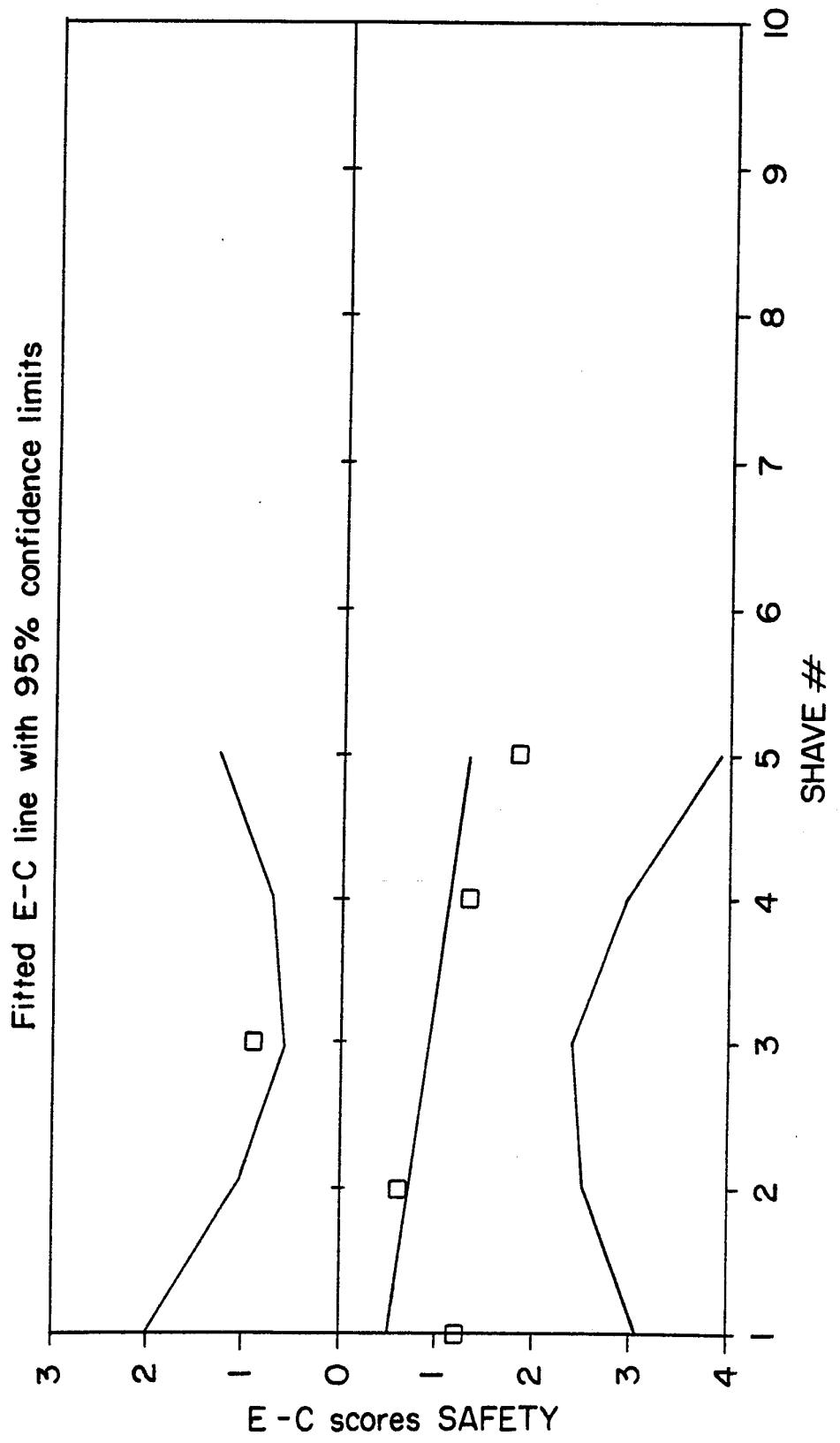

Fitted E-C line with 95% confidence limits
E-C scores SAFETY
SHAVE #
3
2
1
0
1
2
3
4
1
2
3
4
5
6
7
8
9
10

FIG. 15A

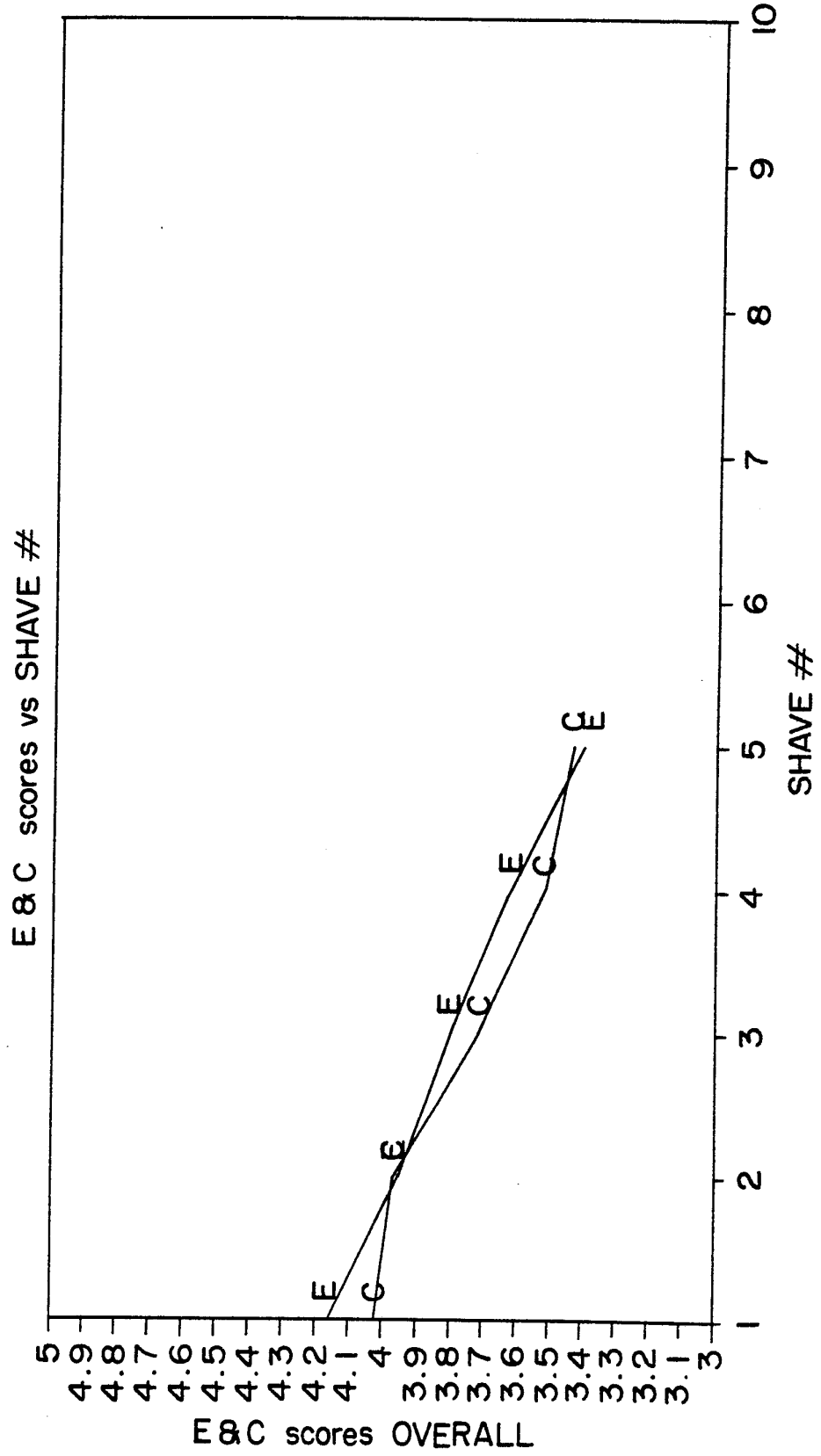

E&C scores vs SHAVE #
SHAVE #
E&C scores OVERALL
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E
C

FIG.15B

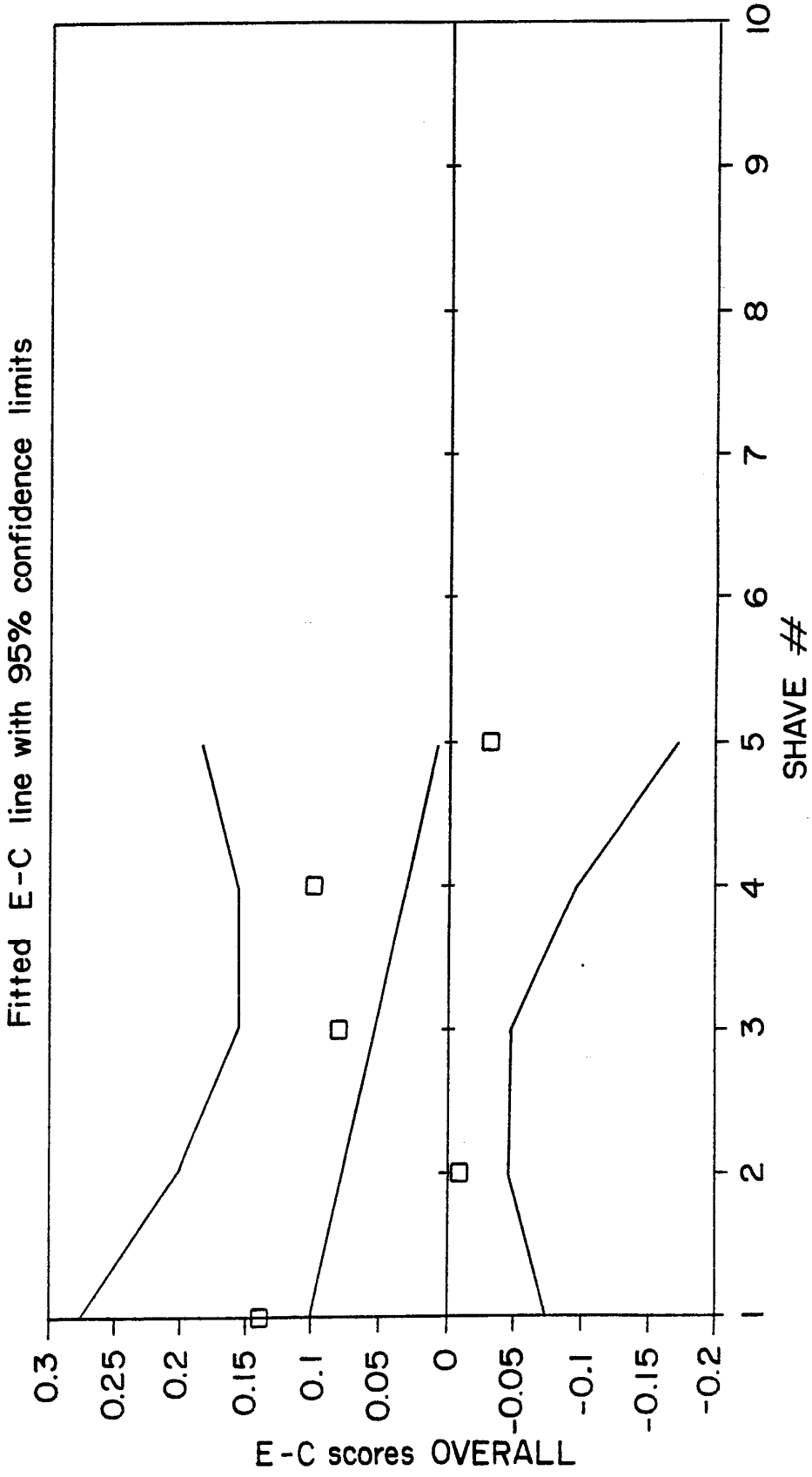

Fitted E-C line with 95% confidence limits
E-C scores OVERALL
SHAVE #
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1
2
3
4
5
6
7
8
9
10

FIG. 16 A

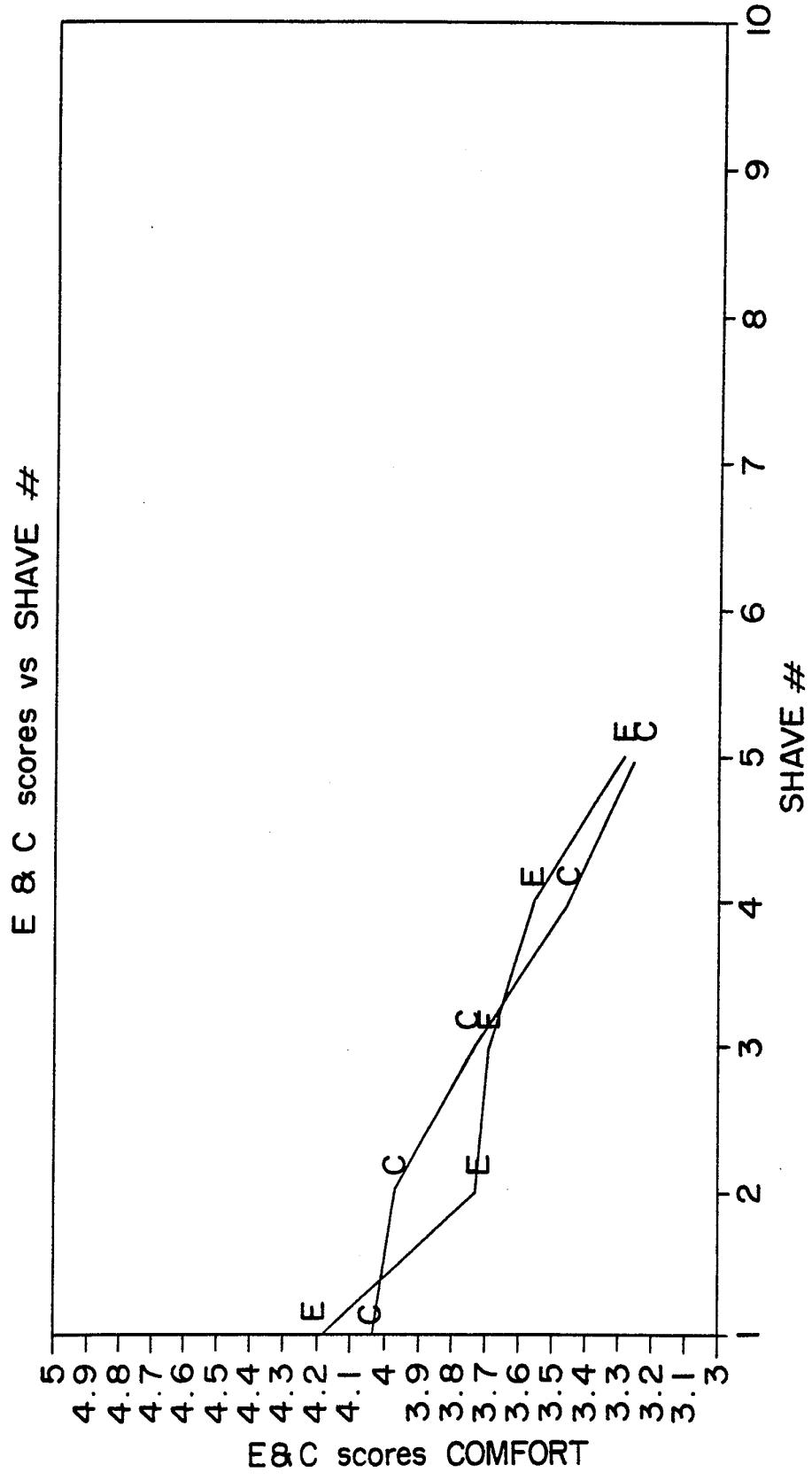


FIG. 16B

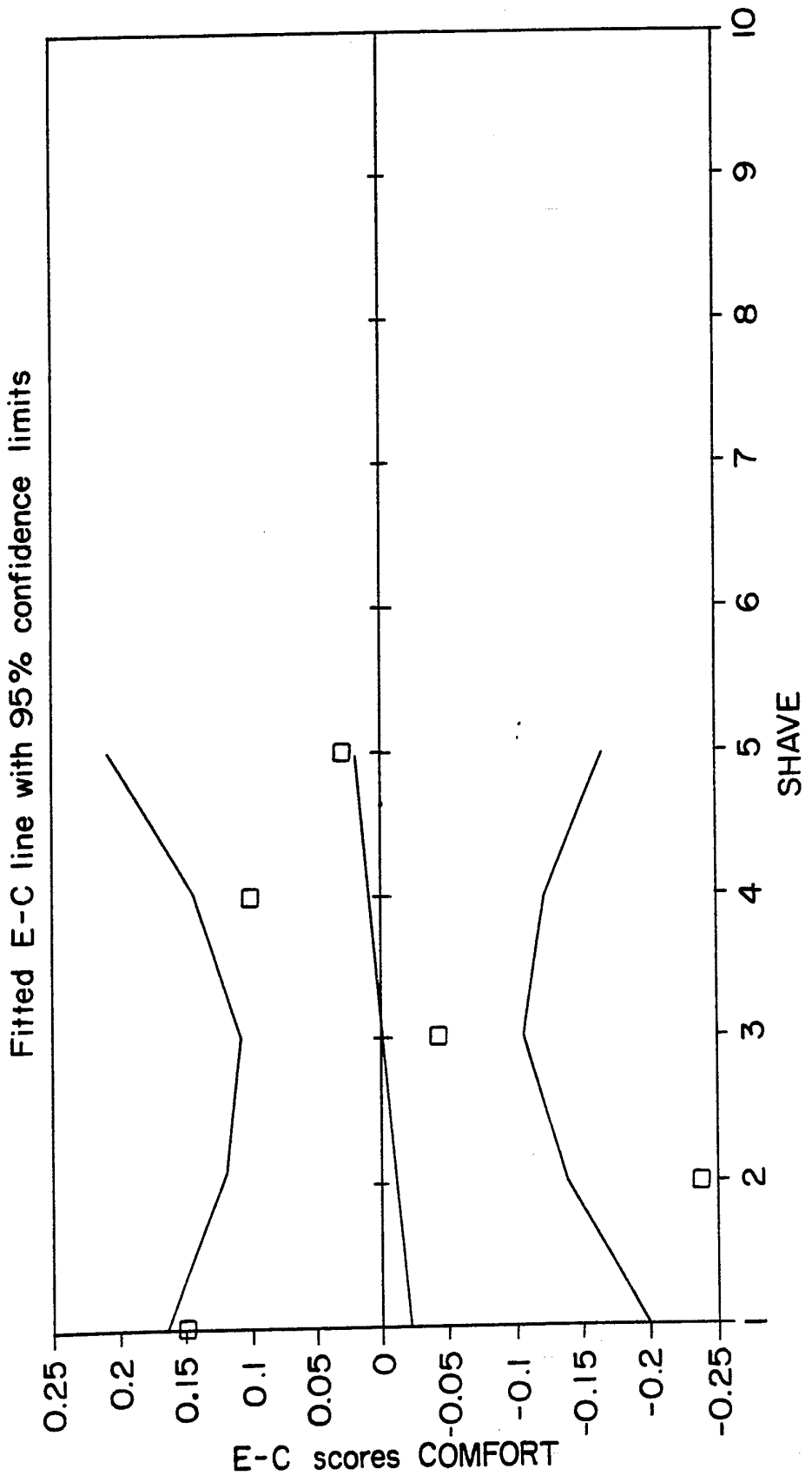

Fitted E-C line with 95% confidence limits
E-C scores COMFORT
SHAVE
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1
2
3
4
5
6
7
8
9
10

FIG. 17A

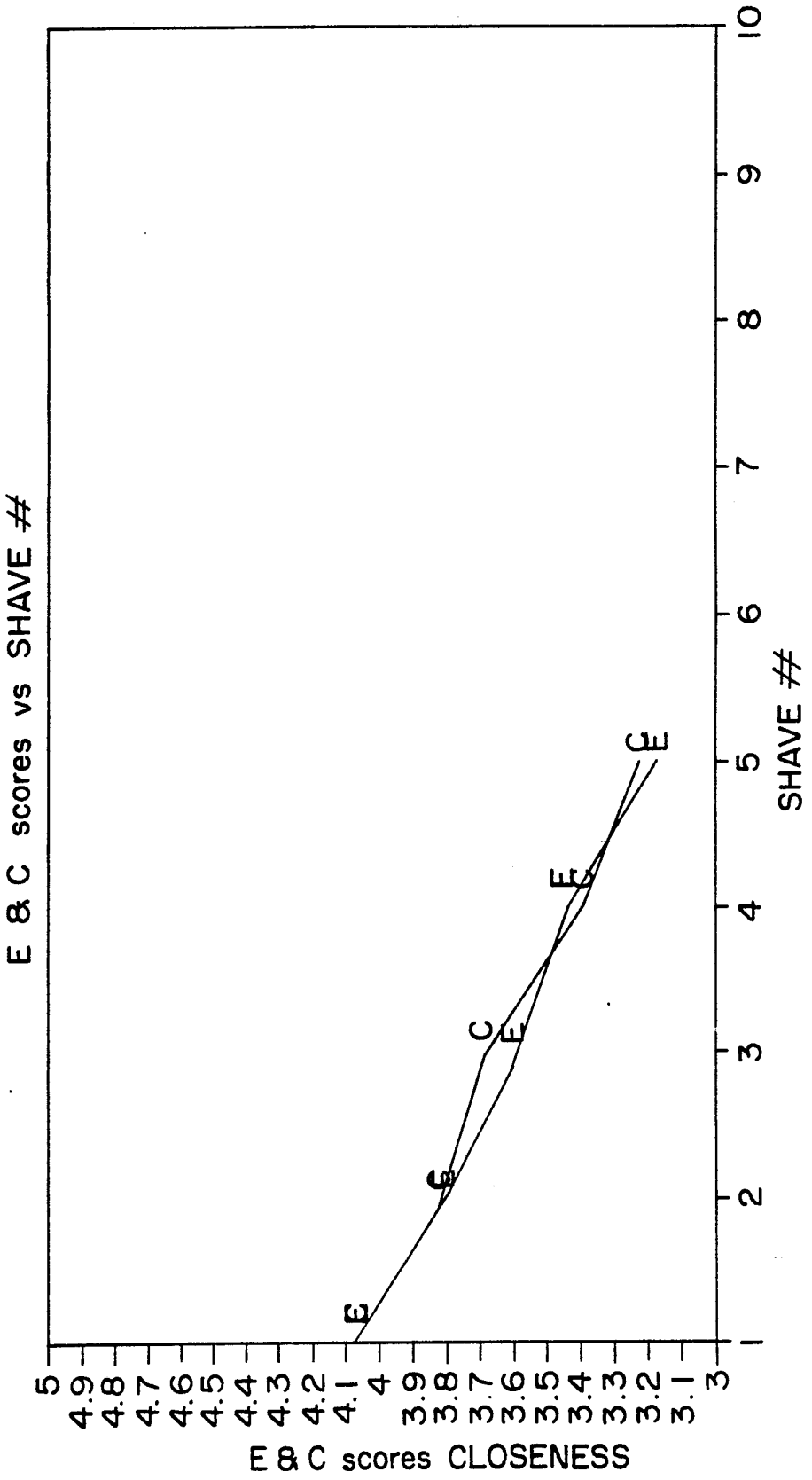

E & C scores vs SHAVE #
SHAVE #
E & C scores CLOSENESS
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E
C

FIG. 17B

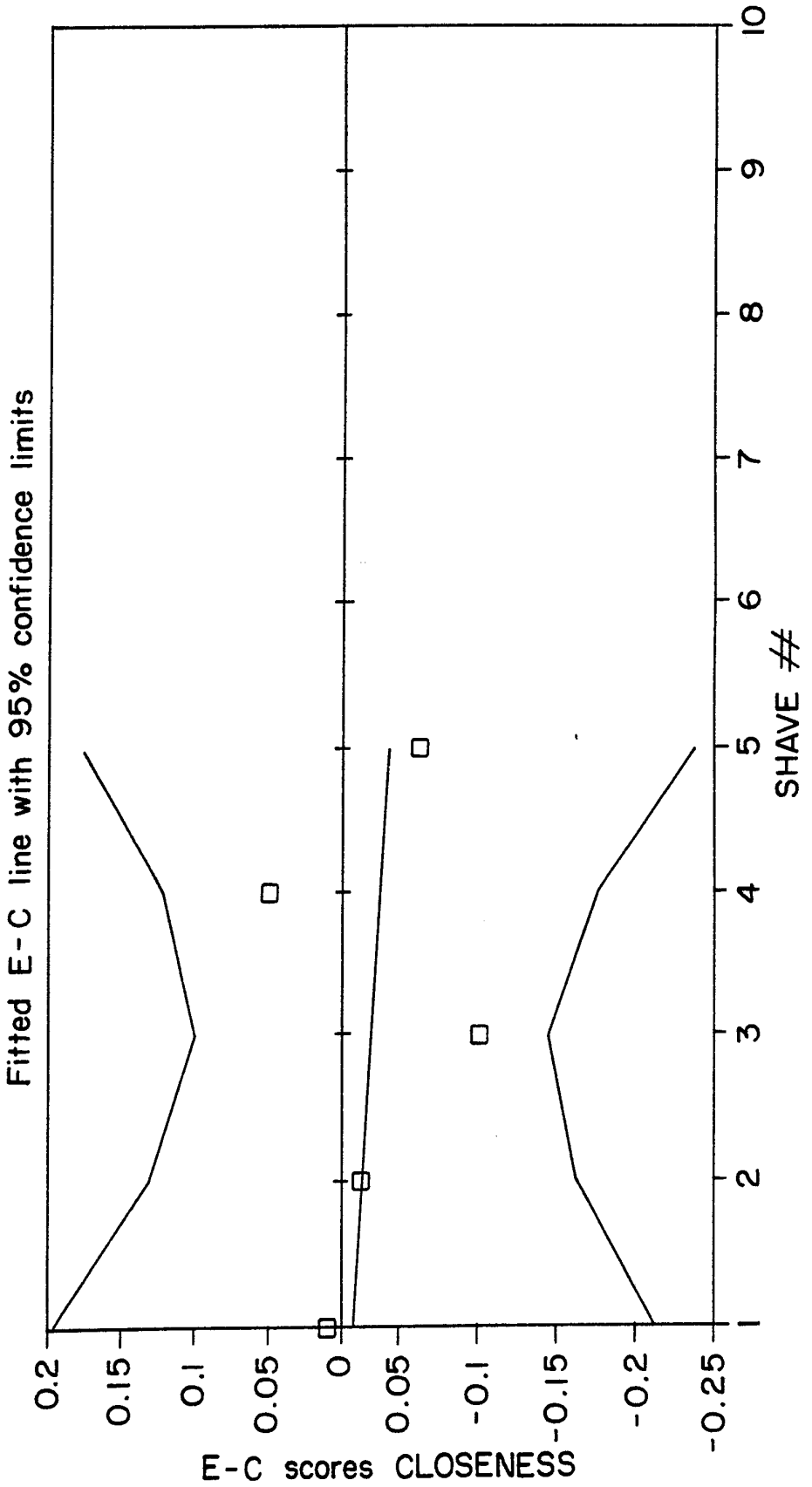

Fitted E-C line with 95% confidence limits
E-C scores CLOSENESS
SHAVE #
0.2
0.15
0.1
0.05
0
0.05
-0.1
-0.15
-0.2
-0.25
1
2
3
4
5
6
7
8
9
10

FIG. 18A

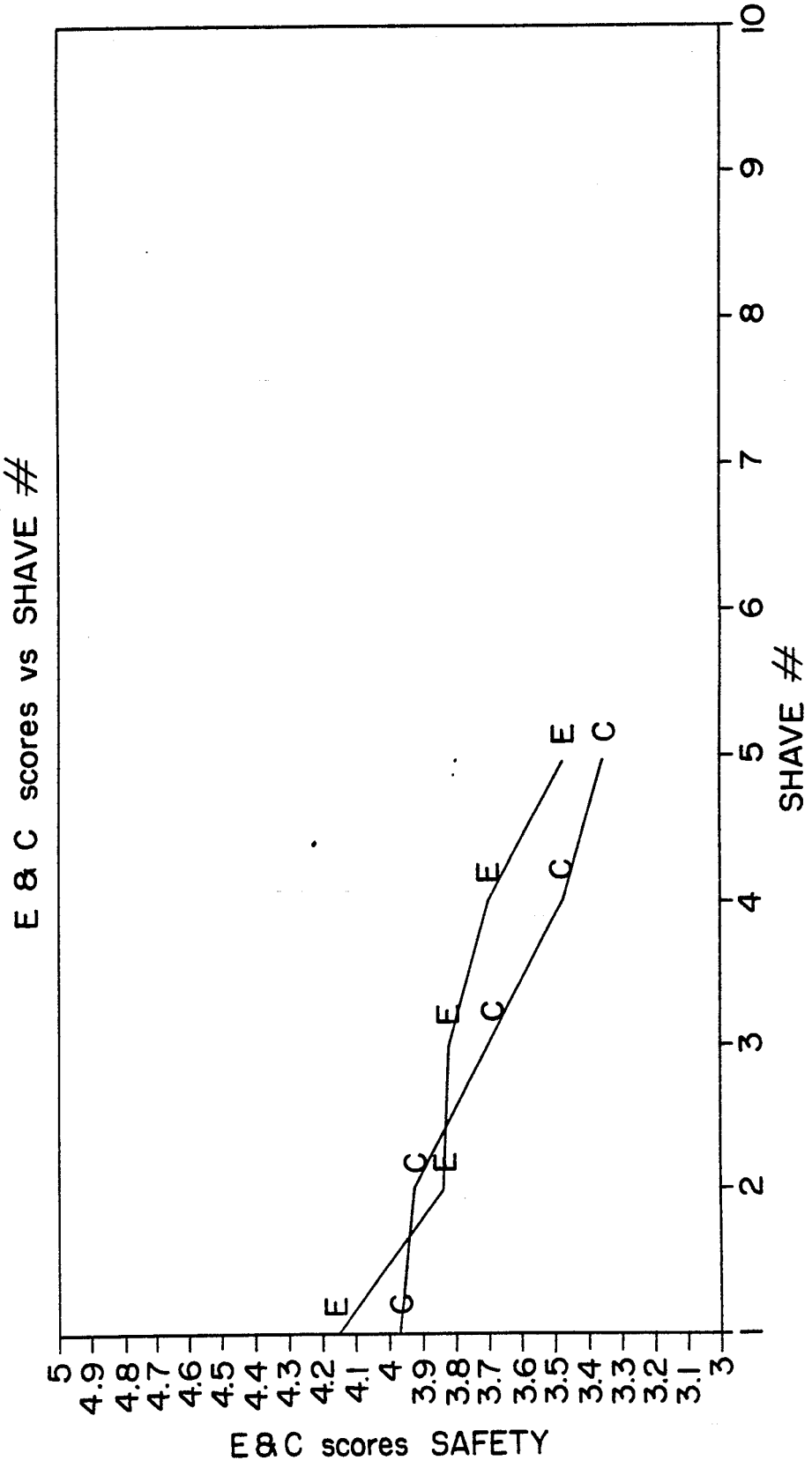
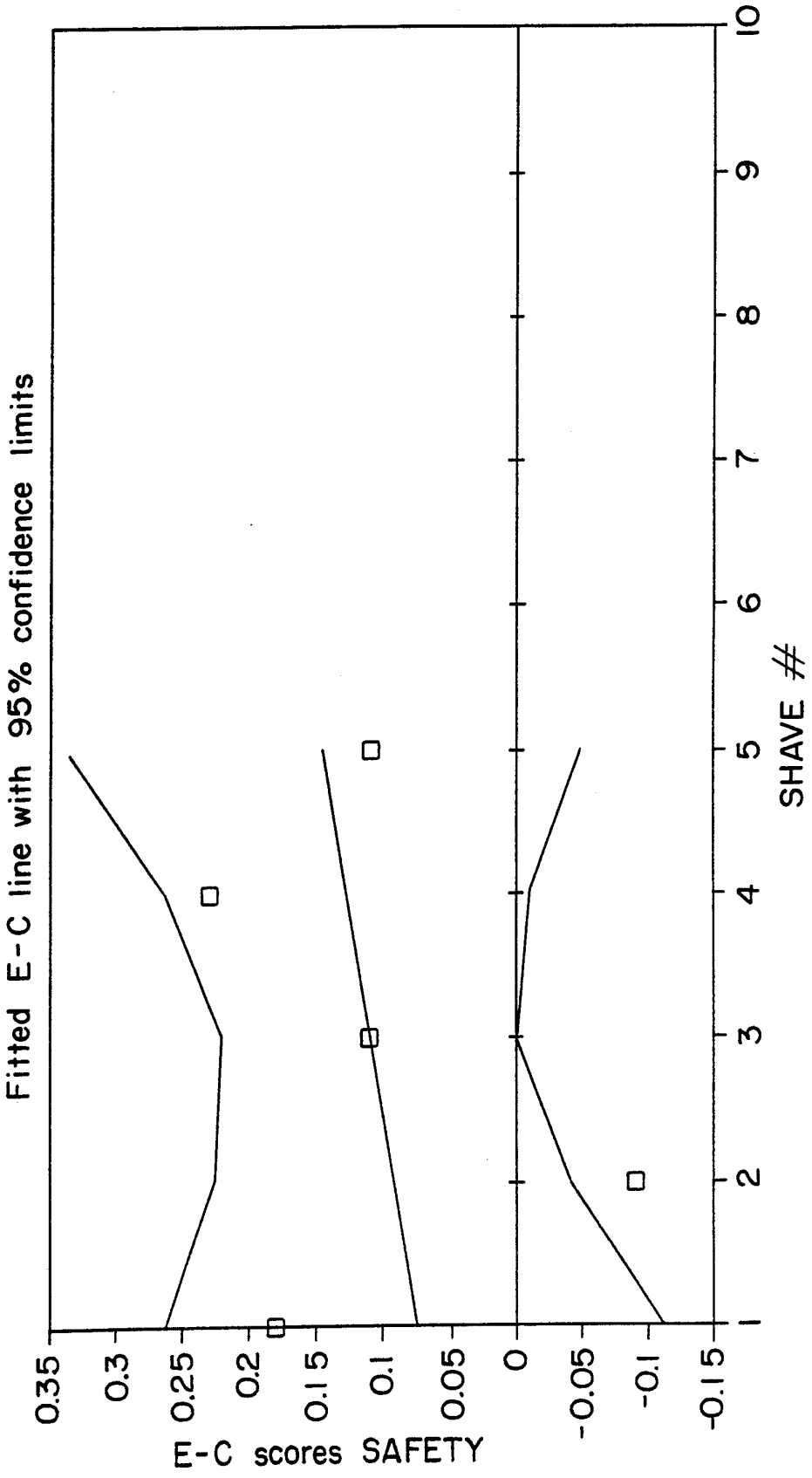

E & C scores vs SHAVE #
SHAVE #
E&C scores SAFETY
1
2
3
4
5
6
7
8
9
10
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
E
C

FIG. 18B


Fitted E-C line with 95% confidence limits
E-C scores SAFETY
SHAVE #
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1
2
3
4
5
6
7
8
9
10

TERNATIONAL SEARCH REPORT

International Application No PCT/US 92/01946

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B26B21/60

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	B26B ; C23C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	FR,A,2 187 941 (GILLETTE INDUSTRIES LTD.) 18 January 1974 see page 1, line 1 - page 2, line 28 see page 3, line 33 - page 5, line 5	1-3,5,7, 13,14, 16-18, 21,22
Y		10-12, 15,23, 24,28

Y	US,A,3 802 078 (P. A. DENES) 9 April 1974 see column 1, line 17 - line 41 see column 2, line 52 - column 3, line 67 see column 6, line 45 - line 49	10-12, 24,28
A		1-3,26, 27

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° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
11 AUGUST 1992	21. 08. 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	RAVEN P.

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	EP,A,0 351 093 (WARNER-LAMBERT CO.) 17 January 1990 cited in the application see page 3, line 2 - line 6 see page 6, line 14 - line 22	15,23
X	US,A,3 774 703 (M. D. SANDERSON) 27 November 1973 see the whole document	1-3,5, 6-8,13, 14, 16-18, 21,22
A		24,25
X	FR,A,1 600 109 (WILKINSON SWORD LTD.) 20 July 1970 see the whole document	1,2,5,7
A	EP,A,0 089 818 (UNITED KINGDOM ATOMIC ENERGY AUTHORITY) 28 September 1983 see page 1, paragraph 1 see page 4, paragraph 2 - page 5, paragraph 2	1,2,4,7, 8,16,17, 19,24
A	US,A,4 933 058 (BACHE ET AL) 12 June 1990 cited in the application see column 1, line 36 - column 2, line 68; figure 1	1,2,5-7, 16,17, 20,24
A	WORLD PATENTS INDEX LATEST Section Ch, Week 8949, 26 October 1989 Derwent Publications Ltd., London, GB; Class M, AN 89-360030 & JP,A,1 268 857 (HATTORI & IWASAKI MEKKI) 26 October 1989 see abstract	1,5,9

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 9201946 SA 59614

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 11/08/92

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		US-A- 4470895	11-09-84
US-A-4933058	12-06-90	None	

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