CP 03-2

PETITION

Requesting the Consumer Product Safety Commission To Initiate Rulemaking for Table Saws

We, the undersigned, hereby petition the Consumer Product Safety Commission under 5 U.S.C. §553(e) and 15 U.S.C. §2058(i) to initiate rulemaking for table saws. We propose a rule substantially as follows:

> Every table saw designed primarily for cutting wood with a blade having a nominal diameter of 12 inches or less shall be equipped with the following:
>
> 1) a detection system capable of detecting contact or dangerous proximity between a person and the saw blade when the saw blade is a) spinning prior to cutting, b) cutting natural wood with a moisture content of up to 50%, c) cutting glued wood with a moisture content of up to 30%, and d) spinning down after turning off the motor;
> 2) a reaction system to perform some action upon detection of such contact or dangerous proximity, such as stopping or retracting the blade, so that a person will be cut no deeper than $1/8^{th}$ of an inch when contacting or approaching the blade at any point above the table and from any direction at a rate of one foot per second;
> 3) a self-diagnostic capability to verify functionality of key components of the detection and reaction systems; and
> 4) an interlock system with the motor so that power cannot be applied to the motor if a fault interfering with the functionality of a key component in the detection or reaction system is detected.
>
> The detection and reaction systems shall be designed to function automatically when the saw is turned on, however, the saw may include a bypass function to allow a user to volitionally bypass the system to cut, for example, conductive materials such as aluminum. The detection and reaction systems may be designed to function with only certain saw blades as specified in an operation manual or in markings on the saw.

Regulated Products

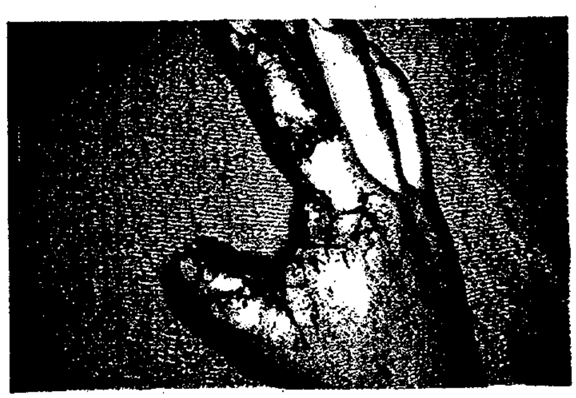
The products regulated under the Consumer Product Safety Act for which a rule is sought are table saws, including bench top table saws, contractor saws, hybrid table saws, cabinet saws, and tilting arbor saws.

Specific Risks of Injury Addressed by the Petition and Severity of Injuries

Every year in the United States there are over 30,000 serious injuries involving table saws. That's one injury every eighteen minutes. About 90% of these injuries are to fingers and hands. About 10% of these injuries are amputations. Around 70% of these injuries occur at home, and about 1.5% occur at schools. About 8% of these injuries are to teenagers and young adults.[1]

These are serious injuries that change people's lives. It is important to understand the gravity of these injuries. Here is a photograph of an injury to a 22-year-old carpenter who cut off his index finger and the tip of his right thumb on a saw.[2]

The amputated thumb fragment was too badly damaged to be reattached. The amputated index finger fragment was intact, but was not reattached because it would likely have poor function. Instead, the tip of the index finger was used to make a new thumb, as shown in the following photograph.



SEE PAGE 37

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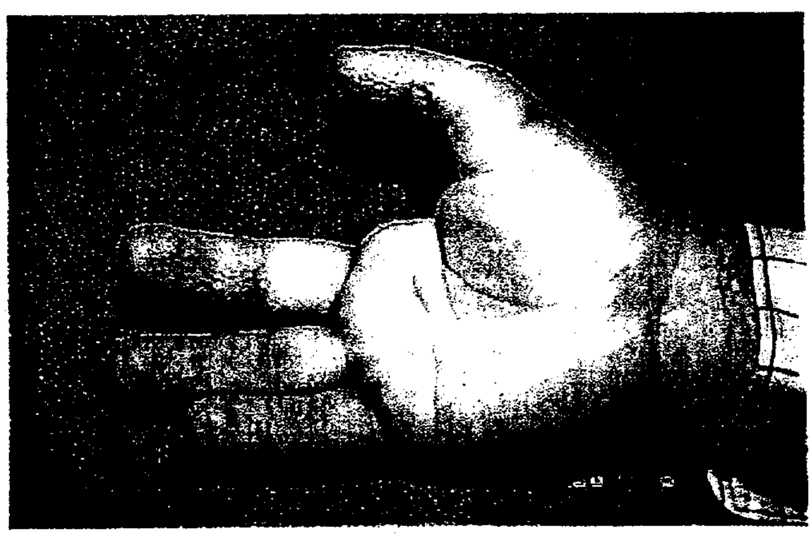
[1] U.S. Consumer Product Safety Commission, National Electronic Injury Surveillance System, Directorate for Epidemiology, statistics for calendar year 2001.

[2] The Buncke Clinic, http://buncke.org/book/ch2/ch2_5.html#. The web site refers to the accident simply as a "saw" injury. It is believed that the injury is typical of an injury involving a table saw.

A 42-year old cabinet maker suffered saw amputations of his right thumb and index finger and partial amputations of his long and ring fingers, as shown in this photo.[3]

His thumb was reconstructed, but he lost his index finger, as shown below.



[3] The Buncke Clinic, http://buncke.org/book/ch2/ch2_5.html#. The web site refers to this accident simply as a "saw" injury. It is believed that the injury is typical of a table saw injury.

Possible Reasons for the Existence of the Risk of Injury

A table saw is an inherently dangerous machine. It includes a spinning blade that must be exposed to cut a work piece. A person uses a table saw by holding a work piece and feeding it past the spinning blade. If a user accidentally places their hand in the path of the blade, or if their hand slips into the blade, then the user could receive a serious injury or amputation. Often a person would lose one or two fingers before they could react to pull their hand away from the blade. This is a typical accident scenario.

Accidents also happen because of what is called kickback. Kickback may occur when a work piece contacts the downstream edge of the blade as it is being cut. The blade then propels the work piece back toward the user at a high velocity. When this happens, the user's hand may be carried into the blade because of the sudden and unexpected movement of the work piece.

Table saws sold in the U.S. include blade guards to try and prevent these injuries. However, many people using table saws do not use blade guards because the guards interfere with the operation of the saw. For example, blade guards cannot be used and must be removed for any cutting operation where the blade does not extend through the work piece, such as dado cuts (cutting a groove or channel in a work piece) and rabbet cuts (cutting a channel from an edge or corner of a work piece). Guards also must be removed for plunge cuts, where the blade is raised up through the middle of a work piece. Once guards are removed, they are often difficult to reinstall, which means that some people do not to bother to do so. Table saw users also complain that guards block the view of the cut, and they interfere with narrow cuts.

Estimated Cost of Injuries

Accidents involving table saws extract a tremendous toll in suffering on the part of the victims, and they represent a significant economic cost to society for treatment and lost productivity. The average cost per serious injury, including acute medical treatment, rehabilitation and lost productivity could easily exceed $5,000 to $10,000 per injury, with the cumulative cost of 30,000 injuries being $150 to $300 million per year. The total retail market for table saws in the United States is probably somewhat less than $200 million per year. Thus, the yearly economic cost of the injuries involving table saws may well exceed the total annual retail cost of the saws themselves.

Current Safety Standards are Insufficient

The current safety standards for table saws are promulgated by Underwriters Laboratories (UL) as Standard 987 for Stationary and Fixed Electric Tools. Virtually all table saws sold in the United States meet those safety standards. Nevertheless, table saw accidents continue to occur in large numbers. Clearly, the number of injuries, the tremendous toll in suffering, and the significant economic costs of the injuries demonstrate the need for more effective safety standards for table saws.

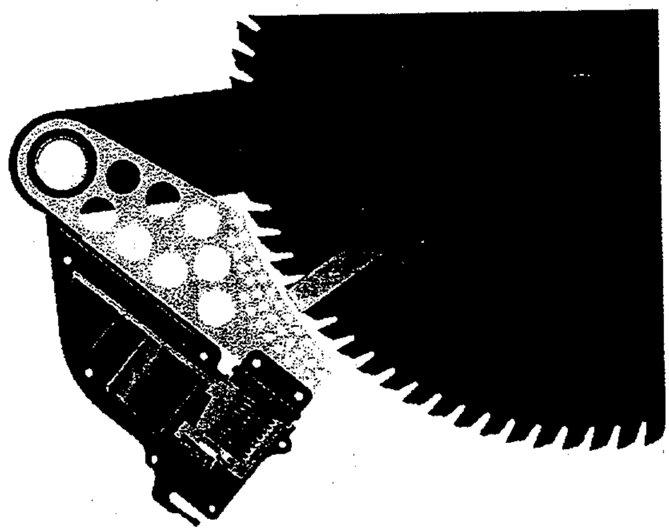
Reasons to Initiate Rulemaking

Two-and-a-half years ago Dr. Stephen Gass, one of the petitioners, invented a new technology called SawStop that can tell the difference between cutting wood and cutting a person. The SawStop technology detects accidental contact between a person and a saw blade, and then reacts to minimize any injury, much like an airbag in a car or a ground fault circuit interrupter in an electric outlet. Typically, a saw equipped with the SawStop technology would detect accidental contact and then stop the blade within just a few milliseconds, dramatically reducing the potential for serious injury.

The SawStop technology utilizes two systems: a contact detection system and a braking system. The contact detection system works by recognizing differences between the electrical properties of wood (or any non-conductive material) and a person. In particular, the saw blade is electrically isolated and a small electrical signal is induced upon it. This signal is relatively unchanged when cutting wood or other non-conductive material because of the small inherent capacitance and conductivity of the material. However, when a person touches the blade, the signal immediately changes because of the relatively large inherent capacitance and conductivity of the person's body. If a person is wearing a glove, then the blade would cut through the glove and the signal would change as soon as the blade contacted skin.

The drawing below shows what happens to the electrical signal when an actual finger touches the teeth of a spinning saw blade. The line in the drawing represents the signal, and the signal drops quickly when the blade contacts a person's body. The dips in the drawing represent individual teeth on the blade touching a finger. When the detection system sees dips like those shown, it knows that a person has touched the blade.

The braking system then acts to minimize the injury. The braking system uses a spring to push a block of aluminum or plastic, called a brake pawl, into the teeth of the blade to stop the blade from spinning. The spring is held in compression by a fuse wire until the detection system detects contact. When the detection system detects contact, the reaction system sends a surge of electricity through the fuse wire to burn the wire and release the spring. The spring pushes the brake pawl into the teeth of the spinning blade, and the teeth cut into the brake and bind, thereby stopping the blade. This is shown in the drawing on the next page. The arrow in the drawing shows how the aluminum brake pawl pivots into the teeth of the blade. The brake pawl is part of a replaceable cartridge that includes the spring, fuse wire and electronics necessary to burn the fuse wire.



The action of stopping the blade also causes the blade to retract and drop below the table. The system also interrupts power to the motor when the system detects accidental contact.

Detecting accidental contact and releasing the brake pawl happens within 100 microseconds, or 1/10,000th of a second. Stopping the blade happens within about three to five milliseconds, or 1/200th of a second. At that speed, the typical resulting injury would be a relatively minor nick. In contrast, the same accident without SawStop could easily result in the loss of several fingers.[4]

The SawStop technology also includes a self-test system that continuously tests to make sure key components of the contact detection and braking systems are functioning. If one of those components fails or is not in place, then the system prevents a user from starting the saw until the problem is corrected. If the saw is running and the self-test system detects a problem, then the system turns the saw off until the problem is corrected.

Commercial embodiments of a cabinet saw and a contractor saw including the SawStop technology have been built. A prototype cabinet saw is currently being used in production in a major cabinet factory, and has been for some time. That saw is performing as expected.

Prototype table saws with the SawStop technology also have been reviewed by the U.S. Consumer Product Safety Commission (CPSC), the German BIA and the French INRS, and those agencies have issued reports concerning the technology. Copies of those reports are attached. SEE PAGE 385

[4] It is important to understand that SawStop will not prevent all serious injuries or even all amputations from table saws. The SawStop technology works to minimize injury. The severity of an injury will depend on the speed at which a person contacts the blade. Additionally, like any mechanical or electrical system, SawStop may have some failures. Nevertheless, SawStop has the potential to enormously reduce the severity of injuries in most table saw accidents.

Additionally, most of the major saw manufacturers in the United States have studied and tested an early prototype saw equipped with this technology.[5] During those studies, the manufacturers raised several issues with the prototype saw that they said justified not adopting the technology. Those issues have now all been resolved.

First, the manufacturers said that the reaction system could be made to fire when cutting very wet or green wood. The prototype saw that the manufacturers tested would cut most wet and green wood without problem. It was only extremely wet or green wood that would trip the system. One manufacturer described going to Home Depot to select the wettest board from the middle of a stack of pressure-treated lumber and having to cut that board within an hour of purchase to cause a false trip. Only a tiny fraction of wood that is cut on table saws is extremely green or wet, and even if the saw misfired in those cases, the result would be a safe stopping of the saw – not an injury. Nonetheless, the detection system has now been modified to distinguish even very wet or green wood.

The manufacturers also said that the reaction system in the saw included a brake cartridge that was not sealed against sawdust and could therefore malfunction. The brake cartridge the manufacturers reviewed was a prototype built to demonstrate the technology. A brake cartridge has now been developed and built that is sealed against sawdust and other possible pollutants, and that is suitable for manufacturing.

Finally, some manufacturers have suggested that the technology should not be adopted because it will promote carelessness by users. It is absurd to suggest that table saws should not be made safer because that will somehow make them more dangerous. Following the logic of this argument, we should remove blade guards from saws because the guards will cause people to be more careless. Of course, we should also remove seatbelts and airbags from cars so that people will drive more carefully. It is unlikely that manufacturers really believe this argument. It is more likely that manufacturers have raised this argument in an attempt to avoid the cost of implementing this new technology. Clearly, if the existing standards can be changed to make table saws safer at a reasonable economic cost, we should do so.

The SawStop technology has received numerous awards and endorsements, including:

- **Chairman's Commendation.** In July 2001, the U.S. Consumer Product Safety Commission awarded SawStop a Chairman's Commendation for significant contributions to product safety.
- **Challenger's Award.** At an Atlanta trade show where the technology was first introduced, SawStop won the Challenger's Award, which is the woodworking industry's highest honor. It recognizes the most innovative and technically advanced improvements to woodworking equipment.
- **Popular Science – One of the 100 Best New Innovations.** The magazine *Popular Science* has named the SawStop technology one of the 100 best new innovations of 2002.

[5] The companies that have studied a prototype SawStop saw are: Black & Decker (Black & Decker and DeWalt brands), Ryobi (Craftsman and Ryobi brands), S-B Power Tool Co. (Skil and Bosch brands), Emerson (Ridgid brand), WMH Tool Group (Jet and Powermatic brands), Hilti (Hilti brand), and Rexon (Craftsman and Tradesman brands). Other companies that have studied the technology or various components of the SawStop system include Delta Machinery (Delta and Porter Cable brands) and Makita (Makita brand).

- **Workbench Magazine – One of the Top 10 Tools for 2003.** *Workbench* magazine named SawStop to its list of the top ten innovative tools for 2003.
- **Woodwork Institute of California Endorsement.** The Woodwork Institute of California has endorsed the SawStop technology, stating:

> As a Trade Association in the construction industry (representing over 250 manufacturers of architectural millwork with an excess of 4,000 employees, all of whom use saws of one type or another) we find your SawStop technology and its potential of eliminating or reducing worker injury of extreme significance. Generally, we would not endorse a commercial product; however the potential benefit to our members and their employees of implementing the SawStop technology on the tools used within our industry overrides such. (Letter dated 11/30/00 from Stanley R. Gustafson, CEO/Secretary, Woodwork Institute of California, to Stephen Gass.)

- **Editor's Choice Award, Tools of the Trade.** The magazine *Tools of the Trade* awarded SawStop the 2001 Editor's Choice Award in recognition of the significance of the new technology.

The SawStop technology also has been the subject of extensive media coverage, including national coverage by CNN Headline News, by the television program NEXT@CNN, and by the Associated Press.

Availability of the SawStop Technology

Dr. Gass, David A. Fanning and James David Fulmer, three of the petitioners, are members of a limited liability company called SD3, LLC, that owns patent rights related to the SawStop technology. SD3 will make the SawStop technology available for license at a rate of not more than 8% of the wholesale cost of a saw if this standard is adopted. If saw manufacturers license the SawStop technology, then those three petitioners will likely benefit financially from the adoption of this new standard. However, the proposed standard is performance based, and is worded broadly enough to allow any type of solution to the problem. The SawStop technology demonstrates only one way to meet the proposed standard. There may be other systems that could be used to satisfy the proposed standard.

Cost to Implement the SawStop Technology

Dr. Gass believes the SawStop technology can be implemented for less than an average cost increase of 25% per table saw, including any royalty. That cost is likely to decrease as the technology matures.

Rulemaking Should be Initiated As Soon As Possible

The Consumer Product Safety Commission should adopt the proposed standard now because technology is available to make table saws safer, and that technology is demonstrably viable. Adoption of the proposed new standard would result in substantially safer table saws, and the economic savings that would result from reducing the number and severity of table saw injuries would more than make up for the economic cost of implementing the new standard.

The only significant issue that can be raised regarding adoption of the proposed standard at this time is that table saws meeting the standard have not yet been produced on a commercial basis. Under some circumstances, that could be a sufficient justification to delay adoption of the standard. However, in this case, the technology to comply with the proposed standard has been available to all of the major saw manufacturers for more than two years. During that time, not one manufacturer has even attempted to implement a commercial saw with the technology. One would have expected the manufacturers to work diligently to incorporate this technology into their saws or to conclusively demonstrate that it couldn't be done. On the contrary the manufacturers have done everything they could to avoid implementing the technology. In fact, an attorney introduced as the lead product liability litigation coordinator for one major saw manufacturer, said at a legal education conference for attorneys specializing in defending power tool injuries that if a couple of years go by without anyone implementing the technology, then manufacturers could argue that the technology was not viable because no one had adopted it. In the same talk, that attorney also suggested that manufacturers should argue that the technology was not viable because it was not an industry standard. In other words, this attorney said that if manufacturers never voluntarily adopt the technology, they might never have to. The president of another major saw manufacturer said it could be in his company's interest to delay introduction of the SawStop technology as long as possible in order to maximize the return on his existing manufacturing tools. A vice-president of a third major saw manufacturer said that his company wasn't interested in the SawStop technology because "safety doesn't sell." Under these circumstances, where manufacturers are looking for reasons not to implement safer technology, it is appropriate to take action to protect the public from unnecessary injury even in the absence of a commercial product.

In view of the fact that saws incorporating SawStop technology are not yet on the market, a high level of proof of viability should be required before taking regulatory action. As such, Dr. Gass is willing to make a saw incorporating this technology available for testing and evaluation by the CPSC to confirm the viability of the technology.

Lastly, some people have suggested that a mandatory standard is unnecessary — they say we should let consumers choose whether to buy safer saws or not. We disagree. Mandatory standards should be enacted because consumers do not have the information necessary to make a fully informed choice. Specifically, consumers do not know the number of injuries occurring on table saws, the severity of those injuries, the likelihood that they will suffer an injury, the economic cost of those injuries, or the cost of implementing a system like SawStop. If consumers had that information, it is likely that they would choose to pay the extra marginal cost to obtain a saw equipped with something like SawStop. The Consumer Product Safety Commission, on the other hand, has that information, and the information demonstrates that the public interest is best served by adopting the proposed standard.

Finally, rulemaking should be initiated now because a voluntary standard is unlikely. The SawStop technology has been discussed by the UL panel responsible for safety standards concerning stationary and fixed electric tools, and that panel has decided not to take any action because it says it does not have the ability to independently review the technology. That panel is comprised mainly of representatives from saw manufacturers. Additionally, it would be difficult for one company to voluntarily adopt the new technology if other companies do not because of the cost of implementing the technology.

For the reasons stated above, the undersigned hereby petition the Consumer Product Safety Commission under 5 U.S.C. §553(e) and 15 U.S.C. §2058(i) to initiate rulemaking for table saws.

Sincerely,

Date: 4/15/03

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Date: 4-15-03

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Date: 4-15-03

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Additional Signatures Follow on Subsequent Pages.

SEE SUPPLEMENTAL
INFO AT PAGES 44-04

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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11

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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12

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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13

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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15

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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16

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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17

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

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86.	FORD, Joseph D., Jr.	49 Warbler Lane W. Yarmouth, MA 02673 508-398-3544	
87.	FOSLIEN, Patrick	12500 18th Avenue N. Plymouth, MN 55441 612-644-1005	
88.	FOURNIER, Karl, M.D.	2400 Patterson St., Ste. 300 Nashville, TN 37203 615-342-6300	
89.	FRANCIS, William	P.O. Box 305 Stowe, VT 05672	Signature is on the page with Ralph Waddell.
90.	FRANTZ, Gary,M.D.	541 Edgewood Road Mansfield, OH 44907 419-756-3117	
91.	FREDKOVE, Joe	12020 Mayflower Circle Minnetonka, MN 55305 952-544-2785	
92.	FULMER, James David	19930 S.W. 59th Terrace Tualatin, OR 97062 503-885-1040	
93.	FUSSELL, Del D.	11455 N. Antelope Lane Parker, CO 80138 303-805-2663	
94.	GAMMAN, Steve	2318 N. 38th Street Seattle, WA 98103 206-547-1286	
95.	GANJE, Josh	1101 3rd Street SW Clear Lake, WI 54005 715-263-2113	
96.	GANS, Shannon	6650 Vista del Mar #2 Playa del Rey, CA 90293 310-823-2050	
97.	GASS, Stephen F.	22409 S.W. Newland Road Wilsonville, OR 97070 503-638-6102	
98.	GOCHOEL, Susan	5107 N. 39 Street Tacoma,WA 98407 206-498-4167	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

Name	Address & Phone Number	Notes
99. GOCHOEL, Brian C.	5107 N. 39 Street Tacoma, WA 98407 206-498-4167	
100. GODBOUT, Ronald E.	2 Woodlawn Avenue Northfield, NH 03276 603-286-7741	
101. GOLDEN, Daniel T.	641 Hillwood Court St. Paul, MN 55119 651-721-1519	
102. GOLDSTEIN, Albert	3666 Middleton Drive Ann Arbor, MI 48105 734-662-4780	
103. GOTTGFEB, Larry	160 Cooper Road West Berlin, NJ 08091 856-768-9600	
104. GOUGH, Kerry M.	6212 Auburn Avenue Oakland, CA 94607 510-832-5800	
105. GOUGH, Matthew	649 Canyon Drive Auburn, CA 95603 530-823-6024	
106. GRANITZKI, Jeff	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
107. GRANITZKI, Jesse	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
108. GRATZNER, Matthew	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	
109. GREENWALD, Jessica	3835 S.W. 58th Court Miami, FL 33155 305-667-2418	
110. GRETILLAT, Lon	14 Quarry Road Mason City, IA 50401 641-422-9962	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
111.	GRIECO, Patrick	27 Niagara Street Toronto, ON M5V 1C2 Canada 416-979-8162	
112.	GROENKE, Kevin	89 Church Street S.E. 139 Rapson Hall Minneapolis, MN 55455 612-624-9093	
113.	GROW, Sara	8550 Evanston Ave. N. Seattle, WA 98103 206-320-5237	
114.	GUNTER, Peter	1625 Morris Avenue S. Benton, WA 98055 206-779-5917	
115.	HADACEK, Matthew W.	13281 Elizabeth Street Thornton, CO 80241 303-280-4683	
116.	HALES, Sherman R.	P.O. Box 1118 Magalia, CA 95954 530-873-0579	
117.	HALL, Tim	11912 Spring Drive St. Louis, MO 63131 314-997-2901	
118.	HALL, Amy K.	7407 W. Manchester Ave. #8 Los Angeles, CA 90045 310-410-9407	
119.	HANEY, Harry	1945 Wallinford Circle Sun Prairie, WI 53590 608-834-1057	
120.	HANSEN, Todd	5 Michael Blvd. #9 Whitby, ON L1N 5P4 Canada 905-430-7529	
121.	HARDS, Margaret M.	50 North Medical Drive Salt Lake City, UT 84132 801-581-2137	
122.	HARDY, Sarkis	2703 S. 10th Avenue Arcadia, CA 91006 626-447-9811	

20

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
136.	HOULE, Roger	34 Oxford Street W. Moose Jaw, SK S6H 2N1 Canada 306-694-0654	
137.	HOWELL, Ken	17501 S.E. 16th Circle Vancouver, WA 98683 360-892-7461	
138.	HUISINGA, R. E.	17425 N. 16th Dr. Phoenix, AZ 85023 602-452-4439	
139.	HULTGREN, Gregory D.	202 Ridgewood Avenue Minneapolis, MN 55403 612-870-9924	
140.	HUNTER, Ian	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	
141.	HYSON, Donald E.	601 S. Church Street Winnebago, IL 61088 815-335-2966	
142.	ISHAM, Timothy W.	151 Moore Street Bailey, CO 80421 303-816-2164	
143.	JACOBSEN, Kirk L.	990 N. Phoenix Road Medford, OR 97502 541-857-4226	
144.	JACOBSEN, Andrew	3420 Skillman Lane Petaluma, CA 94952 707-765-9385	
145.	JOCIUS, James M.	1005 Hiawatha Drive Elgin, IL 60120 847-741-5954	
146.	JONES, Jeffrey B.	603 S.E. 6th Street Battle Ground, WA 98604 360-723-5142	
147.	KALRA, Camellia	5905 Washburn Avenue S. Minneapolis, MN 55410 952-920-8252	

22

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

Name	Address & Phone Number	Notes
148. KAPLAN, F. Thomas	7203 N. Charles St. Lutherville, MD 21093 410-825-3265	
149. KASDAN, Morton, M.D.	P.O. Box 6048 Louisville, KY 40206 502-897-1601	
150. KEATON, Alan L., M.D.	218 Rainbow Drive Livingston, TX 77399 541-953-3751	Submitted individual comments.
151. KEESLING, Brooke	4107 Redwood Avenue Los Angeles, CA 90066 310-578-9929	
152. KELLEY, William C.	606 20th Street East Tifton, GA 31794 229-382-2857	
153. KELLIHER, Steve	4664 Baxter Road Cottage Grove, WI 53527 608-846-3010	
154. KELLY, Michael	Swedish Hospital Providence Campus 500 - 17th Avenue Seattle, WA 98124 206-320-2404	
155. KING, James T., J.D.	813 Patterson Avenue Glendale, CA 91202 818-242-1100	
156. KJOME, Eric B.	492 Montrose Ave. Elmhurst, IL 60126 630-833-5153	
157. KLUGE, Steven C.	29 Long Creek Drive Burnt Hills, NY 12027 518-399-0758	
158. KLUGE, Tamara	29 Long Creek Drive Burnt Hills, NY 12027 518-385-9755	
159. KNAPP, Terry S.	1299 N. Orchard, Ste. 110 Boise, ID 83706 208-336-0801	Submitted individual comments.

25

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
160.	KNEBEL, Kyle C.	1107 S. Burnside Avenue Los Angeles, CA 90019 323-936-1037	
161.	KNEBEL, William E.	32108 Beachmeadow Lane Westlake Village, CA 91361 818-889-8010	
162.	KURSTEN, Henri	4410 Budd Road Lockport, NY 14094 716-434-0994	
163.	KWAK, Anita L.	2329 Halbeck SW Seattle, WA 98116 206-937-1791	Submitted individual comments.
164.	LAFFERTY, William B., Esq.	512 Lakeshore Drive Atlanta, GA 30307 404-378-7253	
165.	LANDGRAF, Donald R.	409 Hillcrest Drive Waterloo, IL 62298 618-939-7714	
166.	LANGILLE, Aletta	15 Douglas Court W. Brooks, AB T1R 0B6 Canada 403-362-4007	
167.	LARU, Kevin S.	720 Cleveland Avenue Racine, WI 53405	
168.	LaRUE, David R.	7609 Baimbridge Downers Grove, IL 60516 630-810-9543	
169.	LAU, Shirley	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9139	From UL Int'l Ltd.
170.	LAURO, Paul M.	259 Anzio Rd., #B Ft. Lee, VA 23801 804-734-0075	Submitted individual comments.
171.	LEACH, Robert S.	1551 Irene Street Bethlehem, PA 18017 610-758-3288	

24

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
172.	LeFEVRE, Brian	12149 E. Exposition Drive Aurora, CO 80012 303-344-3903	
173.	LEIDIG, Peter, P.T.	22310 34th Place W. Brier, WA 98036 206-320-3273	
174.	LEONARD, Lawrence M., M.D.	26 Amerescoggin Road Falmouth, ME 04105 207-781-2426	
175.	LIDDLE, Curtis B.	51 Jordan Road Plymouth, MA 02360 508-747-0109	
176.	LIN, Jacky	No. 78, Yuang Feng Road Taiping, Taichung Taiwan, ROC 886-4-22700258	
177.	LINDSTROM, Mark	305 Sunnyvale Lane Minnetonka, MN 55305 612-359-1341	
178.	LITWIN, Ralph	72 Dean Road Mendham, NJ 07945 973-543-9779	
179.	LLOYD, Michael D.	4226 Pillsbury Avenue S. Minneapolis, MN 55409 612-822-6308	
180.	LOCKWOOD, C.K.	10508 N.E. 36th Avenue Vancouver, WA 98686 360-546-3329	
181.	LUDKE, Harry	4721 Bennett Road Cuyler, NY 13158 607-842-6781	
182.	LUDWIG, Robert	9 Rose Lane Chappaqua, NY 10514 914-666-6692	
183.	MACHER, Robert J.	777 River Hills Drive Fenton, MO 63026 314-968-3222	

25

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
184.	MacINTOSH, Randy	50 Riverstar Circle Sacramento, CA 95831 916-427-2556	
185.	MAN, Fung Wing	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9589	From UL Int'l Ltd.
186.	MANCINELLI, Troy	427 River Isle Court Longwood, FL 32779 407-786-4938	
187.	MANSHIP, James L.	9029 Jeffery Avenue South Cottage Grove, MN 55016 651-458-3241	
188.	MARENICK, Robert M.	912 Gristmill Drive Rock Hill, SC 29732 803-366-8727	
189.	MAROTTA, David	1562 Rugby Circle Thousand Oaks, CA 91360 805-374-2052	
190.	MARSELLOS, Richard E.	5173 Ute Road, Box 411 Indian Hills, CO 80454 303-697-5894	
191.	MARTI, M. Felix	66 Bluestem Ridgway, CO 81432 970-626-4169	
192.	MASTERS, Celeste	7600 W. Manchester Playa del Rey, CA 90293 310-827-8518	
193.	McADAMS, Richard S.	8550 Evanston Ave. N. Seattle, WA 98103 206-320-5237	
194.	McCANDLESS, Stuart C.	5 Cozy Hollow Road Danbury, CT 06811 203-791-3500	
195.	McCORMICK, Kathy	2318 N. 38th Seattle, WA 98103 206-547-1286	

26

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
196.	McDADE, Thomas W., Jr.	6925 S.E. 34th Street Mercer Island, WA 98040 206-232-0249	
197.	McDANIEL, Patricia A.	3723 Highway One Rehoboth Beach, DE 19971 302-227-5754	
198.	McGOEY, Vince	660 Corrigan Crescent Peterborough, ON Canada 705-743-3982	
199.	MERRITT, Kip	4020 N. 85th Street Scottsdale, AZ 85251 480-990-2290	
200.	MILLER, Bob	5180 Commerce Dr., Ste. X Murray, UT 84107 801-262-8888	
201.	MILLER, Corwyn	108 Parkland Way Brooks, AB T1R 0M4 Canada 403-362-4558	
202.	MILLER, Eric W.	280 Brubaker Drive New Carlisle, OH 45344 937-845-0211	
203.	MILLER, Melissa	801 Pine Street Seattle, WA 98101 206-284-5527	
204.	MILLER, Ronald L.	95-1025 Hakala Street Mililani, HI 96789 808-626-2590	
205.	MINNEY, Kurtis C.	2002 Crestmont Street Norman, OK 73069 405-366-7562	
206.	MIYANO, John	9701 44th Avenue NE Seattle, WA 98115 206-985-8439	
207.	MOFFETT, Scott	111 S. 13th Street Nashville, TN 37206 615-226-8182	

27

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
208.	MOLEDOR, John	2684 Shaffer Road Atwater, OH 44201 330-628-9626	
209.	MONTGOMERY, Matt	2020 Fox Hunt Drive Troy, VA 22974 434-296-5097	
210.	MORETZ, Sarah	514 Ebenezer Avenue Rock Hill, SC 29730 803-417-0595	
211.	MORGAN, Chris H.	1102 Ellard Drive Hickory Creek, TX 76210 972-977-8705	
212.	MORRIS, Chad	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
213.	MOSKAU, Mike	920 Loveland Street Golden, CO 80401 303-279-0294	
214.	MOTA, Raymond N.	3026 Patricia Court Santa Maria, CA 93455 805-938-3185	
215.	MUNRO, Alick	1330 Delese Circle Reno, NV 89511 775-851-1518	
216.	NABORS, Jane	13109 NE Vinemaple Road Brush Prairie, WA 98606 360-892-1614	
217.	NANCOLLAS, Michael, M.D.	475 Irving Avenue, Suite 418 Syracuse, NY 13210 315-426-0190	
218.	NELSON, Timothy M.	1306 Meadows Lane Greenwood, MO 64034 816-537-8891	
219.	NEWLAND, Doug	P.O. Box 753 Northfield, MN 55057 612-298-3068	
220.	NEWMAN, Donald W.	7200 Treeridge Drive Cincinnati, OH 45244 573-231-7922	

28

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
221.	NIEBERGALL, John	24033 S.W. Cascara Terrace Sherwood, OR 97140 503-625-4107	
222.	NIELSON, Charlie	557 E. 3200 N. North Ogden, UT 84414 801-782-1892	
223.	NORMAN, Doris	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
224.	NOVOTNY, James A.	Livingston High School Livingston, NJ 07039 973-535-8000	
225.	NYSTUEN, Leslie, M.D., MSPH	234 Concord Avenue #1 Cambridge, MA 02138 617-492-8567	
226.	OBERMEYER, Thomas	1501 Hennepin Avenue Minneapolis, MN 55403 612-359-1523	
227.	ODOM, William R.	700 Iowa Avenue Whitefish, MT 59937 406-863-4890	
228.	OLSON, Elder J.	103 Blasingame Street St. Simons Island, GA 31522 912-638-2731	
229.	OVARD, David	615 E. Whitehall Meridian, ID 83642 208-363-1583	
230.	OVERSTREET, William H.	not specified	
231.	PAPE, James G.	4 Duchess Avenue S. Burlington, VT 05403 802-651-7021	
232.	PARKER, John C.	908 Highland Ave., Ste. #1 Kenai, AK 99611 907-283-3007	
233.	PATTON, George	205 Creek Drive Glassboro, NJ 08028 856-256-1663	

29

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
234.	PEFFER, Bryan	15836 Hyland Pointe Court Apple Valley, MN 55124 952-953-4719	
235.	PERCY, Ty	6604 N.E. 163rd Avenue Vancouver, WA 98682 360-883-0516	
236.	PIERCE, Thomas H.	39 Laurelwood Lawrenceville, NJ 08648 609-896-8106	
237.	PLUMMER, Jeanne	49745 N.W. Schmidlin Lane Buxton, OR 97109 503-324-7586	
238.	PORTER, Bill	2117 N.E. Kim Lane Bend, OR 97701 541-388-3892	Submitted individual comments.
239.	POTTER, Robert P.	1324 So. Vermont Avenue Davenport, IA 52802 563-323-0382	
240.	POTTS, David W.	7819 S.E. 105th Avenue Portland, OR 97266 503-520-7005	
241.	POULIN, Earl	3924 Terrace Street Kansas City, MO 64111 816-753-4121	
242.	POWELL, Benjamin O.	1128 Barstow Avenue #6 Clovis, CA 93612 559-324-7179	
243.	POWERS, Roger N.	926 Trevino Road Southport, NC 28461 910-845-2178	
244.	PRICE, Robert O.	2192 Shady Run Road Vinton, VA 24179 540-890-6887	
245.	PURDUE, Patrick	14284 Neptune Road Seminole, FL 33776 727-517-9112	
246.	QUINN, John	4635 Bridle Trail Santa Rosa, CA 95409 707-537-8691	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
247.	RAMIREZ, Ricardo A.	1705 Corpus Christi Street Laredo, TX 78040 956-726-4817	
248.	RAY, Larry A.	1409 North Fifth Street Red Oak, IA 51566 712-623-4086	
249.	REBER, Cheryl	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
250.	REED, Gerald, Dr.	10 Crescent Drive Glencoe, IL 60022 847-835-7053	
251.	REED, John	24700 McBean Parkway Valencia, CA 91355 661-255-1050	
252.	REGEHR, Ralph	867 McLeod Avenue Winnipeg, MB R2G 0Y4 Canada 204-668-0079	
253.	REYNOLDS, Joseph	99 Grow Avenue Montrose, PA 18801 570-278-1179	
254.	REYNOLDS, William E.	412 Englewood Drive Lufkin, TX 75901 936-639-9725	Submitted individual comments.
255.	RICHMAN, Jonathan, M.D.	1 Atwell Road Cooperstown, NY 13326 607-547-3468	Submitted individual comments.
256.	RICHTER, Christel	330 Oak Grove St., #M15 Minneapolis, MN 55403 612-813-0632	
257.	RIVERS, Richard "Brent"	2325 Woodcrest Drive Smyrna, GA 30082 770-805-0733	
258.	ROBB, Jill A.	P.O. Box 675550 15563 La Madreselva Rancho Santa Fe, CA 92067 858-756-2078	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
259.	ROBERTS, Simeon B., Jr.	7015 Brooklyn Blvd. Brooklyn Park #306 Minneapolis, MN 55429 763-503-4702	
260.	ROIRDON, Ray	Box 9726 Seattle, WA 98109 206-284-5527	
261.	ROLAND, William A.	3627 Leeville Road Mt. Juliet, TN 37122 615-449-6646	
262.	RÖSELER, Kurt	64560 Highway 30 Deer Island, OR 97054 503-366-1472	
263.	ROSEN, Paul	226 N. Rouse Street Mundelein, IL 60060 847-566-2805	
264.	ROSENBERGER, Jack B.	2286 Encino Loop San Antonio, TX 78259 210-337-1234	
265.	ROSENTHAL, Andrew H.	1500 E. Medical Center Dr. 2130 Taubaum Ann Arbor, MI 48109 734-936-5895	
266.	ROYER, Christopher	8245 Carriage Oaks Way Antelope, CA 95843 916-729-1325	
267.	SCARIN, William J.	401 Washington Blvd. #10 Mundelein, IL 60060 847-566-6979	
268.	SCHNEIDER, Scott	22045 Del Valle Street Woodland Hills, CA 91364 818-999-9017	
269.	SCHUEFER, Casey	3055 Remington Drive West Linn, OR 97068 503-723-5004	
270.	SHAW, Gloria E.	182 E. Walnut Avenue Realto, CA 92376 909-820-7700	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
271.	SHAW, John R.	241 Rifle Range Road Sparta, NC 28675 336-372-8001	
272.	SIMPSON, Wendy	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
273.	SINCLAIR, David	11705 N.W. 26th Avenue Vancouver, WA 98685 360-576-6323	
274.	SINK, Pak Hiu	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9514	From UL Int'l Ltd.
275.	SKLIVAS, Howard	600 Denbury Avenue Ottawa, ON K2A 2P1 Canada 613-722-2724	
276.	SLAUGHTER, Robert G.	P.O. Box 448 Wanchese, NC 27954 252-473-5363	
277.	SLOAN, Scott	519 West 36th Street New York, NY 10018 212-279-0790	
278.	SMITH, Donald L.	809 Spring St. NE, Apt. 406 Minneapolis, MN 55413 612-789-5135	
279.	SMITH, James F., COHN-S, CSP, CPEA	P.O. Box 5108, MS12-04 Denver, CO 80217 303-978-3324	
280.	SNEDEKER, Orland D.	P.O. Box 92 Bunker Hill, IL 62014 618-585-4466	
281.	SNYDER, Thomas	9573 Cedar Mist Cove West Cordara, TN 38016 901-382-0874	
282.	SOPCHAK, Andrew M.	5003 Derringer Drive Jamesville, NY 13078 315-469-5752	

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
283.	SPENCER, Michael J.	179 Pine Hill Crive West Berlin, VT 05663 802-485-6442	
284.	STEIDER, Donald L.	60427 CR 21 Goshen, IN 46528 574-534-6276	
285.	STEINGRAEBER, John J.	1085 Hague Avenue St. Paul, MN 55104 651-645-2968	
286.	STEPHENS, Ramona K.	11564 Steeldust Court Rathdrum, ID 83858 208-773-7807	
287.	STEPHENSON, David R.	248 Remps Road Libby, MT 59923 406-293-9772	
288.	STRAIN, Kirk L.	2959 Walden Road Fayetteville, NC 28303 910-822-5277	
289.	STRZEMBOSZ, Andre, M.D.	P.O. Box 270207 St. Louis, MO 63127 314-945-1059	
290.	SUNDBY, Ray	195 W. Elm St. Louisville, CO 80027 303-666-6840	
291.	SUTTON, Bret J.	3005 S. College Street Seattle, WA 98144 206-723-9044	
292.	SVEHLA, Michael R., Jr.	9222 Virginia Court Orland Park, IL 60462 708-757-5200	
293.	SWARTZ, Timothy H.	P.O. Box 491 Northfield Falls, VT 05664 802-485-4760	Signature is on the page with Thomas W. Yacawyen.
294.	SWIERCZ, John R.	742 Cobb Avenue Placentia, CA 92870 714-572-9504	
295.	SWINTON, Stephen F., Sr.	15 Horton Drive Watervliet, NY 12189 518-271-8355	

34

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
296.	TATMAN, Craig A.	5957 Lyndale Avenue N. Brooklyn Center, MN 55430 763-560-6396	
297.	TEDESCO, Allen	202 Park Road Parsippany, NJ 07054 201-513-3234	
298.	TETZLAFF, James	3448 N. Narragansett Chicago, IL 60634 847-295-4664	
299.	THIELING, Stan	129 Firecrest Drive Brandon, MS 39042 601-825-8723	
300.	TIBBETTS, Gary	106 Jimney Drive Westford, MA 01866 978-692-1950	
301.	TONG, Marco	18th Floor, Delta House 3 On Yiu Street Shatin, NT Hong Kong 852-2276-9146	From UL Int'l Ltd.
302.	TONJUM, Randy	1517 11th Avenue Minneapolis, MN 55404 612-343-7084	
303.	TOUHY, James E.	911 Cedarcrest Drive Schaumburg, IL 60193 847-895-0401	
304.	TRAFTON, Tom	1942 Kirkland Avenue San Jose, CA 95125 408-279-8905	
305.	TRAVERS, Kevin	10 North Niantic Road Charlestown, RI 02813 401-364-0427	
306.	TUKROOK, Juanita	1910 11th Avenue S. Minneapolis, MN 55404 651-637-1284	
307.	TUMA, Jeanne M.	4240 Fulton Avenue #311 Studio City, CA 91604 818-981-8862	

35

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
308.	UFFER, Philip	724 Milford Mill Road Pikesville, MD 21208 410-602-1762	
309.	URQUHART, James R.	104 Village Common Fishkill, NY 12524 845-896-9683	
310.	VAILLANCOURT, Brian	58 Juniper Drive Goffstown, NH 03045	
311.	VAN ZEE, Pieter J.	1149 N.W. Alder Creek Corvallis, OR 97330 541-715-8658	
312.	VAN DERWERKEN, Joseph B., Sr.	19 Brenda Drive Hudson Falls, NY 12839 518-747-7816	
313.	VISAGE, Robert Melvin	410 Virginia Avenue Baltimore, MD 21221	
314.	WADDELL, Ralph	7 Highland Ave Randolph, VT 05060	
315.	WAGNER, Karl	719 Dove Path Lane Colonial Heights, VA 23834	
316.	WALKER, Brett	50 North Medical Drive Salt Lake City, UT 84132 801-585-2677	
317.	WALL, John	706 Garvey Hill Northfield, VT 05663 802-485-9871	Signature is on the page with Jeffrey D. Foley.
318.	WALLACE, Robert	735 Fairview Ave., SE Salem, OR 97302 503-364-8361	
319.	WALTZ, Samantha Ducloux	37 Walking Woods Drive Lake Oswego, OR 97035 503-699-3377	
320.	WARD, Nelson	2530 Blaisdal Ave., Apt. 302 Minneapolis, MN 55404 612-870-4767	
321.	WEINBERG, Larry	53 Campus Club Drive Cuilderland, NY 12084 518-869-1680	

36

Index of Petitioners
Petition to Initiate Rulemaking for Table Saws

	Name	Address & Phone Number	Notes
322.	WERNER, Kent R.	258 Country Way Scituate, MA 02066 781-545-0114	
323.	WHEAT, Annie-Laurie	220 Driftwood Lane Rock Hill, SC 29732 803-323-2397	
324.	WHITE, Sanford	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
325.	WHITE, Vicki	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
326.	WHITE, Jared	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
327.	WHITE, Lonny	561 Dover Court Buffalo Grove, IL 60089 847-913-1778	
328.	WIERS, Eric E.	507 Pumpkin Hill Road Ledyard, CT 06339 860-572-8608	
329.	WILCOX, Robin	7426 Keen Way N Seattle, WA 98103 206-525-9583	
330.	WIND, Ted, Jr.	1827 Fillmore Avenue, NE Minneapolis, MN 55418 612-722-0952	
331.	WINSON, Si B.	311 Pointer Pl. Arlington, TX 76002 817-466-4085	
332.	WRIGHT, David S.	49 Laurel Ridge Greenville, SC 29609 864-246-4066	
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37

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Petition to Initiate Rulemaking for Table Saws

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38

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: July 19, 2001

TO : Ronald L. Medford, Assistant Executive Director
Office of Hazard Identification and Reduction

THROUGH: Hugh M. McLaurin, Associate Executive Director
Directorate for Engineering Sciences

FROM : Caroleene Paul, Division of Mechanical Engineering
Roy W. Deppa, Division of Mechanical Engineering
Dean LaRue, Division of Electrical Engineering

SUBJECT: Evaluation of Prototype Tablesaw Safety Device

INTRODUCTION: The Directorate for Engineering Sciences received a sample of a prototype tablesaw safety device, as well as a detailed demonstration from its inventor, on July 11, 2001 to evaluate its potential to address injury. The inventor also provided an information package that combines the extensive technical information of the 26 different patents obtained in designing the safety system. The device consists of a modified commercial consumer-grade tablesaw, including an electrical blade contact detection circuit, logic circuit, and electromechanical device that stops blade rotation and lowers the blade below the table surface upon contact with a human body part. This system is under development and was demonstrated by SawStop LLC. of Wilsonville, OR.

BACKGROUND: Tablesaws account for approximately 30,000 injuries to the hand or finger per year, with approximately 10% of these injuries involving amputation. Tablesaw blades are typically 10 in. in diameter and rotate at about 4,000 rpm. A typical 40-tooth blade's teeth cut at a rate of about 2,700 cuts per second; these saw teeth are travelling at about 120 mph. Resulting injuries are usually severe.

Review of In-Depth Investigations shows that typical incident scenarios involve inadvertent contact with the blade. The operator allows his hand to contact the blade while sawing due to inattention, or the workpiece slips or moves suddenly and the operator reaches, falls, or slips and contacts the blade from the top or rear of the blade. In some cases the work piece is kicked back by the blade and draws the operator's hand into the blade.

Safety engineering on a systematic basis takes a tiered approach to address hazards:

1. The most effective measures are those that design the hazard out of the product. This has not been possible with tablesaws; the operational requirements of tablesaws seem to preclude the possibility of removing the hazard.
2. The second most effective measures are those that guard or shield against the hazard. This is the approach that has been applied to tablesaws, but it has not been effective because the guards are optional and they do not work very well.
3. When design and shielding approaches do not work, the next most effective method is to introduce an intervention strategy in the development of the hazard. That is, allow the events that lead to injury to begin, but introduce some element that stops or diverts the process before the injury occurs, or at least before the injury becomes very severe. This is the philosophical basis for the SawStop. The operator's hand actually contacts the spinning blade, but the device senses this contact and stops the blade and moves it before severe injury occurs. This approach is sophisticated and potentially vulnerable. Timing is everything; the blade begins to cut into the operator's finger before the system can work, and it must work reliably and very quickly to limit the injury.

The SawStop demonstration model is a prototype, therefore issues of reliability and robustness over the life of the product cannot be evaluated. These issues will be dependent upon choices made in the development and manufacture of production products, and they are likely to differ significantly between manufacturers. While the ability of the product to function properly under different conditions, or incident scenarios, can be addressed with a prototype, these factors may differ depending upon the manufacturing design. Consideration of details that are dependent upon design and manufacturing must be evaluated on production products, or may be considered in establishing standards of performance.

What can be evaluated at the prototype stage is whether the basic concept of the device addresses the known hazard pattern in an effective way, and thus can establish whether the device demonstrates the feasibility of eliminating or reducing the hazard. The basic concept of the SawStop is to electrically sense when contact with a body part has been made, and to mechanically remove the cutting hazard before severe injury can occur. In the next three sections, the electrical operation, the mechanical operation, and the testing will be discussed.

Electrical Operation

The theory of operation is based upon the electrical capacitive nature of the human body, or the ability of the human body to store electrical charge. A small electrical field is placed by the SawStop circuitry onto the saw blade by a supply electrode, and a sensing electrode senses the electrical field coming from the saw blade. If a person touches the saw blade, some of the electrical field is redirected into the person's body rather than into the sensing electrode. When the field measured by the sensing electrode drops below a pre-determined percentage of the normal value, the stopping mechanism is activated.

The electrodes are not actually in contact with the saw blade. They are a small distance away from the blade. This is what is called capacitive coupling. Two conductive materials with a dielectric material (in this case air) between them creates a capacitor. Essentially, there is a capacitor created by the supply electrode to the saw blade in series with another capacitor created by the saw blade to the sensing electrode. Electrical energy can therefore flow between the supply electrode to the saw blade and from the saw blade to the sensing electrode.

In the prototype received for evaluation, the supply and sensing electrodes are capacitively coupled to the arbor shaft. In most cases, this is not a problem because the saw blade is electrically connected to the arbor shaft. However, a few saw blades used in the evaluation had plastic hubs. The safety mechanism will not work with these blades because the plastic hub insulates the metal part of the blade from the arbor shaft. In this particular implementation, there is no means to determine whether an appropriate saw blade is attached to the arbor shaft or that the blade is actually coupled to the circuit. This is an issue that will need to be addressed in the development of manufactured products, to ensure that a user knows when they are protected. This does not affect the evaluation of the basic safety mechanisms and principles of this device.

The remainder of the circuitry is designed to detect and react to a person touching the saw blade. The circuitry is controlled by a microcontroller. The microcontroller reads various inputs and makes a decision to activate the saw brake or to allow the saw to keep running. Using the example of the 40-tooth blade operating at 4,000 rpm, one tooth goes by a point every 370 μs. The circuit samples the status and makes a decision every 18 μs, which is more than 20 times per tooth. The circuitry reacts quickly enough to minimize the damage to a person's hand should it come in contact with the saw blade.

The microcontroller is programmed to react quickly to a person touching the saw blade while adjusting itself for scenarios involving wood that may be slightly conductive. Wet green wood or wet pressure treated wood can be conductive and could make the saw brake trip without any danger. Logic has been built into the program to monitor not only the magnitude of the signal but also the rate at which it changes. Conductive wood would cause a slow change in the signal magnitude where a person would generate a quick change in the signal magnitude. If the controller detects a slow change in the signal magnitude, it changes the supply voltage to maintain a relatively constant sensing voltage. However, it is designed so that it cannot change the supply voltage fast enough to miss an actual human event. This is designed to reduce nuisance trips without reducing the protection to people.

There are several self-tests designed into the circuitry to ensure that the safety mechanism will work if needed. If any of these self-tests fail, the saw will either stop if running or will not start if not running. The self-tests are:

1. Watchdog error – this is monitoring the status of the microcontroller.
2. Saw brake triggered or trigger circuit open – this will sense if the saw brake has already been spent or if the electrical connection to the saw brake is missing.
3. Supplies out of regulation – this senses the voltage on the power supply to ensure that it is adequate to operate the circuitry.
4. Capacitor over voltage – this senses the voltage on the capacitor to ensure that the capacitor is working properly.
5. Hall sensor defective – the Hall sensor detects motion of the saw blade. This is used to allow protection during a shut down of the saw. The electronics is capable of activating the saw brake as long as the saw blade is rotating, even after the saw is turned off.
6. Capacitor not charging – senses to see if the capacitor is charging to prevent a misfire.
7. Capacitor under value (discharges too fast) – the system is measuring the time constant during operation to ensure that the capacitor is properly charged.
8. Sense calibration circuit error – the microcontroller monitors the sensing portion of the circuit to verify adequate signal.
9. Sense circuit error – the microcontroller monitors the sensing portion of the circuit to verify it is receiving the signal it expects.

Mechanical Operation

The mechanical theory of operation uses the potential energy stored in a spring to force a plastic brake into the teeth of the rotating saw blade, and the angular momentum of the rotating blade to retract the blade below the surface of the table saw. A brake cartridge consisting of a spring loaded plastic pawl and controller circuitry is positioned on a shaft directly behind the blade arbor. Once a saw blade has been installed, care must be taken to adjust the pawl side of the brake cartridge as closely to the blade as possible without interfering with the blade's free movement. An electrical lead from the microcontroller attaches to the brake cartridge. When the microcontroller determines that a person has touched the saw blade, it sends a signal to discharge a capacitor in the brake cartridge. The capacitor is discharged through a thin wire whose function is to suppress a 100 lb spring against the plastic pawl. When the current from the capacitor goes through the wire, the wire melts and releases the spring. The plastic pawl is then forced into the teeth of the saw blade. The plastic pawl begins to stop the saw blade rotation within milliseconds of when the detection circuitry senses human contact.

The saw blade is raised and lowered by way of a worm screw, keyed to a shaft that is manually rotated by the operator. The worm screw slides freely on this shaft until a U-pin on the worm screw locks into a groove on the shaft. When the worm screw is locked into place, rotation of the worm screw drives the saw blade up and down. The sudden braking of a rotating blade creates so much momentum that the worm screw is knocked loose from its locked position on the shaft. With the worm screw now free to slide on the shaft, the angular momentum of the blade carries the blade straight down below the table saw surface. As with the blade braking, the blade retraction occurs in the time frame of milliseconds.

SawStop Prototype Testing

A table saw is among the most diverse of power tools. A variety of blades can be installed to make straight thru cuts, angled bevel and mitre cuts, or non-thru dado and rabet cuts. The SawStop was tested using a variety of blades to make common cuts. Contact between the saw blade and a finger was simulated using a hot dog in lieu of a finger. The signal change (detected by the SawStop circuitry) caused by contact with a human finger is comparable to the signal change caused by contact with a hot dog that is in contact with a human body. The inventor verified this similarity in signal changes by measuring the signal of a human finger as it was cut on a saw blade and measuring the same on a hot dog as it was cut on a saw blade. The following table summarizes the testing performed on the SawStop.

Trial	Blade		Type Cut	Blade Stop	Hot Dog Damage	Comments
	Type	Teeth				
1	10" carbide	40	straight cut	6 ms	no	slow feed, hot dog on wood piece
2	10" carbide	40	straight cut	4 ms	no	fast feed, hot dog on wood piece
3	10" plywood	250	straight cut	24 ms	no	blade retract prevented injury
4	10" rip	12	straight cut	___	no	blade retracted before stop and prevented injury
5	10" rip	12	straight cut	___	no	blade retracted before stop and prevented injury
6	10" carbide	40	35 deg bevel 60 deg mitre	4 ms	no	average feed, hot dog on wood piece
7	10" carbide	40	kick back into rear of blade	4 ms	no	contact to rear of blade simulated kick back
8	10" carbide	40	contact during coast to stop	1 ms	no	blade stopped immediately contact made approximately 4 seconds after shut off
9	10" carbide	40	straight cut with glove	4 ms	no	cut thru glove, activation upon hot dog contact
10*	7" dado with plastic hub	24	NA	NA	NA	no reaction, blade insulated from arbor
11*	7" dado with plastic hub	8	NA	NA	NA	no reaction, blade insulated from arbor

* These tests were performed with the drive belt removed from the blade and a specialized test box in place of the brake cartridge. The test box simulates braking by cutting power to the motor.

The reaction time of the SawStop system is too fast for the human eye to detect. Each test trial was recorded using a high speed camera at 1000 frames per second. The slowest replay of events possible is 1 frame per second. A typical SawStop reaction to contact with a hot dog resulted in almost immediate retraction of the blade and cessation of the blade rotation within 4 milliseconds. Time for the blade to retract below the surface of the table saw depends on the blade height set for the cut. An important factor is the fact that however long it takes for the blade to stop rotating, the hazardous cutting edge of the blade is already moving away from the contact point.

A 40 tooth, 10" carbide blade stopped in approximately 4 milliseconds. This was true whether it was contact made during a straight cut, during a compound cut, from the rear of the blade, or through a glove. A straight cut made with a 250 tooth, 10" plywood blade resulted in a longer blade stop time of 24 milliseconds. However, despite the longer blade stop reaction time, minimal damage to the hot dog occurred because the blade still retracted from the point of contact almost immediately. Similarly, cuts made with a 12 tooth, 10" rip blade resulted in a blade stop time of approximately 35 milliseconds (the blade retracted below the table saw surface before blade stop), but minimal damage to the hot dog occurred because of the immediate blade retraction.

As stated before, because the prototype design capacitively couples the arbor, conductivity between the blade and the arbor is necessary in order for the system to react to contact between the blade and a body part. Two different blades with plastic hubs were tested and resulted in operation of the table saw in an unsafe condition -- if contact were made, the system would not have worked. The blades were specialized dado blades; however, their use is not uncommon among serious woodworkers.

The limited amount of time allotted for evaluation did not allow for electrical interference testing. Electrical interference transmitted through the electrical supply line or the air could potentially cause nuisance tripping or possibly prevent the circuitry from detecting someone touching the saw blade. If any of these types of interference should cause problems with the circuitry, the problems could likely be remedied by minor changes to the circuitry or how they are shielded from outside interference. Testing for the effects of electrical interference should be conducted in future evaluations of this product.

CONCLUSION

Based upon the evaluation reported here, it appears that the SawStop concept is valid and the prototype impressively demonstrates its feasibility. The electrical and mechanical components operated without failure in a time frame that would greatly reduce blade contact injury. The design concept is very flexible and can be modified to address foreseeable areas of concern.

The device that was evaluated is a prototype, with handmade, non-production components. Production products will include modifications due to design and manufacturing decisions that may result in different performance. In addition, the robustness and life-cycle details of production units will be different from those of the the prototype. The evaluations that were performed therefore concentrated on the validity of the concept and the performance of the components used in the prototype system. A significant amount of further development work may be required before this device could be incorporated into production saws, both because of the need to adapt the concept to mass production, and to address some issues that still require refinement.

Of highest concern are those areas where the SawStop may not perform, and more importantly, may not indicate to the user that it will not perform. As discussed earlier, the device is dependent upon electrical conductivity from the hand through the blade to the saw arbor and thence to the circuitry. There are tablesaw blades that have plastic or other non-conductive hubs or centers, and even a painted or coated metal blade may not make electrical contact with the arbor. In this event, the saw may be operated, but the SawStop will not work as presently configured. This failure may likely be addressed through further design refinement.

Of secondary concern are those areas where the SawStop system may be perceived as a nuisance and therefore a candidate for bypassing by the user. The prototype SawStop uses a brake cartridge that may only be used with a 10 inch blade. The cartridge location does not accommodate smaller diameter blades or thicker specialty blades. In addition, specialized blades such as molding sets, which only have one to three teeth, may not work with the current brake configuration. As stated before, these areas of concern would need to be addressed during production design of each specific table saw.

Zwischenbericht

1 Beschreibung des Untersuchungsziels

Gegenstand der Untersuchung ist ein neuartiges Schutzsystem zur Reduktion der Unfallfolgen an Kreissäge- und ähnlich gearteten Holzbearbeitungsmaschinen. Das Prinzip der Schutzeinrichtung basiert im wesentlichen auf zwei Funktionseinheiten: der kapazitiven Detektion eines Berührungskontaktes des Bedieners mit dem rotierenden Werkzeug und der Stillsetzung der gefahrbringenden Bewegung innerhalb von Sekundenbruchteilen.
Ein besonderer Schwerpunkt wird in dieser Untersuchung auf die Abschätzung der sicheren Detektion beim Einsatz verschiedener Holzwerkstoffe gelegt. Dabei werden verschiedene Holz-Materialien und Feuchtegrade berücksichtigt. Die Auslegung der Elektronik hinsichtlich Steuerungskategorien ist beim derzeitigen Stand der Untersuchung noch nicht vollständig betrachtet worden, da es sich beim vorliegenden System um ein Labormuster handelt. Neben der Beleuchtung der Detektionseigenschaften wird eine Abschätzung der Reaktionszeit des Bremssystems vorgenommen, um erste Empfehlungen für primäre Applikationsfelder des Schutzsystems möglich zu machen.
In Form einer Erstabschätzung soll dieser Zwischenbericht als Entscheidungsgrundlage für die Planung weiterer Untersuchungen und Fördermaßnahmen dienen.

2 Systembeschreibung

Die Basis dieses Berichts wird gebildet durch die Dokumentation „SawStop, Descriptions of Safety Systems For Power Equipment, SawStop, Inc., Wilsonville, Oregon 97070" (persönlich am 01.02.01 im BIA überreicht) der Entwickler des SawStop-Schutzprinzips sowie durchgeführte Messungen an einem zur Verfügung gestellten Labormuster. Dabei handelt es sich um eine in den USA serienmäßig erhältliche Tischkreissäge mit höhenverstellbarem Sägeblatt, welche von den Entwicklern durch kapazitive Sensoren und Auswerteelektronik sowie eine Stillsetzungsmechanik umgerüstet wurde, um das Schutzprinzip zu verwirklichen.

2.1 Detektion

Die Detektion einer Berührung des Sägeblatts durch den Bediener wird durch ein kapazitives Sensorsystem realisiert. Eine sinusförmige Wechselspannung wird von einer Einkoppelelektrode über das metallische, isoliert aufgehangene Sägeblatt auf eine Auskoppelelektrode übertragen (Abbildung 1, Bild 1). Die Berührung des Sägeblatts bewirkt dabei eine Amplitudendämpfung des übertragenen Signals. Die Amplitude des Eingangssignals wird durch eine Regelelektronik nachgeführt, so dass die Amplitude des Empfangssignals immer konstant gehalten wird (Abbildung 1, Bild 2).

385

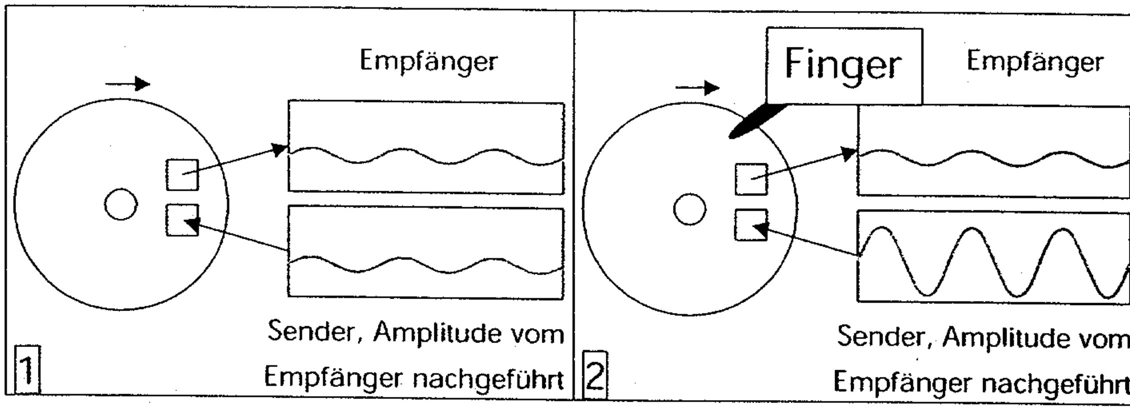


Abbildung 1 zeigt schematisch das rotierende Sägeblatt mit Ein- und Auskoppelelektroden. Grün sind die Amplituden von Ein- und Ausgangssignal je nach kapazitiver Last am Sägeblatt dargestellt. Die Eingangsamplitude wird nachgeregelt, so dass die Ausgangsamplitude konstant bleibt.

Die Berührung des elektrisch isoliert aufgehangenen Sägeblatts durch ein Werkstück oder einen Bediener wirkt wie ein mehr oder weniger starker Kurzschluss gegen Masse (Abbildung 2). Dabei spielt nicht nur die Veränderung des ohmschen (Wirk-) Widerstands zwischen Sägeblatt und Masse eine Rolle, sondern in besonderem Maße auch die des kapazitiven (Blind-) Widerstands. Die kapazitive Leitfähigkeit ist gegeben durch $2\pi fC$ und die Frequenz f des Sinussignals liegt mit 500 kHz sehr hoch, wodurch schon kleine kapazitive Lasten die Amplitude stark dämpfen können. Setzt man z. B. 100 pF als Kapazität des menschlichen Körpers an, so entspricht dies einem Widerstand von ca. 3 kOhm.

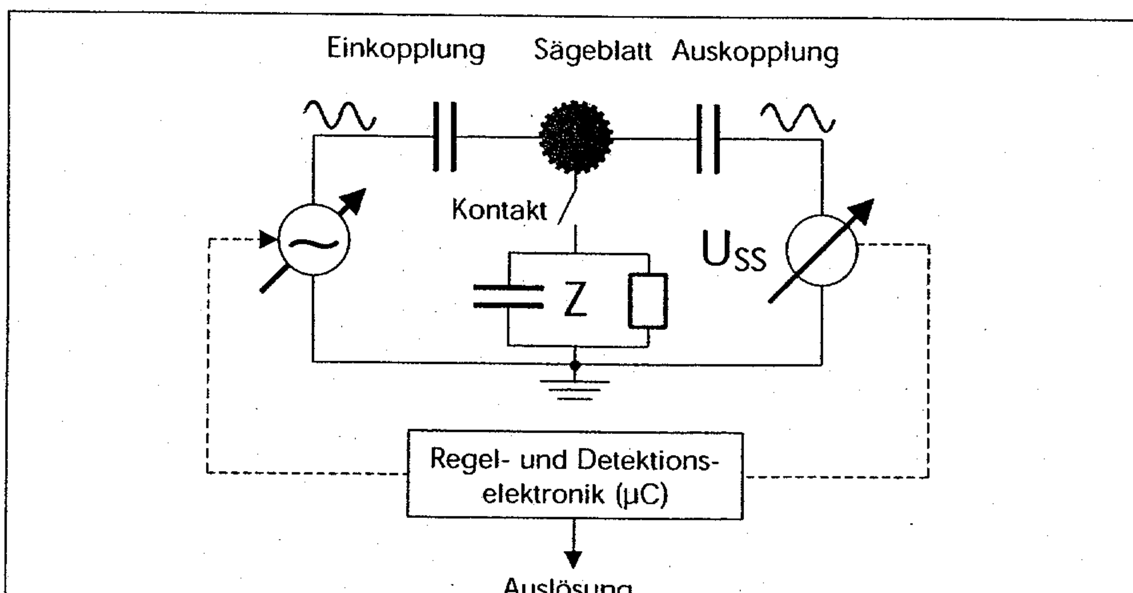


Abbildung 2 zeigt ein Ersatzschaltbild des elektronischen Detektionskreises (µC: Mikrocontroller, U_{SS}: Spitze-Spitze-Spannung, Z: komplexer Widerstand).

Zur Erkennung der Berührung des Sägeblatts durch den Benutzer wird neben der Stärke der Amplitudendämpfung auch die Geschwindigkeit der Änderung ausgewertet (siehe auch Abbildung 3). Änderungen auf einer langsamen Zeitskala (Millisekunden bis Sekunden) werden als Änderung der Umgebungsbedingungen interpretiert, z.B. Berührung des Werkstücks beim Schnitt, Änderung der Luftfeuchte oder ähnliches. Nur starke Amplitudendämpfungen innerhalb von Zeitspannen deutlich unterhalb einer Millisekunde werden als gefährliche Berührungen interpretiert und führen zur Stillsetzung des Sägeblatts. Generell kommt es nur dann zur Auslösung, wenn die Amplitudenänderungsgeschwindigkeit durch Berührung des Sägeblatts größer ist als die Amplitudenanpassungsgeschwindigkeit durch den Regelkreis. Dabei ist die Anpassungsgeschwindigkeit ein variabler Parameter im Regelprogramm und lässt sich auf die jeweiligen Umgebungsverhältnisse abstimmen.

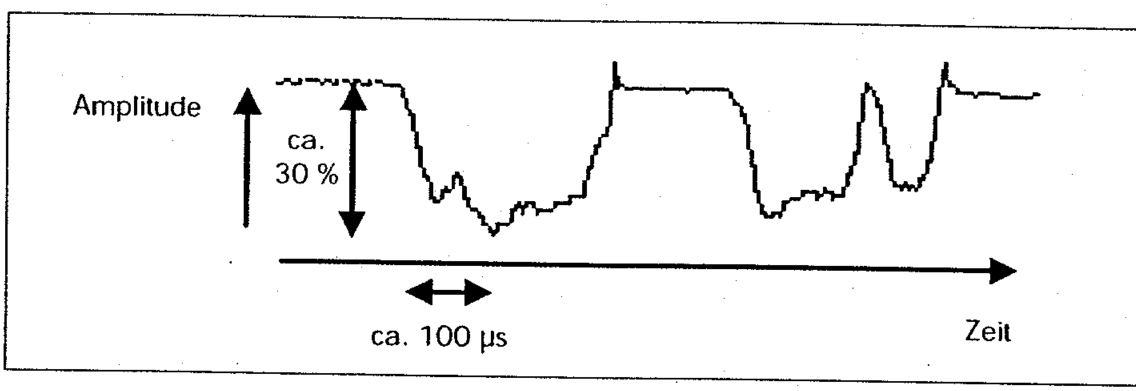


Abbildung 3 zeigt schematisch die Amplitudendämpfung an der Auskoppelelektrode bei Berührung eines simulierten Fingers durch die vorbeistreichenden Zähne des Sägeblatts. Das Bild ist der SawStop-Dokumentation entnommen und wurde nicht selbst gemessen.

2.2 Stillsetzung des Sägeblatts

Nach der Detektion einer Berührung des Sägeblatts sorgt eine zentrale Steuerelektronik für die Auslösung eines mechanischen Bremssystems. Dieses besteht im Wesentlichen aus einem unterhalb des Sägeblatts befestigten Bremsklotz. Dieser wird von einer kräftigen Feder in Richtung Sägeblattmittelpunkt gedrückt, aber im Normalbetrieb durch einen Edelstahl-Schmelzdraht gehalten (Abbildung 4, Bild 1). Bei der Auslösung wird dieser Schmelzdraht mit einer hohen Energie innerhalb kürzester Zeit durchgebrannt, woraufhin der Bremsklotz in Richtung Sägeblattmittelpunkt in die Sägezähne gedrückt wird. Er besteht aus einem Material, in dem sich das Sägeblatt sofort festfrisst, so dass das Blatt sehr schnell gestoppt wird (Abbildung 4, Bild 2). Die Einheiten Bremsklotz, Feder, Sicherungsdraht und Auslöseelektronik sind in einem Bremsmodul zusammengefasst, welches nach einer erfolgten Auslösung als Ganzes gegen ein neues Modul ausgetauscht wird (Abbildung 5). Das für die Untersuchung zur Verfügung gestellte Labormuster war außerdem mit einem höhenverstellbaren Sägeblatt ausgerüstet. Die vorhandene Mechanik zur Höhenanpassung des Sägeblatts wurde erweitert, so dass die bei der plötzlichen Stillsetzung des Sägeblatts auftretenden Kräfte in ein Bewegungsmoment umgelenkt werden, welches zur Versenkung des Sägeblatts komplett unter Tischniveau führt (Abbildung 4, Bild 3). Damit wird die gefahrbringende

37

Bewegung effektiv stillgesetzt und das rotierende Werkzeug vom Bediener entfernt. Gleichzeitig mit der mechanischen Stillsetzung wird auch die Energiezufuhr zum elektrischen Motor unterbrochen, welcher das Sägeblatt über einen Keilriemen antreibt.

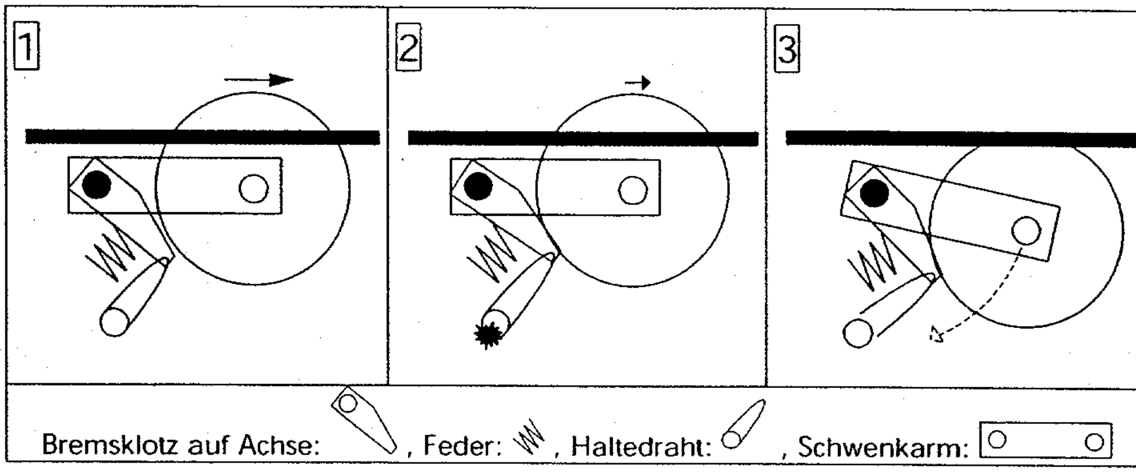


Abbildung 4 zeigt das Prinzip der Stillsetzung und Versenkung des Sägeblatts.

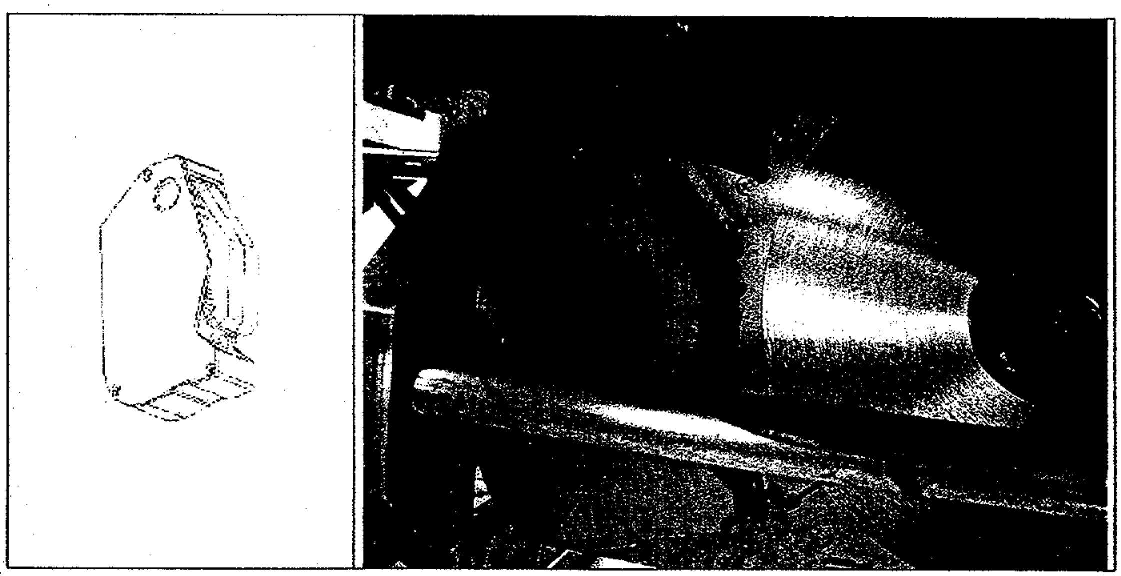


Abbildung 5 zeigt ein austauschbares Bremsmodul als Skizze und im ausgelösten Zustand mit stillgesetztem und versenktem Sägeblatt.

2.3 Sicherheitsgerichtete Elektronik

Innerhalb der komplexen Steuerungselektronik, welche in die Detektion und Entscheidung über eine reale Gefährdung ebenso eingebunden ist, wie in die Stillsetzung des Sägeblatts, sind eine Reihe von Selbsttests und Überwachungsfunktionen eingebaut. Dazu zählen Einschalt-Selbsttests ebenso wie laufende Tests zur Überwachung bestimmter Teile der Detektions-Sensorik und der Auslöseelektronik. Eine redundante mehrkanalige Ausführung sicherheitsrelevanter Bauteile ist nicht bekannt.

3 Durchgeführte Untersuchungen

Durch an der Praxis orientierte Schnittversuche mit trockenem und feuchtem Holz wurde die Zuverlässigkeit und Verfügbarkeit des Schutzsystems unter verschiedenen Umgebungsbedingungen überprüft. Dabei wurde der Schwerpunkt auf den Aspekt der Detektion gelegt. Die Zuverlässigkeit der Stillsetzung wurde durch Vermessung der typischen Reaktionszeit bis zum Stillstand des Sägeblatts abgeschätzt.

3.1 Schnittversuche an trockenem und feuchtem Holz

3.1.1 Beschreibung der durchgeführten Messungen

Um die Verfügbarkeit der Kreissäge mit eingeschaltetem Schutzsystem zu testen, wurden Schnittversuche mit 24 verschiedenen Hölzern durchgeführt. Es handelte sich dabei um zehn Massivhölzer, drei Leimhölzer, sieben Spanplatten, beschichtet und unbeschichtet, sowie vier MDF-Platten. Alle Hölzer hatten die Maße 20 cm mal 40 cm und wurden in der Länge geschnitten, wobei sie entlang des Parallelanschlags geführt wurden. Die Sägeblatthöhe war fest auf 5 cm oberhalb des Tischniveaus eingestellt, so dass für alle Holzstärken (10,6 mm bis 38,7 mm) die Bretter in ihrer ganzen Dicke durchschnitten wurden. Die Möglichkeit der Säge, durch Schrägstellung des Sägeblatts einen Gehrungsschnitt auszuführen, wurde nicht genutzt. Alle Schnitte wurden bei montierter konventioneller Schutzausrüstung durchgeführt, das heißt mit Spaltkeil und Schutzhaube.
Die Schnittversuche wurden in der ersten Versuchsreihe mit trockenem Holz durchgeführt. Die 24 Probehölzer waren zuvor mehrere Jahre in einem trockenen Keller gelagert worden, ihre Restfeuchte betrug zwischen 5 % und 10 %. Für die nachfolgende Testreihe an feuchtem Holz wurden 14 der Hölzer ausgewählt und zwölf Stunden im Wasserbad gelagert. Im Anschluss daran wurde von allen Hölzern, den noch trockenen und den nass gelagerten, die Restfeuchte mittels eines Sekunden-Hygrometers (Hygrotest 6500 von Fa. Testoterm) gemessen. Die Restfeuchte ist definiert als das Verhältnis des Wasseranteils zum trockenen Holzanteil und kann daher Werte von 0 % bis über 100 % annehmen. Da der Messbereich des verwendeten Hygrometers aber auf 100 % begrenzt war, wurden darüber gemessene Werte auf 100 % gekürzt. Unmittelbar nach der Feuchtemessung wurde mit den 14 jetzt feuchten Hölzern eine zweite Reihe von Schnittversuchen zur Abschätzung der Verfügbarkeit unternommen. Die Bearbeitungsbedingungen waren identisch mit den Versuchen am trockenem Holz.

3.1.2 Messergebnisse

In der folgenden Tabelle 1 sind für die 24 Probehölzer neben ihren Eigenschaften Holzart und Brettstärke die Ergebnisse der Schnittversuche und die gemessenen Restfeuchten aufgetragen. Die Schnittversuche am trockenen Holz wurden mit allen 24 Brettern durchgeführt, danach wurden diese mit einer Auswahl von 14 nassen Hölzern wiederholt. Da die Restfeuchte erst zu dem Zeitpunkt gemessen wurde, als die 14 Hölzer schon gewässert waren, stehen ihre Restfeuchtegrade im trockenen Zustand nicht zur Verfügung. Mit großer Wahrscheinlichkeit liegen sie aber auch im Bereich der zehn trocken verbliebenen Hölzer, nämlich 5 % bis 10 %. Als zusätzliche Information wurde bei einer Fehlauslösung die Länge des Schnitts vermessen. Durch Berücksichtigung der Brettstärke und Näherung der geschnittenen Fläche als Trapezform lässt sich die beidseitige Kontaktfläche zwischen Sägeblatt und Holz abschätzen. Diese Fläche dient als ungefähres Maß der Empfindlichkeit für eine Fehlauslösung beim Schnitt von sehr nassem Holz. Die Fußnoten zur Fehlauslösung beim Schnitt von feuchtem Buchen- und Tropenholz resultieren aus dem Umstand, dass wegen der starken Aufquellung der Hölzer kein kompletter Durchschnitt möglich war. Trotz mehrfacher Schnittversuche wurde das Sägeblatt nach einer Schnittlänge von 11 bis 30 cm durch Einklemmung gebremst, es kam aber zu keiner Auslösung durch das SawStop-Schutzsystem.

Nr.	Holzart/Material	Stärke	Fehlauslösung		Kontakt-fläche	Rest-feuchte
		[mm]	trocken	feucht	[cm²]	[%]
Massivhölzer						
1	Rotbuche	10,6	nein	nein		39,5
2	Rotbuche	10,6	nein	- [1]		6,4
3	Buche	20,6	nein	- [1]		7,9
4	Buche	29,6	nein	nein [2]		59,5
5	Eiche	10,6	nein	nein		27,0
6	Eiche	20,6	nein	- [1]		8,7
8	Fichte	10,6	nein	nein		34,3
9	Fichte	20,6	nein	nein		27,8
11	Fichte, rau	34,9	nein	nein		60,0
12	Tropenholz	20,6	nein	nein [3]		15,3
Leimhölzer						
13	Leimholz, 5-fach	7,0	nein	- [1]		6,9
14	Leimholz, 11-fach	14,5	nein	- [1]		9,8
15	Leimholz, 11-fach	14,5	nein	ja	4,2	100,0
Spanplatte, beschichtet						
16	Spanplatte, weiß beschichtet	10,5	nein	- [1]		5,0
17	Spanplatte, weiß beschichtet	19,1	nein	ja	1,5	100,0
18	Spanplatte, buchenfurniert	19,0	nein	- [1]		6,0
19	Spanplatte, dekorbeschichtet	38,7	nein	nein		55,0
Spanplatte, unbeschichtet						
20	Spanplatte	19,1	nein	ja	5,5	100,0
21	Spanplatte	19,1	nein	- [1]		6,0
22	Spanplatte	32,2	nein	ja	2,3	100,0
MDF-Platte						
23	MDF	6,1	nein	- [1]		5,8
24	MDF	6,1	nein	ja	1,2	100,0
25	MDF	25,0	nein	- [1]		5,7
26	MDF	38,2	nein	ja	2,5	55,1

[1] diese zehn der 24 Hölzer wurden nicht feucht geschnitten

[2] feuchtes Holz bei zwei Schnittversuchen verklemmt, Schnittlängen 11 bzw. 15 cm

[3] feuchtes Holz beim Schnittversuch verklemmt, Schnittlänge 30 cm

Tabelle 1 zeigt die Ergebnisse der Schnittversuche an trockenem und feuchtem Holz.

3.1.3 Interpretation der Messdaten

In trockenem Zustand, der bei allen Hölzern einem Restfeuchtegrad von 5 bis 10 % entspricht, treten bei keiner Holzart und -stärke, unabhängig von Verarbeitung und Beschichtung, Fehlauslösungen auf. Das System bleibt immer verfügbar. Ein anderes Bild ergeben die Schnittversuche an feuchtem Holz. Die Ergebnisse für die 14 feucht geschnittenen Hölzer aus Tabelle 1 sind dazu in Diagramm 1 grafisch dargestellt.

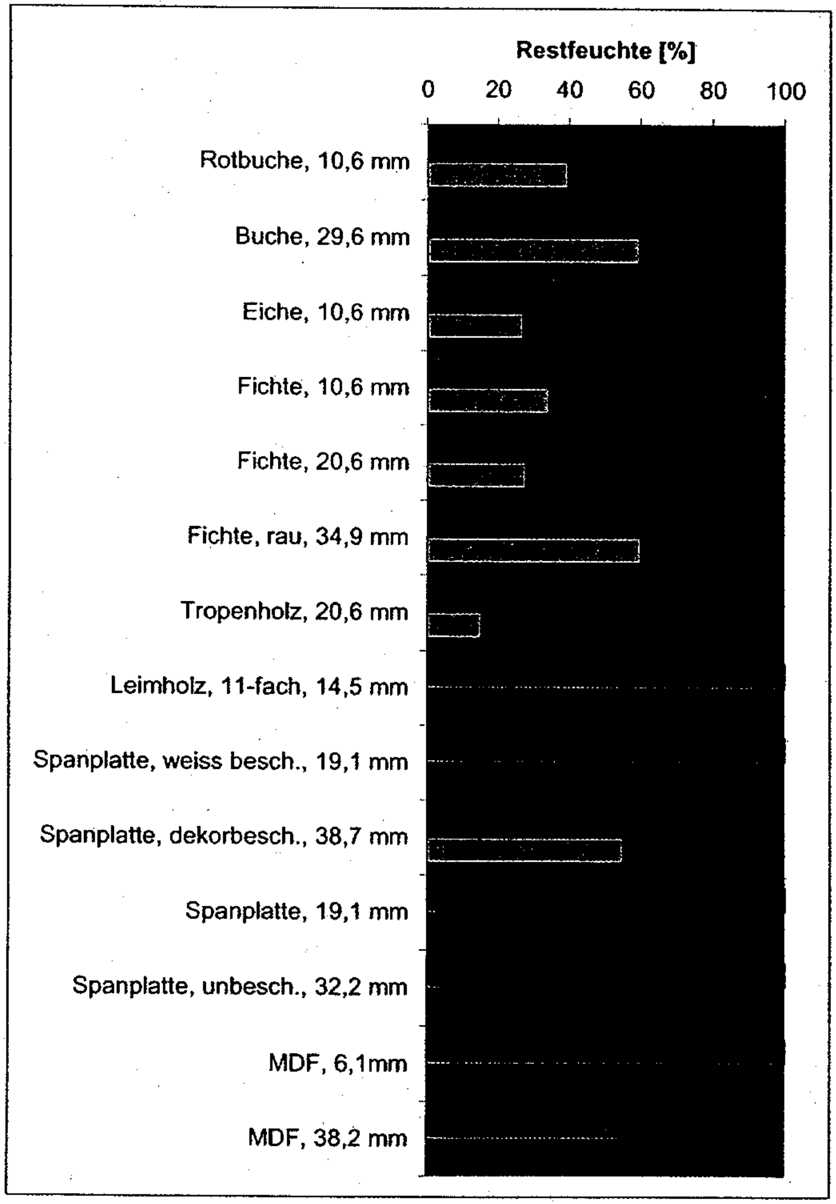


Diagramm 1 zeigt die Auslösung des Schutzsystems beim Schnitt verschiedener feuchter Hölzer. Die Hölzer sind nach ihrer Beschaffenheit und Stärke geordnet und mit ihrem Restfeuchtegrad aufgetragen. Die rote Balkenfärbung kennzeichnet dabei die Hölzer, bei denen eine Fehlauslösung auftritt. Als zusätzliche Angabe ist am Ende der roten Balken ein Zahlenwert vermerkt. Dieser gibt die beidseitige Kontaktfläche in cm² von Holz und Sägeblatt im Schnittbereich zum Zeitpunkt der Auslösung an.

Auffällig ist zunächst, dass bei allen Massivhölzern keine Fehlauslösung auftritt, selbst wenn diese Restfeuchtegrade bis zu 60 % aufweisen. Die Verbundhölzer, nämlich Leimholz, Spanplatte und MDF-Platte, weisen nach der zwölfstündigen Wasserlagerung größtenteils Restfeuchtegrade von über 100% auf und erfahren in der Regel Fehlauslösungen innerhalb der ersten Zentimeter Schnittlänge. Der Übergangsbereich zwischen diesen beiden Extremen wird durch zwei Verbundhölzer markiert: während eine ca. 4 cm starke dekorbeschichtete Spanplatte bei einer Restfeuchte von 55 % ohne Fehlauslösung durchschnitten wird, kommt es bei einer ähnlich starken und feuchten MDF-Platte nach wenigen Schnittzentimetern zur Fehlauslösung.

3.2 Simulation einer Gefährdungssituation bei rotierendem Sägeblatt

3.2.1 Beschreibung der durchgeführten Messungen

Um einen Test der Zuverlässigkeit unter realen Einsatzbedingungen durchzuführen, wurde eine Gefährdungssituation beim Schnitt von Holz simuliert. Ein frischer Schweineschwanz diente dabei als Verlängerung des Fingers und wurde beim Holzschnitt, auf dem Werkstück aufliegend, in den Schnittbereich gebracht (siehe Abbildung 6). Das für diesen Versuch benutzte Holz Nr. 13 (Leimholz, 5-fach, 7 mm stark) war trocken gelagert und enthielt eine Restfeuchte von ca. 6,9 %. Als elektrische Schutzmassnahme stand der Bediener während des Sägevorgangs ungeerdet auf einer Isolationsmatte, allerdings über die Hände in Kontakt mit dem geerdeten Sägetisch.

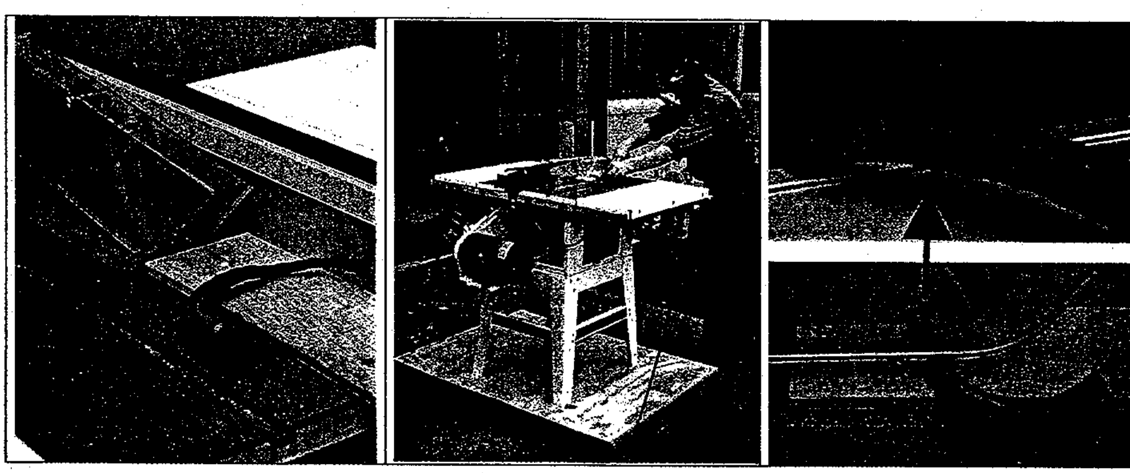


Abbildung 6 zeigt die Simulation einer Gefährdungssituation mit Hilfe eines Schweineschwanzes. Links ist die Anordnung des Werkstücks und des simulierten Fingers zum rotierenden Werkstück gezeigt. In der Mitte ist der Schneidvorgang kurz vor der Auslösung des Schutzsystems zu sehen. Die beiden Bilder rechts zeigen den Zustand danach: das Sägeblatt ist versenkt und der Schnitt im Schweineschwanz ist kaum zu erkennen.

392

3.2.2 Messergebnis

Die Auslösung des Schutzsystems erfolgte sofort mit der Berührung des Schweineschwanzes, nachdem die ersten Zentimeter Holz ohne Fehlauslösung gesägt worden waren. Der resultierende minimale Einschnitt war kaum zu sehen und weniger als einen Millimeter tief. Dabei ist allerdings zu berücksichtigen, dass der Schweineschwanz am Rand des Werkstücks gehalten wurde und ein wenig zurückfedern konnte.

3.2.3 Interpretation der Messdaten

Die Versuchsbeobachtung deutet auf eine zuverlässige Detektion der Gefährdungssituation hin. Dies kann aber nur als beispielhaftes Ergebnis dienen, welches in einer umfangreicheren Studie unter verschiedenen Einsatzbedingungen und unter Berücksichtigung der genauen Funktionsweise des Detektionsmechanismus überprüft werden muss. Bemerkenswert ist allerdings, dass die Gefährdungssituation unmittelbar mit der Berührung erkannt wurde, während die Fehlauslösungen bei den feuchten Hölzern erst nach mehr oder weniger tiefen Einschnitten einsetzten.

3.3 Reaktionszeit des Bremssystems

3.3.1 Beschreibung der durchgeführten Messungen

Zur Abschätzung der Reaktionszeit des Bremssystems wurde mit Hilfe zweier induktiver Näherungsschalter ein Versuchsaufbau erstellt, der eine Zeitmessung mit einem Speicheroszilloskop ermöglichte.

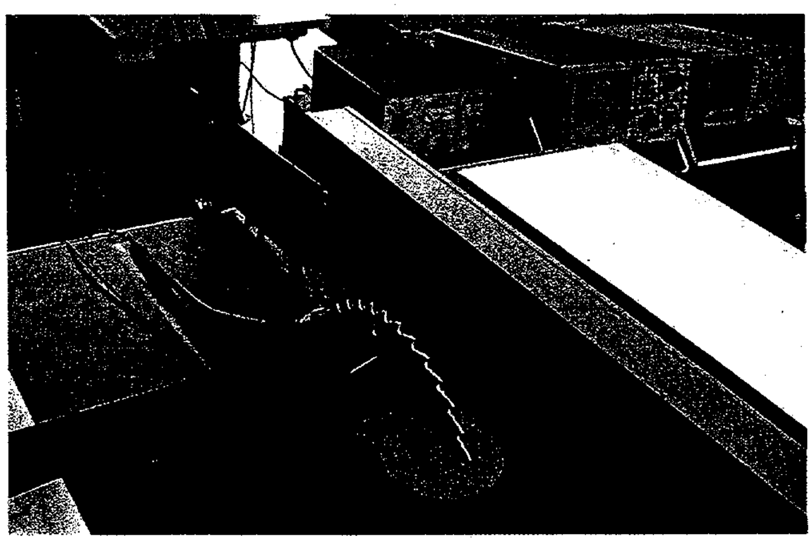


Abbildung 7 zeigt den Messaufbau zur Bestimmung der Reaktionszeit des Bremssystems.

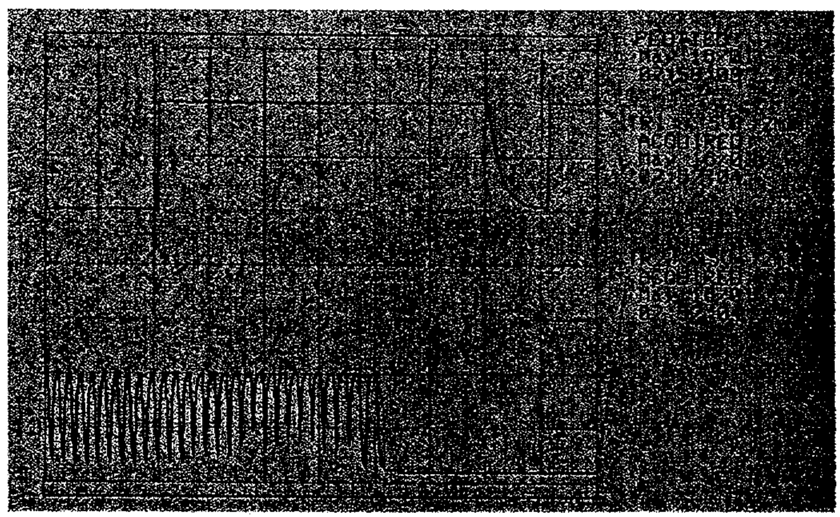
Ein Sensor mit metallischem Gehäuse wurde zügig seitlich an das metallische Sägeblatt herangeführt, wobei der Sensor an einem Haltestab befestigt war und dessen Metallgehäuse von der Hand des Bedieners berührt wurde. Durch diese Berührung wird das Schutzsystems in dem Moment ausgelöst, in dem der Sensor das Sägeblatt berührt.

Da der induktive Näherungssensor gleichzeitig auf die Annäherung von Metall in seinem ca. 1 mm reichenden Detektionsbereich mit einer Änderung seines Schaltausgangs von 0 V auf ca. 10 V reagiert, ist die Triggerung des Speicheroszilloskops mit diesem Signal möglich (obere, schwarze Linie in Diagramm 2). Ein zweiter Näherungsschalter zur Rotationsüberwachung, der am Sägetisch angebracht ist, signalisiert mit seinem Schaltausgang das Vorbeilaufen der einzelnen Sägezähne. Das Verschwinden des regelmäßigen Signalwechsels zeigt die Kombination aus Stillsetzung und Versenkung des Sägeblatts, in jedem Fall aber die Einleitung der gefahrabwendenden Bewegung an.

3.3.2 Messergebnisse

Die mit dem Speicheroszilloskop aufgezeichneten Signale der Näherungsschalter sind in Diagramm 2 abgebildet. In den ersten vier Millisekunden ist der ungehinderte Lauf des Sägeblatts zu erkennen. In dieser Zeitspanne bewegen sich etwa neun Zähne am Drehzahlsensor vorbei. Das Sägeblatt trägt 40 Zähne, die Dauer für eine Umdrehung beträgt also 40 x 4/9 ms, was einer Motorfrequenz von ca. 56 Hz oder einer Drehzahl von 3375 Umdrehungen pro Minute entspricht.

10 V
(5 V pro Skaleneinheit)



8 ms
(2 ms pro Skaleneinheit)

Diagramm 2 zeigt das Oszillogramm der Reaktionszeitmessung des Bremssystems. Die obere, schwarze Linie markiert mit der steigenden Flanke den Zeitpunkt des Sägeblattkontaktes. Die untere, blaue Linie zeigt die an einem Peripheriepunkt vorbeilaufenden Zähne des rotierenden Sägeblatts.

Etwa acht Millisekunden nach der Auslösung des Schutzsystems verschwinden die Signale des Rotationssensors, wobei schon nach etwa 6 bis 7 ms eine Verringerung der Rotationsgeschwindigkeit erkennbar ist.

3.3.3 Interpretation der Messdaten

Der Teilaspekt der Bremsung des Systems wird am aussagekräftigsten durch die Reaktionszeit bewertet. Die Zeitspanne von der ersten Berührung des Sägeblatts bis zur Einleitung der gefahrabwendenden Bewegung kann nach der Messung mit etwa acht Millisekunden abgeschätzt werden. Bei Annahme eines Messfehlers von 20 bis 50 % ist ein Maximalwert von 12 ms anzunehmen. Zu beachten ist weiterhin, dass die Bremszeit abhängig ist vom Material des Bremsklotzes und des Sägeblatts sowie der gewählten Zahl und dem Profil der Sägezähne.
Die EN 999 (Sicherheit von Maschinen - Anordnung von Schutzeinrichtungen im Hinblick auf Annäherungsgeschwindigkeiten von Körperteilen) nennt 2,0 m/s als Richtwert für maximale, kurzfristige Annäherungsgeschwindigkeiten. Eine Reaktionszeit von 12 ms entspricht unter dieser Annahme reflexartiger Bewegungen 24 mm zurückgelegtem Weg. Die Reaktionszeit des SawStop-Systems erscheint unter diesen Annahmen zu hoch, um einen wirkungsvollen Zugriffsschutz sicherzustellen. Geht man allerdings von typischen Werkstück-Vorschubgeschwindigkeiten bei der Holzbearbeitung aus, so lassen sich die angenommenen Werte etwa um einen Faktor 10 reduzieren. Bei Bewegungen, die an das Werkstück gebunden sind, kann daher von einem wirksamen Schutz gesprochen werden.

4 Zusammenfassung

Die Aussagekraft der vorliegenden Untersuchung ist im Sinne einer Erstbewertung naturgemäß begrenzt. Zur ersten Kernfrage, der Eignung der Sensorik für unterschiedliche Holzwerkstoffe und Abmessungen, lassen sich einige Ergebnisse feststellen:

- Trockenes Holz mit einem Restfeuchtegrad kleiner 10 % wurde während der Testschnitte ohne Fehlauslösungen gesägt, unabhängig von der Holzart und Verarbeitung. Das System scheint daher beim Schnitt trockenen Holzes mit hoher Verfügbarkeit arbeiten zu können.
- Bei sehr feuchten Hölzern mit mehr als 50 % Restfeuchte treten abhängig von der Holzart Fehlauslösungen auf. Bei Massivhölzern zeigt sich keine Beeinträchtigung, während Verbundhölzer in Verbindung mit ihrem hohen Wasseraufnahmevermögen regelmäßig Fehlauslösungen verursachen.

Die zuverlässige Detektion einer gefährlichen Berührung des Sägeblatts ohne spürbare Einschränkung der Verfügbarkeit scheint bei der Arbeit mit trockenem und leicht feuchtem Holz möglich zu sein. Lediglich sehr feuchtes Verbundholz führt zu Fehlauslösungen und kann daher ebenso wie z.B. Aluminium nur mit abgeschaltetem Schutzsystem geschnitten werden. Für genaue Aussagen über den Übergangsbereich ist allerdings eine umfangreichere Untersuchung unter Berücksichtigung dynamischer Effekte und Analyse des genauen Detektionsprinzips notwendig. Wie die simulierte Gefährdungssituation zeigt, sind wegen der Fehlauslösungen an sehr feuchtem Holz eher Probleme bei der Verfügbarkeit als bei der Zuverlässigkeit der Auslösung im Gefahrenfall zu erwarten.
Eine Einschätzung der Elektronik hinsichtlich Steuerungskategorien ist im momentanen Laborstadium nur sehr beschränkt möglich. Eine Reihe bewährter Sicherheitsprinzipien, wie Selbsttests, sind schon implementiert, ein Großteil der Regelelektronik ist aber noch einkanalig realisiert und auch die für den Schnitt von Metall vorgesehene zeitweise

Abschaltung des Schutzsystems erscheint noch zu wenig gegen Ausfall oder Manipulation gesichert.
Die Ergebnisse zur Eignung der Sensorik ebenso wie die auf etwa acht Millisekunden abgeschätzte Reaktionszeit des Systems legen folgende Applikationen nahe:

- Holzbearbeitungsmaschinen im feuchtigkeitsgeschützten Innenraumbereich, wo verschiedenartige Hölzer mit Restfeuchten bis zu ca. 25 % verarbeitet werden,
- Maschinen, an denen die regelmäßig erwartete Annäherungsgeschwindigkeit, z. B. auf Grund der Art der Zuführung des Werkstücks, einen Wert von 0,2 m/s nicht überschreitet,
- Maschinen mit hohem Gefährdungspotential, an denen der erreichbare Schutzeffekt eine eventuelle Minderung der Verfügbarkeit überwiegt.

Die Ersteinschätzung des SawStop-Schutzsystems ist positiv: sichere Detektion lässt sich mit hoher Verfügbarkeit verbinden. Die grobe Analyse kann aber neben der Aussage, dass es sich um ein vielversprechendes System handelt, nur Anhaltspunkte für eine detailliertere Untersuchung liefern: z. B. die genau Bestimmung der von Holzart und Restfeuchte abhängigen Fehlauslösungsschwelle oder die detaillierte Überprüfung des dynamischen Detektionsprinzips auf eventuelle Blindstellen. Für eine Bewertung verschiedener Einflussfaktoren, wie die Beschaffenheit des Sägeblatts, mögliche Abschirmungs- und Erdungseffekte, Verschmutzung, Nägel im Holz etc. ist ein genaues Verständnis der physikalischen Prinzipien und Algorithmen der Detektion unumgänglich. Auch die elektromagnetische Verträglichkeit hinsichtlich Störbeeinflussung und Störaussendung muss noch überprüft werden. Sinnvoll wäre die begleitende Untersuchung eines über das momentane Laborstadium hinausgehenden serientauglichen Modells in einer dauerhaften Applikation in einem der oben genannten Felder. Für ein solches Modell ist auch eine konkrete Einschätzung des Systems bezüglich Steuerungskategorien möglich.

i. A.	Sachbearbeiter
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Dr. M. Schaefer	Dipl.-Phys. M. Hauke

Translation of the Summary of the BIA Report

As a first evaluation of this study, the significance is limited. Regarding the first key question of how suitable the sensor technology is for different kinds of wood materials with varying dimensions, the following results were obtained:

- in tests, dry wood with a moisture content of less than 10% was sawed without any misfires. This was independent of the type of wood and the processing. Thus the system appears to be able to work with great reliability for dry wood.
- used on very damp wood with a moisture content of more than 50%, there were misfires independent of the type of wood. With solid wood there was no misfiring whereas with very damp plywood the system misfired frequently.

A reliable detection of accidental contact with human flesh by the blade without any noticeable malfunction seems possible with dry and slightly damp wood. Only with very damp plywood does the system misfire. As is also the case with aluminum, wet plywood can be cut only when the system is turned off. A closer and more detailed examination of the system, taking into consideration dynamic effects and an analysis of the principles behind the system of detection is necessary to determine the exact limitations. As the simulation shows, because of misfires with very wet wood, problems of misfiring are more of an issue than the reliability of the device triggering during accidental contact.

An assessment of the electronic system with regard to control and feedback is only partially feasible at this stage of the laboratory tests. A series of established safety principles such as self-tests have already been implemented, however, a large part of the electronic system is still on one circuit, and the temporary disabling of the safety system still seems to be inadequately safeguarded against misfires of manipulation.

The results obtained from the tests of suitability of the sensor technology and the tests of the approximately 8 millisecond reaction time suggest the following applications:

- wood processing machines in buildings that are protected from dampness, where different types of wood with a maximum moisture content of 25% are processed.
- machines with which the regularly expected cutting speed (e.g., because of the way the wood is fed into the saw) does not exceed .2 meters per second.
- machines with a high-accident potential for which the protection provided is more important than the range of use.

The first assessment of the SawStop safety system is positive: reliable detection is combined with high range of use. This rough analysis, apart from demonstrating that the system shows promise, can only be considered as a guide for a further, more detailed study of, for example, the exact threshold at which the system misfires given the type of wood and the moisture content, or the dynamic principle of detection for possible blind spots. For an evaluation of various factors influencing the operation of the system such as the characteristics of the saw blade, possible effects of grounding and shields, dirt, nails in wood, etc. a precise understanding of the physical principles and the algorithms of detection is vital. In addition, the electromagnetic compatibility with regard to disturbances has to be tested. It would also be useful to do additional long-term testing outside the laboratory in the areas mentioned above on one of the models. For this model, a concrete assessment of the control system would also be possible.

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Short Study Report (Study N° 586)
ANALYSIS OF A CAPACITIVE DETECTION SYSTEM MOUNTED ON A CIRCULAR SAW

Raymond KLEIN

Abstract

The aim of this study is to analyze and assess the capacitive detection principle implemented in a blade stopping device recently developed by the Sawstop[1] company. This promising device is designed to reduce the seriousness of accidents occurring on different types of woodworking machinery. This analysis should specifically highlight possible situations involving failure to detect human touch. The detection mechanism is initially analyzed in the absence of wood with different touch characteristics, then in the presence of both dry wood and wood with various moisture contents. The result is that the capacitive principle can be implemented for dry wood (moisture content to be defined) without affecting working equipment availability and that it ensures human touch detection in all cases representative of an accident situation.
Various recommendations and reservations have been issued with regard to the electronic circuit processing detection-related data and emitting the blade stopping and retraction command.

Keywords: Capacitive detection / Saw / Woodworking machine / Stopping

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401

Contents

Pages

1. Analysis aim 1

2. System description 1
   2.1. Operating principle 1
   2.2. Detection principle 1

3. System implementation on a saw 2

4. Analyses performed 4

5. Static measurements 5
   5.1. Aim and method 5
   5.2. Measurements without wood 5
   5.3. Measurements with dry wood in contact with blade 6
   5.4. Measurements with moist wood in contact with blade 6
   5.5. Measurements with two pieces of dry wood 7
   5.6. Measurements with different size pieces of moist wood 7
   5.7. "Green wood" static compensation 8

6. Dynamic measurements 8
   6.1. Aim and method 8
   6.2. Blade touch in the absence of wood 8
   6.3. Influence of output voltage variation rate Vs 9
   6.4. Blade touch in the presence of moist wood 9

7. Capacitive circuit failure modes 10

8. Complementary analysis 10

9. Similar existing detection devices 10

10. Another existing circular saw blade stopping device 11

11. Conclusion 11

Annex

402

1. Analysis aim

The present study concerns a device recently developed by the SAWSTOP company[2] to reduce the seriousness of accidents occurring on workbench circular saws. The system comprises a capacitive detection system based on contact of the person with the dangerous section of a rotating saw blade, a detection and data processing circuit and a blade stoppage and retraction mechanism. This device acts in less than about 8 milliseconds.
The aim of the present study is to analyze and assess this capacitive detection principle for this type of work equipment under foreseeable conditions of usage and to highlight situations involving possible non-detection of human touch. Provision of possible device improvement suggestions is also intended.
The study concerns neither system action on work equipment availability dependent on wood qualities used nor its reaction time. These parameters form the subject of analysis performed by the BIA. Neither does the study involve assessing the operating safety of the electronic circuit that processes data originating from the detection circuit.

2. System description

2.1. Operating principle

Figure 1 illustrates the operating principle in diagrammatic form. The data processing circuit transmits a command to the tripping circuit if capacitive detection occurs when the saw blade is touched by a person. The tripping circuit causes the release of a spring to thrust a plastic block into the blade teeth resulting in stoppage of the blade. The kinetic energy of the whole kinematical circuit causes the blade to retract through tilting of the shaft + blade assembly.
The power supply to the motor is also shut off as soon as the tripping command is issued.

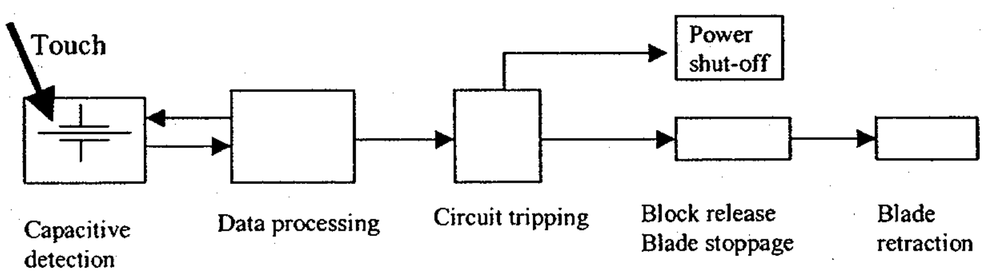

Figure 1: Diagrammatic representation of system operating principle

2.2. Detection principle

The detection circuit is made up of a capacitive bridge that includes the saw blade itself. The bridge is formed by two electrodes, each one facing the blade or shaft. Several mechanical arrangements are possible. The capacitive bridge is supplied by a 500 KHz frequency sinusoidal signal. The bridge output voltage is permanently measured by the data processing circuit. Human touch constitutes a charge of a highly capacitive nature that causes a variation in bridge impedance and thus in output voltage. Variation amplitude and gradient are analyzed by the processing circuit, which sends a tripping command if these reach predetermined values.

The processing circuit also features a "green wood" compensation mechanism. The capacitive bridge input voltage is adjusted to maintain a constant output voltage for slow variations in bridge input

[2] Sawstop, Inc., 22049 S.W. Newland Road, Wilsonville, Oregon, 97070.

voltage that correspond usually to sawing green or moist wood. This mechanism is designed to prevent untimely saw blade stoppages for certain wood qualities.

Figure 2 shows the combined detection and data processing system in diagrammatic form. Z represents the impedance introduced by a person coming into contact with the saw blade.

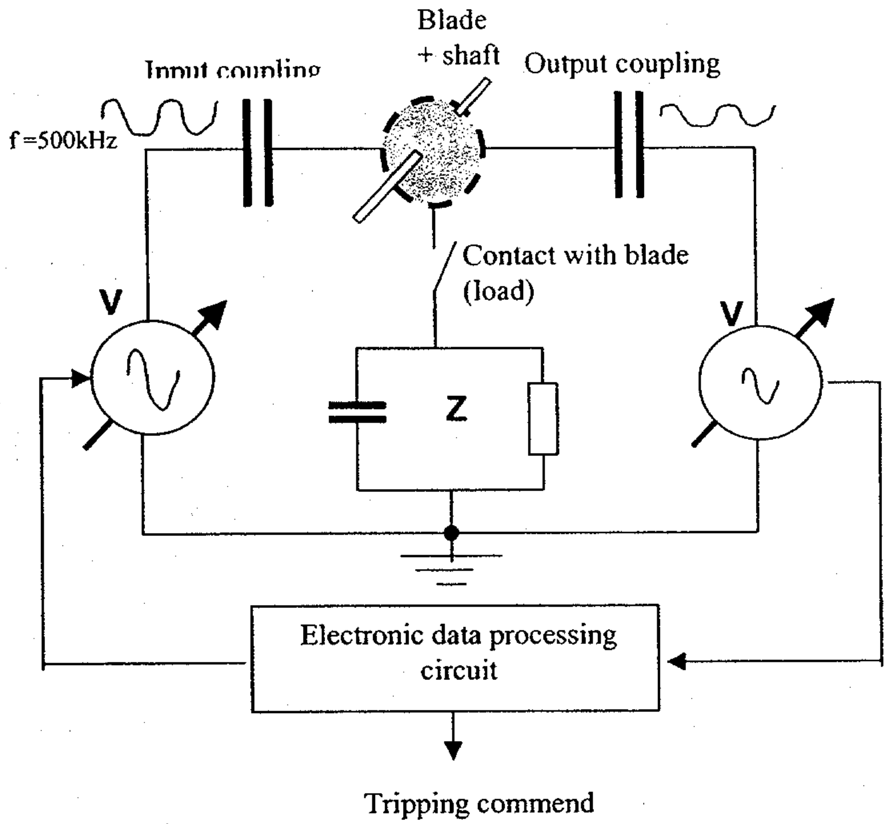

Figure 2: diagram of detection and data processing system

3. System implementation on a saw

The study was conducted on an off-the-shelf workbench circular saw with a 500 x 350 mm platen and a 165 mm diameter blade (cf. photo 1). For study requirements, this saw was fitted with a detection system complying with the specifications given in the machine descriptive document provided by the designer[3]. The latter also supplied us with the electronic data processing circuit.
The semi-circular electrodes were placed around the shaft (cf. photo 2) to form the capacitive detection system (cf. fig. 3). Values of the input and output capacities thus obtained were approximately 40 pF and were essentially equal to those recommended by the designer. The latter recommends using screened cables to connect the electrodes to the data processing circuit.

3 Description of Safety Systems For Power Equipment, Sawstop, Inc., Wilsonville, Oregon, 97070.

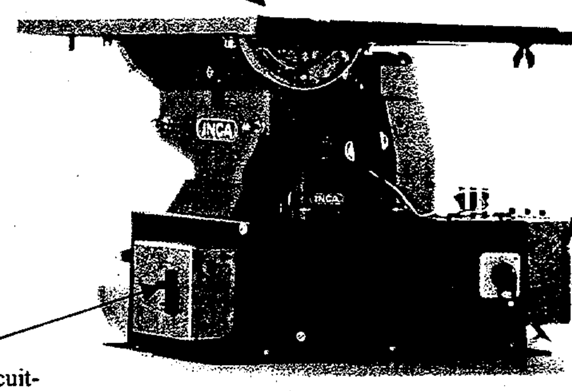

Photo 1: Workbench saw fitted with detection system

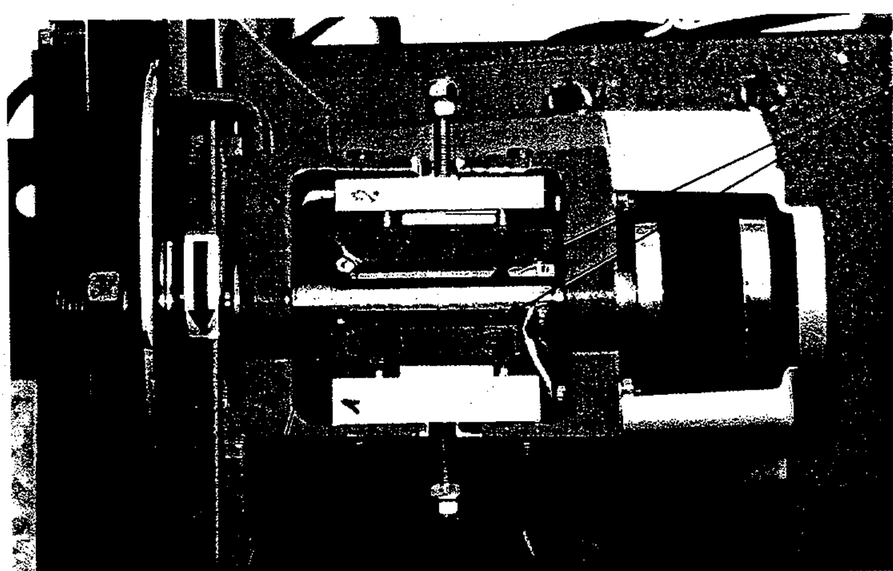

Photo 2: Semi-cylindrical electrodes around shaft

Remark: It was not possible to obtain the good input and output voltage values (Vd and Vs) required for device operation, despite the use of a screened cable whose length (30 cm) and linear capacitance (67 pF/m) were as small as possible. These values are attenuated by the impedance introduced by the screened cable capacitance. Proper operation was only achieved with an unscreened cable.

The shaft was mounted on two insulating ceramic ball-bearings. However, there was a spurious impedance between the blade+shaft assembly and machine frame. This is made up of the shaft/frame capacitance in parallel with the impedance of the belt running between the pulleys.