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Proof of Product Defect (Metallurgical Case)

Ellis B. Brannon

Robert F. Hehemann

Keith E. Weigle Jr.

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Advertised-Product Liability:
Proof of Product Defect (Metallurgical Case)

Ellis B. Brannon (on law and practice)*
*Robert F. Hehemann** (on engineering aspects)*
*Keith E. Weigle, Jr., M. D.*** (on medical aspects)*

THIS ARTICLE DESCRIBES some of the problems of proof encountered in the preparation of a unique product liability case. The plaintiff was an employee of a service station, which performed some light repair work on automobiles. In the course of repairing an automobile, a tie-rod tool, which had a fork end and a blunt end (Ill. A, Fig. 1) was used by the plaintiff to disengage the automotive part. When the tool was struck with a two-pound hammer, a chip flew from the hammered end of the tool into the right eye of the plaintiff (Ill. C, Fig. 3). It was expected that there would be an abundance of case material. But, to the contrary, investigation discloses that case law is scant. No single case regarding a defective hand tool was found which presented a standard of conduct by which the plaintiff could claim the defendant was negligent in causing the plaintiff his unfortunate injury—the loss of an eye.[1]

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* Undergradute study, University of Akron; LL.B., University of Arizona Law School; member of the law firm of Brannon and Renswick of Cleveland, Ohio.

** B.Sc., University of Michigan; M.S., Ph.D., Case Institute of Technology; Associate Professor in the Department of Metallurgical Engineering of Case Institute of Technology; member of the American Institute of Mining, Metallurgical and Petroleum Engineers and of the American Society for Metals; past Chairman of the Cleveland Section of the American Institute of Mining, Metallurgical and Petroleum Engineers.

*** B.S., M.D., Western Reserve School of Medicine; Diplomate of the American Board of Radiology; member of the American College of Radiology, North American Radiological Society, The Society of Nuclear Medicine, The Ohio State Radiological Society, and The Cleveland Radiological Society; Clinical Instructor in the Department of Radiology, Western Reserve School of Medicine.

[1] No reported cases involving a defective tie rod tool were found, but the following cases illustrate the rule that liability attaches whether or not the product itself be "imminently dangerous," so long as the manufacturer knew or should have known that improper manufacture of the product involved an unreasonable risk of harm to those lawfully using the product and those who would likely to be in the vicinity of its probable use (Restatement of Torts, Section 395):

REFRIGERATOR—Beadles v. Servel, Inc., 344 Ill. App. 133, 100 N. E. (2d) 405 (1951).

COFFEE URN—Reed and Barton Corp. v. Maas, 73 F. (2d) 359 (C. A. 1, 1934).

SHOE DYE—Steber v. Kohn, 149 F. (2d) 4 (C. A. 7, 1945).

(Continued on next page)

ILLUSTRATION A

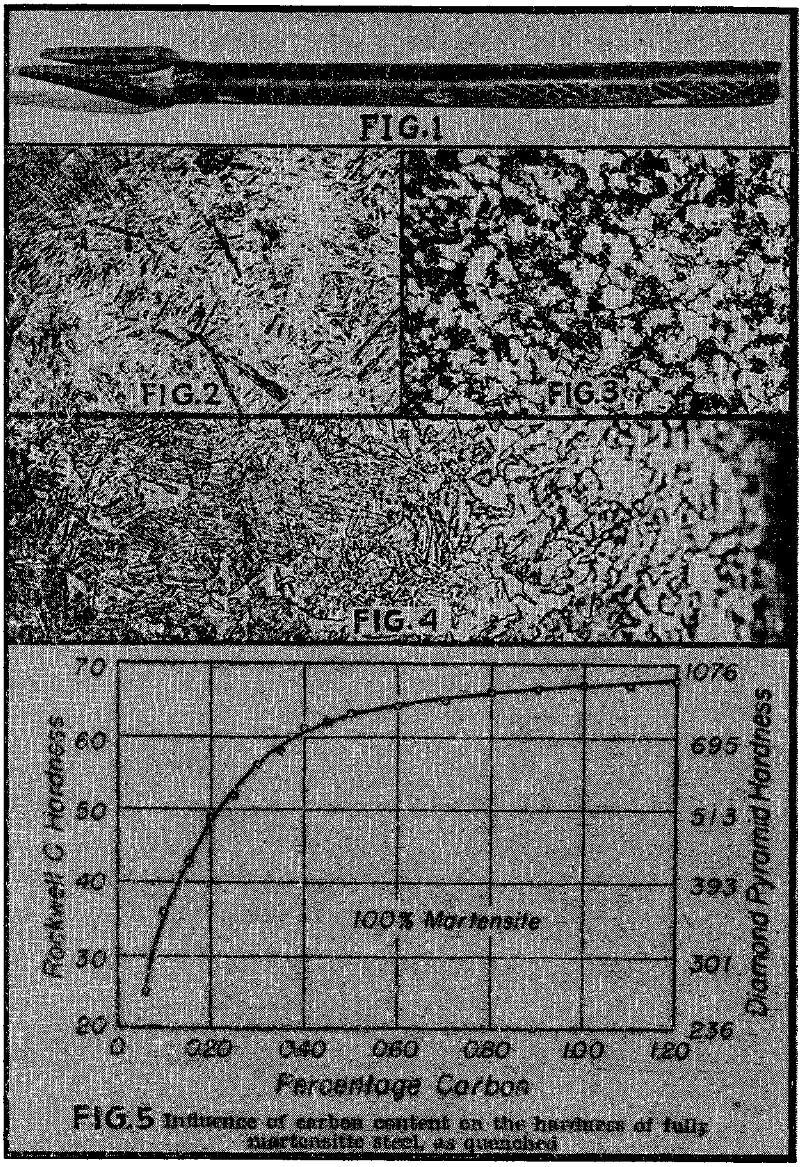

FIG.5 Influence of carbon content on the hardness of fully martensitic steel, as quenched

If the accident involving the defective tool occurs on the job, it may give rise to a Workmen's Compensation claim or a third-party action. On the other hand, if the accident occurs at home or other similar place, then a claim should be filed directly against the manufacturer of the defective item. In the first two situations the attorney is usually consulted with regard to bringing the respective actions mentioned, but in the home type of accident an attorney is seldom consulted, or if one is consulted, many times liability against the manufacturer is not recognized.

Although the usual hand tool is not accompanied by descriptive material prepared by the manufacturer, and dealing with the multiple uses of its product or stating that the product is expressly intended to perform a particular use, the do-it-yourselfer may often be induced to purchase a particular tool because of the representations made in the manufacturer's advertisements.

Warranties in advertisements often are broader than they should be. So, it is important for the attorney to determine whether the action lies in express warranty or in negligence. The doctrine of implied warranty has been limited, almost exclusively, to cases involving defective food and drink, or cases of statutory liability. The greatest areas of potential liability from product defect are in the field of negligence and express warranty. The advantages of a claim based on express warranty are obvious.

If the case is one which is to be pleaded in negligence, then warranty information, which would be found in a catalogue of the manufacturer in the hands of a retailer or supplier, must be utilized as the foundation for the preparation of the negligence action. The instant case was one of negligence of the manufacturer. However, many of the facts to be proved would also have to be proved in an express warranty case. The crux

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(Continued from preceding page)

LOUNGE CHAIR—Matthews v. Lawnite Co., Fla., 88 So. (2d) 299 (1956).

BED—Simmons Company v. Hardin, 75 Ga. App. 420, 43 S. E. (2d) 553 (1947).

SEWING MACHINE—White Sewing Machine Co. v. Feisel, 28 O. A. 152, 162 N. E. 633 (1927).

MATTRESS—Maecherlin v. Sealy Mattress, 145 Cal. App. (2d) 275, 302 P. (2d) 331 (1956).

PERMANENT WAVE SOLUTION—Higbee v. Giant Food Shopping Center, 106 F. Supp. 586 (D. C. Ohio, 1952).

VAPORIZER—Lindroth v. Walgreen Co., 407 Ill. 121, 94 N. E. (2d) 847 (1950).

of the case lies in the expressions the manufacturer chose to use—i.e., *warranty*—in its catalogue.

The issue of express warranty did not arise directly, but it is implicit in the case here discussed. The catalogue distributed by the manufacturer to the retailer contained the following printed guarantee: ". . . automotive service tools are forged from the finest tool steels and will be found to be scientifically heat-treated by the latest proven methods to give long life and satisfactory service." Immediately opposite a photograph of the tool in question appeared the following language: ". . . an essential wedge tool that all garage mechanics, service station operators, etc., have been waiting for. All are forged from Chrome Nickel Alloy Steel—heat-treated throughout for long life and hard use." Inasmuch as the consumer had no knowledge of the above information, the issue of express warranty did not arise. However, the above information bore directly upon the time element in connection with the life of the tool at the time of injury to the plaintiff.

The basic problem connected with the preparation in the case of *McCaul vs. Lydle,*[2] was to establish that the defendant tool manufacturer was negligent or had breached some duty owed to the plaintiff McCaul. More specifically, it was necessary to prove that the manufacturer was negligent in that it manufactured, for use by the general public, a tie-rod tool which was both too hard and lacking in toughness. These deficiencies would not permit the tool to absorb the energy created by the impact of a hammer against the blunt end of the tool, without failure. This would mean that the tool was manufactured contrary to sound metallurgical standards.

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[2] McCaul vs. Lydle, District Court of the United States, Northern District of Ohio, Eastern Division, No. 33358 (October, 1958).

[3] Parker v. Ford Motor Company, 296 S. W. (2d) 35 (Mo., 1956) (18,000 miles on automobile); Beadles v. Servel, Inc., 344 Ill. App. 133, 100 N. E. (2d) 405 (1951) (Second hand Servel refrigerator, 7 months); Quackenbush v. Ford Motor Co., 167 App. Div. 433, 153 N. Y. S. 131 (length of time not conclusive) citing Reed and Barton Corp. v. Maas, supra n. 1 and Till v. Murphy Door Bed Co., 290 Ill. App. 328 (1937) 8 N. E. (2d) 714; Willey v. Fyrogas Co., 366 Mo. 406 (1952) 251 S. W. (2d) 635 (defective valve hot water heater—23 months from date of purchase to injury—did not relieve manufacturer of liability); Okker v. Chrome Furniture Manufacturing Co., 226 N. J. Super. 295 (1953) 97 A. (2d) 699 (bar stool broke 3 years after manufacture); Fredericks v. American Export Line, 227 F. (2d) 450 (C. A., 1955), (30 months—Stevedore skid); Hart Leib v. General Motors Co., 10 F. R. D. 380 (D. C. Ohio, 1950) (fly wheel disintegrated 2 to 3 years ofter manufacture; Reed and Barton Corp. v. Maas, supra n. 1 (coffee urn—at least 7 years after manufacture); International Derrick and Equipment Co. v. Croix, 241 F. (2d) 216 (C. A. 5, 1957) (defective derrick with defective weld—lapse of time 7 yrs.).

One of the factors in the instant case was to determine the length of time the tool had been in use[3] This would be a factor in an express warranty case; also in order to establish that period of time, the date of manufacturer had to be determined and the retail outlet had to be discovered. The date of sale to the owner of the service station and the length of time during which the user of the tool had possession of it prior to the injury also had to be established.

Another problem in this case was the question of assumption of risk, which will not be discussed in any detail in this article.[4] The fact that eight chips were missing from the blunt end of the tool before the plaintiff McCaul struck the tool was asserted by the defendant, in his answer, to support the defense of assumption of risk.

In the instant case, the mechanic McCaul did not dress the tool prior to using it. The tool had not been dressed during the 4¼ years of its use. His judgment, whether good or bad, was a question of fact to be decided by a jury. And, in the same tone, a stronger case against contributory negligence would be stated if the accident occurred in the home, where the tool might be used by one not familiar with the reason for dressing the tool. Ill. A, Fig. 1.

A further important fact problem was the need to establish that the chip, which pierced the eyeball, penetrated the globe in its entirety and lodged in a cavity in the eye socket, was in fact the same chip that spalled or flew from the blunt end of the tool. The same issue would arise in an express warranty case.

In the instant case, a giant magnet was utilized by the attending opthamologist, shortly after the injury, in an effort to remove the fragment from its position in the eye socket. This was not successful. The issue of whether the chip came from the tool in question or whether it flew from the hammer being used or from the vehicle part being struck, became important as a matter of proof of the plaintiff's case. This was because a nurse's note indicated that the chip in question came from the hammer being used. This later statement was incorrectly put into the

[4] Dennis v. Wilford, 338 Mich. 297, 61 N. W. (2d) 154 (1953) (employee assumes the ordinary dangers of his employment and the risks of defective machinery and methods known to him, or so obvious that he should have known them, but the employee need not make a minute investigation of machines and methods to ascertain the dangers, though he does owe caution and care). See, Debusso v. Cement Plaster Co., 165 Mich. 318, 130 N. W. 702 (1911).

record. In any event, it accentuated the need to positively prove that the chip came directly from the tool in question and from no other source. To obtain this positive proof, special x-ray technique was employed by a roentgenologist[5] working with a dentist to produce an inlay of the chip believed to be the one which caused injury to the plaintiff's eye. How this was accomplished will be explained in detail, below.

The plaintiff, William McCaul, was employed in 1951 at a service station in Detroit, Michigan, as a mechanic and service station attendant. He remained in the employ of the service station until approximately January of 1956.

The defendant tool manufacturing company, beginning in 1950, started to market a wedge tool to be used primarily in service stations to disengage tie-rod ends. The tool in question was purchased in Detroit, Michigan, from a retailer by the proprietor of the service station in the last quarter of 1950. This tool was in the possession of the employer at that service station prior to the hiring of the plaintiff McCaul.

The plaintiff had no recollection of using this particular tool in 1951. During the years 1952, 1953 and 1954, the plaintiff used this tool between ten and twenty times. He again used it on January 21, 1955, its use then being described in detail herein. All told, the wedge tool was used about twenty times during a period of approximately four and a quarter years.

On January 21, 1955, at about 8:30 A. M., plaintiff McCaul was removing the oil pan from an automobile, which had been placed on a lift and elevated so that the plaintiff was in a standing position, facing the rear of the automobile. It was necessary for him to use the wedge tool for the purpose of removing a tie-rod end in order to complete the dismantling of the oil pan from the automobile. The plaintiff tapped the wedge tool 2 or 3 times in order to get it into place on the tie-rod end, and then struck the blunt end of the tool one blow, and instantly felt terrific pain in his right eye. His right eye began bleeding, and, within a minute or two after the injury, he looked at the tool and saw a shiny spot on the radius of the blunt end, which was different in character from the remainder of the blunt end of the tool. The plaintiff immediately showed the tool to the service station proprietor.

5 Dr. Keith Weigle, Jr.

The plaintiff saw a doctor concerning his eye injury immediately after the accident occurred, and at one o'clock in the afternoon on January 21, 1955, the plaintiff was admitted to the Detroit Memorial Hospital, where surgery was performed. He was confined at said hospital until January 28, 1955.

Since the accident occurred in Michigan, and an insurance company paid Workmen's Compensation on account of the accident and injuries suffered by the plaintiff in the course and scope of his employment, it necessarily became a party plaintiff in this action to recover its subrogated interest from the tool manufacturer.

The deposition of the manufacturer, one of the members of a partnership operating the tool company, disclosed the steps necessary in the production of the wedge tool. The basic steps of cutting bar steel to length, upsetting the steel and basic forging processes, such as the drop forge operation where the tool was shaped, were not important in considering whether or not the manufacturer was negligent. These operations were the usual ones current in the small tool industry.

One critical step in production involved the heat-treating operation, where the tool was placed in a Lindbergh furnace, which was automatic and fully instrumented, for an appropriate length of time at a temperature of 1550° F. After the tools reach 1550° F. in the Lindbergh furnace, they are oil quenched and subsequently tempered at 750° F. This is a critical operation with respect to the qualities the finished product will possess. The defendant company omitted this step in manufacturing this tool.

Metallurgical Examination and Findings

Visual examination revealed that a number of chips had spalled from the hammered end of the tool (Ill. C, Fig. 1 and Ill. A, Fig. 1). The nature of this spalling suggested that the tool had failed in a brittle fashion. Such failures may result for a number of reasons, for example, inadequate quality of the steel, improper heat-treatment, or other reasons associated with fabricating procedures. Thus, it was important to establish clearly the reason for the brittle failure of this particular tool.

The manufacturer specified that these tools were made from a Chrome-Nickel Alloy steel, and that they had been heat-treated by oil quenching from 1550° F. and then tempered at 750° F. This treatment, when employed properly, would produce a hardness in the range 42 to 47 Rc.[6] A hardness in this range should be adequate for the anticipated application and should not result either in excessive mushrooming (from too low hardness) or in spalling (from too high hardness). A desirable Rockwell range would be between 40 and 45 Rc.

A metallurgical examination was conducted in order to determine if the tool had been made from steel of high quality and had received the treatment specified by the manufacturer. All of the tests conducted for this purpose were carried out near the hammered end of the tool. Since the tool in question was manufactured some years ago, six tools of recent manufacture also were examined, for comparison with the tool in question.

Chemical analysis was employed in order to determine the composition and type of steel used in manufacturing this tool. One of the tools of recent manufacture also was analyzed chemically for comparison purposes. This examination revealed that the tool in question was manufactured from a Chromium Molybdenum steel—4140,[7] and that a Chromium-Nickel-Molybdenum steel—8640 was used for the tool of recent manufacture. Both steels were within specification limits for their respective types.

Metallographic methods were employed to study the structure and the quality of the steels used for these tools. This examination revealed that the steels employed for both the tool in question and the new tool were fine grained, sound and of high quality. Thus, the brittle failure of the tool in question is associated with the specific treatment employed in manufacturing the tool rather than with the quality of the material employed in its manufacture.

The microstructures of the tool in question and of the new tool are shown in Ill. A, Figs. 2, 3, and 4. Figure 2 in Ill. A was taken at approximately ¼″ below the surface of the tool in question and shows that the micro-structure is typical of that for a martensitic structure tempered at a very low temperature. However, the surface of the tool was decarburized[8] severely, as demonstrated by the structural gradations illustrated in Ill. A, Fig. 4.

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6 Rc stands for the hardness measured on a standard Rockwell testing machine using the C scale.

7 4140 was not a chrome nickel steel as advertised by the manufacturer.

8 The term "decarburized" means that the carbon has been removed from the surface by heat treatment in air. This could be prevented by appropriate heat treating atmospheres. In any event, best commercial practice would call for removal of this layer by grinding after heat treatment.

The structure of the new tool (ferrite plus pearlite, as shown in Ill. A, Fig. 3) indicates that this tool had not been quenched properly from an adequate hardening temperature (such as 1550° F.)

Hardness tests were conducted on both the tool in question and on several tools of recent manufacture. These tests demonstrated that the hardness of the tool in question was 55 to 56 Rc., and that the hardness of the tools of recent manufacture were in the range 27 to 30 Rc. Thus, none of these tools had been subjected to the specific heat-treatment outlined by the manufacturer.

The heat treatment of steel is a sensitive procedure involving several successive operations. Precise control must be exercised over each of the stages in any heat treating process, if satisfactory properties are to be obtained in the finished product. Although the theory of heat treatment cannot be discussed in detail here, the principles essential to an understanding of this particular tool failure will be discussed briefly.

Composition, Heat Treatment and Microstructure

When cooled from a high temperature (*above* about 1500° F. for most 0.40% carbon steels), the structure of a steel depends on how fast it is cooled and on its composition. The steels employed by the manufacturer in the instant case were 0.40% carbon steels. For steel of a particular composition, a critical cooling rate exists. When cooled more rapidly than this critical rate, transformation occurs to a structure termed martensite and the steel is then said to be hardened (Ill. A, Fig. 2). However, when cooled more slowly than the critical rate, transformation to other structures (ferrite, pearlite, and others) takes place and the steel is not hardened.

Data in the literature[9] indicates that, for section sizes smaller than 1.4″ in diameter, 8640 steel will be hardened throughout when oil quenched from 1550° F. while 4140 will harden throughout in section sizes up to 2.0″ in diameter when quenched under the same conditions. Thus, since these tools are less than 1″ in diameter, the hardening treatment specified by the manufacturer (oil quench from 1550° F.) would produce hardening (produce a martensitic structure) over the entire cross section of the tool. This was the case for the tool in question (see Ill. A, Fig. 2) but

[9] Republic Alloy Steels Book published by Republic Steel Corporation, 1949.

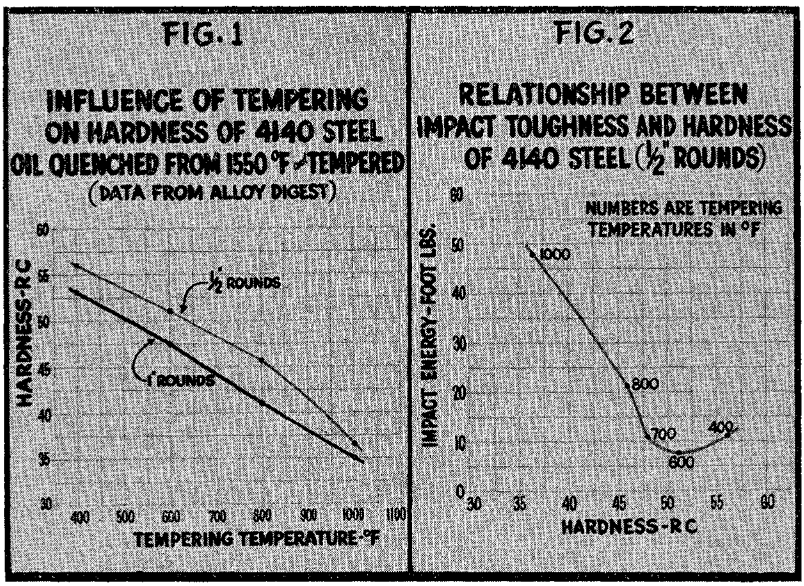
was not true for the tools of recent manufacture. The hammered ends of the new tools either were never heated above about 1350° F. or else they were cooled so slowly from a higher temperature (such as 1550° F.) that they failed to harden (see Ill. A, Fig. 3).

Structure, Composition and Properties

The properties (hardness, toughness, etc.) of a heat treated steel depend on its structure and carbon content and are essentially independent of alloy content except in so far as this determines the structure (through the influence of alloys on critical cooling rate). Since correct heat treating practices for this tool involve the formation of a hardened (martensitic) structure, further discussion will be limited to the influence of carbon content on the properties of martensite.

As shown in Ill. A, Fig. 5, martensite does not have a unique hardness. Rather, its hardness is determined by its carbon content—increasing carbon content increases the hardness of martensite. Thus, the hardness can vary from less than Rc 25 for very low carbon martensite to greater than Rc 60. For a steel with 0.40% carbon the hardness of martensite in the as quenched condition is approximately Rc 60. Thus, in the as quenched con-

ILLUSTRATION B



dition, martensite in a 0.40% carbon steel is extremely hard and brittle.

Hardness can and *must* be relieved by tempering (or drawing) the steel at an appropriate intermediate temperature. The influence of tempering on the hardness of oil quenched 4140 steels is shown in Ill. B, Fig. 1.[10] Note that the hardness decreases rapidly as the tempering temperature is increased. Tempering at 750° F would produce a hardness in the range 42 to 47 Rc. Thus, the tool in question (55 to 56 Rc) was not tempered at 750° F. Either the tempering operation was omitted completely, or, in any event, this particular tool did not attain a temperature in excess of about 400 to 500° F.

As the hardness of martensite is lowered by tempering, other properties also change. Of particular importance to the present tool failure is the way in which toughness changes with tempering. Toughness is the ability of the tool to absorb energy without breaking. Thus, it is a combination of other properties such as strength (hardness) *and* ductility. A steel that requires a lot of energy to break it has high toughness and one that requires little energy has low toughness (or is brittle).

Toughness is measured qualitatively by determining the energy required to break a sample in an impact test. Illustration B, Fig. 2 shows the influence of hardness on the toughness of 4140 steel.[11] Note that the toughness increases rapidly as the hardness is lowered (by increasing tempering temperature). Thus, it is apparent that hardness and toughness are essentially reciprocal properties, i.e., a hard steel has low toughness and consequently will break in a brittle fashion.

The practical significance of these observations in the present problem is that at a high hardness (56 Rc), a quenched and tempered steel is brittle. Thus, it takes little energy to break the steel so that it will chip or spall cataclysmically under a single blow. At lower hardness (higher toughness), the steel will deform gradually under repeated blows (called mushrooming) and thus give adequate forewarning of impending failure.

The importance of proper heat treating practice is recognized clearly in specifications and in publications of the National Safety Council. The following is quoted from a National Safety Council Pamphlet:

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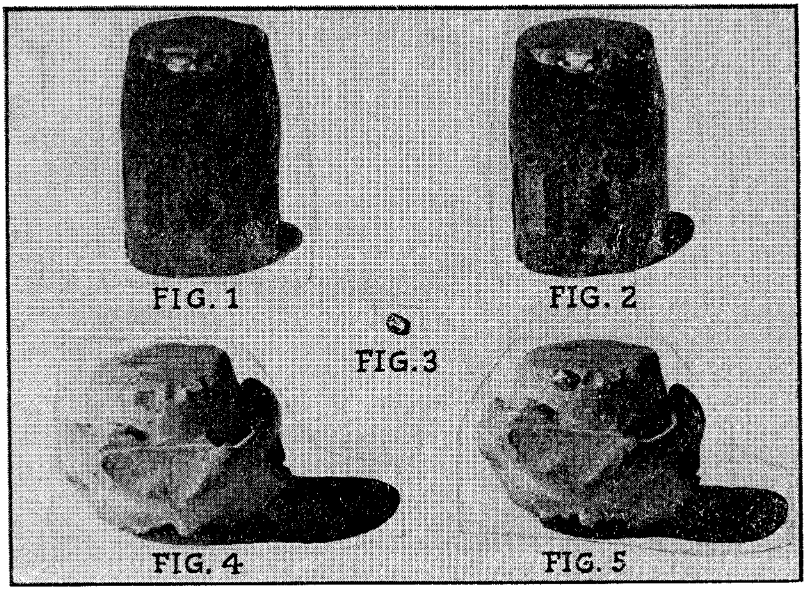
10 Actual chart size for jury presentation (44" x 30").

11 Actual chart size for jury presentation (44" x 30").

Hammer-struck and striking tools (chisels, stamps, punches * * *) should be made of carefully selected steel and heat-treated so that they are hard enough to withstand blows without mushrooming excessively, and yet are not so hard as to chip or check.

For safety it is better that shock tools, some of which can be dressed frequently, be a little soft rather than too hard, because a chip may fly from an excessively hard tool without warning when the tool is struck with a hammer or sledge[12] (Ill. C, Figs. 1 and 3).

ILLUSTRATION C



Medical Findings Relative to the Right Intra-Ocular Foreign Body

Plaintiff McCaul was admitted to the Detroit Memorial Hospital, January 21, 1955. The plaintiff's medical history prior to this injury was non-contributory and his general health good.

The physical examination of the right eye, upon the patient's admission to the hospital, showed an anterior chamber full of blood, and a corneal laceration of three millimeters length at six o'clock on the limbus. The vision was light perception in the

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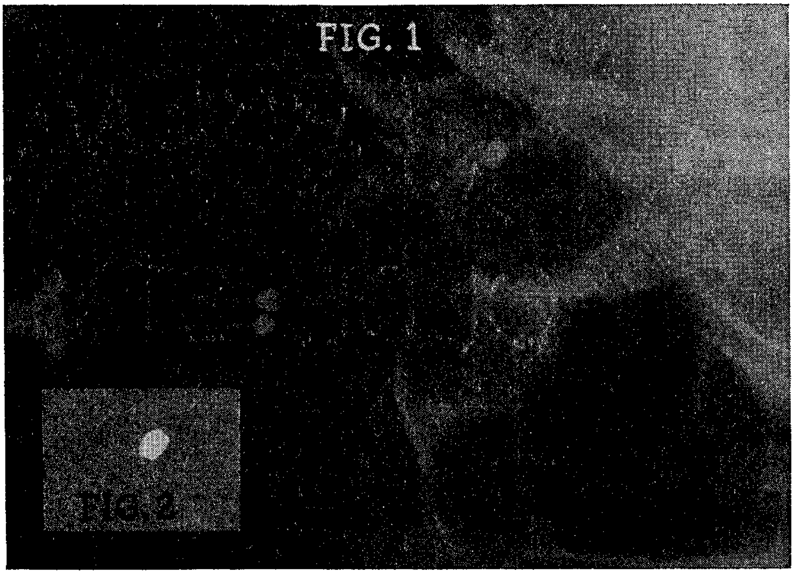
12 Hand Tools—Safe Practices Phamphlet No. 41 of the National Safety Council.

right eye and twenty/twenty in the uninvolved eye. It was noted that the patient was in considerable pain. Radiographic examination at that time demonstrated a single radiopaque foreign body within the right orbit, measuring four by three by two millimeters. Utilizing the Sweet method of localization,[13] (see Ill. D, Fig. 1), it was determined that the metallic foreign

ILLUSTRATION D



body was fifteen millimeters posterior to the center of the cornea, eleven millimeters above the horizontal plane of the cornea, and fourteen millimeters to the nasal side of the vertical plane of the cornea. These determinations placed the foreign body within the right orbit, but outside of the globe of the eye.

After admission to the hospital, the patient was taken to surgery and the three millimeter laceration of the cornea was sutured. Surgical exploration of the right orbit at that time showed an exit laceration near the equator of the eye, posterior-

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[13] The Sweet method of localization is a widely accepted method to localize foreign bodies in the orbit. This method locates a foreign body in relation to fixed points outside of the globe, and determines its position in relation to the center of the pupil and surface of the cornea. (In Illustration D, Figure 1, the Sweet localizer can be seen on the extreme left). By the principle of triangulation, the position of the foreign body in the orbit can be plotted on a chart.

ly, and this laceration was sutured. The metallic fragment could not be found in the soft tissues surrounding the eyeball, even when the area was exposed to a giant electromagnet. Following this, it was felt that the conservative treatment would be to leave the foreign body in its orbital cavity, but extra-ocular position, in which location it would be inert. The patient's hospital course was uneventful and he was discharged January 28, 1955, with a final diagnosis of an extra-ocular foreign body in the right orbital cavity, and a through and through penetrating laceration of the right eye.

Following discharge from the hospital, plaintiff McCaul was disabled for a period of six to eight weeks, following which he returned to work. Examination of the involved right eye on March 7, 1955, revealed complete healing of the anterior laceration, and an absence of activity in the anterior chamber. The fundus of the eye could not be visualized due to the fibrosis of the posterior segment following the original hemorrhage. The vision was noted as being twenty/four hundred. In addition, the eye turned outward ten degrees, due to the original trauma and the foreign body passing out of the eye and through the medial rectus eye muscle. Repeat radiographic examination of the right orbit, done October 14, 1955, again showed the foreign body in the right orbit and using the Sweet localization method, it was not felt that there had been any essential change in its position since an earlier examination of January, 1955.

Subsequent eye examinations done on November 30, 1956 and again on October 21, 1958, showed similar findings. The right eye remained divergent, but the extra-ocular movements otherwise normal. The right eye showed light perception. The right eye was unimproved with correction. The left eye showed a visual acuity of twenty/twenty. Examination of the right eye further showed a through and through corneal scar just off the limbus at five o'clock. Intra-ocular tension was within normal limits. The fundus of the right eye was not visualized because of a dense traumatic cataract involving the lens. Following these examinations the medical opinion remained the same, namely that there would be no value in removing the metallic foreign body lying in the right orbit, but outside of the eyeball. No further treatment was felt indicated, as it was the feeling of the ophthalmologists that there had been sufficient intra-ocular damage to destroy the vision, and that even if the traumatic cataract were removed, in all probability useful vision would not be obtained. Radiographic examination of the right orbit, done for the final time on October 20, 1958, showed essentially the same findings as previously described, namely that the metallic foreign body lies in the right orbit, outside of the eyeball. It had not changed significantly in position since the first examination of January 21, 1955.

Method Used to Identify the Foreign Body as a Chip From the Wedge Tool

Having determined that it would be of no advantage to remove the metallic fragment lodged in plaintiff McCaul's right orbit, the problem presented itself as to how this metallic fragment could be identified as the chip which had been released from the blunt end of the wedge tool. As mentioned earlier, the patient had noted a shiny defect on the radius of the blunt end of the wedge tool shortly after the original injury. The appearance certainly suggested that the shiny defect was the site of the fragment which was lodged in the orbit medial to the right eyeball. The fact that the electromagnet was unable to remove the metallic fragment at the time of surgery, most likely means that the fragment, even though it is magnetic, was lodged so deeply and intimately within the soft tissues of the orbit that the magnet was unable to dislodge it. Because the fragment was not available for direct comparison with the defect in the blunt end of the wedge tool, an indirect method was carried out which seemed to substantiate the identity of the fragment quite clearly.

When plaintiff McCaul presented himself for radiographic examination on November 22, 1957, he brought with him the wedge tool which he was using at the time of his original injury. Upon inspection of the radiographs, showing the patient's orbit in the lateral projection, it became apparent that the configuration of the metallic foreign body in the orbit was very similar in size and shape to one of the defects around the radius of the blunt end of the wedge tool. Measurement of the foreign body on lateral films of the orbit, taken in such a manner that magnification would be kept to a minimum, showed the longest diameter to be four millimeters and the shortest diameter three millimeters. The defect on the blunt end of the wedge tool measured the same. With these preliminary observations, a more definitive method to identify the fragment was attempted.

The wedge tool was presented to a dentist with instructions to make a gold inlay, reduplicating the fragment from a specific defect in the tool as closely as possible. The defect in the blunt end of the tool is shown in Illustration C, Fig. 1. The inlay was made using a direct technique which consisted of filling the cavity with wax to contour, then casting the wax impression in gold using a dental procedure known as the "Lost Wax Technique." The gold inlay representing the fragment is seen in Illustration C, Fig. 3. A perfect fit was obtained when the gold inlay was placed in the defect around the radius of the blunt end of the tool (Ill. C, Fig. 2). To polish the gold inlay to as near perfect a fit as possible, another procedure was carried out which allowed the inlay to be polished without disrupting in any way the edges or the contour of the defect in question on the wedge tool. This procedure consisted of making an impression of the blunt end of the tool in a dental impression material (in this instance an irreversible alginate). Dental stone was poured into this impression resulting in a model of the blunt end (Ill. C, Fig. 4). The gold inlay then was finished and given its final form by being polished while it was situated in the defect of the model (Ill. C, Fig. 5). The next step was to obtain radiographs of the artificially created gold fragment, approximating as closely as possible the same conditions prevailing when films of the patient's orbit were obtained. When this was carried out, using standard techniques, direct comparison of the profile of the gold inlay (Ill. D, Fig. 2) to the profile of the metallic foreign body seen in the patient's right orbit (Ill. D, Fig. 1) showed a striking similarity relative to both size and configuration. Fortunately, the fragment presented several features relative to its configuration that made comparison, and hence identification quite certain. For further clarification, radiographic magnification techniques[14] were carried out, and this allowed further comparison of the magnified views of the patient's orbit containing the metal fragment (Ill. E, Fig. 1) with the magnified views of the gold inlay (Ill. E, Fig. 2). The results of this investigation seemed to show quite conclusively that the metallic foreign body in the patient's right orbit matches

[14] Radiographic magnification can be obtained by using a small focal spot tube, and obtaining radiographs with a greater distance between the object and the film than is used in the standard techniques. This produces magnification and distortion is kept at a minimum by the small focal spot x-ray tube.

the gold inlay created from the defect in the blunt end of the tool, both as to size and configuration. There was little doubt that the source of the metal fragment imbedded in plaintiff McCaul's right orbit had been established.

ILLUSTRATION E