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SAFETY BRIEF

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ON RUBBER AUGERS—FAILURE MODES AND EFFECTS

by

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SUMMARY:
Contrary to reported notions, the flexible flight auger gives rise to a new set of hazards and risks without fulfilling its promise of eliminating the amputation hazard. Increased jamming, elevated temperatures, grain damage, and rubber flight damage are among the failure modes observed.

KEYWORDS:
rubber, auger, conveyors, safety

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I. Introduction

The popularity of the screw conveyor arises in part from its simplicity, efficiency, light weight, low cost, and serviceability. An extensive literature exists which addresses the analysis of the screw conveyor from the point of view of its volumetric delivery as a function of diameter, pitch, inclination, speed, product, and intake geometry [1-20]. The very characteristics that make the screw conveyor capable of entrapping so many types of materials, which it then transports efficiently through its cylindrical housing, give rise to its potential for mischief. The safety literature is replete with suggestions for safeguarding the infeed and access systems associated with these conveyors [21-34].

The following three damage mechanisms are associated with auger systems:

1. The inrunning nip hazard between the walls of the infeed housing and the edge of the auger flights.
2. The wrap-around hazard associated with the rotating auger shaft.
3. The interference hazard which occurs between stationary parts of the housing and the progressing faces of the auger flights.

The primary device used to control these hazards on infeed systems has been the mesh guard which admits the product while blocking parts of the body. Unfortunately, the function of the conveyor generally requires larger aperatures in the guards than are dictated by guarding theory [35]. Rubber augers have been manufactured to supplement or replace the infeed guard. There is something intuitively attractive about the flexible flight auger from a safety point of view. Its forgiving nature would appear to minimize the damage potential of the nip point and interference hazards when compared to the rigid auger flights. Unfortunately, we cannot accept this supposition without proof and it is the purpose of this paper to provide elements of a complete safety analysis of the rubber auger.

The literature attributes a number of attractive features to the rubber auger when compared to steel [36-40]:

- Grain damage reduction of up to 60%.
- Four times longer life than steel.
- Decreased shock loading to the auger drive.
- Easier withdrawal of large objects trapped at the entrance of the cylindrical tube.
- Virtual elimination of auger hazards.

Shortcomings of rubber auger systems are also outlined in the literature:

- Capacity is reduced to 73% of a steel auger.
- Cost increases to $23 over the cost of $39 for a 61.0 cm (2 ft) section of a 12.7 cm (5 in) diameter steel screw and $31 over the cost of $51 for a 61.0 cm (2 ft) section of a 17.8 cm (7 in) diameter steel screw.

The safety claims contained in the literature are not persuasive and are based on an insignificant number of tests. Indeed, this paper represents a small contribution to the safety problem by examining several failure modes and effects which must be incorporated in an overall evaluation of flexible flight augers. This research does not support the foregoing safety claims and points out the need for continuing research.

II. Thrust/Torque/Rotation Relationships

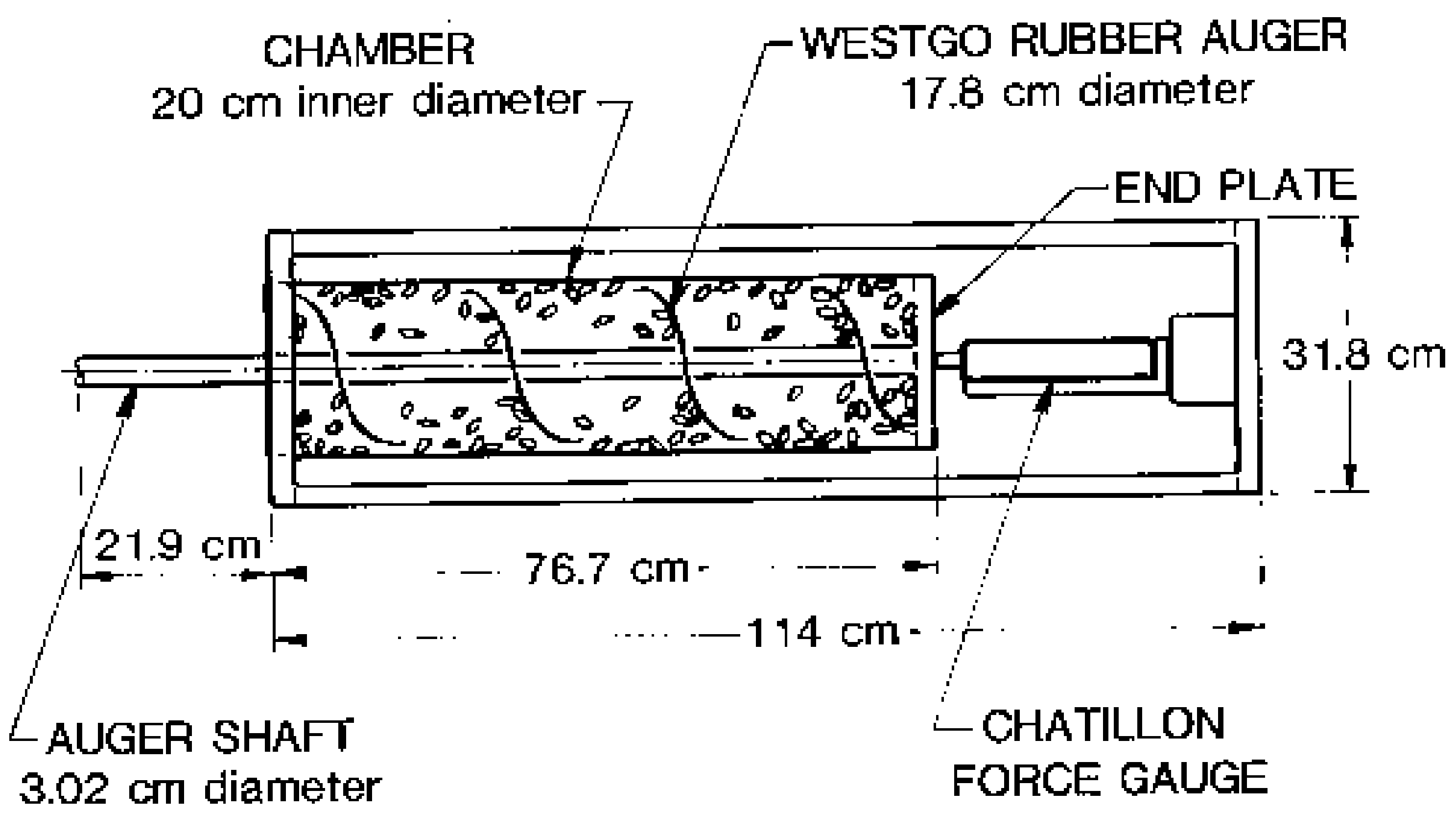
One of the serious functional problems exhibited by the agricultural screw conveyor is its tendency occasionally to lock up which prevents the transport of material. The conveyors operate under a wide range of environmental conditions and handle a variety of products which exhibit adhesive characteristics. Furthermore, each product displays highly variable physical properties such as moisture content, density, friction, angle of repose, and tenacity. Lock-up manifests itself most frequently when the conveyor is often stopped and started.

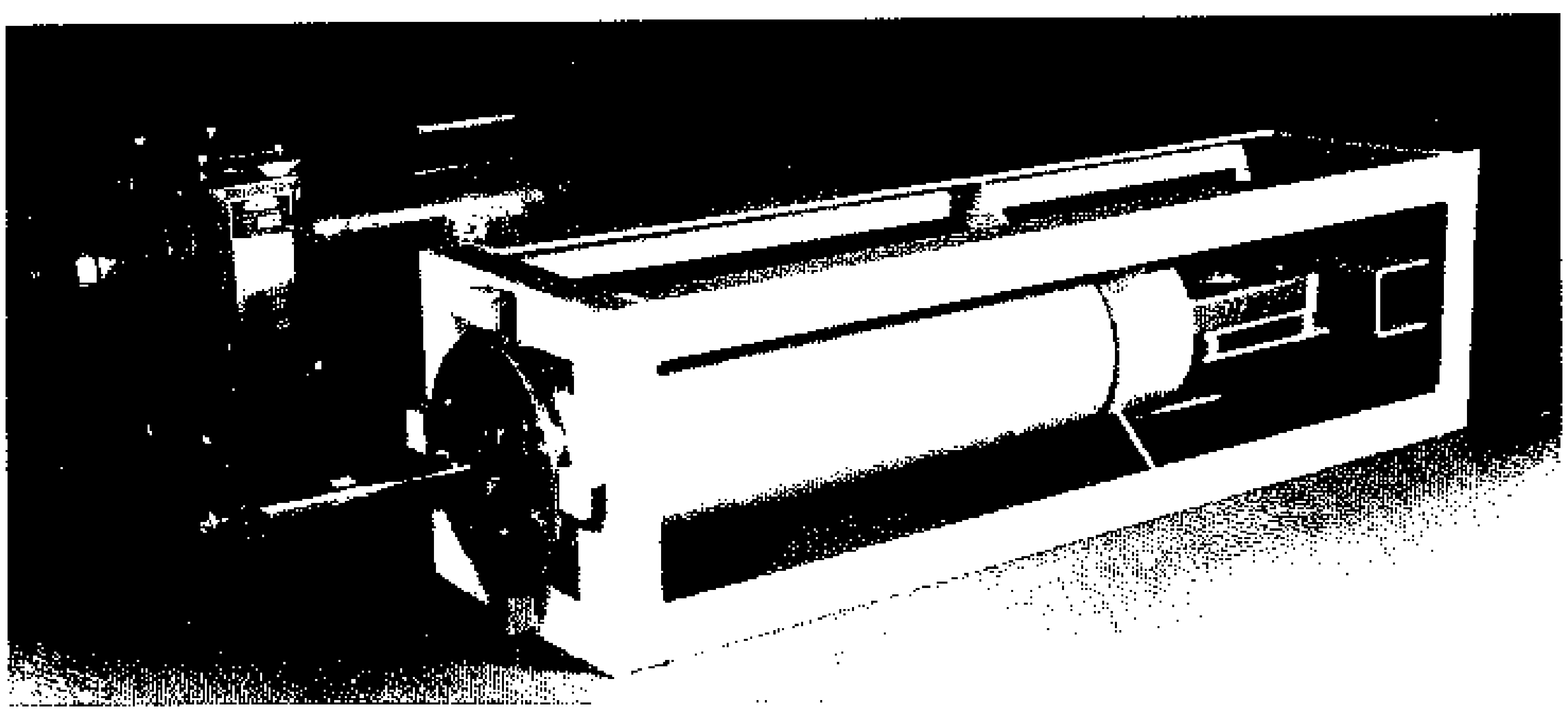
A. Testing

To study the characteristics of steel and rubber auger systems under jamming or non-flow conditions, the test fixture shown in Figure 1 was constructed which confines the product in a cylindrical chamber containing a 17.8 cm (7 in) diameter rotating auger. The rotation, torque, and thrust of the auger was recorded for corn (12.3% moisture), wheat (11.3% moisture), and milo (10.2% moisture) under jamming or non-flow conditions. In a typical test, the chamber was filled with grain and the auger was slowly rotated with a torque wrench which forced the grain against an end plate which was instrumented to measure axial force. The resulting torque and thrust were plotted against the angular rotation of the auger shaft and the resulting thrust-rotation curves are shown in Figures 2 and 3 for the steel and rubber augers respectively. Torque-rotation curves are shown in Figure 4 for the steel auger and Figure 5 for the rubber auger.

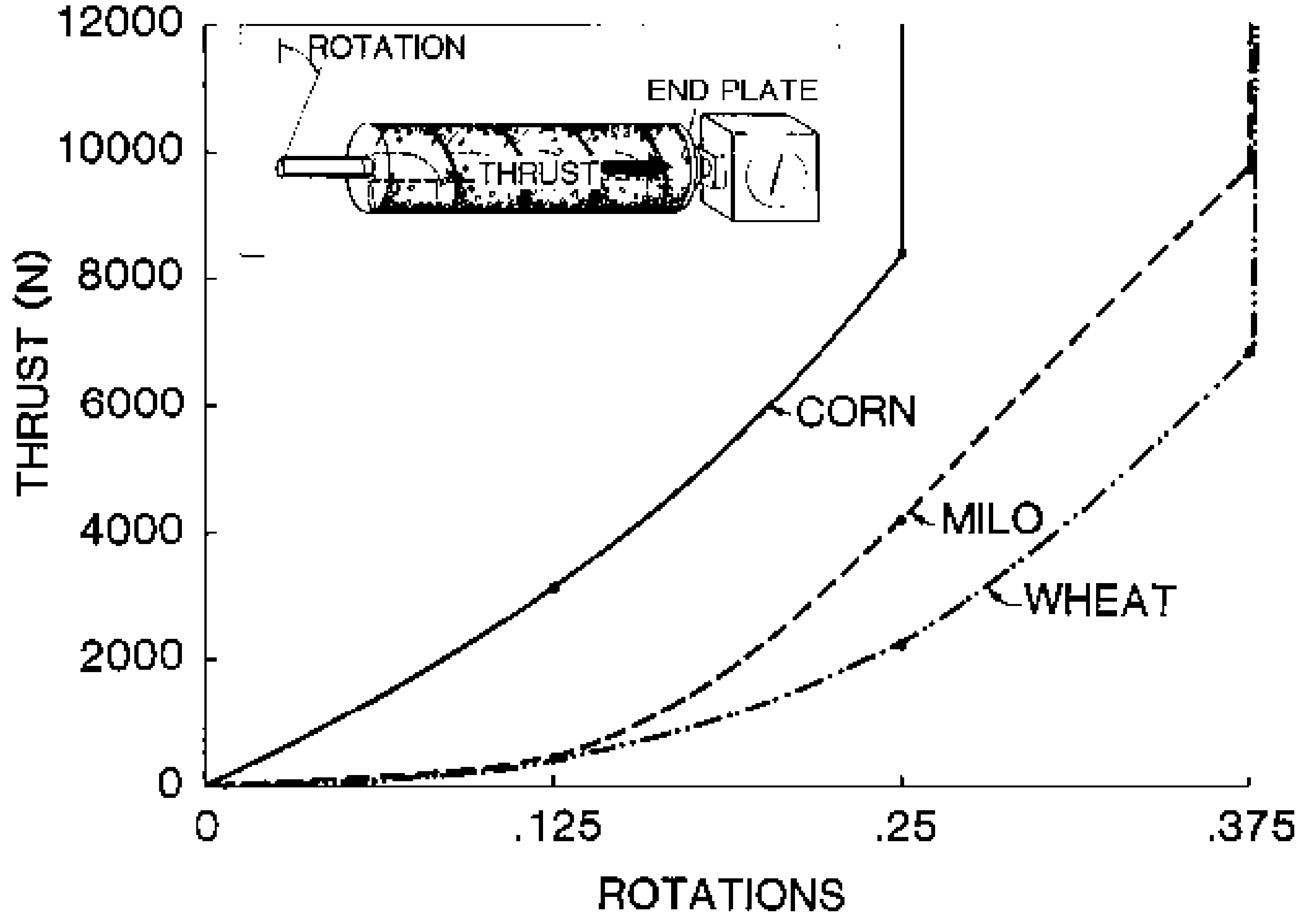
Referring to Figures 2 and 4 for the thrust and torque curves associated with the steel auger, we observe an *elastic lock-up* behavior which terminates the rotation within a fraction of a turn. Under these circumstances, you would expect the limiting value of thrust or torque to be associated with slipping clutches, belts, or other elements in the power train.

Figure 1. Test Fixture ▼

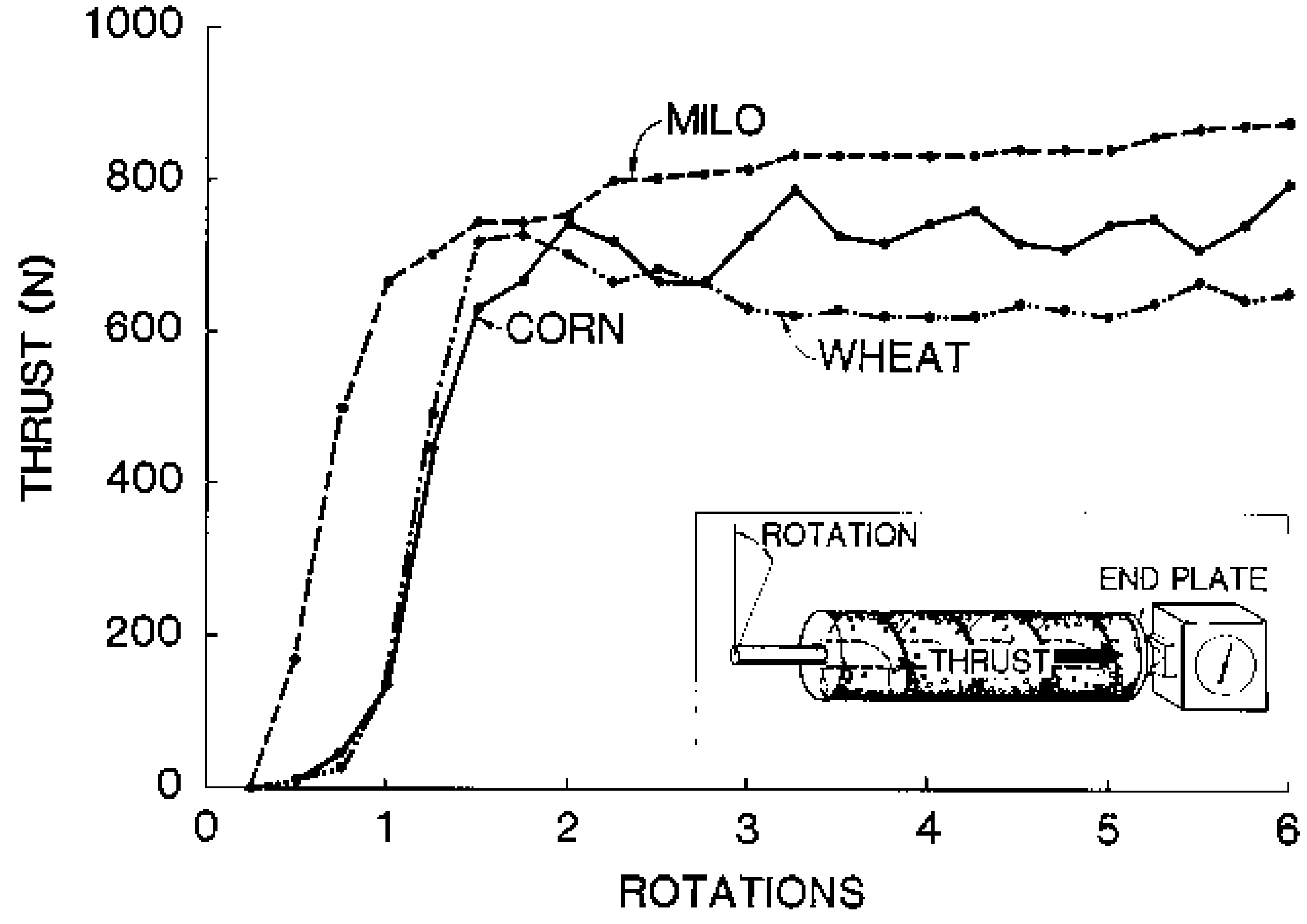




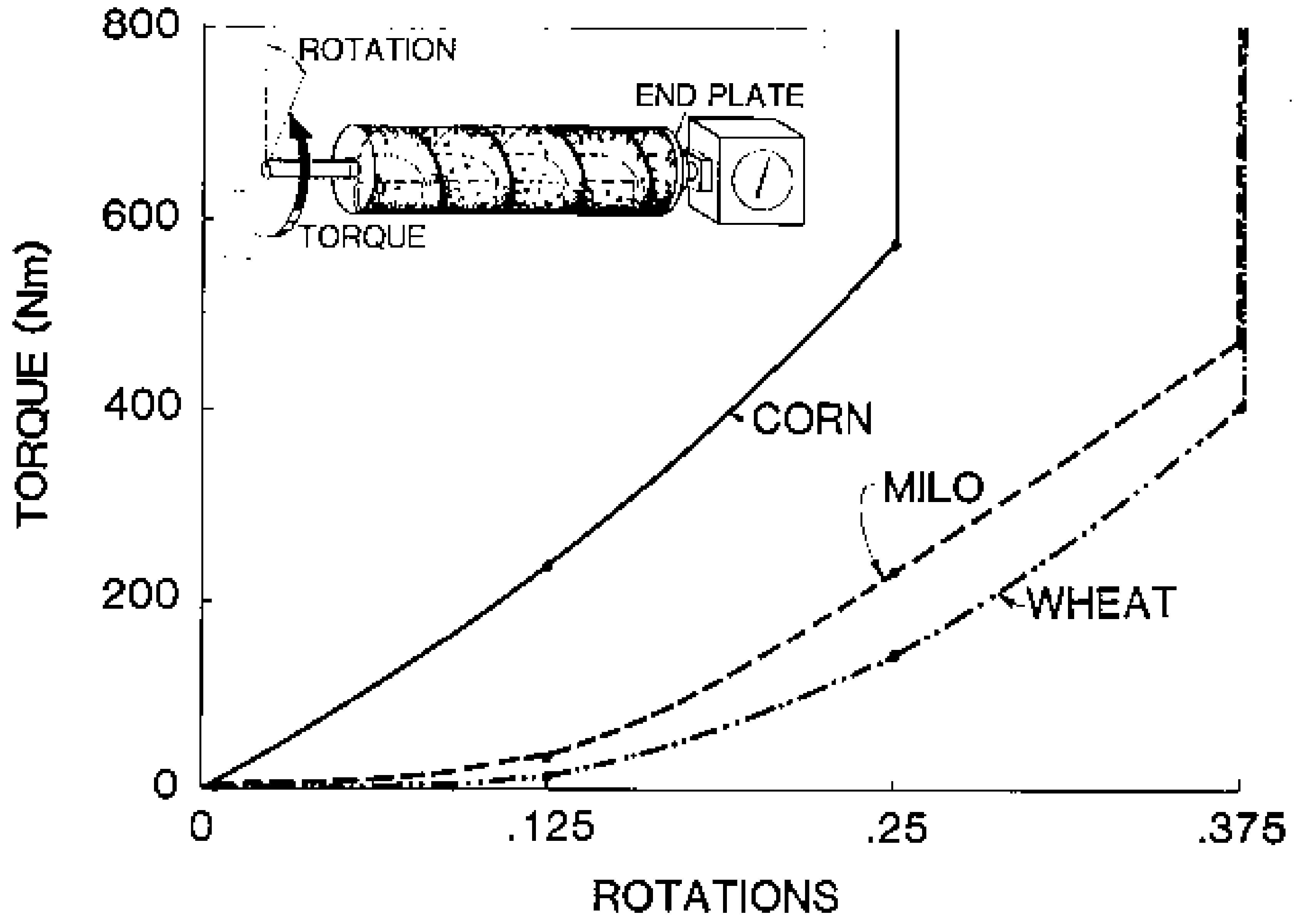
▼ *Figure 2. Thrust-rotation curves for steel auger*



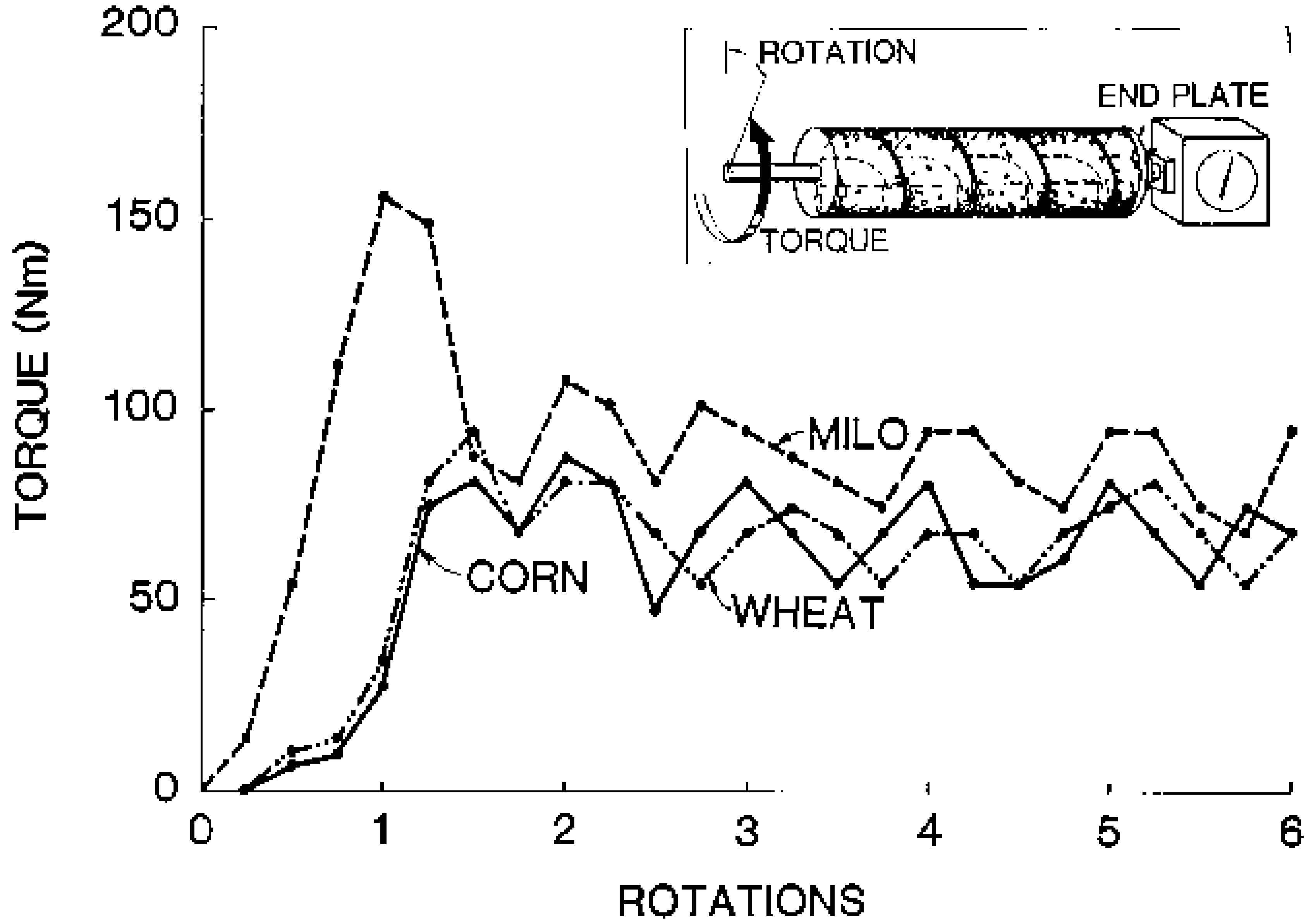
▼ *Figure 3. Thrust-rotation curves for rubber auger*



▼ *Figure 4. Torque-rotation curves for steel auger*



▼ *Figure 5. Torque-rotation curves for rubber auger*



Figures 3 and 5 for the rubber auger portray completely different behavior which we will characterize as *elastic perfectly plastic*. Here, the deflection of the rubber flights occurs suddenly and allows the auger to rotate under constant resistance. The horizontal portions of these curves reflect the ranges where the material bypasses the rubber flights. Figure 6a shows the distortion of the rubber flights as photographed through a transparent plastic cylindrical chamber. This distortion is highlighted in Figure 6b.

B. Safety and Operational Characteristics

1. Minimize Risk
   Jamming is more easily overcome with the steel auger than the rubber auger because the steel auger delivers torques and thrusts that are one or more orders of magnitude greater. Consequently, one would expect a greater number of manual unjamming operations with the use of a rubber auger with the attendant risk of exposing operators to the rotating auger.
2. Achievement of ZMS
   The lock-up characteristic of a steel auger normally causes the auger system to achieve a zero mechanical state (ZMS) for the following reasons:
   a. Electrical motors achieve their stall torque which trips the breakers or overload devices.
   b. Excessive resistance in the drive train causes internal combustion engines to stall out.
   c. Slippage of belts, clutches, and other elements in the drive train produces noise, vibration, and odors which are so pervasive and unrelenting that the operators are compelled to shut off the power plants.

   Under the above conditions, unjamming activities may take place immediately under the protection of ZMS which is currently acknowledged to be the most advanced safety maintenance philosophy [41].

   By contrast, the rubber auger does not lock up under jamming conditions. Its continuing rotation does not produce feedbacks which would coerce an operator to shut down the machine. Here, one would expect a statistically significant number of operators to attempt to perform unclogging operations while the rubber auger is rotating. Indeed, it will be perceived that the rotation will aid in the unjamming task.
3. The Start-Up Problem
   Under full load conditions, the starting torque and thrust requirements are usually greater than the corresponding levels that are necessary to sustain conveyor flow. For example, Allis-Chalmers experiments with combine bin unloading augers showed start up torques for corn (30% moisture) of 1084 Nm (800 ft - lbf); flow was sustained at a torque level of 447 Nm (330 ft-lbf). Our experiments showed that these torque levels were easily obtained with the steel auger; however, the equivalent rubber auger did not produce torque levels greater than 156 Nm (115 ft - lbf). Consequently, at such torque levels, the rigidity of the rubber flights must be increased with a concomitant increase in their hazard level.

III. Heating/Grinding

A. Rubber Flights

Under jamming conditions, our experiments utilizing rubber augers showed that the augers continued to rotate at a constant torque level as depicted in Figure 5. The auger rotating in a sea of grain conjures up the experiments performed by Joule where a paddle wheel was rotated in a tank of water or mercury to establish the temperature rise as a function of mechanical work input. In our experiments, the temperature of the 3.18 mm (⅛ in) thick steel shell shown in Figure 1 was monitored as the rubber auger was rotated at 600 rpm under jammed non-flowing conditions. The time-temperature relationship is shown in Table 1 for milo (10.2% moisture).

A rapid temperature rise occurred, followed by a decreasing rate of temperature increase as the heat transfer to the environment became more efficient. An equilibrium temperature of 179°C (355°F) was achieved for milo after one hour and 32 minutes. Wheat (11.3% moisture) reached an equilibrium temperature of 143°C (290°F) after 1 hour and 45 minutes. Corn (12.3% moisture) began "popping" after 30 minutes at a temperature of 66°C (150°F).

Time (Hours)	Temperature (°C)
0:00	22.8
0:28	83.9
0:39	93.3
0:56	103.9
1:05	110.0
1:10	126.7
1:15	140.0
1:19	148.9
1:20	151.1
1:25	160.0
1:30	167.8
1:32	179.4

Table 1—Time-Temperature Relationship For Rotating Rubber Auger In Milo Under Jammed Non-Flowing Conditions.

B. Steel Flights

The use of steel flights under jamming conditions caused almost instantaneous lock up which precluded the introduction of mechanical work into the grain media; no temperature rise was experienced.

C. Observations

1. Discoloration
   When milo, wheat, and corn were exposed to the elevated temperatures described above, discolorations were observed in all cases ranging into a black char.
2. Mechanical Damage
   In the case of corn, a significant number of the kernels were fractured mechanically.
3. Fire Hazard
   The elevated temperatures experienced in our test program would be expected to achieve even higher levels depending on the insulation surrounding the auger tube. Such conditions are common when the conveyors are located in the bottom of hoppers and bins filled with grain. Individual situations must be analyzed to establish whether or not the elevated temperatures become a source of ignition.
4. Rubber Flight Damage
   The exposure of the rubber flights to elevated temperatures in our experiments caused their stiffness to decrease from an original durometer reading of 77 to a final reading of 65.[1]

IV. Mechanical Hazards

A. Test Programs

1. Small Diameter Dowel Rods
   To examine the shear hazard created between the progressing flights of the rotating auger and the stationary tube, hard wood dowel rods were inserted in a 5.08 cm (2 in) square hole cut in the top of the cylinder shown in Figure 1. The auger was rotated at 600 rpm and 3.18 mm (⅛ in) and 6.35 mm (¼ in) diameter white birch hard wood dowel rods were inserted vertically and allowed to fall into the grain filled chamber under gravity. In both cases, the long dowel rods were diced into short cylinders whose lengths were 2 to 3 diameters.
2. Large Diameter Dowel Rods
   The tests described for the small diameter dowel rods were repeated for white birch hard wood dowel rods with 9.53 mm (⅜ in), 12.7 mm (½ in) and 15.9 mm (⅝ in) diameters. In the tests using the 9.53 mm (⅜ in) and 12.7 mm (½ in) diameter rods, the shafts were

[1] Measurements were made with a PTC · Model 306 Type A Durometer.

pulled into the chamber where they sustained a single bending fracture. The 15.9 mm (⅝ in) diameter rod was pulled into the chamber, but sustained no bending damage. Each of the dowel rod tests was repeated 3 times using a new rubber auger that was not subjected to elevated temperatures.

3. Empty and Full

It was hypothesized that the grain would stiffen the rubber auger flights and thereby increase their damage potential. To examine this notion, static tests were run by inserting hard wood dowel rods vertically into the 5.08 cm (2 in) square hole in the top of the cylinder where they were subjected to the shear and bending forces arising from the flight/auger tube interface. The first tests were performed without the use of grain by inserting white birch rods whose diameters were increased in 3.18 mm (⅛ in) increments. Here, fractures were obtained at all diameters up to and including 12.7 mm (½ in). No damage was sustained by the 15.9 mm (⅝ in) diameter rod.

The above procedure was repeated with a chamber packed with wheat grain. All of the dowels fractured up to and including the 15.9 mm (⅝ in) diameter rod; the 19.1 mm (¾ in) diameter rod did not fracture. The increased severity with the use of grain was observable through the 5.08 cm (2 in) square port in the top of the cylinder. It was clear that the flights had less tendency to wrap around and bypass the dowel rods when grain was stabilizing the flights. In all cases the failure mechanism was single shear at the flight/conveyor tube interface.

B. Observations

1. Severity Level

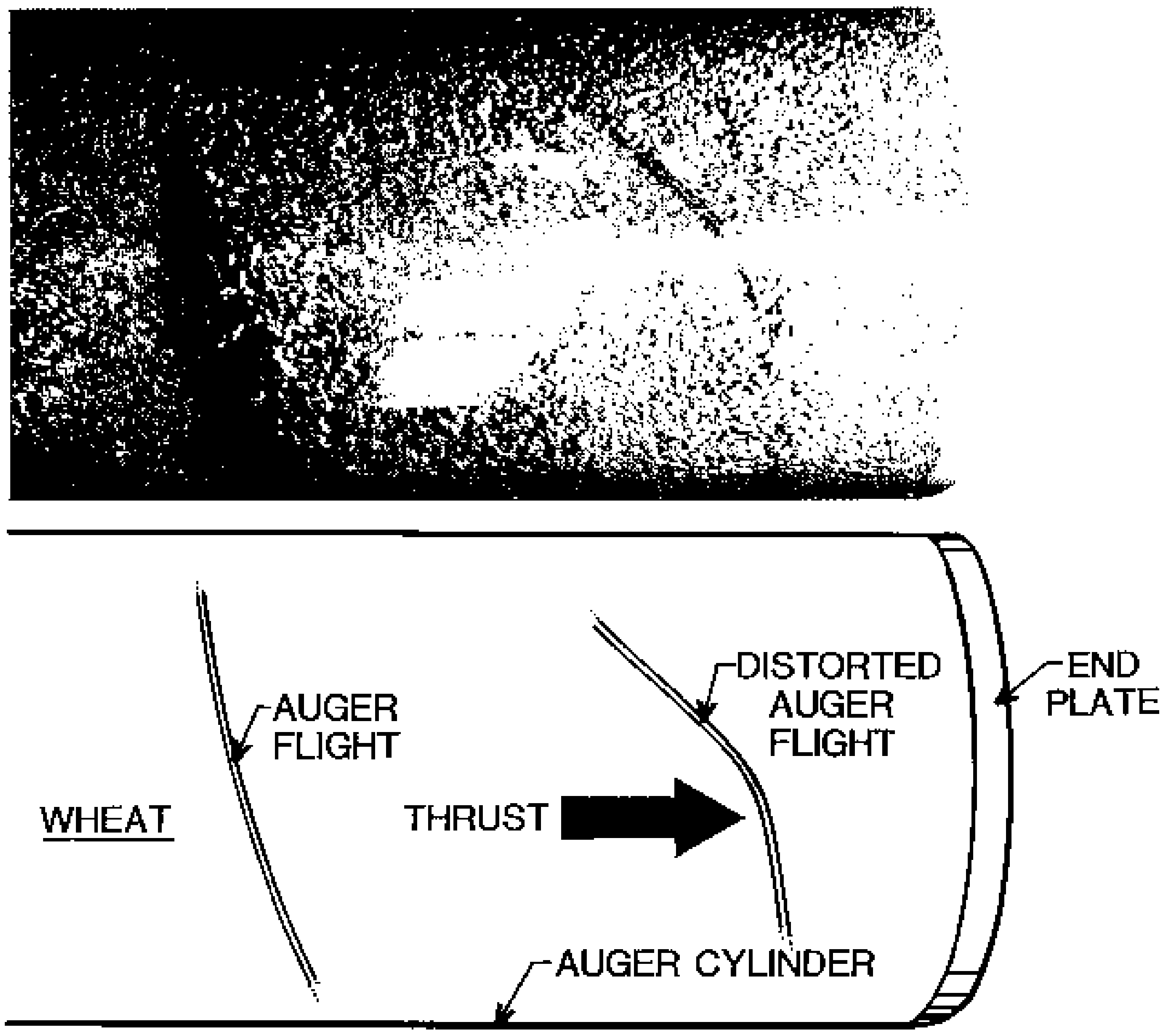
It is an enormously sophisticated task to establish the resistance of fingers and hands subjected to the flight/auger tube hazard. The use of hard wood dowel rods cannot simulate the strength of the human finger, however, it does provide engineers guidance in establishing severity. It is hard to imagine anyone being comfortable or feeling safe in the presence of a mechanism which regularly shears hard wood dowel rods of 12.7 mm (½ in) to 15.9 mm (⅝ in) in diameter. This becomes more poignant in view of the fact that practical functional requirements for rubber augers will probably demand stiffer flights than those tested in our program.

2. Wrap-Around Hazard

The severity of the wrap-around hazard is the same for both the rubber and steel flight augers. The risk of exposure to such a hazard has not been compared in these two systems and must await future inquiry.

3. Dependency Hypothesis

According to *The Dependency Hypothesis* [42-43], a statistically significant number of users will depend on the rubber auger to protect them in the manner represented by proponents of this auger. This will increase the risk or probability of exposure to the rubber auger compared to conventional auger systems. One must be circumspect about increasing risk when the severity levels produce amputations.



▲ *Figure 6. Distortion of rubber flights*

V. Conclusions

Failure modes and effects analysis has been applied to physical systems with the laudatory objective of improving their safety. Unfortunately, application of this technique is infrequently applied to candidate safety systems and devices with the consequence that dangerous side effects of ill-conceived safety devices are not discovered in a timely fashion. This paper examines some of the failure modes associated with rubber flight screw conveyors with the view that our observations be incorporated in more comprehensive evaluations.

Some of our findings may be summarized as follows:

- The limited thrust/torque capacity of the rubber flight auger compromises its ability to overcome jamming of the screw conveyor. This will result in an increase in manual unjamming activities.
- Functional requirements will often demand greater torque/thrust characteristics than those studied in this paper using available rubber flight augers. Satisfaction of these requirements will demand higher stiffness flights which will in turn increase the shear and bending hazards associated with the flight/auger tube interface, which is already critical in the commercially available rubber flight augers studied.
- Without lock-up capability, the rubber flight conveyor will not automatically bring the auger system to a state of ZMS during unjamming or compel operators to utilize this philosophy. Indeed, without the disincentives associated with lock-up and with the general perception that unjamming is easier in the face of a rotating auger, one would expect an increase in risk taking during unjamming operations.
- Without lock-up capability, rubber augers will input mechanical energy into a grain mass that can easily achieve temperatures that act as an ignition source.
- The lack of a lock-up capability leads to mechanical grain damage and elevated temperature damage to both the grain and the rubber flights.

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What is a Defect?

The definition of defective product in a state may be found in the case law of that state. In each issue we explore leading product liability case law from several states. Triodyne relies on the trial bar for the selection of the cases cited.

Illinois (Part 2)

Derrick v Yoder Co.

[88 Ill. App. 3d 864]

The plaintiff, Mr. Derrick, was employed by Leavitt Tube Company as a slitter helper in a tube production facility. He worked on a slitting machine, designed by Yoder Company, which slit flat steel into smaller strips which would later be shaped into tubing. The flat steel fed into the slitting blades from a 72" diameter coil and the strips were recoiled on another drum after slitting. This was a high speed process ranging from 150 to 400 feet of material per minute.

Because of insufficient tension, individual strips would often sag making tight recoiling impossible. To restore proper tension, slitter helpers would insert paper at the pinch point created by the sagging strip and the developing coil.

Yoder engineers and salespeople who visited Leavitt and saw the unsafe paper stuffing warned against the practice and sent written materials to purchasers for distribution to employees. There were no safety devices or warning signs at the danger area of the machine.

At the time of the accident the plaintiff was stooped below the fast horizontal flow of steel stuffing paper in the pinch point of almost every strip; the steel was coming from behind him. A steel sliver on the edge of a strip snagged Derrick's glove and pulled his arm into the recoiler. As a result, his arm had to be amputated.

Yoder presented five defenses to the Appellate Court. First, Derrick assumed the risk of his injuries. Derrick testified that he knew the pinch point was dangerous and he knew slivers were common on the strips and he knew a supervisor had lost his arm on the machine, though Derrick didn't know exactly how it had happened. Yoder contended that with this knowledge he appreciated and understood the risk yet deliberately exposed himself to it.

Derrick countered saying that because he knew the pinch point was dangerous, he stooped at what he considered to be a safe distance from the point. He did not know he could be injured from that distance by a burr catching his glove, pulling him off balance and into the recoiler. As Derrick was not aware of the particular risk, the jury found he had not consciously exposed himself to it. The Appellate Court upheld the jury decision.

In the second argument, Yoder insisted that under the doctrine of strict tort liability the plaintiff had to prove that a defect existed at the time the product left the manufacturer's control which made it unreasonably dangerous when used in the manner and for the purpose intended. Yoder claimed that although the product was dangerous, it was the hand stuffing of paper which made it unreasonably dangerous. The court held:

> "The conduct of the operator of machinery is a defense to a product liability action only where it is shown that such conduct amounted to a misuse of the product (*Williams v. Brown Manufacturing Co.* (1970), 45 Ill. 2d 418,425). The causal connection between an allegedly defective product and the injury is broken only where the misuse was not reasonably foreseeable. (*Lewis v. Stran Steel Corp.* (1974), 57 Ill. 2d 94, 102, 311 N.E.2d 128). Reasonable foreseeability in this context is measured by an objective standard (*Anderson v. Hyster Co.* (1979), 74 Ill. 2d 364, 369, 385 N.E.2d 690). The record demonstrates in the present case that Yoder's employees visited Leavitt's plant as often as twice per month at least as far back as the time its slitter No. 3 was purchased by Leavitt in 1969. It was well aware of the need to stuff paper into coils in order to maintain necessary tautness. It knew of the manual paper stuffing practices involved in the use of its slitters. It was apprised of the fact that although these practices were condemned in its letters and manuals disseminated to its purchasers, nevertheless manual paper stuffing was commonly utilized not only at Leavitt but in the entire industry. If hand stuffing of paper into the recoiler to take up slack can be considered a misuse of the slitter, under the foregoing evidence it hardly rises to the level of being a misuse not reasonably foreseeable. *Williams v. Brown Manufacturing Co., Lewis v. Stran Steel Corp.*, and *Anderson v. Hyster Co.*"

In the third argument, Yoder asserts that because the danger was obvious, it could not be deemed unreasonable. The court held that though the pinch point danger was unquestionably obvious to Derrick, the jury had the right to believe that the unexpected snagging of his glove by a metal sliver pulling him into the recoiler was not obvious.

The court later referred to an earlier Yoder case ruling [*Dorsey v Yoder Co.* (E.D.Pa. 1971), 331 F. Supp. 753, aff'd (4d Cir. 1973); 474 F. 2d 1339.] stating:

> "The danger of unguarded rotary blades, although obvious to Dorsey, did not *ipso facto* preclude recovery and was but one of the factors in determining whether or not the danger was unreasonable. Among other factors to be considered were whether a guard would eliminate the machine's usefulness; whether its cost would be prohibitive; and the balancing of these factors against the seriousness of the potential harm. These, the court held, were fact questions to be weighed by a jury in determining whether, under all the circumstances, the machine was "defective."

The court also referred to the theses advanced in *Palmer v Massey-Ferguson, Inc.* (1970), 3 Wash. App. 508, 476 p. 2d 713, and *Pike v F.G. Hough Co.* (1970), 2 Casl. 3d 465, 85 Cal. Rptr. 629, 467 p. 2d 229, saying,

> ". . . the manufacturer of an obviously defective product ought not to escape liability because the product design was patently bad; rather, it should be discouraged from misdesigning its product instead of encouraged to produce it in an obviously defective form (331 F. Supp. 753, 757-63) . . . The foregoing analysis when applied to the facts in this case provides an additional basis for our holding. Here, although the dangerous pinch point of the recoiler may have been obvious to Derrick, and the utilization of Yoder's remote paper stuffer may have somewhat interfered with production, its cost was not prohibitive, and the seriousness of potential harm was manifest. These factors would have entitled the jury to conclude that the slitter was defectively designed resulting in Yoder's liability."

Yoder's fourth claim was that it had no duty to provide a safety device at the danger point of the recoiler. The court quotes the Illinois Supreme Court which held to the contrary in *Rios v Niagara Machine & Tool Works* (see Part 1 of this article in Triodyne Safety Brief v. 4 #1):

> "In Bexiga [v. Havir Manufacturing Corp. (1972), 60 N.J. 402, 290 A. 2d 281] the New Jersey Supreme Court stated that where a [machine] is unreasonably dangerous absent a safety device, the manufacturer is under a nondelegable duty to install such a device. The court stated: 'The public

interest in assuring that safety devices are installed demands more from the manufacturer than to permit him to leave such a critical phase of his manufacturing process to the haphazard conduct of the ultimate purchaser. The only way to be certain that such devices will be installed on all machines—which clearly the public interest requires—is to place the duty on the manufacturer where it is feasible for him to do so."

The court continued:

"In the case *sub judice*, no safety device of any kind was provided at the recoiler although Yoder was fully acquainted with the need and had in fact produced a relatively inexpensive remote paper stuffing device of its own, which automatically performed that task without creating any risk of harm to the operator. The reason given as to why this safety device was not made a component part of the machine, stated in oral argument, was because Yoder believed that the fractional expense (about 2.56 percent) when added to the $164,044 cost of the slitter would have put it at a competitive disadvantage in the marketplace. That any machine will cost less to manufacture without a safety device than one with a device is ineluctable; however, where the cost is relatively small as compared with the total cost of the machine and the likelihood of injury without it is great as in this instance, failure to provide the device becomes critical. The jury could have regarded the availability, but absence, of a safety device as a component part of the machine sold to Leavitt as evidence of Yoder's culpability in having placed in the stream of commerce an unreasonably dangerous, defectively designed product."

Yoder's final argument was that a manufacturer has no duty to produce a machine that is accident-proof. The court agreed but found this contention inapplicable in this case:

"The requisite safety device undoubtedly would not 'accident-proof' the slitter in every event, but would have eliminated the need for manual paper stuffing. The absence of a safety device of any kind simply was not sanctioned by the jury in these circumstances."

Yoder claimed that a safer alternative was not available or feasible. The court found the claim unpersuasive:

"Yoder's own remotely operated paper stuff could have demonstrated to the jury that a safety device was indeed technologically possible, feasible and economically available at the time its slitter No. 3 was sold to Leavitt, but was not made a constituent part of the equipment."

Ruggeri v Minnesota Mining and Manufacturing Co.

[380 N.E. 2d 445]

Mr. Ruggeri was a handyman at L.H. Kiefer Company, an air-conditioning and heating contractor. In the process of manufacturing sheet metal ducts Kiefer used fiberglass insulation which it attached to the duct with an adhesive called 33 Red manufactured by Minnesota Mining and Manufacturing (3M). The adhesive was sprayed onto the duct work with a spray unit manufactured by Binks Manufacturing Company. Each can of the adhesive bore a wrapper which warned that it was extremely dangerous and that all pilot lights and flames should be extinguished before its use.

Mr. Ruggeri decided to clean the hoses and nozzles of the spray unit in a pressure tank of nonflammable cleaning solvent at the Kiefer's maintenance shop. When Ruggeri removed the top of the tank, the pressure did not bleed off and pressurized adhesive was released into the room. Eye witnesses saw Ruggeri covered with adhesive trying to clean the floor. A flame shot from a furnace pilot light 14 feet away and ignited the adhesive enveloping the room and Ruggeri in flames. Aflame, Ruggeri ran from the room. His co-workers extinguished the flames and rushed him to the hospital where he died.

3M admitted that the product was dangerous but denied that it was unreasonably dangerous since it was not sold to the general public.

A technical analyst and manager from 3M was called by the plaintiff as an adverse witness and testified that 3M manufactured a similar non-flammable adhesive called 35 Blue.

The court defined the questions before it:

"The issue in our view is a narrow one: are there products with such dangerous qualities that they should not be placed in the stream of commerce; or if so placed that the risk of harm to the public is so great that liability should be imposed on the manufacturer if harm befalls one exposed to the product."

The court answered these questions in the affirmative:

"The foundation of a defective product cause of action based on strict liability in tort is that the plaintiff's injury resulted from a condition of the product which rendered it unreasonably dangerous and that the condition existed at the time it left the manufacturer's control. (*Dunham v. Vaught & Bushnell Mfg. Co.*, 42 Ill.2d 339, 247 N.E.2d 401 (1969); *Suvada v White Motor Co.*, 32 Ill.2d 612, 210 N.E.2d 182 (1965).) Thus, there exists an affirmative duty on the manufacturer not to place into commerce articles or products which are unreasonably dangerous when used for their intended purpose. (*Rivera v Rockford Mach. & Tool Co.*, 1 Ill.App.3d 641,274 N.E.2d 828 (st Dist. 1971).) Defendant admits that the cleaning of the spray equipment by Ruggeri was a related necessary function to the use of 33 Red which was foreseeable and not an unintended use. However, defendant contends that the evidence adduced at trial proved only that the adhesive had dangerous properties and not that it was unreasonably dangerous. We disagree . . .

We find no merit in the defendant's contention that 33 Red was not the only product available for use by Kiefer Company. Allowing a user to select the safer of two or more products is not an option available to the defendant. Rather as a manufacturer, the defendant is under a duty to manufacture a product which is 'reasonably safe.' (*Robinson v. International Harvester Co.*, 44 Ill.App.3d 439,444, 3 Ill.Dec. 150, 154, 358 N.E. 2d 317, 321 (5th Dist. 1976), rev'd on other grounds, 70 Ill.2d 47, 15 Ill.Dec. 850, 374 N.E.2d 458; *Scott v. Dreis & Krump Mfg. Co.*, 26 Ill.App.3d 971, 985, 326 N.E.2d 74, 84 (1st Dist. 1975).) This principle holds true regardless of whether an alternative product was available inasmuch as the state of the art is no defense in strict products liability actions. (*Cunningham v. MacNeal Memorial Hospital*, 47 Ill.2d 443, 266 N.E.2d 897 (1970); *Kerns v Engelke*, 54 Ill.App.3d 323. 12 Ill. Dec. 270, 369 N.E.2d 1284 (5th Dist. 1977).) . . .

In short, we find the warning given adequate . . .

Defendant finally contends that Ruggeri assumed the risk of his injuries and resulting death when he cleaned the spray unit which contained the flammable adhesive. Again we disagree. The test of whether a user has assumed the risk of a product known to be dangerously defective is a subjective one rather than an objective one. (*Williams v. Brown Mfg. Co.*, 45 Ill.2d 418, 261 N.E.2d 305 (1970).) Hence, the burden is on the defendant to prove that the user knew of the defective condition, but nevertheless deliberately and unreasonably exposed himself to the danger, or that the defect and danger were so open and obvious that the plaintiff must have comprehended them. (*Collins v. Musgrave*, 28 Ill.App. 3d 307, 328 N.E.2d 649 (5th Dist. 1975); *Sweeney v Matthews*, 94 Ill.App.2d 6, 236 N.E.2d 439 (1st Dist. 1968), aff'd, 46 Ill.2d 64, 264 N.E.2d 170). We find nothing in the record which would tend to show that plaintiff's intestate had knowledge of the flammable and dangerous characteristics of 33 Red . . . It appears that Ruggeri was an alert and conscientious worker who would not have cleaned the spray unit inside the maintenance shop had he been aware of or appreciated the danger."

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SAFETY BRIEF

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