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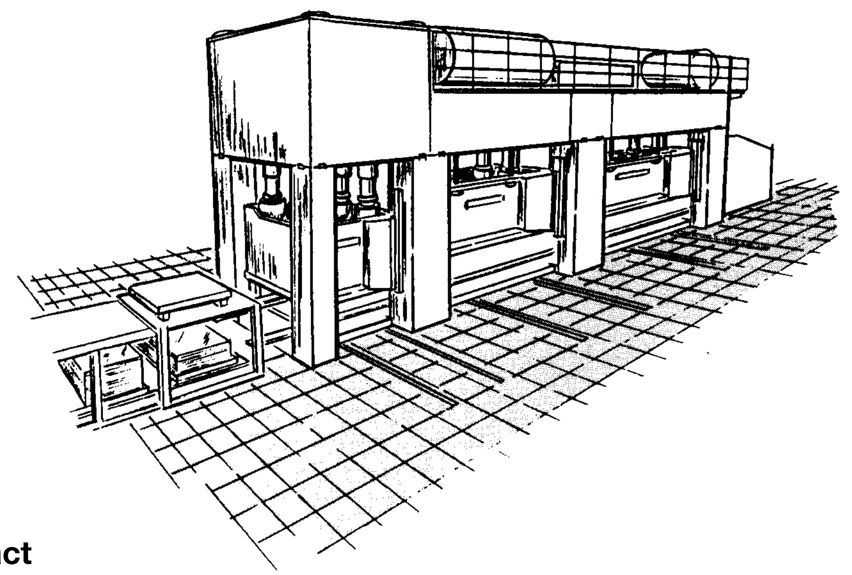
The Care and Feeding of PLC-Controlled* Machinery: Part 3

OR Everything you've ever wanted to know about PLC's and were afraid to ask concerning their relationship to: Products Liability, Safety/Ergonomics, Documentation, Engineering Design, Hi-Tech, Hi-Speed Machinery, The New Industrial Revolution and TRI-AXIS Transfer Presses

by Lawrence K. Bell, P.E.[1]



Abstract

Part 3 of this series of articles on PLC-controlled machinery (and the concluding one) continues in this issue of The Triodyne Safety Brief.

In the first two parts of this series, which appeared in the June 1993 issue of the Safety Brief, Vol.8, No.3, and the February 1994, Vol.9, No.4 issue, the concept of the second industrial revolution, based upon the ***mass production-short run*** *idea, was developed. As a specific example, a large tri-axis transfer press was used as an embodiment of the idea and encompassing all of the necessary ancillary equipment required to support it.*

The history of the ***mass production-long run*** *basis of American industry, extending back to the Civil War, but coming into its own during World War II, was explored. Additionally, the role of postwar global competitive forces in influencing the decision of American business to implement the* ***mass production-short run*** *concept was also analyzed.*

* PLC: Programmable Logic Controller

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These first two articles also presented the technical concepts for the example tri-axis press, mainly the design philosophy employed and the functional design parameters utilized. The importance and relevance of engineering documentation and record keeping were also emphasized.

Part 3 concludes this series with a thorough analysis of the Product Liability aspects of the likely impact of the second industrial revolution, as described in this series of articles. This includes the effects of the fact that the tri-axis transfer press must be considered as a dedicated machine system with respect to guarding the point of operation. Conclusions and recommendations are made for attorneys, insurance companies and manufacturers. Please see the Part 3 Table of Contents for details. Finally, the Table of Contents is again listed for Parts 1 and 2 to provide continuity for the reader.

IV. PRODUCT LIABILITY/LEGAL ASPECTS

Introduction

The purpose of Part 3 of these articles is to discuss the legal, economic, instructional and documentational aspects of the impact of the second industrial revolution as presented in this series of articles (see Parts 1 and 2). A number of important items will be analyzed that are of vital concern to attorneys, insurance companies (particularly risk control groups), and higher management manufacturing personnel. While all of the items discussed are important, there are several salient points that are particularly emphasized because their effects are nonexistent, already have well-defined procedures, or are minimal in standard, non-PLC controlled machinery. These points are as listed below:

1. The PLC-controlled tri-axis transfer press may be considered as a single-

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purpose dedicated press production system, as opposed to a standard punch press (which may or may not be PLC-controlled), which is multi-functional in nature (See IV.D).

2. Completely accurate engineering documentation and record-keeping, while important for all machines, is absolutely necessary for PLC-controlled machinery. In addition, the information must be acceptable from a legal point of view as well (See IV.A).

3. Since it is the attorney's job to educate the jury on the technical complexities of the PLC-controlled equipment, he himself must become familiar with the concepts involved. To achieve this, special efforts are required that are not present in non-PLC controlled machinery (See IV.B.1).

4. Special instructional efforts must usually be made for outside experts, both plaintiffs and defendants. While allegations of inadequate guarding and warning can certainly still be made, if such was in fact the case, it is hard to point out in detail that a design deficiency existed in the control system if the expert is not conversant with reading programming. The defense expert finds himself in a similar situation, since he must be able to read the program in order to defend it. Alternatively, this phase could be bypassed if experts could be retained who were already familiar with programming techniques **and** have had products liability experience, particularly in the courtroom (See IV.C).

Finally, it is extremely interesting to compare the similarities between the general control system block diagram for a production machine operation (not necessarily PLC-controlled), and the general flow diagram that could fit a products liability processing system. It will be recalled that any machine control system, whether it is PLC-controlled or not, consists of the general block diagram shown in Part 1, Section III.A.8, Fig. 4. This block diagram is reprinted in Part 3 as Fig. 1, for the convenience of the reader.

This type of control system, while developed primarily for machine control, can be extended to many areas outside of the machinery field. The handling of a products case is one of these. Figure 2 shows a control system for the processing of a products case. Replacing the logic block is the attorney, who is the central figure. Based upon the inputs received from the clients, witnesses, and other litigants, he analyzes them and makes decisions which he then transmits to the outputs, which take the form of discovery, mediation, settlement, trial, etc. Replacing the power supply of Fig. 1 are the reference sources and outside expert(s). The latter items, while playing a vital role in the processing of the case, just as the power supply does, have no part in the direct chain of events; this is left to the clients, litigants, and attorney. It is the job of the expert/consultant to advise and technically instruct the attorney. The type of

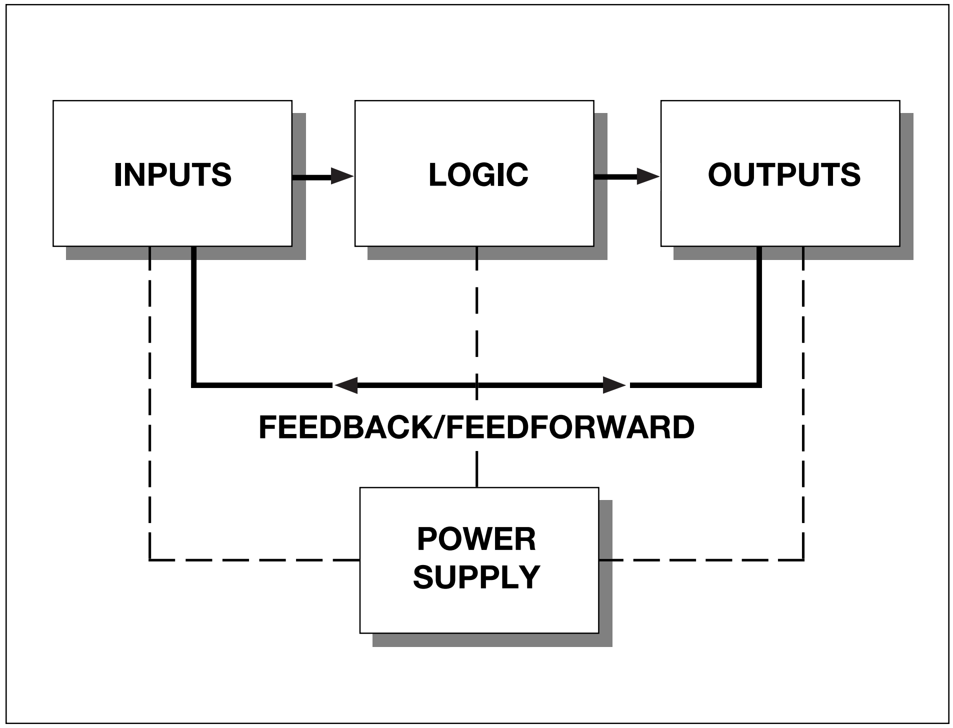

Figure 1. General Control System Block Diagram

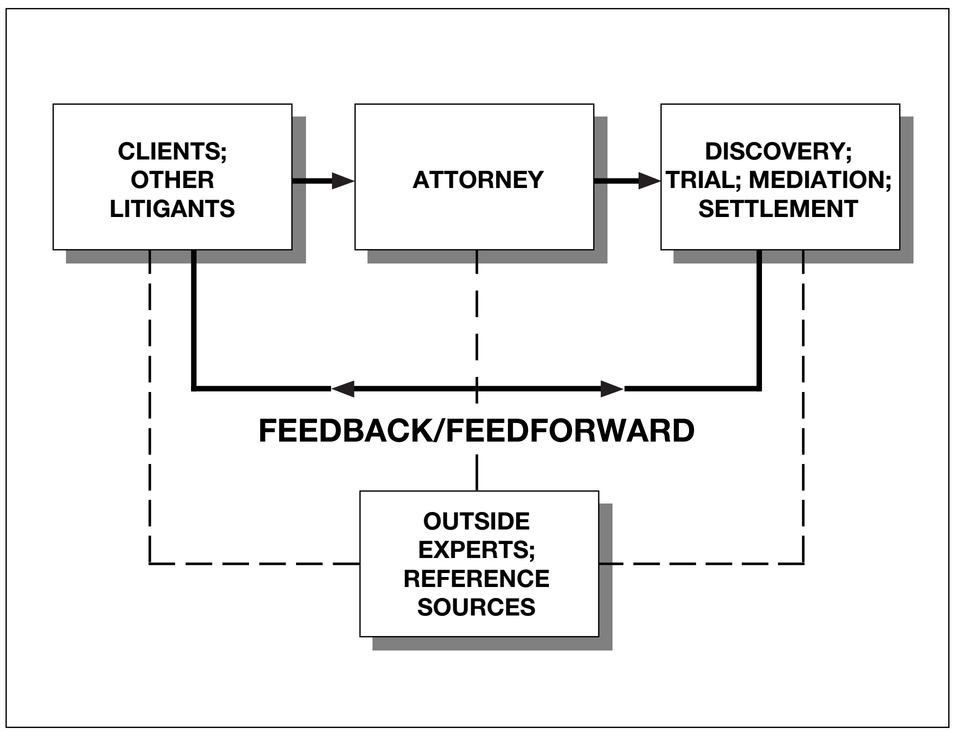

Figure 2. General System Block Diagram for Products Liability Litigation

advice and instruction required is constantly being modified by the feedback* and feedforward* flow of information to and from the outputs.

The concepts presented above will be further discussed later on in this section.

A. DOCUMENTATION

In Part 2, Section C, the importance of engineering documentation and record keeping was discussed. To be sure, the standard reasons for keeping records over prior years of machine design are still valid for PLC-controlled machine systems. The types of records kept, essentially the information needed to build and assemble the equipment, were in the form regarded in the computer sense as "hard copy" records. These took the form of engineering drawings bound together in a record or file book. This record book, together with the instruction and safety manuals, comprised a complete set of engineering documentation for that particular machine. The Service Dept. usually kept and maintained the records of all shipped machines, together with customer lists, service history, changes in design or ownership, etc. In many instances, the manufacturer would store these record books on their premises, in fire proof vaults, environmentally controlled. Since many capital equipment machines, including punch presses, have extremely long lives extending for decades of service, this type of storage was necessary to provide the proper spare parts servicing that was required over the years.

As "tort reform" took hold in the early 70s, these record books also provided legally acceptable documentation as to the condition of the machine at shipment, and beyond; however, as PLC-controlled machines started to come on stream, it soon became apparent that additional documentation and records were necessary in **addition to** the standard hard copy drawings and records books. Of course, a hard copy printout of the program was essential to the proper engineering description of the control system, but this record reflected the condition of the control only for a given moment in time. Because of the ability of the PLC to be easily changed at any time, there was no guarantee that the printout made prior to shipment reflected the true program "as shipped." This was not a major problem when the control relay represented the primary implementation of the logic system (sequence of operation), since the relays were of necessity "hard wired" and therefore not easily modified. A record of the program on floppy, data cartridge, disk and/or some combination of these thus became necessary as well.

The production of a printout and the recording of the program on floppies, data cartridges, etc., while necessary, still did not completely solve the documentation problem. The question of timeliness now presented itself: at what points in time of the equipment's life should a complete record of the control program be made? Within the author's range of experience four distinct time periods seem to meet all of the requirements to provide adequate documentation. These are reprinted from Part 2, Section C as follows:

> ***As Shipped.*** This period represents the initial approval of the equipment by the customer. It is essential to have a record of the program as it was initially shipped with the machine, and approved by the customer during the checkout period.**
>
> ***After Initial Installation.*** The program at this stage represents the structure of the logic at the customer's site, at the end of installation and after he has given preproduction approval. Another set of tapes, etc. should be stored along with the "as shipped" group.
>
> ***After Customer Approval.*** After the customer has approved the equipment for production, another set of tapes are made and stored with the others.
>
> ***Periodic Program Changes.*** During the operating life of the equipment there may be periodic design changes required, either through some government-mandated change, or through normal design evolution. After each of these occurrences, another set of tapes, etc., should be made. In addition, a set of documentation should be made and stored upon the sale of the machine to a new owner.

With the questions of the type of documentation kept, and the timeliness of it now settled, the salient point #2 raised in the introduction to this section (IV) now applies: that of appropriate document storage. Again, because of the extreme ease in the ability to modify the program logic, what guarantee is there that the manufacturer at some point in time didn't modify the tapes, etc. to mask an unfavorable "bug" or gliche, that may have been overlooked before, and which may have been involved in some malfunction of the machine?

The doubts that the preceding point could easily raise in a products liability case virtually excludes the prudent manufacturer from storing the computer documentation at his own facility. One answer would certainly lie in an outside disinterested party performing the storage service. In this way, there is absolutely no possibility of an allegation being made that the computer records may have been tampered with. This is especially true if such a record depository is established across the product line board, and is a result of long-standing company policy, and not just in response to a particular piece of litigation. Figure 3 illustrates the type of computer program documentation that may be involved.

There is another advantage to the manufacturer in storing their machine computer records outside their own facilities, particularly with regard to PLC-controlled capital machinery, such as punch presses. Because of the extreme longevity of this type of equipment, this type of storage represents a valid record in case of disputes with either the original or subsequent owners of the machine. Even though a disclaimer is usually made by the manufacturer at the time of shipment cautioning the customer not to make any changes in the program

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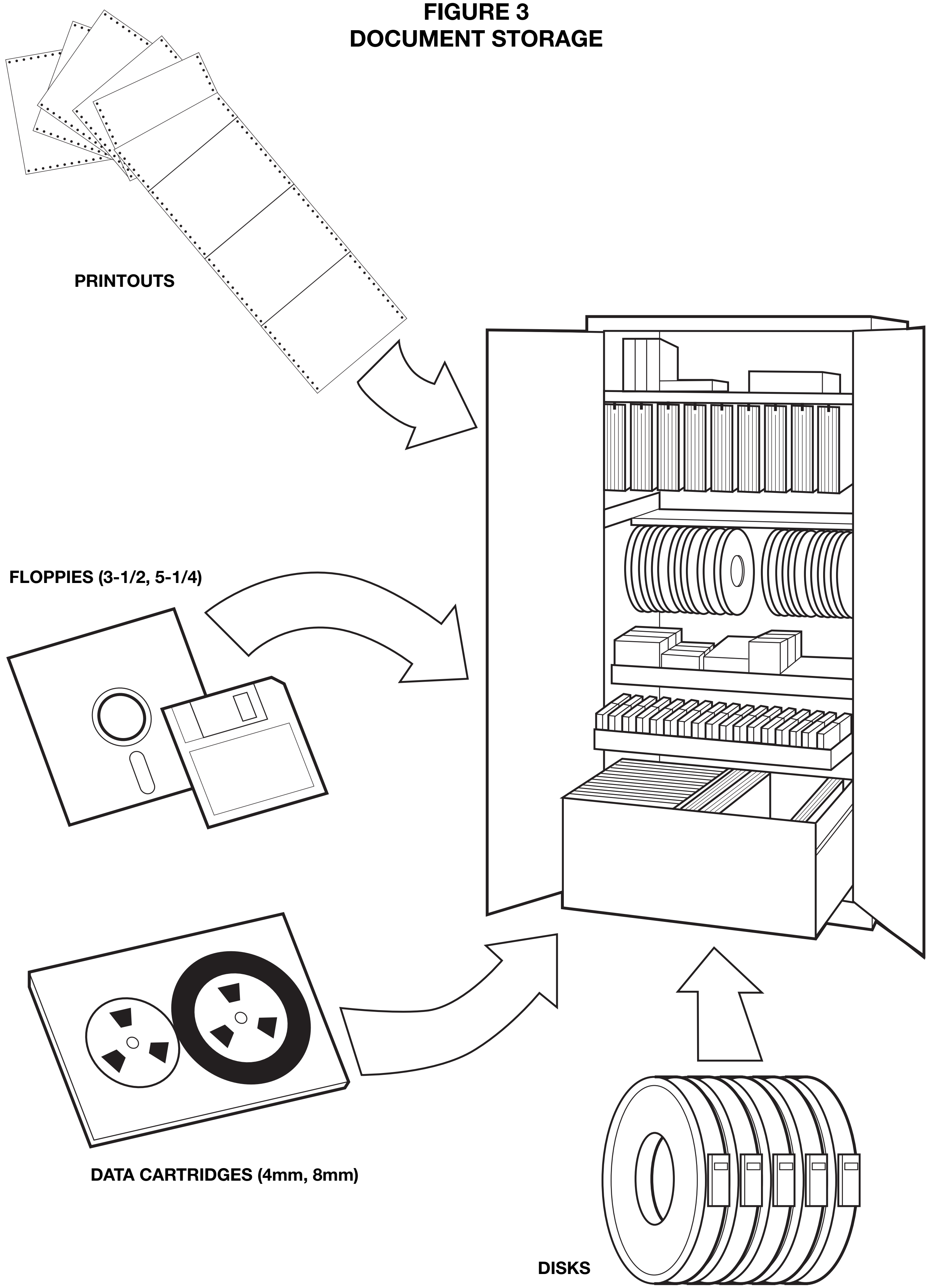
* The terms *feedback* and *feedforward* used in the control theory sense, are as follows:

feedback - information received by the inputs from the outputs after the latter have been modified by the logic block in response to a command from the input; the feedback information is used for further command corrections.

feedforward - information received by the outputs from the inputs, utilized directly by the outputs in an anticipatory manner, to an expected future condition.

** It Is common practice for purchasers of large capital equipment, such as punch presses, to completely check the machine in an operational sense at the manufacturer's facility, prior to giving approval for shipment. Depending upon the complexity involved this could take two days or two weeks.

FIGURE 3
DOCUMENT STORAGE



without discussing them with the manufacturer, there is no guarantee that this will in fact be done, especially as time goes by and different owners take possession of the equipment.

Finally, the proper storing of computer records provides an undisputed back-up to any government-initiated inspections, etc. OSHA would of course be the prime example.

In summary, then, the main advantages to be obtained by proper generation and storage of PLC-controlled equipment records may be listed as follows:

1. Provides vital and necessary information to allow for prompt, efficient maintenance and servicing of the machine.

2. Provides a legally acceptable way of storing computer records, for products liability litigation and other purposes.

3. Provides an acceptable record for purposes of any customer and subsequent owner problems.

4. Provides a valid record for any OSHA or other government initiated inspection.

As an afterthought, it might also be mentioned that if company managers commit to a storage program like this one, their own awareness of the necessity for accurate records cannot help but be significantly increased.

B. ATTORNEY EDUCATION OF TECHNICAL FACTS

1. Basic Understanding of System

As any experienced products trial attorney will agree, successful processing of products liability litigation requires an understanding on the attorney's part of the basic operation of the equipment involved, whatever it may be. This will allow for a centralized and cohesive discovery effort. It also minimizes the possibilities of surprises and unexpected attacks by the other side. Additionally, the relevant standards and OSHA regulations, as well as the practice of the industry as a whole, must be made familiar to counsel. Finally, as discussed in the next paragraph, it is the attorney's job to educate the jury as to the technical aspects involved in the case, without confusing them by an excessive volume of information.

It is the job of the outside expert (if he in fact is qualified) to educate the attorney as to these basic concepts in general, with more precise detail in the area where the accident occurred. This instruction must be as balanced in nature as the four-legged design stool concept: see Parts 1 and 2, Sections II and III.B, respectively.

PRODUCT DESIGN =

ENGINEERING
+
SAFETY ASPECTS
+
ECONOMIC CONSTRAINTS
+
ERGONOMIC CONSIDERATIONS

There is no greater danger in the presentation of the case to the jury than to be overly verbose in the explanation of how the equipment works. This not only loses the jury, but it also bores them. On the other hand, it is just as dangerous to be too close-mouthed and general, and therefore inadequate; this confuses the jury. Exactly the right balance must be struck. The role of the attorney in being able to reach this balance is crucial to any ultimately satisfactory resolution to the case. Certainly, without a basic understanding on the attorney's part, it is difficult if not impossible to transmit the proper information to the jury.

It is apparent that the job that the expert does in explaining the technical concepts is vital under any conditions. When the machine system involves PLC-controlled equipment such as the example tri-axis transfer press, the instruction job becomes probably an order of magnitude higher. At this point in time, this is primarily because this type of products case is new and is only now beginning to make itself felt. Consequently, there is a great deal of unfamiliarity on the part of not only attorneys, but also insurance companies, many outside experts, and higher management executive personnel as well, even those associated with the manufacturing company that made the transfer press. Case precedents are small in number right now. Additionally, for those readers who have studied Parts 1 and 2 of this series, the technical complexities involved are very much greater than those previously encountered.

Where PLC-controlled equipment is concerned, a modification of Figure 2 is required. See Figure 4.

Note that the two additions to this figure are document storage and technical instruction. It can almost be stated as a cardinal rule that a case of this type cannot be successfully defended without these two items being adequately completed. Salient point #2, in the introduction, proper document storage, was thoroughly discussed in section IV.A. This section (IV.B) addresses salient point #3, that of attorney and jury technical instruction.

Obviously, the question arises that if the outside expert himself must be educated, who is to impart the necessary knowledge? Normally, in such a case, the company's inside technical expert performs the function. This is addressed in more detail in section IV.C.

2. Jury Understanding and Education

The prerequisite for adequate jury understanding and attentiveness is indicated in section IV.B.1—the degree of understanding that the attorney himself has, and his ability to articulate this knowledge to the jury. While no one expects the attorney to be an engineer, a reasonable grasp of basic mechanical principles would be desirable. The logic employed by the attorney is very similar to that used by the engineer in pursuing design work, and engineering investigations.

One thing that would be extremely helpful at trial would be a close familiarity with the machine under consideration by both the expert and the attorney, working together in the courtroom, and complementing each other. This, together with appropriate trial exhibits, would go a long way towards properly educating the jury not only in the mechanics of the system, but also in promoting greater understanding of the circumstances of the accident. A look at Figure 4 may be helpful to the full understanding of the products/liability control process.

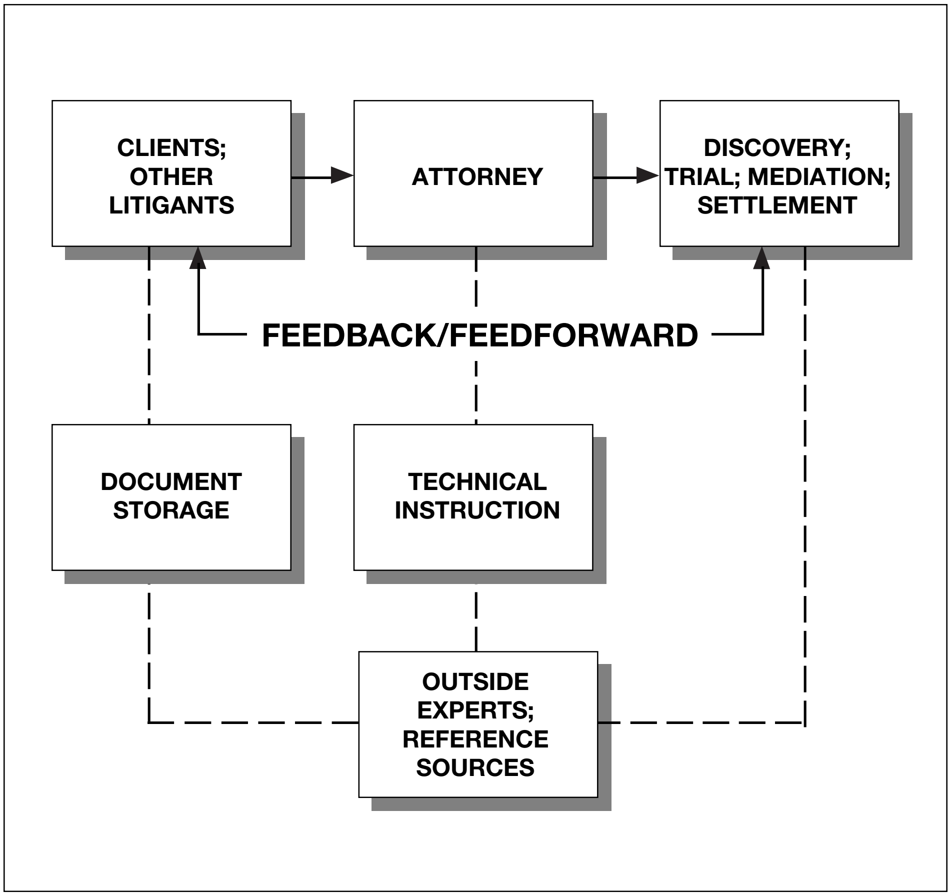


Figure 4. General System Block Diagram for Products Liability Litigation with Computer Controlled Machinery

The case starts with a complaint to the client (defendant), who in turn engages the services of an attorney. As indicated, the latter is the central figure in the litigation, and coordinates the entire scenario. It is the attorney, with the permission of the client, who selects a suitable outside expert. It is the attorney who sets the whole process in motion beginning with answering the complaint, and starting the discovery process. Other litigants may be joined in the action as discovery proceeds.

The outside expert monitors the whole process, including review and analysis of the computer document storage from the client, technical instruction of the attorney and recommendations to him. As the attorney receives information from the clients, witnesses, and other litigants, as well as the expert, he makes a constant series of decisions that affect the progress of the case. In turn, these decisions are fed back (feedback) to the clients, attorney, and other litigants, where they are further modified. This constant flow of information back and forth is what makes the whole process a "closed loop" system. As an example of "feedforward" information, assume something comes up of an emergency nature, say an unexpected allegation or potentially damaging fact that could affect the direction of the whole case if not acted upon immediately. Feedforward data is fed directly to the outputs (for example, an emergency motion) to anticipate and counter any damaging action that could result from the emergency development. The outside expert, of course, is constantly reviewing and sifting these constantly changing events, and making appropriate suggestions to the attorney. One such possibility is that the original complaint may have concentrated on a particular area of the equipment, and then all of a sudden changes direction and emphasizes another area, or an additional area. This new development must, of course, be countered as well.

Most product liability cases are resolved by settlement rather than trial. To a very large degree, whether or not the settlement is favorable to the attorney's client depends almost entirely on the strength of the case that can be built against the opposing litigant. In a PLC-controlled machine system, because of the many technical complexities involved, a strong case is almost by definition attained only by a good understanding of the technical principles of the equipment.

In years past, and even up to the present time, when dealing with more standard industrial machine systems, many firms would have one or two attorneys who would handle that type of machinery exclusively for the firm. Thus, over the years they would develop an excellent expertise for processing that type of case. Of course, they would choose an outside expert who also had a similar expertise, and they would work very well together. In the case of PLC-controlled machinery, the theory is the same, but the necessary work to develop the same kind of expertise is much greater, both because the field is so new and the technical complexity is much higher. Both case costs and trial strategies are significantly affected.

Finally, to give some perspective to this quantum leap in technology, a similar situation might be the differences between an old manually-operated electric typewriter and a modern 486-microprocessor-based computer, and laser printer.

C. OUTSIDE EXPERTS

As indicated in the previous section, the need for outside experts in product liability cases involving the new PLC technology will not only continue but increase substantially. This is because of the technical complexities as well as the fact that it is an entirely new field, involving new strategies (IV.D).

In the Introduction to this section (IV) salient point #4 mentions the instructional efforts that will be required for outside experts. The type, duration and intensity of these efforts will depend almost entirely upon the PLC case experience of the expert. Even if the attorney involved has himself developed some experience along this line, the expert must be tutored on some of the basic technical characteristics of the machine. The exact method of this instruction can take several different forms:

1. Client's inside expert/engineer performs the familiarization task.
2. The attorney engages the services of

a technical consultant to perform the instruction.

3. The attorney engages the services of an expert with whom he is already familiar and comfortable, and who is already familiar with PLC concepts and also has litigation experience, and therefore needs no prior instructions.

Ideally, a combination of (1) and (3) is most desirable since in most products cases, the defense makes use of both an inside expert and an outside expert. It is therefore very important that these two people can communicate with each other. Certainly, the inside man would (or should) know most about the technical characteristics of the equipment; the outside expert can always increase his technical knowledge, and thus be able to make better recommendations to the attorney. Lastly, both the inside man and the outside expert can together further fill in the attorney.

As far as specifics are concerned, and using the exemplar PLC-controlled transfer press system, the basics would consist of learning the technical details by expanding upon the subject matter of the first two parts of the Article (Parts 1 and 2). The outside expert can then react to changes in plaintiff's emphasis, such as concentrating on a different portion of the machine than was alleged in the original complaint, and can conduct an effective accident investigation.

Lastly, because of the increased time (and costs) involved in properly training both the engineer and the attorney (See IV.E), this will most likely result in attorneys using the same expert(s) on most of their cases.

D. TRIAL STRATEGIES

In the Introduction of Section IV, salient point #1 emphasizes the fact that the PLC-controlled transfer press line must be considered as a single-purpose dedicated press production system, as opposed to a standard punch press, which is multi-functional in nature, and is essentially an incomplete product as shipped by the manufacturer. Because of the far-reaching ramifications of this development (which is true even without dies mounted on the bolsters) the reasons for this, which first appeared in Part 1 of this series of articles, Section II, Product Liability and Legal Considerations, are repeated here to provide continuity and understanding to the reader who may not have received Part 1.

Product Liability and Legal Considerations

It was stated in the General Introduction that the tri-axis transfer press would have tremendous impact upon both the users and manufacturers, not only upon production, costs, operations, etc., but also upon product liability and safety considerations. The primary reason for this is that the tri-axis transfer press can be considered as a **dedicated single-purpose system, hence susceptible to point-of-operation guarding by the press manufacturer**.

To understand the significance of this, it should be emphasized that the press industry, its users, and the government itself (in the form of OSHA) all recognize that the conventional power press by itself is a multifunctional machine, and can accept a virtually infinite number of dies and feeding methods. It is therefore impossible for the press manufacturer to install die-space safeguards that will fulfill all of the infinite die and feeding combinations that can be put on that type of press. Even a perimeter guard would not work in all cases because so many dies and/or parts to be worked on extend beyond the die space perimeter. In other cases, environmental considerations make the development of a **universal** guard impossible.

The responsibility for guarding the point of operation of a press system under the above circumstances very properly falls to the user, since he alone can determine all of the various factors that go into the making of a specific press production system.

The courts have generally agreed with this distinction, while on the other hand, they are tending more and more to assign the responsibility of guarding the point of operation of the machine (whatever kind it might be) to the machine manufacturer, if the machine was produced and sold as a dedicated single-purpose piece of equipment.

While conventional power presses still fall under the multi-functional category and are basically incomplete pieces of equipment as sold, the tri-axis transfer press must be considered as a single-purpose dedicated machine. This places the basic responsibility for guarding the point of operation on the manufacturer of the press.

The reason for this distinction is that by its very design, even though an infinite number of die types can be used, they must all conform to the dimensional constraints imposed by the tri-axis transfer feed system. Clearly this must be done so that the processed parts can be transferred from station to station and ultimately to the finished discharge conveyor (or other discharge means) to be taken to subsequent processing areas.

This means that any part made by the tri-axis transfer press system must **necessarily** fit within the perimeter of the die space areas of the transfer feed system; therefore it is a dedicated single-purpose system, and is susceptible to guarding techniques to be supplied by the press manufacturer which will accommodate any die configuration that can be utilized by the transfer press. This guard must be part of the press design, and of course the cost must be figured into the original price quotation to the customer.

While this aspect of tri-axis transfer press systems certainly relieves the user employer from a good deal of safeguarding responsibility for his particular job runs, he is not freed in any way from the responsibility of developing and implementing an effective employee safety program. Additionally, some states now require that if a user removes or otherwise negates the effectiveness of a safety guard furnished by the press manufacturer, the protection afforded to the user by worker's compensation laws is withdrawn, and he may be brought into the suit by his injured employee.

In summary, since most presses in the future will undoubtedly be of the bi/tri-axis transfer type, every facet of all the areas touching this equipment will affect the engineering, costs, safety methods, ergonomics, the users, their suppliers, the operators, and litigation procedures in cases of personal injury.

Because of the above reasons, the transfer press production system must be considered as a single-purpose machine and therefore subject to appropriate safeguarding measures by the manufacturer.

To complicate matters, this is true even with no dies mounted in the transfer press. Although no production will or can be achieved without dies, the hazards are still present. This is primarily true because the point of operation boundaries are established not by the dies themselves, but by the dynamic throw of the tri-axis transfer feed mechanism. Since this throw extends significantly beyond the perimeters of the dies, its limits must be considered as part of the point-of-operation.

It is clear that the trial strategies developed for multi-purpose presses over the years are no longer viable, and different ways to approach the situation are required. The first and cardinal rule for an effective strategy in the event of an injury and subsequent litigation rests squarely on the shoulders of the manufacturer, and is simply this: **A tri- or bi-axis transfer press system must be manufactured, designed and shipped with a point-of-operation guard in place.**

One example of such a guard would be automatic safety gates that open while changing dies and providing maintenance, and close when the press line is running in automatic operation.

The second cardinal rule (also for the manufacturer) is: **Detailed and effective documentation of the press is required.**

One appropriate method for implementing this rule is as described in section IV.A of Part 3 of this series of articles.

It cannot be overemphasized that failure to implement these two rules will make a subsequent case extremely difficult or even impossible to defend.

When a case does develop, the procedures followed by the attorney should be along the lines illustrated by Figures 2 and 4. Assuming that the manufacturer has correctly followed the two rules stated above, the general approach taken by the attorney is very similar to the methods he normally employs, except the choice of expert becomes extremely critical, and the thrust of his strategy must be that the manufacturer has supplied an appropriate and acceptable point-of-operation guard. In addition, the employer also has the responsibility for developing a safety program for his employees. Finally, the employer must be enjoined by the manufacturer not to alter, modify or remove any safety guards or devices installed by the manufacturer. This also applies to subsequent owners of the equipment, providing they are known to the manufacturer.

E. CASE COSTS

As might be expected, the costs of pursuing product liability litigation involving tri-axis transfer presses will undoubtedly be significantly higher, both for defendant and plaintiff. For both, the costs of finding a suitable expert will be much higher simply because of the scarcity of this type of individual. Initially, the lack of precedent setting cases will cause both plaintiff and defendant to proceed very conservatively. This of course also raises costs. On the plus side, this higher cost will tend to inhibit the filing of frivolous and/or questionable cases. In addition to the higher costs just described, more time must be allowed for discovery, and if the case goes to trial, the decision regarding trial exhibits and technical presentations to the jury must be carefully considered and weighed.

Higher premiums may be expected to be assessed by the insurance carriers, at least until they have some case experience to go by. The biggest cost containment factors, once the initial cost surge has been completed, are as follows:

1. Assignment of one or two attorneys within a firm to handle this type of litigation, so that the learning curve may be eliminated.
2. A gradual and increasing supply of qualified experts.
3. The accumulation of appropriate precedent setting cases.

It should be emphasized that at the time of publication of this series of articles (Parts 1, 2, 3) the author is not aware of any products liability cases involving this type of equipment, although he has handled a number of cases with PLC-control on conventional multi-purpose punch presses, as well as other types of machinery. Because of these factors, the timing is right for manufacturers, insurance companies, and law firms to have the appropriate programs in place. Finally, it is also to be noted that while the exemplar PLC-controlled machine is a tri-axis transfer press production system, **any** PLC-controlled machine, no matter what type, is certainly subject to most of the statements made in this series of articles.

In summary, there is no question that case costs for tri-axis transfer presses specifically, and PLC-controlled machinery in general will be significantly higher than the average industrial case cost at the present time. Exactly how much higher is impossible to say, particularly with the unknown factors involved at this point.

F. INJURY FREQUENCY

The obvious question that must be asked here is that, given the more stringent guarding methods that must be employed by PLC-controlled industrial machine systems, will the injury rate increase or decrease from what it has been for the last few years?

The answer must be found in the context of two general areas: a PLC-controlled system where the equipment can be classified as a single-purpose dedicated system, and one where it is PLC-controlled but is multi-functional in nature.

In Parts 1 and 2 of this series of articles, there is a detailed presentation of the susceptibility of PLC-controlled machinery to electrical noise conditions, and the methods used to increase its operating reliability. In particular, the sections involved are as follows:

Part 1:
Section II Comparison of Relay and PLC Circuits
Section III.A.2, 3, 4, 5 Electrical Noise
Section III.A.7 Relays, Hardwired Components
Section III.A.12 Clutch/Control Dual Processors

Part 2:
Section III.B.1. Control

As was discussed in detail, PLC-controlled circuits can be made virtually noise immune; however, extreme care must be taken in all areas of design. Even if the noise immunity were absolutely perfect, there is still the possibility of existing software "bugs." Studies at the University of Washington as well as at the University of California in Irvine show conclusively that it is extremely unlikely that any computer program of even moderate complexity is completely free of bugs. There are any number of incidents on record that support this thesis. There have been documented occurrences at hospitals where the radiation therapy machine has inexplicably delivered massive radiation overdoses to the cancer patients it was designed to treat. Electronically controlled go-carts used by the handicapped have suddenly gone into full speed, unfortunately some of them at busy traffic intersections with tragic results. Finally, there have been any number of movies with the theme of the failure of "failsafe" computer programs.

What this means to the injury frequency is as follows:

- If the machine production system is PLC-controlled and is multifunctional in nature, and the additional noise immune safeguards have been carefully designed into the system, the injury frequency will probably be about the same as it is at the present time.

- If the machine production system is PLC-controlled and is a single-purpose dedicated machine, such as the exemplar tri-axis transfer press, the chances are that there will be fewer injuries because of the automatic point-of-operation safety gates and other safety devices and guards. It is also likely, however, that when an injury does occur it will be more severe than the first category.

V. CONCLUSIONS/RECOMMENDATIONS

Summary and Discussion

From a thorough review of the three parts of this article, it is clear that the two major themes or tenets were developed as follows:

1. Computer and press technology have advanced to the point where manufacturing production has reached the level which might be termed a second industrial revolution; i.e., from the mass production-long run concept to the mass production-short run concept.
2. This second industrial revolution is destined to change not only the way industrial America operates and does business, but it will also have a deep and profound effect on associated activities such as safety and ergonomic concepts, and the way in which products liability litigation is handled.

The implementation of these themes is, in fact, proceeding at a strong pace, and will be pretty much completed by the turn of the century. A nationally distributed trade magazine had for its lead article in the latter part of 1992 a description of a number of tri-axis transfer presses that were up and running in the stamping plant of one of the three big auto makers in the U.S. A few of the actual statistics were as follows:

- One tri-axis transfer press replaces up to an eight press-tandem line.
- The PLC-controlled transfer press has increased production from 500 parts per hour on the tandem line to over 800 parts per hour on the transfer press.
- The die change time has gone from approximately six hours to under 5 minutes.
- The PLC monitors a full set of diagnostic parameters, in addition to controlling the transfer press, such as cycle time, tonnage, shut height, counterbalance pressures, fault messages, production information, and preventative maintenance messages.

The second theme listed above is exemplified by the fact that the tri-axis transfer press is a single-purpose dedicated piece of machinery. This has certainly been addressed by these three articles, both regarding the implications involved, as well as the procedures suggested to handle the potential problem.

A. CASE COSTS V. SYSTEM COMPLEXITY

In section IV.E the magnitude and type of case costs was discussed. What was not mentioned was the complexity of the control system. PLC-Controlled machinery can range from less than a thousand words of memory to well over five hundred thousand words. Obviously with such a disparity the time required to review and analyze such a broad range will naturally significantly affect the overall case cost. This is the primary reason that a quantitative dollar figure cannot be assigned to PLC cases in general.

B. TECHNICAL EDUCATION

Because of its importance, the matter of technical education with respect to attorneys and outside experts is mentioned here in the conclusions to reiterate very strongly the necessity to include this factor in any handling of cases involving transfer presses. The details are thoroughly discussed in Section IV.B, C, and are vital to the successful resolution of the case.

C. TRANSFER PRESS SAFETY IMPLICATIONS

In the introduction to this section, the second of the two basic themes—the single purpose nature of the transfer presses—the special procedures necessary to accommodate these new requirements were discussed in detail. In many respects the fact that the manufacturer must put up the main point-of-operation guard is very positive, since he then has control over it, and can integrate it into the overall press design in an efficient manner. In addition, the employer, while he can certainly add to the safety features and designs, is not at liberty to modify, remove, or alter the guard(s) that are supplied and shipped with the transfer press. Of course, the preceding discussion applies only to tri-axis transfer presses and other single-purpose dedicated production systems. It does not apply to multi-functional punch presses and other similar types of machine tools.

D. THE "OVER INTERLOCKING" SYNDROME

This concept was treated in detail in Part 2 of this series, Section III.B.1.d., "Stopping and Interlocking Levels." It is given special emphasis in the Conclusions section because it is an often overlooked phenomenon. This syndrome is actually an example of the "too much of a good thing" proposition. It is like circuit redundancy; some redundancy might be desirable, but too much not only results in diminishing returns, but also actually turns around and creates negative actions and results. The problem here is that the PLC by its very nature is extremely easy to change. This lends fuel to the fire of too many additions of interlocks that are not needed. It only leads to confusion and unnecessary complexity. The designer must be extremely careful not to fall into the trap of either too many interlocks or too few.

E. PLC – STRENGTHS/WEAKNESSES

This series of articles would not be complete without a comment on the strengths and weaknesses of the PLC. No one doubts the effectiveness of the computer, and computer programs. They are part of the American scene, and in a few years there may be as many household computers as there are TV sets. There are pitfalls, however, to their use that the good designer will recognize and avoid. If there is one primary rule to keep constantly in mind, it is this: **However complex its operating protocol may be, the computer must be looked at only as a tool, to serve the designer and the programmer. In other words, the computer must be a slave to the designer, and not the other way around.**

Unfortunately, in all too many instances, programmers, and indeed entire companies, will change their operating procedures and practices to fit a particular computer program, even if it is inconvenient and inefficient for them. The obvious answer, of course, is to change the program to fit the company's needs.

In addition to the rule stated above, the PLC's greatest strength lies in its flexibility to be easily and quickly modified and changed. Ironically, however, when applied to industrial machinery, its greatest strength also becomes its greatest weakness. Once a design has been made and debugged, it is detrimental to be able to change it easily, not an advantage. Parts 1 and 2 discuss in detail the many ways to work around this problem.

F. DOCUMENTATION ASPECTS

It was emphasized in Section IV.A along with Fig. 4 that documentation and technical instruction play extremely vital roles in handling products liability cases involving transfer presses. Technical instruction and education are again emphasized in Conclusions, Section V.B. Similarly, the need for documentation is reemphasized here in this section.

G. GENERAL RECOMMENDATIONS FOR:

System Design is the Responsibility of the Manufacturer. He should be following the "design stool" approach:

PRODUCT DESIGN =

ENGINEERING
+
SAFETY ASPECTS
+
ECONOMIC CONSTRAINTS
+
ERGONOMIC CONSIDERATIONS

In addition, with the implementation of a proper documentation system, the manufacturer has an excellent design program procedure as well as a good functional product design.

Product Liability Cases. Realistically, despite the best precautions and employer safety programs, there will be injuries from time to time, for a variety of reasons. When this occurs, particularly with a tri-axis transfer press or similar industrial production systems, and a complaint is filed, the best ammunition that the defense attorney can have is adequate documentation and technical instruction from the manufacturer. In addition, of course, there is also the outside expert that the attorney selects. Please refer to the discussion in Section IV.D., and other appropriate sections.

Trial Exhibits. While most products liability cases are settled before they get to trial, there are occasions where trials do occur. Currently, in such an event, the plaintiffs prevail slightly more than fifty percent of the time. As was discussed in earlier sections of this series, the most difficult part of a trial of this type is to educate the jury in the technical aspects of the case. At the very least this requires the attorney and outside expert working very well together in order to present the facts properly to the jury. An essential ingredient in this jury understanding is appropriate trial exhibits. Again, the type of exhibit must strike an exact balance, and can neither overwhelm nor underwhelm a jury. There is certainly no question about whether trial exhibits should be used or not; the only question is what types of exhibits should be used.

VI. ACKNOWLEDGMENTS

It is obvious that a project of this magnitude was not and could not be a one man show. The author wishes to express his appreciation to his colleagues with whom he worked over the years for their efforts that resulted in one of the first tri-axis transfer presses engineered and built for use in this country by a major auto maker.

The author hesitates to mention specific names because there were so many excellent people involved that he would not want inadvertently to fail to mention any one of them.

It was truly exciting to be able to participate with these individuals as well as with many others on a project that will have such a significant effect upon virtually all aspects of American industrial operations for years to come.

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As an author he has contributed many technical articles to the trade journals in the field, and has written a number of articles on machine safety, including the new factors brought to the forefront of machine design and safety by the high-tech impact of computer controls (of which the three recently published articles in the Triodyne Safety Brief are a good example). He has pioneered and developed the "four-legged" stool concept of product design (engineering, economics, safety, ergonomics), and has done original work in digital control of proportioning hydraulic servo valves. He has also contributed articles to Encyclopedia Britannica Junior on Transistors, Computers, and Fluorescent and Phosphorescent lighting phenomena. Mr. Bell has presented many technical talks to various groups at seminars and trade shows, and is a lecturer at a number of different technical schools.

He earned his Bachelor of Science degree (with honors) in Electrical Engineering from Marquette University in Milwaukee, and his Master of Science in Electrical Engineering from the University of Minnesota, Main Campus. He is a member of Tau Beta Pi and Eta Kappa Nu national engineering honor societies, as well as Pi Mu Epsilon, the national honor society for mathematics. One of his thesis papers was an original contribution to the practical implementation of solid state gyrators. He has taught at the graduate level at the Honeywell evening school, and at ITC (Illinois Technical College), where at the latter he was also the evening academic supervisor. Additionally, he has taught electronics, mathematics and control systems design for many years as a Navy instructor, while in the Naval Reserve.

His engineering experience has been a unique blend of academic theory, engineering application, and practical hands-on experience in the field of industrial machinery control systems design and maintenance with: Central Foundry Division of General Motors (where he also received a journeyman's card as an electrician); the Applied Physics Laboratory of Johns Hopkins University; Honeywell Inc. (Machine Controls Div.); Racine Hydraulics Co. (RVA Div.): Amtron Inc.; Sherwin-Williams Corp.; and Clearing Div. of USI. Mr. Bell has spent over two decades in the product liability field working with attorneys and insurance firms in the areas of forensic engineering and developing trial strategies in Product Liability litigation. His professional capacities have ranged from principal project design engineer and Manager of Electrical Engineering and Advanced Planning, to Product Liability Manager, Assistant Maintenance Superintendent and Vice-President and General Manager.

Upon leaving the general work force at the end of 1992, Mr. Bell has formed two consulting companies, SafeTec, P.C., and SafeTec Engineering Co., Inc. The former specializes in forensic engineering and expert witness consulting in product liability cases, and the latter deals in engineering consulting work and presentation of seminars on OSHA, safety, and the impact of hi-tech control systems on industrial machinery Product Liability Litigation practices.

He is a member of the NSPE (National Society of Professional Engineers), ISPE-PEPP Section (Illinois Society of Professional Engineers-Professional Engineers in Private Practice Section), ASSE (American Society of Safety Engineers), a former member of the IEEE, the NMTBA (AMT), and has served on a number of society and technical committees, including the NFPA-Electrical Standards Committee.

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