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The Product Safety Newsletter

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What's Inside

Technically Speaking

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More on the Grounding Impedance Test

Last time, I suggested that the production-line high-current grounding impedance test was unlikely to identify damaged or cut strands in a stranded wire.

I presented test data and an explanation that, for 3 mm lengths, 4 or more strands of 36-strand, 18 AWG wire will carry 30 amperes for 1 minute or more. I noted that a 30 AWG in free air, with only 5 amperes, will fuse open in a few seconds.

The reason the stranded wire, with most strands open, passes the 30-ampere test is due to the short length of the current-carrying strands together with the heat-sinking provided by the other strands.

Ironically, since I wrote that article, we incurred an incident where the power cord ground wire was damaged and only a few strands remained over a distance of 10 mm or so.

Our production-line test is 30 amperes for 2 seconds. This test is required by one of our product certifiers.

Continued on Page 7

The Product Safety Newsletter

The Product Safety Newsletter is published quarterly by the Product Safety Technical Committee of the IEEE EMC Society. No part of this newsletter may be reproduced without written permission of the authors. All rights to the articles remain with the authors.

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Area Activities

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The following is a brief overview of recent and planned activities for the various Local Groups around the USA. As you can see, some of the Groups are very active and facilitate the sharing of useful information with PSTC members in their area. If your area is quiet or there is no contact, I encourage you to get active, liven things up a bit, and get together to share information or just to have some fun!

Central Texas Chapter

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Meetings are the last Wednesday of each month.

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March Meeting: March 5, 1997 at Exabyte - Held at the Exabyte facilities in Boulder, CO. Presentation by Dave Pedersen of UL Boulder regarding creepage and clearance in ITE.
July Meeting: July 9, 1997 at the Exabyte facilities in Boulder, CO. Good discussion about safety and EMC being handled by the same staff and possibly having joint meeting with the EMC Society.
September Meeting: September 10, 1997 - To be held at the HP facilities in Colorado Springs, CO. Hosted by Ron Duffy.
November Meeting: November 5, 1997 - To be held at the Electro-Mech Co. in Colorado Springs. Hosted by William LaFollette.

Northeast Product Safety Society

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web site: http://www.safetylink.com/npss.html

February Meeting: Paul d'Entremont, Director of Industrial Design at Teradyne Corp discussed ways to better communicate between safety/compliance and design engineers and how to facilitate the product development cycle.
April Meeting: Third Annual NPSS, Inc. Membership Recruitment Dinner. Presentation by Charles Ludolph, Director, Office of the European Union and Regional Affairs, International Trade Administration, US Department of Commerce discussed the status of US-EU Mutual Recognition Agreements and their impact on conformity assessment in the US.

Continued on next page

Orange County, Southern CA
Charlie Bayhi
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Beginning in January 1997, the 'Test of the Month' show and tell at each meeting where practical safety topics will be discussed.

February Meeting: Sid Kritzstein of Technologies West and Michael Hopkins of Therm Voltek/Keytec demonstrated the Keytek CE Master for testing of products for conformance to the IEC-1000-4X Basic EMC standards requirements. Mr. Hopkins presented an overview of the IEC-1000-4 standards as they apply to products being evaluated for compliance with the EMC Directive.
March Meeting: Brief overview of ITI Conference by Charlie Bayhi. Henry Lurch of Power Engineering Associates conducted a demonstration on how to measure and record the line input voltage, current, power, and harmonics generated by a switcher power supply using the Fluke Model 97 ScopeMeter and current transformer clamp.
April Meeting: Henry Lurch of Power Engineering Associates presented an informative narrative on the use and selection of transient surge suppression devices.

May Meeting: New Location - Newport Corporation, 1791 Deere Ave., Irvine, CA. Open forum discussions.

June Meeting: Newport Corporation, open forum discussion about certification agency issues and job opportunities.

July Meeting: July 1, 1997, Newport Corporation.
August Meeting: August 5, 1997
September Meeting: September 2, 1997
October Meeting: October 7, 1997

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Meetings are on the fourth Tuesday of each month.

February 25, 1997: Geoffry Hutto of TUV PS gave a presentation on the Machinery Directive. The first annual Product Safety Awards (aka The Michael J. DeMartini Award) were presented to Murlin Marks and Rich Pescatore for their contribution to the product safety profession.
March 25, 1997: Richard Pescatore of Hewlett Packard gave a presentation regarding the overall process and recent developments related to IEC 950.
April 22, 1997: Larry Holbrook of Hewlett Packard gave a presentation covering HP's approach to new and proposed global environmental requirements
May 27, 1997: Alan Flandez, Product Safety of Hardware/Software
June 24, 1997: Michael Royer - Part 6 of IEC 950, Third Amd.

That is it for now. If you are aware of any "activities" information that may be of interest to readers, please forward it to the above address and I will try to include the information in the next issue.

Again, support your local Chapter by getting involved - or start a new Chapter!

Live Long and Prosper,

Kevin L. Ravo ■

Product Safety Abstracts

By Dave Larusso
lorusso@sonic.net

"Using Legal Decisions to Help Prevent Products Liability - Design Defects," was published in the January/February, 1996 issue of "Power Quality Assurance."

Barry Fleishman, writes about the judicial system providing meaningful guideposts for manufacturers seeking to avoid liability resulting from defective products. These legal decisions can provide a checklist for manufacturers to use in analyzing whether they have implemented reasonable precautions against the design and manufacture of defective products.

" Safety and the Stationary Battery," was published in the January/February, 1996 issue of " Power Quality Assurance."

Richard M. Tressler writes about important concerns employers should have on the topic of battery servicing. Proper training and clarification of misnomers and misinformation is described.

" What Changes to UL 1449 Standard for Safety Transient Voltage Surge Suppressors May Mean to You," was published in the January/February, 1996 issue of "Power Quality Assurance."

J. Rudy Harford explains changes in UL 1449 and reviews some of the changes to electrical tests, the basis for the tests are discussed, and the likely impact on both manufacturers and consumers.

"Product Liability: An Overview of Critical Loss Control Factors," was published in the April, 1996 issue of "Professional Safety."

Kenneth E. Ryan explains how manufacturers ensure product safety and minimize product exposure liability. The focus is on six key areas: management support, design evaluation, legal review, quality assurance, labeling and marketing.

"Qualified Person, Unqualified Person," was published in the July, 1996 issue of " Professional Safety."

Authors, William S. Watkins and Thomas M. Kovacic present information on what determines whom a "qualified person" is. The article is based on the definition of a qualified person as it applies to electrical work. Definitions of the term " qualified person" are reviewed and examples are cited.

"Prevent Your Test Station from Tipping," was published in the November, 1996 issue of "Test & Measurement World."

Michael T. Freeman provides stability design tips that provide a reasonable level of safety with minimal cost. The basic mechanics of rack tipping are also described in this article.

If you have any articles or abstracts you would like included in the next issue, please send them to:
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News and Notes

By John Rolleston
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UL ANNOUNCES COUNTERFEIT-PROOF MARK

Underwriters Laboratories(UL) in cooperation with the U.S. Customs Service has announced new marking techniques which defy counterfeiting.

Using holographic techniques in production of the UL labels and training of U.S. Custom agents counterfiet goods may be stopped at the border instead of waiting for complaints from field representitives, manufacturers, jurisdictional authorities, consumers and the like reporting after the good reach the marketplace. For more information contact UL, ResearchTriangle Park, N.C.

NEMA TO PROVIDE INPUT FOR SAFETY SIGNS TO INTERNATIONAL COMMITTEE

NEMA(National Electrical Manufacturers Association) administrating the ISO Technical Committee 145 is in position to influence international standard ISO 3684 Safety Colours and Safety Signs. Expected is increased harmonization in the standards for safety and signs between the US ANSI 535 and the European ISO 3864. For more information and membership information contact Molly Bolger, NEMA, 703-841-3227.

NEWS FROM DOWN UNDER

Australia is undergoing major revisions to their regulatory process. Effective July 1, 1997, Austel (previously responsible for Telco regulations) and the Spectrum Management Agency (SMA - responsible for EMC and Radio regulations) are being combined into a single body called the Australian Communications Authority (ACA). All permits previously held under the old organizations need to be replaced by new authorizations issued by the ACA. For more information go to a web browser, WWW.DCA.GOV.AU and WWW.SMA.GOV.AU.

AGENCY NEWS

BABT, TUV Product Services, UL and VDE have teamed up to offer the international EMC mark that can be used to provide independent verification of compliance to the EMC requirements of Europe, North America and Japan.

Inchcape Testing Services has changed its name to Intertek Testing Services. All 176 labs and 342 offices world wide will operate under this new name.

ANOTHER INTERNET REGULATORY RESEARCH RESOURCE

WWW.Compliancenet.Com is a resource for regulatory requirements world-wide. It is a fee based site offering regulatory information on EMC, product safety, ergonomics, environmental, quality and functional requirements.

Continued on next page

News and Notes
Continued from previous page

CSA ACQUIRES INTERNATIONAL APPROVAL SERVICES(IAS)

As of June 30, 1997 CSA became owner of the IAS which includes the Divisions owned by the Canadian Gas Association (CGA) and the American Gas Association (AGA). This move will make CSA a one-stop North American provider in Canada of standards, certification and registrations needs for natural gas, oil-fired, electric and nechanical products. This announced by John Kean, President and CEO, CSA April of 1997.

ANSI LAUNCHES NSSN, A GLOBAL STANDARDS RESOURCE

NSSN, formally known as the National Standards System Network has been officially opened by ANSI on the WWW. This service provides a comprehensive source of information on regional, national and international standards from private-sector organizations and federal government agencies. Contact Jim Winger 301-975-4034 (james.winger@nist.gov) at ANSI for more information. NSSN basic services can be found on the WWW at http://www.nssn.org

UL TO INCREASE INSULATION THICKNESS FOR LAMP CORDS

Starting 1999 lamp cords standard UL153 will require 50% more insulation thickness. Type SPT-2 lamp cord is affected by this change. The change will reduce the risk of fire and electric shock. This reported in the Spring 1997 UL "On The Mark" journal. ■

Technically Speaking
Continued from page 1

Our power cord supplier, in molding the plug onto the cord, stretched the ground wire such that most or all of the strands of the ground wire were broken. The connection was intermittant, and was a function of bending the cord at the plug end.

As predicted, our 30-amp test did not find the problem.

We found the problem because the connection was intermittant. We saw the stretched and broken wires with x-ray photos of the plug.

We measured the impedance of a good power cord ground as 45 ± 1 milliohm at 10 amperes. With only 6 strands (of 36), the impedance increased by 6 milliohms to 51-52 milliohms.

We used 10 amperes because, at higher currents, the wire heats up and the resistance increases with time until the temperature stabilizes. When measuring resistances in the 50 milliohm range, it is important that the resistance remains constant during the measurement. At 10 amperes, heating is negligible, and the resistance does not change more than 1 milliohm.

This is more proof that the 25- or 30-amp test as a production-line test is no better than a simple continuity test!

Let's now consider whether or not the high-current test will find a loose screw connection.

I set up an experiment consisting of a Taptite threaded hole in sheet steel, an M3 screw with integral lockwasher, and a closed-loop terminal.

I connected one terminal of the high-current sourc-

Continued on next page

ing milliohmeter to the steel chassis. I connected the other terminal to the closed-loop terminal.

I connected the terminal to the chassis by means of the screw, moderately tight. I measured about 4 milliohms at 25 amperes.

I tightened the screw firmly. 3.2 milliohms.

Then, I loosened the screw so that the terminal was free, but still captive to the screw. The resistance increased to 7milliohms at 25 amps. The resistance could be increased up to 60 milliohms, but not steady, and the current dropped to less than 25 amps.

Or, the circuit was open.

I then removed the screw and just touched the terminal to the steel chassis. Again, if a connection was made, the resistance was 7 to 4 milliohms, or else was open.

I conclude that a loose screw is either open, or it is a few milliohms. The 25-ampere test, in itself, will not identify a loose screw.

CONCLUSION
For production-line testing, the 25- or 30-amp grounding continuity test is not likely to identify construction anomolies that would not also be identified by a simple low-current test.

ACKNOWLEDGMENTS

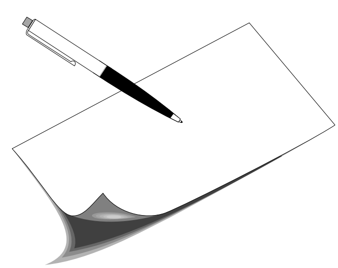
Thanks to Bruce Campbell of Hypatia, Inc. for providing equipment and advice in testing the wire.

*****

Your comments on this article are welcome. Please address your comments to the Product Safety Newsletter, Attention Roger Volgstadt, c/o Tandem Computers Inc., M/S 55-53, 10300 N. Tantau Avenue, Cupertino, California 95014. Or, you may send your comments via e-mail to VOLGSTADT_ROGER@Tandem.COM or richn@sdd.hp.com

If you want to discuss this article with your colleagues as well as with the author and editor, e-mail your comments to emc-pstc@ieee.org. ■

We are looking for Product Safety Articles!



Please send your articles to:
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Handling Safety Incidents

Paul W. Hill

[We are grateful to the author for providing a series of condensed installments from his book "Managing Product Safety Activities." This text is a registered copyright of Paul W. Hill & Associates, and is reproduced with permission. Details about the book may be obtained by calling (704) 892-6982. -ed.]

A safety incident is an event which results in electric shock, property damage, or personal injury. Serious degradation of the air, land or water environment might also be included if the product uses toxic or hazardous materials. Apart from any irresponsible use and abuse of a product, safety incidents signify some failing in the design, components, materials, operating instructions or servicing procedures. A safety incident generally indicates that some element in the safety attributes of the product is marginal or inadequate.

Safety incidents must be properly managed for several reasons. First, the safeness deficiency must be determined and corrected quickly to avoid repetitive incidents. Secondly, prompt corrective action prevents adverse user or public reaction to the product should the incident become general knowledge. Thirdly, it is likely that the potential for litigation actions can be minimized when the incident is promptly and properly managed. In addition, if the product manufacturer or importer does not respond quickly and constructively others will begin to assume control of the situation.

The following sections outline the basic elements of a product safety incident handling procedure. The elements covered include necessity for prompt reporting channels, report information and the general management of safety incidents.

Incident reporting system.

The first critical element of incident reporting is the prompt management notification that an incident involving electric shock, fire, personal injury or damage to the environment has occurred. These reports should not be restricted to user related incidents but must include all phases of the product life cycle including:

- prototype testing
- manufacturing tests
- quality control tests
- demonstration and feasibility models
- warehoused units
- re-manufactured products
- disposal of consumables
- used equipment market
- final disposal of the product

Safety incident reports must have a clearly defined report **transmission channel**. These reports should not be coupled to other reports such as field service data, product compliant reports and the like which may be complied periodically or transmitted by routine mailing procedures.

Slowly transmitted or delayed incident reporting usually complicates the ultimate resolution of the incident for the following reasons:

1. Management may lose control of the situation as others become involved and begin to influence or direct the outcome of the incident.

2. Delays in detection or response is often perceived as insensitivity to product safety and user concerns for safeness of products. They may also perceive a lack of creditable responsibility for environmental factors if toxic substances are associated with the product.

All safety related incident reports should be considered **priority communications** and transmitted to the organization's management by telephone or similar means which assure prompt notification of the incident.

Many organizations provide all field personnel with toll free telephone numbers for reporting safety incidents. One of these numbers should be for after normal business hours, holiday and weekend contact of the senior manager assigned product safety responsibilities for the organization. Some organizations provide these contact numbers to the organization's service and customer contact personnel and to distributors as well.

It is important to instruct incident reporting individuals of the need for confidentiality of the information being reported. Safety incident information should be distributed only to those with a need to know. Strict confidentiality of information about the incident will reduce unnecessary speculation, premature judgments and early publication of the incident before investigations are completed and actual causes are known with certainty.

Report content.
It is necessary to provide instructions to field personnel for making a safety incident report capable of providing meaningful information to management from which the initial approach to the incident can be formulated. Initial report information may be incomplete, and in some cases impossible to confirm immediately, but this situation should not delay the initial incident report which can be supplemented later as reliable information becomes available. To the extent possible the following information should be reported:

1. Type of safety incident or environmental damage, i.e., electric shock, personal injury, fire, property damage, toxic emissions or spill of hazardous consumables.

2. Extent of any injuries, fire, damage to property or to the air, land and water environment.

3. Type of equipment or product involved by model, catalog number or trade name. Additional data such as serial number, date code and the like should be included if available.

4. Date, time, location and name of customer or individual associated with the incident.

5. Name, position and contact information of the individual making the incident report. This is necessary for relaying instructions or making requests for additional incident information.

Field service and customer contact individuals should not attempt to manage, make commitments or become involved in the incident.

Their key role is to promptly make the report and to await instructions from the organization's executive designated to handle field product safety incidents.

Processing safety incident reports.

The overall management of the incident should be in keeping with the procedure outlined in Appendix B [of the book, "Managing Product Safety Activities"] since the incident may be reportable by Consumer Product Safety Commission (CPSC) rules. It is recommended that this process be used under the assumption that the incident is reportable until Step 3 in Appendix B, (determination of the need to report the incident to the CPSC) is resolved.

Upon resolution of Step 3 the process is automatic if reportable, otherwise the organization's internal incident handling plan is followed.

An incident handling plan must first determine if a product safeness risk exists using the criteria given in Appendix B. The first step is to obtain as much reliable information as possible. If the initial report indicates serious injury, extensive fire or environmental damage, it is advisable to dispatch the executive assigned responsibility for handling safety incidents to the incident location to obtain and confirm as much definitive information as possible. This information should include:

- Examination of the equipment and its operating site.
- Adherence to operating and servicing instructions provided by or recommended by the manufacturer.
- The level of instructions provided user and servicing personnel.
- Any comments or conversations with the equipment users or maintenance personnel that relate to the equipment operations and the circumstances surrounding the incident.
- Permission to take possession of the equipment for testing, simulation of the incident or other evaluations and investigations. However, the unit should not be disturbed if fire, police or other authorities have impounded the unit or placed it under their control.

With this incident information a decision can be reached which indicates a safety risk does or does not exist and step 3 of Appendix B can proceed.

Safety Incident Follow-up.

A safety incident must not be open ended. The incident should be brought to a conclusion as early as possible. The incident file must be retained as required by record retention rules. The file must include:

1. Complete identification of the unit(s) involved such as model, type, serial numbers, engineering change level, place of manufacture, importer, etc.

2. The determination of the cause of the incident.

3. Corrective or remedial actions taken indicating the implementation date, serial number or other demarcation indicator.

4. Photographs or other documentation of changes or remedial actions taken.

5. Disposition of units associated with the incident.

6. Report approval signature of the organization's executive assigned safety responsibility for the product.

With the incident report and its investigation file completed the incident can be considered closed. ■

The UL Articulated Accessibility Probe

by Walter Skuggevig, P.E.
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Many product safety standards specify an articulated accessibility probe to determine accessibility of conductive parts in electrical products. Underwriters Laboratories Inc. (UL) developed a probe for this purpose in the early 1970's with an extensive technical rationale for the probe shape.

Accessibility probes are frequently used to determine if a person *can* touch certain parts in products. To assess whether an injury is likely to occur with a given product involves more than simply a measure of accessibility. There is also a determination of the likelihood, motivation, and consequences (perceived and actual) of touching the part. These vary among different products. However, the accessibility probe is intended to gauge accessibility to humans so that potentially hazardous parts will be truly out of reach, and so that parts that are already adequately recessed will not be required to be insulated, guarded, or moved further away from openings. Appropriate determinations of what can and cannot be reached and touched are universally needed, and relate to many products.

A new "child's test finger", also called the "small finger probe", is being introduced in document IEC-1032 ("Test Probes to Verify Protection by Enclosures"). However, this new probe is not needed. The articulated accessibility probe developed by UL and specified in many UL product-safety standards was designed to include children as well as adults, and there is extensive technical rationale to support its design.

Over twenty-five years ago when UL's articulated probe was developed, international exchange of technical information was limited. UL's articulated probe was a requirement in many UL product-safety standards, but was not promoted for adoption in international standards. Later, international standards harmonization became a priority, and product standards began to merge into single documents to be used by many nations. UL478 which covered Electronic Data-Processing Equipment in the USA was replaced by UL1950 which was harmonized with IEC-950 — an international document. In this transformation process, the IEC articulated probe replaced UL's articulated probe for this product category. This same process was utilized in a number of standards where international harmonization was a priority.

It should be noted that the two accessibility probes are substantially different in shape and that the results of accessibility determinations using the two probes differ significantly. UL requested the technical rationale for the shape of the IEC accessibility probe, but technical information about the development of the IEC accessibility probe was not available. To determine the effect of the differences between the probes, UL compared the maximum possible penetrations of the two probes through slots and circular openings to the penetration data that was originally used to develop UL's probe. The results of this analysis are contained in UL's Abstract titled "Accessibility Probes." This document illustrates the degree of correlation between each of the two probes and the experimental data. It is available from UL's publications department in Northbrook, Illinois (847 272-8800 extension 43731). Similar information is available from UL regarding the new IEC child's test finger.

DESIGN OF THE UL ARTICULATED PROBE

The shape of the UL Articulated Probe replicates the shape suggested by data describing opening dimensions (slots and circular openings) versus the maximum measured depth of human finger/hand penetration. The probe shape is not related to a "standard finger."

The design of the UL articulated accessibility probe is the result of extensive research by UL engineers. Each of 300 volunteers was asked to reach through 30 different openings in a test fixture, and to push the end of a rod the maximum possible distance away from the opening. The volunteers consisted of 100 men, 100 women, and 100 children. The children ranged in age from 1 to 10 years. The rod was located behind, and pointing to, the center of each opening. For each opening and volunteer, the distance was measured from the end of the rod to the plane of the opening. Each volunteer reached through 15 slots and 15 holes ranging from 1/8 inch to 1 inch in width or diameter. For the small children, the head of a toy bear was secured over the rod so that they could push the bear's nose. A slot might permit entry of more than one finger, and perhaps all or part of the hand. For many size openings, a hole with diameter comparable to the slot width will not permit such entry. The UL articulated accessibility probe is designed from data points describing the measured penetration distances for each opening beyond which 95% of each volunteer group could not reach with aggressive attempts to penetrate the openings.

Figure 1 shows the apparatus used to develop the data describing how far beyond a slot or hole people can reach. There are two interchangeable boards that contain the openings — one with various diameter holes (shown installed in the apparatus), and the other with various width slots. Each board is designed to slide in a groove across the front of the apparatus. Alignment holes permit locking the board in place with the chosen size hole or slot directly in front of the rod attached to the centimeter scale for measuring finger/hand penetration past the plane of the opening.

Figure 1

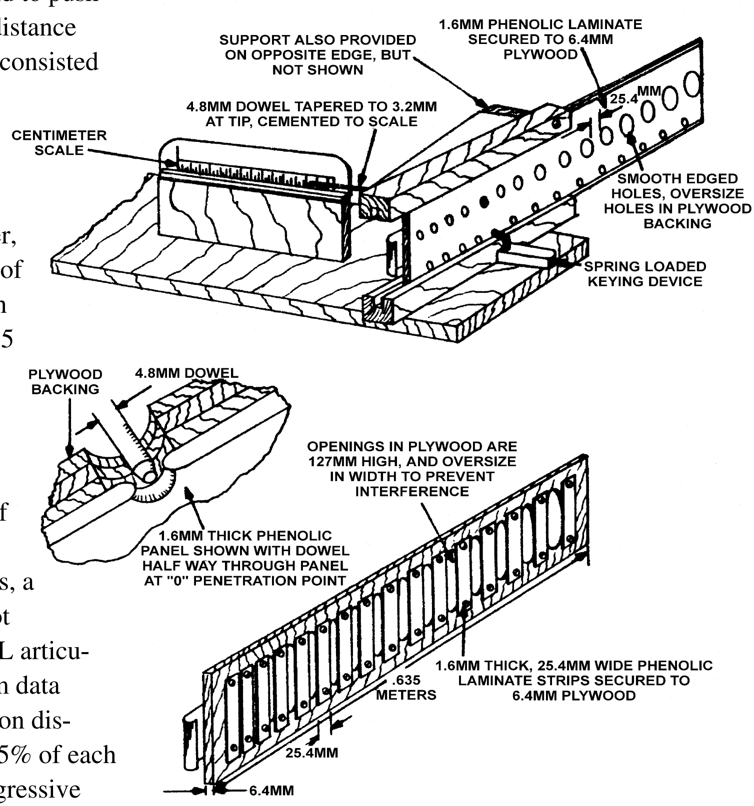
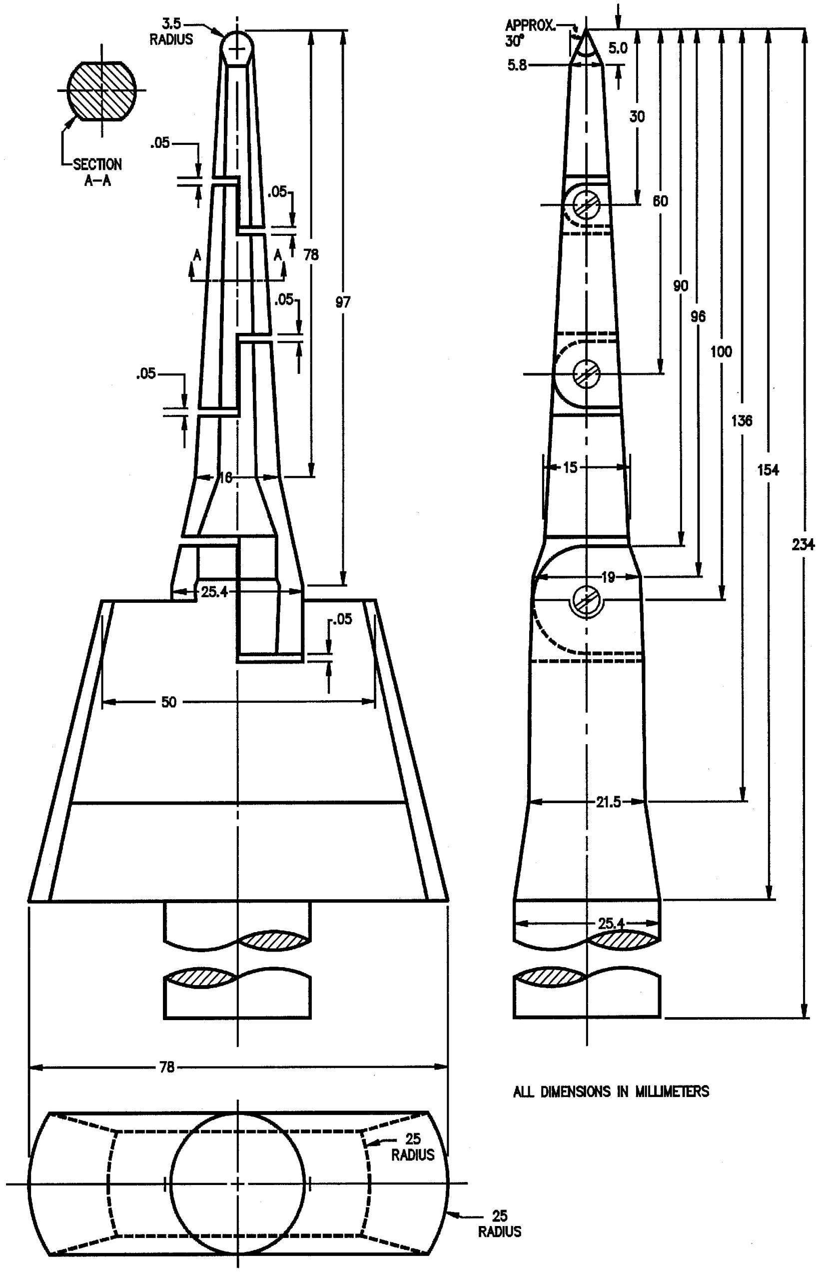


Figure 2 shows the dimensions of the
UL Articulated Accessibility Probe



PA100A

The probe is to be used only as a gauge and inserted with minimal force. The probe shall be rotated with the movable sections straight or in any possible position resulting from bending one or more sections in the same direction.

The shape of the probe profile in the right-hand drawing of Figure 2 is determined by the penetration data from people reaching through slots; the shape in the left-hand drawing of Figure 2 is determined by the penetration data from people reaching through holes.

Table 1

Minor Dimension of Opening	Minimum Allowable Distance Between Opening and Part **
254. mm (1 inch)	165 mm (6-1/2 inches)
31.8 mm (1-1/4 inches)	190 mm (7-1/2 inches)
38.1 mm (1-1/2 inches)	318 mm (12-1/2 inches)
47.6 mm (1-7/8 inches)	394 mm (15-1/2 inches)
54.0 mm (2-1/8 inches)	444 mm (17-1/2 inches)
>54,0 mm but not more than 152 mm (>2-1/8 inches, but not more than 6 inches)	762 mm (30 inches)

** Interpolation is to be used to determine the limit values for openings with minor dimension less than 54.0 mm (2-1/8 inches).

The UL articulated probe is designed to be used to evaluate openings with the minor dimension less than one inch (25.4 mm). The probe is not pliable and cannot simulate folding the hand by tucking the thumb into the palm and rounding the knuckles thereby reducing the width across the hand for squeezing through a hole. For openings 1 inch or more in the minor dimension, the opening is to be evaluated by using the limits shown in the following table.

CORRELATION BETWEEN PROBE SHAPE AND ACCESSIBILITY DATA

Figures 3 and 4 illustrate the correlation between the human accessibility data and the UL probe shape. The figures show the ranges of the human penetration data for each opening dimension, and the probe dimensions that resulted from these data.

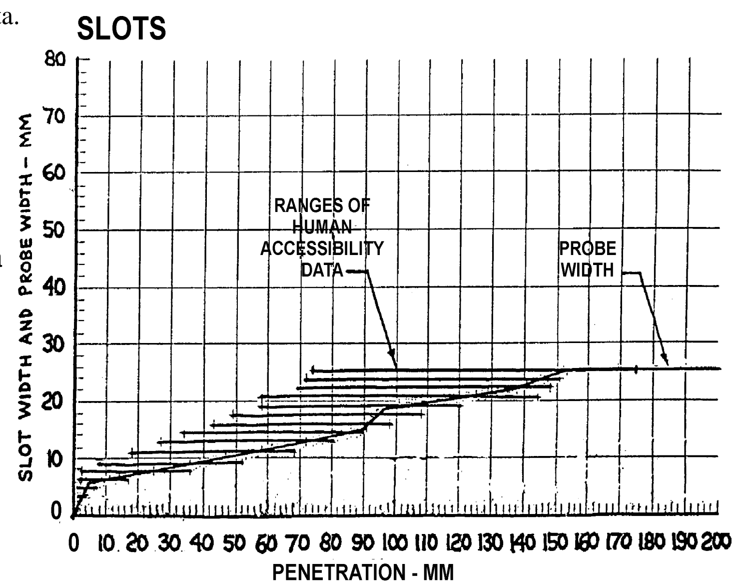
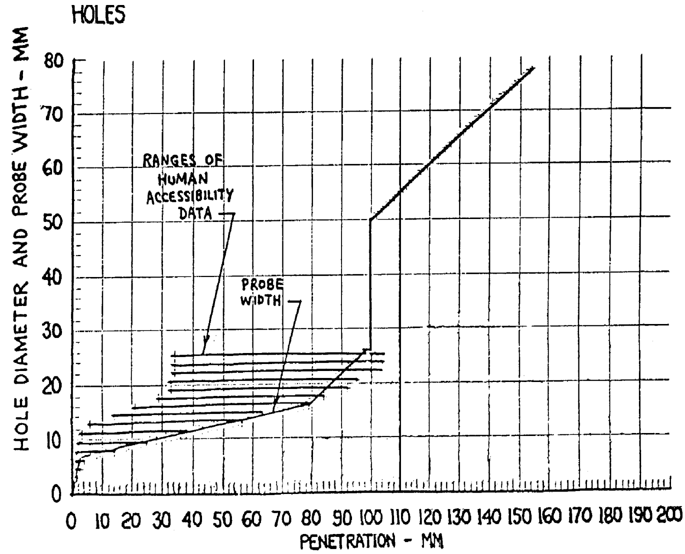


Figure 3

The UL Articulated Probe and the Human Accessibility Data Reaching through Slots

Figure 4

The UL Articulated Probe
and the Human Accessibility Data
Reaching through Holes



Ideally, the curve corresponding to the probe shape should be on the right side of, and next to the ranges of human data. The probe should be able to reach beyond most of the people, but the probe shape should not be away from the data that so that it does not represent the people. The shape of the UL accessibility probe was designed to follow the 95th percentile points of the data describing human contacts.

The wedge-shaped tip of the UL probe accounts for the fact that human finger tips are pliable, and when pressed against a small opening, will bulge into the opening. For example, the contacts behind the face of a general-use receptacle need to be recessed to keep them unaccessible. A probe with a hard blunt tip would permit these contacts to be almost flush with the receptacle face.

The UL articulated accessibility probe has three points of articulation, two to account for the joints in human fingers and one to account for the knuckle at the base of each finger.

THE "STOPS" ON THE PROBE

For the evaluation of larger openings, the probe has a "web-stop" between the articulated "finger" and the probe handle that prevents penetration of the probe into areas that the human hand cannot access as determined by UL's research data and the published anthropometric data[1 2]. However, as previously indicated, the UL articulated probe is not intended to evaluate openings with a minor dimension of 1 inch or more. Table 1 is to be used for this purpose.

SUMMARY

The shape of UL's articulated accessibility probe is derived from extensive research data. Gauging accessibility by using UL's probe considers of most of the population including children, and will not result in unjustified rejections or unneeded modifications of products. It is the only probe that is needed to determine whether a person's fingers can contact a part through an opening. ■

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[1] *HSRI, "Anthropometry of Infants Children, and Youths to Age 18 for Consumer Product Safety Design", prepared for the U.S. Consumer Product Safety Commission by the Highway Safety Research Institute, University of Michigan, UM-HSRI-77-17, Contract CPSC-C-75-0068, Final Report May 31, 1977*

[2] *Dreyfuss, H., "Measure of Man, Human Factors in Design", second edition, Whitney Library of Design, 1967*
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Safety By Design

(The editor wishes to thank the editors of Machine Design for their permission to reprint the following article by Bruce W. Main of Design Safety Engineering Inc., Ann Arbor, MI, which first appeared in the September 26, 1996 edition of the publication.)

Engineers face increasing pressures to improve the safety of their designs. These pressures include the obvious and ethical desire not to harm anyone, along with product liability and the time and money lost to defending lawsuits rather than design efforts, accident and medical costs, and even European Union CE marking requirements.

No one needs to remind engineers of these pressures. A recent survey showed that most engineers recognize the impact of product liability and the value of safety to good design. The same survey revealed that many design engineers are either unaware of, or not trained in, the methods and techniques which can help prevent products from being involved in accidents. Many prevention methods developed in the safety community could help engineers turn out safer products — if they used them.

Safety Analysis

Safety analyses are fundamental tools in the safety community. They help make and implement decisions regarding product safety, simultaneously preventing accidents, improving product safety, and reducing a manufacturer's liability exposure by systematically identifying and evaluating hazards concerning the product design, its uses, and potential "failures." Safety analysis should advance designs rather than solely reviewing and checking past decisions. Particular focus should be given to areas in which the designer has not been able to concentrate, and where safety problems are often overlooked.

Although some safety analyses are formal and extensive analytical efforts, many of the techniques should be adapted to a product's specific needs. The ensures the analysis advances the design and remains focused on the critical safety issues. Three types of analyses are particularly important: Preliminary Hazard Analysis, Fault Tree Analysis, and Failure Modes and Effects Analysis.

Preliminary Hazard Analysis (PHA) evaluates product safety and identifies potential hazards. This is often the initial safety analysis conducted on a design and helps in developing preliminary design criteria as designers and manufacturers either eliminate or control the hazards they discover.

Hazard analysis is essentially a hazard-discovery process requiring engineers list hazards associated with use and expected misuse of a design in all environments in might potentially see. Engineers must anticipate how accidents or injuries might occur using design and safety data, and experience. The nature of PHA lends itself to a team approach such as brainstorming.

The hazard identification portion of the analysis must be properly executed because without the requisite skill and training, potential hazards can be overlooked. Just as with other engineering analysis, a poorly conducted or incomplete hazard analysis could be counterproductive in avoiding accidents and liability. Missing an important hazard could also raise issues of recall or retrofit warning campaigns which are costly and can hurt a manufacturer's reputation. Proper PHA's can be particularly difficult for smaller manufacturers who do not have engineers trained in safety analyses.

If conducted in the beginning of a design process, PHA evaluates a design's weak points and allows early corrective action. This analysis also provides information concerning resources allocations and prioritizing design activities.

PHA provides a qualitative rather than quantitative risk assessment, meaning it can be largely subjective. PHA also ignores the risks of combined hazards or concurrent failures. As with other engineering design analyses, PHA will not provide good data or information for decision making if the scope of the analysis is too narrow and hazards are missed. Conversely, if the scope is too broad, the effort becomes large and costly to implement.

Failure Modes and Effects Analysis (FMEA) identifies potential product failure modes which could lead to accidents. It breaks down designs into components or subcomponents, then systematically evaluates the potential for and effects of individual failures, focusing on how they can lead to hazards or unreliability in a design. Results of the analysis are used to evaluate and implement preventative measures to eliminate or control hazards.

The first step on conducting FMEA is defining the project's scope. Dividing designs into assemblies of manageable size is useful if it doesn't overlook important failure modes or effects. Working with a complete component list, one can establish the operational and environmental factors affecting each component, and determine significant failure mechanisms for them. Answering the following questions for each component and subcomponent helps identify failure modes for all components: "Will a system failure cause an unacceptable loss? And what are the modes and effects of failure of each element?" Failure modes should also include any special circumstances that would increase the possibility of failure.

When conducting a quantitative analysis, engineers should quantify the risk by providing a probability of occurrence and severity. References can help establish failure severity values, probabilities of occurrence, a failure severity rating system, and overall failure probabilities. Unfortunately, such information often doesn't exist and may be difficult to obtain. In its absence, the analysis' quality and usefulness may be greatly diminished.

However, FMEA is particularly well suited to situations where engineers are unsure what problems might occur or how small problems could lead to larger ones. This kind of analysis is very strong when the coupling or interactions between failures are not complex, and when system and hardware problems are more likely to occur than problems of human interactions or error. FMEA is also useful in determining which of several potential problems should receive priority attention.

As a safety analysis tool, FMEA offers several advantages, particularly its ability to thoroughly quantify overall risk and the consequences. Quantifying risk can take much of the subjectivity out of safety analyses. But FMEA is not without limitations. Perhaps its largest drawback is that it does not include human error. Since many accidents involve human error, this can be critical. A thorough FMEA can also be costly and may not always be necessary. Completing it can consume time evaluating non-critical components or failure modes which don't result in accidents. FMEA typically does not look at system linkages and interactions or multiple-element failures. Finally, the level of design maturity required for a quantitative FMEA is not generally reached until late in the design phase.

Fault Tree Analysis (FTA) is a powerful diagnostic tool for analyzing complex systems. It was originally developed by Bell Laboratories in 1961 to avoid missile disasters in the US Air Force's ICBM system.

FTA consists of a chart of undesirable events using symbols to indicate the relationship between them. Because FTA focuses on identifying how one particular outcome or event could occur, it is often referred to as a "top-down" approach. In comparison, FMEA seeks to identify all failure modes and their effects and is a "bottom-up" approach.

FTA begins with selecting the "top event" (which can be taken from a PHA or FMEA). Then, analysts build the tree of contributory events (branches and gates) using logic symbols. Repeating this process at successive levels using standardized symbols identifies primary and secondary faults. Completing the tree to the bottom level identifies a fundamental failure, error, or other initiating event. Once completed, engineers use the tree to evaluate the system including "cut sets" (the minimum sequence that can cause the top event to occur, or critical path) and "path sets" (events which, if don't occur, guarantee the top event won't occur).

Quantitative FTA determines the likelihood or probability of events and uses the logical relationships to calculate the relative risk of the design. At completion the FTA is used to make and implement decisions regarding product design safety.

There are several potential benefits from FTA. Because it focuses on accident-related events, the costs of the analysis can be tailored to the needs of a project. FTA highlights interrelationships between components and potential failures which are difficult to see in FMEA. An additional advantage FTA has over FMEA is that it can include human error. It can also be beneficial when the top event is known and concern centers on preventing that event, or discovering what initiates that event. FTA is a good tool for prioritizing resources and efforts, and is adaptable for risk-benefit analyses.

The analysis has several limitations. It does not accept "maybe" conditions — events must be a yes or no occurrence. One of the most frequent errors in conducting FTA is neglecting to identify common causes, one which triggers multiple events. Correctly evaluating Boolean logic and probability computations are more complex than most people think, so they are often done incorrectly. Commercial software provides some assistance, but quantitative FTA calculations can still be difficult and costly. As with FMEA, the lack of good probability data hinders analysis.

Preparing FTA requires intensive knowledge of design, construction, and use. Because only one top event or condition is analyzed per tree, designs may need several FTA. And finally, the structure and formality of FTA tempts designers to read more into it than is truly there. FTA shows causes and effects, no more, no less.

Result and Requirements

Safety analyses pay off in several ways, the primary one being a list of hazards associated with the potential uses and foreseeable misuses of the product. Ideas for potential design changes and product improvements also commonly spring from analysis. Other potential outputs can form the basis for specifying maintenance, training, and operating procedures. Safety analyses can also be useful for subsequent design reviews as a product-specific safety checklist. And when it comes to litigation, results from safety analysis may soon become critically important in determining whether a design was defective at the time of manufacture.

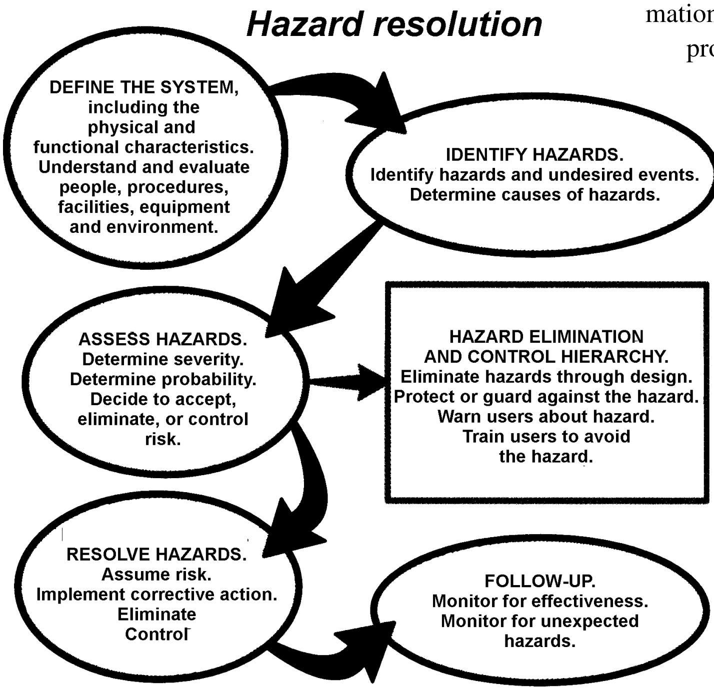
Safety analyses should ideally be part of a concurrent approach to product design, with safety being just one of many analyses. Depending on system complexity and the number of changes made, Follow-Up safety analyses may be necessary. Although usually considered a method for new product development, safety analyses can also benefit a product evaluation at any stage in a product's life cycle (including in the field). In some cases, postdesign safety analyses evolve into a springboard for new ideas and potential improvements.

As with many engineering analyses, better results are obtained by including different perspectives. Obviously designers play a key role in safety analyses since no one knows the product better than they. But they should understand not only the design and general hazards the product presents, but also the analytical tools used. In addition, it's important to include someone knowledgeable and trained in conducting safety analyses. Others, such as users, assemblers, repair and maintenance personnel, and legal counsel can also offer valuable insight to uses, potential misuses, and hazards.

Many safety engineering analyses require information not easily obtained or quantified such as probabilities, failure rates, severity ratings. Obviously the output of a safety analysis will be only be as good as the quality of the inputs. Therefore, quantitative safety analyses tend to be used more often when good information is available or the project warrants developing the data. One of the more difficult aspects of quantitative analyses is determining what amount of risk is negligible, and how safe is safe enough. Answering these difficult questions before starting the analysis usually improves the results.

There are hundreds of other safety techniques, tools, and methods. Which particular technique is best depends on the design, its stage of development, the level of complexity, the availability of data, the

Hazard resolution



The preferred hierarchy for handling hazards becomes apparent when it is examined closely. Eliminating hazards through design produces inherently safe products. Protecting or guarding is less preferred because it can be undone by unsafe behavior. Using warnings has several problems, tha largest being that designers must depend on the users. Training, the least preferred method of handling hazards, also relies on users, but requires training for all potential users and operators. A fifth item, accepting any residual hazards and risks, is often included. While this hierarchy is a valuable tool in design, there's no legal requirement or industry standard mandating its use in the U.S. The European Union, however, has placed explicit legal requirements to do so in its Machinery Directive governing equipment that can be sold in the EU.

project's needs and objectives, and personal preference. But conducting any specific safety analysis and tailoring it to the needs of a particular design is probably more important than which particular analysis is used.

Unfortunately, there are no guarantees. As with other engineering analyses, things can go wrong even when several analyses are conducted. One of the more common errors involves design changes made after a safety analysis is completed. To avoid this, engineers must be aware of how design changes affect a safety analysis and its underlying assumptions. Another risk involved with safety analyses is in identifying a hazard but not resolving it. The analysis summary would then constitute a "smoking gun" — a document showing that the designers knew of a potential hazard but did nothing to prevent it. Designers must follow through when a potential problem is identified.

An engineer's ability to improve safety and avoid accidents may be limited by the amount of safety training he's had. Most have received little or no formal safety training. And although safety engineers have the methods and techniques to address safety issues in a comprehensive manner, they aren't often involved in the actual design process.

Drawing on techniques developed by the safety community can help designers concerned with improving the level of safety in their designs. Integrating hazard evaluation procedures with design can give designers the necessary tools to identify and modify components which have the potential to cause accidents. ■

Methods for identifying hazards:

✔ Brainstorming
✔ Consider all phases of design
✔ Identify and interview groups of users and intended uses.
✔ Understand users' objectives and think of ways to achieve them easier and safer.
✔ Examine expected misuses.
✔ Evaluate failures, failure modes, and consequences, and include human error.
✔ Examine and inspect similar products and their safety studies
✔ Review historical data and experience, including manufacturers' specifications and expectations
✔ Consider basic forms of energy (heat, electricity, mechanical, etc.)
✔ Use checklists if they apply
✔ Monitor costs in terms of activities, dollars, time, and resources, and identify organizational constraints such as deadlines, work rules and social pressures.
✔ Look at various intended activities such as operation and maintenance
✔ Consider the setting and potential environmental or external hazards
✔ Draw from existing safety standards, regulations and codes for similar products
✔ Evaluate system and subsystem interfaces and adequacy of safety devices.

Factors affecting length of safety analysis

✔ Product Complexity
✔ Scope of analysis
✔ Company experience with similar designs (internal experience)
✔ Availability of data
✔ Originality of desgin (external experience)
✔ Availability of industry standards and codes
✔ Formality of the analysis

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