Health & Safety in the Agricultural Engineering Design Process

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1.1 OBJECTIVE

The objective of this research was to investigate the hypothesis that human factors and health and safety are not perceived or incorporated by agricultural engineering designers as a fundamental and essential part of design. Such health and safety issues that are incorporated into designs occur at a late stage in the design process often as bolt on measures to satisfy legislation. This investigation was required to identify what measures were required to remedy this situation and to broadly indicate how such remedies could be implemented.

1.2 THE RESEARCH

The research was comprised of a number of components:

- An investigation of the design culture in agricultural engineering design. This was conducted in two parts; semi-structured telephone interviews with 30 designers; and indepth face to face interviews with 9 designers. These were supported by preliminary desk researches
- Telephone interviews with 5 lecturers delivering agricultural engineering courses
- A review of the history of agricultural machinery design
- A review of the market place for agricultural machinery
- An outline of human factors/ergonomics in the design process.

These researches were drawn together to form conclusions and recommendations.

1.3 THE FINDINGS

The research determined that the fundamental driver in design was to meet the demands of the market place. In doing this the emphasis was on the mechanical design required to carry out the task. The need for functional design dominates the design environment, but unfortunately this functional design does not include the needs of the users of the equipment as a fundamental part of the design process.

Human factors are considered where a specific legislation requires action. For example, to exclude access to drive units, pulleys, belts, shafts. Most often these are addressed at the final stages of production usually by adding guards. This highlights the fact that little, if any, regard is given at the inception of the design process to producing inherently safer designs that recognise human factors, the risks that can arise from miss-directed motivation or the strengths and weaknesses of human adaptability.

The reason for this lack of inclusion of human factors in design in order to produce inherently safer designs resides in three factors:

- Low levels of awareness of human factors amongst agricultural engineering designers
- Poor understanding in the market place of the value of designing for users as well as function

- That the implementation of health and safety is almost wholly reactive through legislation.

Notwithstanding the existing situation, there was encouraging evidence that agricultural engineering designers would welcome measures to improve their knowledge and access to information on human factors, risk, accidents and the reasons why these occurred, legislation, both existing and proposed. The caveat attached to this was that, whatever steps were taken should reduce the burden and cost. Action would also be needed to educate the market place in the advantages of inherently safer designs. Problems would include those situations where existing designs of a fundamental nature were embedded in the industry, for example hitching systems.

Specifically such measures are likely to include: a comprehensive reference list of legislation with full search capability and regular updates; some preferred this on paper, others electronically on CD-Rom or Intranet site; detailed case studies with evaluation of cause and prevention; and courses on risk assessment and human factors.

The investigation of agricultural engineering designers revealed that none had received formal training in risk assessment and training in human factors was extremely limited. Many had 'grown' into the industry rather than having come to design through formal training. Most recognised their weaknesses in this area and were willing to address the issue.

The investigation of training provided by Colleges showed a mixed offering. Some provided little in the way of health and safety or human factors training. In their case the emphasis was on function as driven by the task and the agricultural requirements. Others included this, but balanced this need with human factors/ergonomics and health and safety training. The depth of this investigation did not allow for detailed study of course content, therefore it is not possible to comment on the completeness of this human factors and health and safety training. However, in any event many of the designers interviewed had not attended formal training.

Colleges were willing to modify their course content especially by offering specific courses for career designers. Problems of costs were raised and they would look to specific funding of such courses, from which their students would also benefit.

1.4 CONCLUSIONS AND RECOMMENDATIONS

- The opportunity exists to change the design culture in agricultural engineering so that health and safety and human factors became an integrated part of the design process
- Improvements in the dissemination and access to information in respect of legislation, accidents and their courses is needed
- Training in the broad base of human factors as well as formal risk assessment is needed and would be welcomed by the industry
- To achieve successful implementation such training would need to be at least subsidised if not free
- Complementary action to promote this concept of safer design in the market place is required
- Such steps would shift the emphasis in the design culture towards designing inherently safer machines from first level design concepts.

2. INTRODUCTION

This report investigates the design culture, in particular in respect of health and safety, that exists in the agricultural engineering design process. The important aim of the investigation is to determine the most efficient way of enhancing the role of health and safety in the design process in order to achieve safer designs. There is a presumption in this study that such improvement will be associated with promoting greater awareness of human factors issues and ensuring that future design of agricultural equipment and machinery accommodates these.

The project concept was originally produced in response to the HSE/E's publication 'Mainstream Research Market' which called for proposals for research projects which might help fulfill the HSE/E's mission statement.

3. DEFINITIONS

There are number of terms used in this report which require brief explanation:

Human factors - All psychological, social and physical issues surrounding the user of a piece of equipment.

Ergonomics - Often used to mean the same as Human factors. Ergonomics is the study of the relationship between man and his occupation, equipment and environment and particularly the application of anatomical, physiological and psychological knowledge arising there from. (BS 3138: 1979: 36005).

Health and safety - Human factors issues which relate directly to the safety and well-being of the user.

4. BACKGROUND TO THE PROJECT

Unnecessary agricultural accidents involving machinery and equipment continue to happen. Attempts to change the safety culture in the agricultural industry has been an uphill struggle and of limited success for a number of reasons. The approach has been to legislate, to provide training to end users and to endeavour to improve the safety culture on the farm. Whilst it would be incorrect to say that this approach has not been successful, agriculture accidents have been persistent and remain at too high a level. An alternative, but longer term strategy for reducing these accidents, would be to attempt to design inherently safer machinery in order to reduce the risk of accidents. It is expected that this will require: a change in the safety culture at the design stage; and a greater awareness of human factors pertaining to agricultural machinery and equipment design.

Current machinery design may not be as risk-free as it could be because, designers do the minimum, or only what is required to satisfy legislation. The requirement for a risk assessment is satisfied when laid over the design process, often at the end of it, and is not required to be an integral part of that process. In order to design and produce inherently safer machinery, it is essential for designers to attempt to foresee the risks associated with the use of a piece of machinery. To do this, it is necessary to consider all aspects of design to include:

- How a machine would be used in normal use
- How it might be used in adverse conditions
- How it might be miss-used in order to get a job done more quickly or more easily
- What the state of mind might be of the different people who will come into contact with the machinery.

It is true that risk assessment must embrace these aspects, but machinery must be designed taking into account ease and safety in use and 'foreseeable misuse'. The essential fact is that, to increase safety in use machines and equipment must be designed to best fit the people who use them, rather than for users to adapt/fit to the design presented. These are termed 'human factors' in this report. If human factors issues are properly accounted for then the resultant designs will provide a best fit to all the circumstances of human use (and miss-use), providing a safer environment, resulting in fewer accidents. It follows that, in order to achieve this agricultural engineering designers must have a comprehensive understanding of human factors.

The 'Mainstream Research Market' document recognises the need for health and safety issues to be incorporated into the design process at the conceptual stage. The belief is that health and safety is thought of too late in the design process, not considered thoroughly enough or not considered at all, and that designers' initial concerns revolve around the functions of the machine or equipment, but not embracing the non machine functional requirements of the system, i.e. health and safety and human factors.

This narrow, machine orientated approach increases the opportunity for:

- Less than optimal safety features, or important features missing, because the process of considering health and safety was not thorough enough
- Safety features being compromised because late consideration causes more cost
- Time and effort put into the wrong health and safety solutions
- Safety features being added to cope with a hazard after production or implementation, where it may have been possible to design the hazard out of the system in the first place
- A minimalist approach to design, where the only concern is that the final system meets minimum legislative requirements or guidelines covering that particular system.

The outcome of this is that the levels of risks and hazards with agricultural machinery is often higher than it should or could be. The numbers of accidents occurring within the agricultural industry continue to be a tragic manifestation of inherently poor design.

Evidence of an inadequate approach to health and safety abounds in agriculture, a sector which traditionally has been served by SMEs as well as major national and international suppliers. These suppliers serve an industry with a poor health and safety record; despite the continuing reduction in the number of people employed in agriculture there have been record numbers of accidents and deaths. Many of these are linked to the use of machinery. Because of the nature of the industry, and its safety record, the design of machinery for use in this sector requires consideration of some special requirements. The design culture in which the machinery is created is unique. In order to influence designers working in this sector and try to change the culture to one where safety is seen as part of a system's functionality, the industry needs to be understood and tailored solutions designed to meet its' needs.

5. AIMS AND OBJECTIVES

The introduction and background set out a number of hypotheses based on the considered views of the researchers and colleagues working in and observing the agricultural industry. Whilst these views may be well founded and supported by, for example, accident statistics, there has not been an investigation of the design culture in agricultural engineering to prove or disprove these qualitative views. The aim of this study is to conduct such research into the design culture.

The main objectives are:

1. To understand the design culture in agricultural engineering and design

2. Find effective support solutions

3. Understand the education and training of the agricultural engineering designers

4. Find support solutions for use in education and training

In order to meet each of these objectives a number of information needs have been identified. For each of these four objective the information needs are detailed below.

5.1 INFORMATION NEEDS

5.1.1 Understanding the design culture

To gain an understanding of the design culture in which agricultural machinery and equipment is being produced, including:

- The range of environments in which the design of agricultural machinery and equipment takes place, i.e. from the 'one man band' up to the large multi-national manufacturers

- Measurement of personal attitudes to and perceptions of health and safety issues amongst machinery designers supplying the agriculture, horticulture and amenity sectors

- Measurement of existing levels of awareness of the availability of support material for treating health and safety in the design process

- Examination of the psycho-social structure within the design environments, and how this might affect the resources given to treating health and safety issues, or to the creation of barriers or limits to the consideration given to health and safety issues by designers

- Identification of who in the Company (position, role, level of knowledge) holds the power to set the level of resources devoted to treating health and safety issues in the design process.

5.1.2 Finding effective support solutions

To establish what support material and support systems would be most effective in helping designers better treat health and safety in the design process by:

- Identification of what bodies would exert the most influence over the attitudes of members of the design team, for example, HSE or professional bodies

- Identifying the format of suitable support material which would most effectively and efficiently provide support to the design process in terms of assessing health and safety and building solutions into the product

- Suggesting systems for maximising the take-up of the support material and keeping it up to date.

5.1.3 Understanding the education of the design team

To gain an understanding of the weight given to health and safety in the training and education of the designers and project managers in agricultural engineering. It is expected that this will include:

- An understanding of the attitudes that major educational establishments adopt towards health and safety in the design process

- An evaluation of the actual level of health and safety awareness training, including human factors, that is built into agricultural engineering and engineering management college courses.

- An understanding of the on-job training that is provided to those who are given responsibility for health and safety issues within the design teams.

5.1.4 Finding support solutions for use in education and training

To establish what type of support material and systems would be most helpful and effective for the educational establishments training people in the agricultural engineering design process by:

- Understanding what type of support material the educational establishments would like and what would be most effective in increasing health and safety awareness at the educational stage

- Understanding what systems would be most useful to these educational establishments in terms of supporting them with advice and up to date information

- Broadly specifying the format of support material for colleges that would offer the most immediate and efficient method of increasing health and safety awareness in design.

5.2 POTENTIAL NEED FOR FURTHER RESEARCH

The research detailed above is to define the issues and outline potential solutions, that is to set the framework for the development and implementation of solutions. The specification, development, production and implementation of these support solutions is not part of this project. Dependent on the outcome of this research project such specification etc. would be the subject of separate research. However, it is expected that this research would seek to:

- Encourage and aid designers in adopting human factors and safety as part of the functional design process from conception of the design of the product

- Encourage and aid designers to consider safety taking into account human behaviour, constraints and limitations, strengths and ability to adapt, physical and psychological, i.e. to adopt a human factors approach to design in order to consider all real life situations and risks

- Provide relevant, effective and easy to use support material and/or courses to be incorporated into agricultural engineering design training and education.

6. METHODOLOGY

The methodology can be separated into three stages:

1. Investigation of the agricultural engineering design culture.

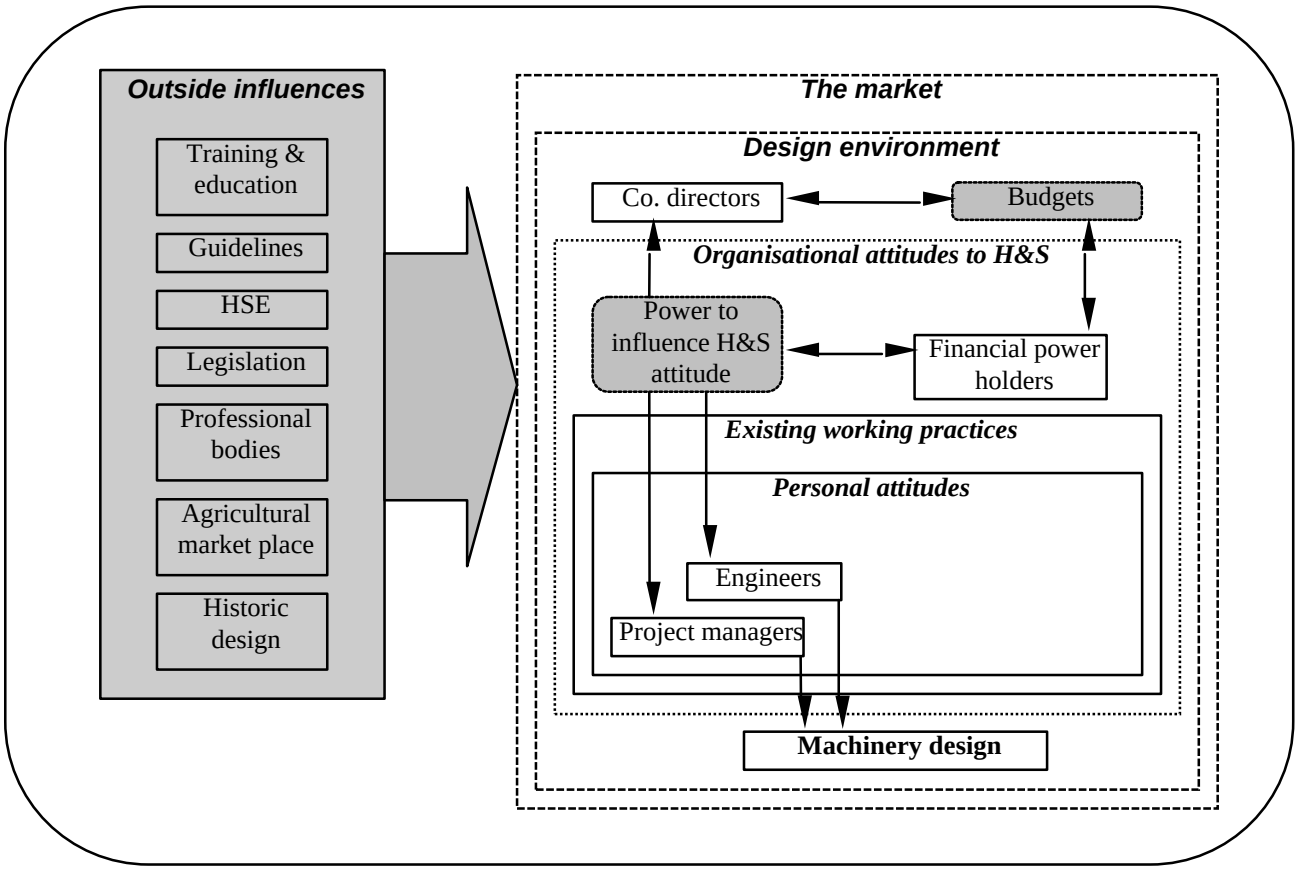
2. Investigation of the education and training of agricultural design engineers.

3. An appraisal of these investigations in order to find solutions to changing the design culture.

6.1 INVESTIGATION OF THE AGRICULTURAL ENGINEERING DESIGN CULTURE

The design culture is defined as the attitudes and traditions of all the people involved in the agricultural engineering design process, and the influences which affect those attitudes and traditions. For the purposes of this project, the design culture will include only those aspects which have a bearing on the implementation of human factors and health and safety in the design process. These relevant aspects of the design culture are illustrated in figure 1 below.

Figure 1: Design culture



To fully understand the agricultural engineering design culture a series of investigations, studies and reviews are proposed. These include:

- A brief review of the history of agricultural engineering design and it's relationship with human factors. This is perceived to be important in that it sets the scene within which the current design culture has developed and the extent by which historic factors constrain current design.

- A brief review of the agricultural market place for machinery. The agricultural market place has characteristics which influence and in some cases will constrain or limit the potential for new, novel or innovative design and these need to be acknowledged in this study.

- Surveys of the agricultural engineering design industry and it's designers. These surveys supported by desk studies and reviews to ensure their effective implementation.

6.2 INVESTIGATING THE EDUCATION AND TRAINING OF DESIGNERS

This investigation comprises interviews with Course Directors/Lecturers delivering relevant courses to agricultural design engineers.

6.3 APPRAISAL OF THE INVESTIGATIONS - CONCLUSIONS AND RECOMMENDATIONS

This appraisal considers and draws together the investigations described above and their outcomes in order to find ways of increasing the use of human factors and the presence of health and safety in the design process. In order to provide a context for appraisal an outline of the human factors which have to be considered in the design process is provided. This serves to compare the current input of human factors into agricultural engineering design to that which is required for improvement in safety performance. It is however not intended to be a human factors design manual and falls short of this since that is outside of the brief of this research.

7. THE RESEARCH

7.1 A REVIEW OF THE HISTORY OF AGRICULTURAL ENGINEERING DESIGN

Agricultural work has been studied since man first tilled the soil. In Saxon times the imperial measure of land area (the acre) was derived from the area of land that a team of oxen could plough in a day. Some teams of oxen ploughed differing sizes of area, the size of the acre varied, work measurement as an economic measure had been introduced. But, increases in the area ploughed due to modified types of plough, which included ergonomic changes to the man-plough interface, for example, heights, shapes and widths of handles, were method improvement. Workers, using the plough, modified its interface to better fit themselves, but at the same time, and within the same process of improvement, they also modified the equipment to be more efficient in its own function. Human factors and machine were one integral function of design.

The evolution of farming equipment and methods throughout the nineteenth and for at least the first part of the twentieth century was very much driven by those working in the industry, the farmers and the farm workers. Designs for hand tools were related to their use, hand tools for digging drains or cutting hedges were formed and shaped to fit the needs of both the job and the person doing the job. A visit to an agricultural museum will show the variety of special shapes of handle and blades designed to meet specific purposes in ditch or drain formation, cultivation, seeding, harvesting and storing. Many of these designs for hand tools still remain in use.

Similarly the development of mechanised equipment was also farm and worker driven and a close relationship with the needs of the people using this equipment was maintained. This relationship can be seen to have been maintained up to the beginning of what might be described as the second agricultural revolution which followed the Second World War. The designs of Harry Ferguson, for example, for trailer hitching were driven by the need for human interaction and maintained a sympathy with human factors. Leaf sprung seating and contoured seats on early Fordson tractors provided a level of comfort and ride free from low level vibration which it has taken many years of research, test rigs and endless trials to achieve in more sophisticated tractor environments. Arguably higher levels of comfort were not achieved until the advent of the JCB Fastrac Tractor with it's full independent suspension.

The boom in agriculture following the Second World War, caused by the drive for greater self sufficiency in food, called forward the need for greater levels of investment in agriculture and in supporting industry, not the least in the area of mechanisation. Whilst the requirements of agriculture drove the development of the equipment and funded its' development, inevitably the close ties between the user and the development/manufacturing environment were stretched. Development and manufacture moved increasingly away from the user and the on farm environment. In this process there has undoubtedly and unfortunately been a reduction in the human factors input to design. Designers and users became separate and independent. The inevitable result has been that design has become, in general, less sympathetic to the needs of the people using the equipment, hands on ergonomics in design fell by the way side. In turn this resulted in an increased chance of accidents occurring, or design being such that, the fit with human needs is poor leading to health problems such as repetitive strain or low back pain.

Despite the severance of design from use, perhaps not surprisingly, the historical roots of agriculture engineering design have been carried forward in the designs in use today. This has resulted in embedded design which, just as with the querty keyboard, is mostly impossible to change because it is a fundamental of historic designs. The classic example in agriculture is that predominantly implements are pulled or 'drawn', a phenomenon derived from horse and oxen power. However, for many tasks employing horse and oxen, man rode on the equipment, or walked behind it, that is the task lay in front of them. The advent of tractors, the adaptation of horse drawn equipment to use with these tractors, saw man sitting on the tractor with the task mostly lying behind them, but with forward direction of travel. Man watches the task behind whilst traveling forward, fundamentally poor design waiting for an accident to happen. In addition some of the original good designs have been carried forward into new equipment where they do not necessarily well fit, the Ferguson tractor/trailer hitch may be a case in point. Originally designed for use with a small low horse power tractor, it has become part of the design culture and subsequently used less successfully on much larger and powerful modern tractors, despite efforts to modify the design to fit these.

Existing designs do therefore, in many situations, determine and limit the level of improvement which can be achieved in the design of new machinery and equipment. This should not however, be an excuse for unsafe design, but a factor to be addressed in the process of producing safe designs.

7.2 THE AGRICULTURAL MARKET PLACE FOR MACHINERY

A major influence on the design effort put into health and safety in agricultural engineering has to be the market place for the end product. If the market demands a high level of safety in machinery supplied then suppliers will compete to meet these demands. Providing "safer" equipment than their competitors will provide additional features and benefits which will mean that farmers either pay more or choose the "safer" equipment, if competitive products are

priced at the same levels. Conversely, if the market does not perceive an advantage from safer machinery, it is unlikely to pay more or to choose on the basis of greater safety at the same cost.

Safety is only one of many elements contributing to the utility derived from the acquisition of new equipment. The utility gained from the acquisition of a new machine will include, not only the potential improvements in machine productivity and/or lower maintenance, but also, for example, the need to defray taxable income in a high profit year. Additional utility will derive from being seen by farmer neighbours to be successful as a result of having the latest tractor, the pleasure of owning and using the latest equipment, and retaining good workers, "toys for the boys".

Human factors may in some cases hold a high rank in the process of choosing, but most likely only where they directly enhance performance in a positive demonstrable way, i.e. greater input from the same labour input, the same output from less labour, or both greater output and lower input. Human factors providing safer working environment, just as health and safety in itself, is unlikely to be seen to provide positive benefit in performance. The benefit they provide in preventing traumatic accidents or disablement long term, is a matter of discounting the financial risk. Arguably in agriculture this is heavily discounted.

In the pecking order of utility in agriculture, health and safety is towards the lower end, if not the bottom. To complement any improvement in the role of health and safety in the agricultural engineering design culture there will be a need to raise its' level of utility in the market place.

The agricultural market in the UK is also substantially varied and in a number ways. For many suppliers it is also only a small part of their global market place, whilst for others it will be their marketplace.

There are some 200,000 holdings in the UK registered as having agricultural land. At least 100,000 of these can be considered as inconsequential in agricultural production terms. Whereas less than 20,000 are considered to be significant producers. Within these farms the levels of mechanisation are substantially varied and the annual spend on machinery replacement varies from, as low as a few hundreds of £s, to tens of thousands of £s. The ADAS Farmers Voice Survey 1999 shows that farmers' average annual spend on machinery replacement over the period 1990 to 1997 ranged from £0 to ££750,000. [Based on 2,500 respondents across England and Wales stratified by farm type and size]

Farm type and size are important variables in the level of mechanisation and the frequency of replacement, for example, beef and sheep farmers have lower levels than large scale arable farmers.

The pattern and frequency of replacement is yet another variable. A major factor in machine replacement is farm profitability and its relationship with taxation. A profitable farming year will call forward new machinery. The decision process is strongly financial, but closely related to taxation.

These on farm drivers for new machinery cause the suppliers considerable difficulty in planning design and production. The modern market place is considerably volatile since it is heavily linked to profitability. In a depressed market, which largely describes UK agriculture at the present time, introducing safer designs, and selling them, because they are safer will be difficult.

7.3 INVESTIGATION OF AGRICULTURAL DESIGN ENVIRONMENTS

It was determined that this should be conducted in two stages:

- A semi-structured telephone interview of 30 machinery manufacturers
- Face to face interviews with 9 machinery manufacturers to explore design issues in greater depth, building on the telephone interviews.

In preparation for the telephone interviews several preliminary researches, desk studies and expert discussion were required. These were to facilitate the interview process and ensure that the information elicited met the objectives and needs of the project.

7.3.1 Understanding the design environment

It was recognised that the health and safety culture within a Company would depend on a range of issues associated with the structure of the Company. The experience of ADAS colleagues, themselves agricultural engineers, was drawn upon to assist in this. Three primary factors were identified:

- The size of Company
- The type of machinery/equipment produced
- Whether a UK only Company or UK subsidiary/plant of a multi-national.

Secondary influences were expected to concern membership of professional bodies, education and experience.

In respect of size, Companies were classified as small, medium and large. Essentially using number of employees as a basis but where appropriate reflecting the number of units produced. It was difficult to make this a precise science. A further category concerned Companies where the parent Company was based outside of the UK but there was a base of designers within the UK.

7.3.2 Identifying the target population for the telephone interviews

Four sources were identified and used to provide a "population" of agricultural engineering manufacturers/designers:

1. The Electronic Yellow Pages listing for "Agricultural Engineers".

2. The Association of Agricultural Engineers membership database.

3. Internet - Company Web Pages.

4. ADAS contacts within the industry.

Having assembled details from these sources, the Company information was filtered to remove suppliers and importers. The aim was to achieve a database of designers and manufacturers. Subsequent contacts in the telephone interviews proved that this exercise was successful. Drawing together the sources of information, the database was then sorted into product groupings and Company size. This was important so that the interviews could be targeted to a representative sample of the population of 180 designers/manufacturers who had been identified. Being able to compare the design environments between size/products groups was not the intention since the number to be interviewed within these groups was too small to

achieve this comparison. However, the commentary on the individual results does refer to these variables where appropriate.

7.3.3 Telephone interview question design

The style of questioning and method of eliciting the required information was a matter of considerable discussion and concern. Asking questions directly about the consideration and input into health and safety was expected to obtain a result that overstated the priority given to health and safety in design. However, unless the issues were raised it was uncertain as to what information concerning health and safety would be called forward. The alternative, and arguably the preferred method, of asking detailed questions about the whole of the design process had to be ruled out since such a survey would have exceeded what could be reasonably expected within the time constraints of a telephone survey.

Moreover, to design such a survey would require preliminary qualitative researches to fully define the elements of the design process. It was therefore decided that the telephone survey had to 'lead' interviewees into the role of health and safety in design.

The questionnaire used for these interviews is at Appendix 1. The intention was that the interviews should not last longer than 30 minutes, although this was always at the discretion of the interviewee. None of the interviewees foreclosed on the interview before completing it in full, although, as will be seen, some did not answer all of the questions.

The subject matter was introduced and with the interviewees agreement was recorded on tape, on the understanding that these recordings would be erased after checking the interviews. The questions led into the evaluation of risk and the stage in the process that risk and health and safety is considered. This leads into human factors issues. Responses are pre-coded where appropriate and open comments were elicited.

Two issues required development to facilitate the interviewing process:

- Identification of the existing health and safety support material currently available to designers; and
- Hypothesising the potential for the development of new support material.

A thorough search was conducted to find existing sources of support material. The source and format of the support was noted. A copy of the list of sources is at Question 5 in Appendix 1. This allowed a prepared list to be offered to interviewees in order to find out which of these sources designers used or were aware.

As noted above this approach is likely to lead designers, that is, if offered a list then there is likely to be higher use recorded than if, they are asked "what support materials do you use" without the benefit of prompts.

The list of existing sources was also used to develop a schedule of potential information sources (Question 6 at Appendix 1), that could be offered to designers to assist in producing safer designs and carrying out risk assessments as follows:

1. Reference list of relevant material

2. Regular updates of current and projected legislation/standards

3. 1 or 2 day training courses on designing out risk

4. Internet site listing current information and research

5. Source book of case studies where design had led to injury

6. Source book of design ideas for treating risk

7. Source book of components for safety and specification for use

8. Help contact at HSE for treating design issues as they arise

9. Interpretation of the legislation for their specific machinery

10. An open response to draw forward other ideas.

In addition comments were elicited on all of these potential sources. Interviewees were asked which would be of most value and also to rank their first, second and third preference.

7.3.4 Telephone interview process

The telephone interviews were conducted using a Computer Aided Telephone Interview System (CATI), specifically developed in Microsoft ACCESS, feeding data directly into the associated database. This avoided the need for separate data entry. Basic date verification was built into the program. CATI enables continuous monitoring of the returns allowing important issues to be identified and changes to be built into the program for subsequent interviews. Using CATI for such a small sample was expensive in design costs. CATI is not usually associated with small samples, in this case 30, but is normally used where several thousand interviews are undertaken. It was however considered that the additional benefits justified the overhead of designing the CATI system.

7.4 SUMMARY OF THE TELEPHONE INTERVIEWS

This summary includes open ended comments made by respondents and the views of the interviewer recorded at the end of the telephone interview as well as providing a summary of the interpretations given to the individual questions.

7.4.1 The sample

Interviews were conducted with 30 Companies representing a range of products and business size. Eight of the Companies employed less than 10, seven between 11 and 30, six between 30 and 50 and five over 90 employees. The number of machines produced ranged from 10 per year to 1500, but this reflects machine value as well as business size i.e. low value producers manufactured more expensive machinery. Nearly 80% of production was supplied to the UK market. On the basis of this small sample it was not possible to discern differences in response relating to business size or product.

7.4.2 Evaluating risk

About half of those responding claim to have a systematic method for assessing risk. Company size does not appear to influence the process of evaluating risk. Risk is assessed at various stages in the design process. About half claim to assess risk at the concept stage and 60% did so at the modeling stage. However, nine do not begin to assess risk until the final production stages, basically too late in the design process to do other than take measures such as adding guards. Six of the respondents claim to assess risk at all five design stages given. All of them

may not have knowledge in sufficient depth to produce safe designs from concept. This is supported by half of those responding having to make modifications to their designs at a late stage in the design process.

Overall the evidence is that, those who do endeavour to assess risk early in the design process, reduce problems at later stages. Their machines may be inherently safer. It follows that improving the risk assessment process and the knowledge required in this would lead to fewer problems and potentially safer machinery. Currently designers are not using task analysis, user trials or applying ergonomic principals. To a large extent the risk assessment process would appear to be naive, largely because of a lack of formal training.

7.4.3 Sources of information used

The use of existing sources of information was relatively low. Out of the 30 respondents, 10 had not used any of the 31 sources listed. Apart from one Company who had used or were aware of 20 of the sources, four had used nine only. In respect of human factors sources e.g. CEN Ergonomics in Safety of Machinery Standards under Development, the maximum use was by one respondent. There was concern that there was confusion between standards, apparently requiring different outcomes.

It appeared that designers who were members of professional associations relied upon these as an important source of information. Those who did not use this route for information may not be well informed of legislation. Some felt isolated in the process of risk assessment.

7.4.4 Potential information sources

These were all well received. Most favoured were a ‘detailed reference list of relevant material’ on paper, CD-Rom or internet. Also, highly favoured were regular updates and a help contact at HSE. Training courses also received considerable interest. However, those Companies with few employees indicated that they did not have time to make use of these support ideas. This poses a considerable problem, since these are likely to be in the greatest need of support.

7.4.5 Preferred standards

On a majority basis EU standards were preferred and a common standard would be welcome. There was not much hope that this could be achieved however, since it was expected that even a common standard would be liable to individual interpretation. Current EU standards were considered to have been developed to the advantage of French/German designers, because they were derived from their designs. This was to the disadvantage of UK design. However, there was no evidence that designers had made any effort themselves to promote their own ideas on design to the EU. Therefore, it is not surprising if French/German designs are advantaged.

7.4.6 Training of designers

Formal training prior to employment was mostly at Agricultural Colleges or Universities. However, many had gained their knowledge and experience from doing the design job. Continuing professional development was minimal and confined to ‘on the job training’. None had had formal training in risk assessment and specific human factors training appeared to be non existent.

7.4.7 Responsibility for safety in use

The view held by about half of respondents was that this was the responsibility of designers. A further 35% considered it was a joint responsibility. There was a general recognition that the safety culture in agriculture was poor.

7.4.8 Training of users

Most felt that this was a lost cause and was ineffectual. It was also recognised that instruction manuals would not be read.

7.4.9 The burden of risk assessment

There was a mixed response on this, just under 20% thought the burden was small and slightly less considered it an integral part of design not creating a great burden. At the other end of the scale 30% thought the burden was substantial and too great in relation to the benefit. The remaining 11 considered the burden was substantial but an essential integrated part of the design process.

7.4.10 Obstacles to risk assessment

Approximately two-thirds of those responding were unsure of what was required to carry out a thorough risk assessment. This was because of the problems perceived in interpreting legislation, so called grey areas and lack of knowledge. The perceived objective of risk assessment is to meet legal requirements likely to be to the detriment of producing inherently safe designs. The problem of having to undertake the burden of recording the assessment was raised by many of those responding. Recording the assessment of risk needs to be seen as valuable in itself, not just as a record of having assessed risk. Carrying out a task analysis as part of the design process would meet this need.

7.4.11 Responsibility for resource allocation

In over 80% of the Companies the final responsibility over the amount of resources applied to risk lay with the owner or Managing Director. In some cases the Managing Director and designer is the same person, but notwithstanding the amount of resources committed to risk assessment it is a financial decision.

7.4.12 Attitude of management to health and safety

A full range of attitudes exist, about 20% are very positive, recognising the need for a high standard of health and safety. However, 20% also take the opposite view, seeing health and safety as an expensive burden, achieving little in terms of improved design. Between these extremes there are indications of tolerance, but not much understanding. Company size does not seem to influence opinion.

7.5 TABULATED RESULTS OF THE TELEPHONE INTERVIEWS

Tabulated results of all the responses to the telephone interviews are presented in this section of the report. The results are supported by comment and interpretation on a question by question basis. In some cases all respondents did not answer a question, where this occurs the table or supporting text shows the number responding.

Table 1: Number of employees

	No.	%	Company ID
1-5	5	19	9, 20, 40, 82, 100
6-10	3	11	29, 73, 112
11-20	4	15	63, 65, 117, 181
21-30	3	11	42, 128, 183
30-50	6	22	58, 77, 97, 101, 179, 187
>90	5	19	37, 60, 182, 186, 191
Total	**27**	**100**	

On a number of employees basis the manufacturers interviewed represent a spread of Company size covering the industry. Three of those interviewed did not provide details of their workforce, perceiving this to be sensitive information.

Table 2: Proportion of customers

	Mean %
UK	79
EU	10
Worldwide	11
Total	**27**

Manufacturers predominantly supplied the UK market, this is important in the context of this study.

Table 3: Number of machines produced each year

	No.	%	Company ID
1-99	11	48	20, 29, 40, 42, 62, 77, 84, 112, 182, 183, 187
100-499	5	22	58, 100, 117, 128, 179,
500-999	3	13	60, 73, 191
>1000	4	17	37, 97, 101,186
Total	**23**	**100**	

The mean number of machines produced was 328. Specialist low volume producers accounted for 43% of the market. Unfortunately not all interviewees were prepared to give information on the number of machines produced each year, only 23 responded to this question.

Table 4 shows the details of the type of machinery produced. Twenty seven of the 30 interviewed gave these details, 3 were not specific about what they made. To provide a picture of the scale of production involved the number of units produced by manufacturer per year is shown where this was provided. The number of units produced ranges from 10, sugar beet harvesters and custom built one offs, to 1500.

Most of those interviewed produced equipment to be attached to tractors, with the exception of those producing sugar beet and tomato harvesters and those producing self propelled sprayers. The range of trailed equipment produced by those interviewed is comprehensive covering most farm activities and providing a good spread of this type of machinery design. Vegetable grading equipment, where there is a high level of human interaction, is also represented in the survey.

Table 4: Type of machinery produced

Question 17: Product lines

ID	Units	Products
9		Forestry machinery
20	10	Sugar beet harvesters
29	55	Cleaner/loader for sugar beet harvesters, custom designs, tomato harvesters
37	1200	All vegetable handling, grading, transport and cleaning equipment
40	10	Custom built one-off specialist equipment
42	20	Tractor base units, spreaders, slurry tanks, cereal and maize drills
49		A range of agricultural equipment
58	450	Sprayers (trailed/powered) and cultivators
60	500	Feeding machinery/chopping bedding
62	65	Sprayers and some one-off custom designs
63		Custom designs and sprayer equipment
65		Grain processing and handling equipment
73	500	Front linkages, PTO systems, packers
77	60	Muck spreaders, bale handling equipment
79		A range of agricultural equipment
84	30	Custom built agricultural. machinery
97	1500	Custom items e.g. onion topping and harvesting equipment, repairs and updates
100	100	Balers and bale wrapping equipment
101	1500	Horticultural, grain dryers, grass management and tillage equipment
112	45	Most types of agricultural equipment
117	100	Trailers, attachments, and self-propelled machinery
128	400	Cultivation machinery
179	150	Grain dryers, milling and mixing equipment, threshing equipment
181		Assessments done for custom engineering
182	60	Flail hedge cutters, front-end loaders, cultivators
183	15	Bale handlers, saw benches, silage and cultivation equipment
186	1100	Ploughs and cultivation equipment
187	50	Post harvest machinery
188		A range of agricultural equipment
191	550	Cultivation and crop establishment equipment, earth moving equipment

Table 5: Methods for evaluating risk

Question 1: Do you adopt systematic methods for evaluating the risks and hazards of a piece of machinery you are designing or modifying?

ID	Comments
9	Yes but no formal written system.
20	No structured system.
29	Yes, but not well documented.
37	Yes - based on own system.
40	No systematic recording, the assessment is done in a haphazard way.
42	None at present.
49	Self certify to Machinery Directive standards. Have safety groups who meet to discuss safety issues.
58	Little and not systematic.
60	Follow flow chart from BS standards at final product stage.
62	Not really systematic - common sense - not recorded.
63	Very little formalised risk assessment.
65	Yes - use formal methods.
73	Just look at it generally - no documents.
77	Work to Machinery Directive standards.
79	Work to Machinery Directive.
84	Work to Machinery Directive. No records kept, just done by looking/thinking about it.
97	Own common sense but quite formalised and thorough, including documenting the assessment.
100	Not yet but will be doing so for imported foreign machinery.
101	Assess imported American products or old products.
112	None.
117	About to (for ISO 9000).
128	Own system, to Machinery Directive.
179	Outside consultant 3-6 months a year.
181	Yes, work to Machinery Directive.
182	Yes, involve a large number of departments in the process.
183	Yes.
186	Yes, but not formally structured.
187	Yes, HSE visit as part of the system.
188	Yes, they do complete 1 year field trials.
191	Only in a crude form. Do as many issues as possible. External HSE consultant employed.

All 30 interviewees responded to Question 1. Eleven of the respondents (37%) did not have a system at all or it was not systematic or recorded. Six stated they worked to the Machinery Directive. Four of those who had a system said that there were limitations to what they did. Interestingly one of the respondents indicated that the HSE visited as part of the process, suggesting that the relationship between HSE and agricultural machinery manufacturers varies geographically. Taking these responses overall it would seem reasonable to conclude that about half claim to have a systematic method for evaluating risk. The size of the Company either measured by number of employees or number of units produced does not appear to influence the process of evaluating risk.

This result does not shed much light on the quality or validity of their systems. However, methods of risk assessment which are not properly structured, systematic or based on task analysis are unlikely to consistently identify 100% of potential problems.

Table 6: Design stages when risk assessment carried out

Question 2: At what stages in the design process does an assessment of potential risks to people generally occur?

Stage	No.	%*
Concept/sketches	16	53
Modeling/drafting	18	60
Prototype	23	77
Final product	17	57
Production	10	33

* Based on total of 30 responses

In this case (Table 6) interviewees could indicate that they did the assessment at more than one stage in the design process. However the number recorded in each stage is out of the 30 responding to the question. Just over half (16) claimed to consider risk at the concept stage of the design process, one (ID 9 - forestry equipment) assessed risk only at the concept stage. All of those assessing risk at the concept stage, with the exception of ID 9, also assessed risk at the modeling stage and 3 others joined them in this, making 60% assessing risk at the modeling stage. Two did not assess risk after the modeling stage. Seven first begin to assess risk at the prototype stage and were joined by 16 others who assess risk at an earlier stage, making 77% assessing risk at the prototype stage. One more respondent starts to assess risk at the final product stage and another does not assess risk until the equipment is in production

It is a disturbing fact that nine designers/manufacturers (30%) do not begin to assess risk until the final production stages, basically too late in the process to do other than take measures such as adding guards. At this stage far too late to produce inherently safer designs taking into account human factors. Whereas, the fact that nine do not assess risk until the late stages of production may be strong evidence that they cannot have incorporated human factors and safety in their designs, it does not follow that those who claim to assess risk at earlier stages produce inherently safer designs. This must depend on the knowledge of human factors which has been applied. Similarly the six who assess risk at all five stages may suggest that they do not have the knowledge to design safer products from concept. It must be concluded, that the responses to this question provide an indication that there is a weakness in respect of designing safely, but leaves the scale of the problem to be determined.

There was no real difference between size of Company or product type, although those with a smaller workforce may be more likely to conduct the assessment throughout the design process than those with a larger workforce.

Table 7: Requirement to make late modifications

Question 3: Do you find that you are having to make modifications to the design of machinery at a late stage in the design process because of needing to satisfy BSI, European or HSE requirements?

Late modifications	No.	%
Yes	13	50
No	13	50
Total	**26**	**100**

Four did not answer this question (Table 7). That half are having to make changes at a late stage in the design, demonstrates a lack of attention to health and safety. It is considered reasonable to suggest that these manufacturers will not have given consideration to human factors or health and safety as an integral part of the whole design process. Although 50% claim not to have to make changes at a late stage in the design, it does not follow that human factors and health and safety are an integral part of the design process. However, 9 of those who do not have to make modifications at a late stage, carry out assessment at the concept stage, the other 4 assess risk only at the prototype stage. This may suggest that the 9 assessing risk at the concept stage are producing inherently safer designs, or at least designs that meet legislation.

It is important to note the continuity in response between Questions 2 and 3, since, one only of the 13 who responded that, they did not have to make modifications at a late stage, assessed risk at the production stage, 4 more did so at the final product stage, 5 more at the prototype stage, 2 more at modeling and one, only assessed risk at the concept stage. This compares with 9 of the 13, who have to make modifications at a late stage, assessing risk at the production stage and the other 4 doing so at the final product stage. This does suggest that carrying out an assessment of risk at the earliest possible stage in the design process reduces problems arising later in the process. It also seems reasonable to conclude that, by improving the quality of the assessment, further reduction of problems could be achieved, providing a better opportunity for safer machines to be produced.

Table 8: Requirement to make late modifications - comments

Question 3: Do you find that you are having to make modifications to the design of machinery at a late stage in the design process because of needing to satisfy BSI, European or HSE requirements?

ID	Comments
9	Not so far
20	Over the years have had to add extra guarding, have a lot of old machines
29	Feedback from customers incorporated
37	Very often happens, often need to fit guards after production
49	All assessment done early in the design process
60	Do modify a lot of the time, often due to different markets
62	Never really happens
63	Standard of build too good
65	Not often but does happen, especially following feedback from customer
73	Not so far
84	Has happened in the past
97	Generally as a result of self assessment
179	Guarding, difficult to foresee
182	95% solved at prototype stage, the remainder after production
183	To keep product up to date - use feedback from users
187	HSE invited to inspect the machine before production
191	Consultant pre-warns engineers of changes/problems

Seventeen respondents commented on this question. Eleven of these respondents were from the group making modifications late in the design process. ID numbers 9, 62, 63, 65, 73 and 187 do not make late modifications and their comments in Table 8 reinforce this. There is a strong indication that some designers only think of health and safety in terms of guards. Even comments such as ‘standard of build too good’ do not imply a good health and safety culture, but rather that if the engineering is good then the view held is that there will be no problems.

Table 9: Factors taken into account in the risk assessment

Question 4: In the design process or risk assessment, do you think about?

Considerations	No.	%*
Risks when using normally	25	83
Risks during miss-use	22	73
Psychological state of the users	16	53
Physical abilities of the users	14	47

* Based on total of 30 responses - those who responded "Yes"

The considerations given in Question 4 are leading, therefore we should expect that all respondents would say 'yes' to all four statements. It can be seen that this is not the case. It is remarkable that 5 stated that they did not consider 'risk when using normally', neither did 8 during miss-use, 4 of these were the same in both cases. These 4 did not think about any of the considerations in design or assessing risk given in Table 9. This is difficult to comprehend and raises questions about the nature and quality of their risk assessments.

The response of these four to Question 1 sheds some light on this. One of the four was ID 100, Table 5 shows that they admit they do not systematically assess risk. Another was ID 49 who 'Self certify to Machinery Directive standards' and have safety groups who meet to discuss safety issues', but apparently do not address the vital issues asked in Question 4. A third was ID 117 who again do not have a systematic method but are 'About to for ISO 9000'. The fourth was ID 188 who in answer to Question 1, Table 5, responded 'Yes, they do complete one year field trials'. At least the responses between questions are consistent. None of these four were making modifications late in the design process. For these four, safe design would only happen by chance not by plan.

About half of the 30 respondents to this question claim to consider the psychological state of the user and their physical ability. It seems unlikely that these claims are based on an in depth understanding of the psychological issues or anything more than superficial physical attributes of users. Given the leading nature of this question, the response indicates a lack of well considered assessment of health and safety in design, based on a sound knowledge of human factors.

In respect of Question 1-4 the interviewer commented as follows:

Importers are often unaware of the whole risk assessment process. One importer had no idea what was required when bringing equipment in from the USA. Since imports account for around 80% of machines being sold in the UK, this is of concern.

New Companies, although there are not many, are likely to be ignorant of what risk assessment is required.

Those who deal internationally would like to know the differences between UK/EU/International standards.

Most producers attempt to make their machinery 'fool-proof' but are not adopting any systematic human factors methods to do this, and so it remains rather hit and miss, i.e. they are not using task analysis, user trials, or applying ergonomic principles.

The arrival of the Machinery Directive caused an initial boost in awareness of health and safety issues in design, and many designers collected relevant information at this time. Many have kept to this level of working and have not updated their knowledge on information and legislation.

Some small Companies who are not members of an Association appear to be isolated in terms of knowing what is happening with the legislation. They are doing their 'risk assessments' simply by using 'common sense' rather than applying any systematic methods. These manufacturers need a line of communication to HSE. They are willing to take up the information and legislation, but need to have it fed to them.

Table 10: Sources of information used

Question 5: What sources of information are used (what are they aware of)?

Sources used	No.
HSE Book - Safeguarding agricultural machinery (big-92/small-98)	5
BSI standards 5304 'Safety of machinery'	7
European/BSI 'The Safety of Machinery' standard - Principles of risk assessment	8
European/BSI 'The Safety of Machinery' standard - Basic concepts	8
European/BSI 'The Safety of Machinery' standard - Safety distances upper/lower	9
European/BSI 'The Safety of Machinery' standard - Gaps to avoid crushing	9
European/BSI 'The Safety of Machinery' standard - Design & construction of guards	9
European/BSI 'The Safety of Machinery' standard - Interlocking devices	7
European/BSI 'The Safety of Machinery' standard - Emergency stop equipment	7
*CEN Safety of Machinery standards under development	*1
*CEN Ergonomics in Safety of Machinery standards under development	*1
HSE book - Application of photo-electric safety systems	1
European/BSI - Prevention of unexpected start-up	1
*European/BSI/ISO - Symbols Standards for operator controls and displays	1
European - Visual, audible and tactile signals	*0
European - Electrical equipment	0
BS - PTOs on tractors (5861)	1
BS - 3 point linkage on tractors	1
Safe use of work equipment (PUWER Guidance) 1992	9
Provision and use of work equipment regulations (PUWER) 1992/1998	7
Supply of machinery safety Regulations (1992)	4
Supply of machinery safety Regulations (1992) + amendments of 1994	3
DTI Blue book - Guidance notes on the UK Regulations (1995)	8
HSE Free Information sheets (any)	3
Safe use of combines	1
Safe use of rotary flail hedge cutters	1
Safe use of big round balers	2
Working safely near overhead power lines	2
No second chances - A farm machinery safety guide	1
Supplying new machinery	1
*Designing safety into products (free from DTI)	*1

Table 10 shows that there was relatively low usage of the information sources listed, given that anyone of the sources could have scored 30, but the maximum achieved was 9 on four occasions. Out of the 30 respondents, 10 had not used or were not aware of any source, 4 others had used only one source, 2 had used two only and 3 had only used three sources. By contrast one (ID 191) had used 20 sources, four (IDs 60, 182, 183,186) had used 9 and five (IDs 37, 49, 65, 84, 182) had used between 5 and 7.

The European/BSI series overall were most used (or highest level of awareness) but, given that they define standards, it is surprising that the level of use is so low. In fact 'surprising' understates the concern that this raises.

The use/awareness of the ergonomics/human factors information sources is nothing short of abysmal. In table 10, four sources are identified with an asterisk (*) scoring 3 hits out of a possible 120, these are all by the same respondent. In principle, the information that these sources convey are essentially those which are needed to be used, if the concept behind this project is to be successfully implemented.

It may be that the problem is lack of awareness of the existence of the sources, but given the facility to track down information sources that exists, this only provides a partial cause of this lack of use. If engineers were human factors and safety in design orientated they would have researched, found and used these sources. However, this evidence does point to the need to raise awareness of existing sources of health and safety and human factors information. In addition the status and importance of these should be reconsidered.

Commenting on this question, some respondents stated that, they have problems trying to decide what they should do when faced with so many sources, legislation and standards, because these do not always appear to reflect a common standard. It also appeared that when the Machinery Directive was introduced designers swatted up on the legislation, but had not since kept upto date.

Table 11: Potential information sources

Question 6: Which of the following would you find most useful in helping you to design safer machinery, and do a more thorough risk assessment?

Most useful	No.	%*
Detailed reference list of all relevant material to help implement legislation, standards etc.	26	87
Regular updates on the current and projected legislation and standards	24	80
Short 1-2 day training courses on designing out risk from machinery	21	70
An internet site which lists all current available information and research	28	93
A source book of case studies where certain designs have led to injury	20	67
A source book of design ideas for dealing with different risks, to stimulate invention	17	57
A source book of components for safety and their specifications for use	15	50
A help contact at HSE for dealing with specific design issues as they arise	24	80
Interpretation of the legislation for their specific machinery	22	73
Other	7	23

* Based on total of 30 responses

All of the potential sources of information presented found substantial support (Table 11). Most favoured were a “detailed reference list of relevant material” and an “internet site listing current information”. These are very similar, basically differing only in the means of access. Also, highly favoured were “regular updates” and a “help contact at HSE to deal with specific design issues”. Importantly there was considerable interest (70%) in short courses, indicating a commitment to increasing knowledge, and to a “source book of case studies”. Four of the respondents considered all 9 of the potential sources listed to be useful and a further 9 regarded all bar one as useful. Five others considered at least 6 of these potential sources to be useful.

On the negative side one respondent, ID 188, did not perceive any of these potential sources as useful, it is worth noting that this respondent did not use any of the existing sources of information listed in Question 5. Information about this respondent is sketchy, e.g. we do not know the size of their business or real information about their product. Three respondents were only interested in 3 of the potential sources.

Seven ‘other’ sources are recorded in the Table, these are in fact comments rather than additional sources, they all reiterate those services listed, with the exception that three raised the issues of wanting assistance in the process of design from HSE. A discussion forum on the internet was suggested in order to share problems in risk assessment.

Some of the smaller Companies were too rushed off their feet to be interested in the support ideas. They felt that they carried out suitable assessments and designed to a sufficient standard. This type of culture is not likely to take up the support systems unless they perceive that it has instant appeal to them.

A consistent approach is required across the country in dealing with risk issues that designers have. HSE needs to be able to provide as much interpretation and help as possible without

entering legal problems. The only people who would not use an HSE contact are the ones who use an outside expert to do their risk assessments. Otherwise, this is a very important point of support, especially for the smaller producers.

Overall the ideas put forward as potential sources of information found considerable favour. These results suggest that if sources of information were perceived to be more useful, pertinent and beneficial, and promoted to the industry, then they would be used in the design process. This is an encouraging response.

Table 12: Potential information sources - preferences

Question 6: Which of the following would you find most useful in helping you to design safer machinery, and do a more thorough risk assessment?

	1st	2nd	3rd	Score
Detailed reference list of all relevant material to help implement legislation, standards etc.	7	4	2	31
Regular updates on the current and projected legislation and standards	3	3	6	21
Short 1-2 day training courses on designing out risk from machinery	3	4	4	21
An internet site which lists all current available information and research	6	2	7	29
A source book of case studies where certain designs have led to injury	0	1	3	5
A source book of design ideas for dealing with different risks, to stimulate invention	0	0	0	0
A source book of components for safety and their specifications for use	0	0	1	1
A help contact at HSE for dealing with specific design issues as they arise	4	9	2	32
Interpretation of the legislation for their specific machinery	4	2	1	17
Other	0	2	0	4

Table 12 shows the ranking of the perceived usefulness of the potential sources offered. A score has also been produced, this accommodates the value of each of the 3 positions by attributing a score of 3 to first preference, 2 to the second and 1 to the third. This shows that the highest preference goes to a “help contact at HSE”, closely followed by the detailed reference list and “internet site”. Regular updates, short courses and interpretation of legislation score well. On the basis of providing the industry with what it says it wants these are all strong runners.

Table 13: Comments on potential information sources

Question 6: Which of the following would you find useful in helping you to design safer machinery, and do a more thorough risk assessment?

ID	Comments
29	HSE person helped at prototype stage. AEA information tends to be non-specific. Short course, maybe in the future. Case studies would be useful to explain legislation. Lists of testing procedures for specific equipment.
37	Need support.
40	Want agricultural specific information. Want known differences between EU/UK and international standards.
42	More detail as to what is specific risk and what needs to be provided. If a source book of ideas was produced then this would force them to read it to remain competitive.
49	Prefer hard copy. Updates to outline specific changes. More consultation.
58	Get updates from their branch in Holland.
62	Implementation of new legislation is too rapid, need open discussion of implications first.
63	Course/case studies/design ideas not interesting unless specific to own products. Electronic searchable format would be good.
65	Need national co-ordination. Need expert in agricultural engineering legislation.
77	Don't really want any form of help.
79	HSE didn't want to know about his guarding problems.
84	Want HSE to be a discussion forum.
100	Do work with local HSE representative.
128	Very unfair with EU competition.
179	Would like accident reports.
181	Help contact at HSE needs national co-ordination because currently there is great regional variation. Need to be able to get just the information we need, not everything which is available.
182	AEA provides much of their information.
183	Case studies, more for new assessors, use to support explanation of legislation
186	Would like information to come from HSE. Would like HSE to inspect and certify machinery.
188	European machinery often falling short of UK standards. Use their own consultant so don't need additional help. Unlevel playing field in Europe.

Table 13 contains the comments made in response to Question 6. These support rather than add to the quantitative responses. A number of respondent, either directly or by inference, raise the issue of varying standards between UK and Europe, perceived to be to the disadvantage of UK manufacturers. The need for closer working relationships and assistance with HSE features strongly in the comments. There is apparent disparity between geographic regions in the level

of help currently perceived to be available to them from HSE. There is a wish among some to shift the burden of safe design onto HSE. Overall the need for better and targeted information provision is highlighted. Unfortunately, but not surprisingly, none raise the need for better or any information on human factors, on the contrary comments, such as that provided by ID 63, that 'information is not of value unless it is specific to their product' indicates a lack of appreciation that sound knowledge of human factors and health and safety are applicable to all design situations.

Table 14: Preferred standards

Question 8: Which would you prefer to work to?

	No.	%
EU standards	15	63
International standards	9	38
Total	**24**	**100**

Not all interviewees chose to answer Question 8 since they apparently had no strong view either way. On a majority basis EU standards are preferred, but the driver is the manufacturers market place. Some respondents commented as here under.

- Even if there was an international standard, it would be interpreted differently in different countries anyway, and would be more of a nightmare to interpret.
- The lack of a level playing field between the EU and UK means that risk assessment is held back to the minimum by a need to remain competitive with EU producers.
- The Machine Directive seems to be developed to the advantage of the French/German designers, because they are based on French/German designs, without considering UK design. This creates great problems for UK designers.

Concerning this last comment, which was made by several interviewees during the course of the interview, it appeared that none of these designers were involving themselves in the process of setting EU standards. They did not seem to appreciate that unless they represented their views on design standards then the views of others would prevail. It is understood that attendance by UK designers at EU standards meetings is at best poor.

Table 15: Preferred standards - comments

Question 8: Which would you prefer to work to?.

ID	Comments
9	International likely to be more complex.
20	Do sell abroad so international.
29	Nice to have one standard - needs harmonisation.
37	Majority of work is EU.
40	Whatever is easiest.
49	Interpretation is a problem when you go international.
58	Debatable - no extra burden.
60	Problems interpreting EU standards.
62	Deal with international separately.
65	Need to know the market you are going to - international standards would still have different interpretations in different countries.
77	No common working level in EU. Danish standards seem to be very different.
79	Whatever is most relevant.
101	Because of being an importer of both EU and World-wide.
117	Depends on how easy to interpret.
179	International even more difficult to interpret plus unfairness likely to be even worse than for the EU.
181	Their international clients seem happy with the Machinery Directive standards.
182	Coordinated EU/International would be best.
183	Deal mostly with EU anyway.
186	EU seems to be the most appropriate.
191	Doesn't matter as long as fair.

The comments on standards, in Table 15, raise the requirement for harmonisation between EU and International Standards. There is a suggestion that within the EU, standards are not in common or are interpreted differently between some EU states. The problem of interpretation also exists with International Standards. A single standard must surely be the aim, although it is unlikely that this will resolve the interpretation issue. It would seem beneficial to all to simplify the position on standards.

Table 16: Location of training and type of course

Question 9: Where did members of the design team get their training and what courses did they do?

ID	Training place	Training course	Training since employment
9	Newcastle Newton Rigg	Engineering Engineering	None
20	-	Trained in house	None
29	Marconi FMC	In-house training In-house training	
37	Coventry Harper Adams	Automation engineering Mechanical engineering Agricultural engineering HND	None
40	Preston		None
42	Writtle	Agricultural course	None
49	Germany	Engineering	On-job awareness
58	College In the field	Agricultural engineering	None
60	Silsoe	Agricultural engineering	Yes - learnt to use own assessment system to meet Machinery Directive
62		Apprenticeship HNC	None
63		Engineering apprenticeship	None
65	TEC college	City and Guilds engineering	None
73	Harper Adams Writtle	Agricultural engineering Agricultural engineering	None
77	Experience		
79	Experience		None
84	Hereford	Agricultural engineering	None
97	Self trained		
101	Harper Adams Silsoe Rycotewood Lackham	Marketing/agriculture. Agricultural engineering	None
117	Writtle	Agricultural engineering	
128	Bishop-Burton Kaythorpe	Agricultural engineering	None
179	Silsoe In-house experience	Agricultural engineering	One chap has had full in-house training in agricultural design.
181	West of Scotland	National diploma in engineering Open University BA	None
182		HND degrees	None
183	Writtle Harper Adams	BSc Agricultural engineering HND	None
186	Harper Adams	Agricultural engineering	Few have been trained in assessment
187	Writtle	Agricultural engineering	None
191	Silso x3 Rycote Wood Grantham	Agricultural engineering	None

Twenty seven respondents answered Question 9 (Table 16). Most working in the industry received their training at Agricultural Colleges or Universities either as part of an agricultural course or more specifically in agricultural engineering. There are none who have identified a human factors background.

A number have developed their skills and experience from 'doing the job' supported by colleagues and, for example, HND and City and Guilds training. Other than by on the job experience there is very little evidence of training since employment or continuing professional development.

What makes this of concern is that design in these Companies will have become a closed system/process with limited exposure to new ideas or concepts to break the mode, other than functional improvement of the machine, driven by customer demand. Combined with the lack of use of information sources this would seem to be a serious problem, needing to be addressed if human factors are to be introduced to improve safety in the design process.

The emphasis in the responses in Table 17 is that the prime responsibility lies with designers, a view held by approximately half of the respondents. Taking into account those who believe it is a joint responsibility about 85% recognise the essential role of the designers. Two identify a "user-centred" approach to design. The others appear to imply greater responsibility on the user or that it is a matter of cost. This is a good response in terms of the objectives of the project, in that in principle the concept of providing safe design is recognised. However, the issue of having the appropriate knowledge, training and application to achieve this remains.

Table 17: Responsibility for safety in use

Question 11: Do you feel it is the responsibility of the user to use the machinery carefully, or the responsibility of the designers to make it difficult to use the machinery unsafely?

ID	Comments
9	Joint 50/50
20	Must be easy to use as possible i.e. designer responsibility
29	Designers responsibility but user must be sensible
37	Onus on user to be careful but must design for brainless
40	If designer cannot make the machine in an economical way then it can't be made at all, so there is a limit to the assessment possible
42	Joint
49	Not practical to design out all of the problems
58	50/50 responsibility
60	Joint responsibility
62	User must take some responsibility but designer must adopt user centered design
63	Adopt a user-centred design but some responsibility must lay with the user
65	Can only go so far, but designers should go as far as they can
73	Designer and user
77	Must be designers responsibility
79	Designer responsible to Machinery Directive, then it is up to user
84	Designers responsibility
97	Operators often under pressure, so designer has high responsibility
101	Combination, feels it is possible to overprotect
112	Joint responsibility, user should be responsible when trained
117	Designers responsibility
128	Lot to do with users
179	Up to designer to make it safe. User must act responsibly
181	Joint, but it is hard to know when the assessment is sufficient
182	Joint responsibility
183	Designer has most responsibility
186	Design out identifiable hazards, i.e. work to proper risk assessment standards
187	Joint responsibility but designers need to design for "Pratts"
191	Designer has a high responsibility to design for safety

Table 18: Effectiveness of user training in respect of safe use versus safe design

Question 12: Do you believe it is more effective to train people to use machinery safely than to try and design out all the risks?

	No.	%
Yes	7	26
No	20	74
Total	27	100

The responses to this question are perhaps surprising, but are nevertheless encouraging. Three quarters believe that efforts to design out the risks will be more effective than training. It seemed to be generally recognised in comments made that the safety culture in agriculture is appalling, and that training is largely ineffectual. Most engineers realise that training of end users is ineffectual and that manuals are never read. However, as long as their legal responsibilities are met this does not cause them great concern. Given the concept behind this particular research this is evidence of a desire to design safely which can be built upon.

In respect of Question 13 (Table 19), five of the 28 responding indicate that the burden is very small, but do not qualify this. It is difficult to determine whether this is due to lack of application or because it is an integral process of design. Another four suggest the burden is not great and is part of the design process. Eight state that it is a high burden suggesting in one way or another that the burden is too great for the benefit. The remainder consider it a large but necessary burden. One of the respondents suggests that customers want functional machines and resent paying for safety features. This indicates again the unfortunate separation of function from safety both in the minds of some designers and farmers/growers. The comment "has not really changed the machinery significantly" is important. It again suggests that legislation has not changed the fundamentals of design but has overlaid existing design and design principles.

The views expressed are not dependent on the size of the business or the output in numbers of units, in other words large and small businesses can equally perceive: a high burden; that it is an essential part of design and necessary; and that it is not great.

Table 19: The burden of risk assessment

Question 13: To what extent do you feel that dealing with risk assessment of your products places a burden on your business?

ID	Comments
9	Can be 25-30% of the cost of production
20	Not great, part of the design process
29	Creates a huge burden, customer wants machine to be functional - resent paying for safety features
37	Adds a lot of time to the process plus pressure
40	Very much so
42	It is a nuisance
49	Essential, but doing any more than legislation require would be too much of a burden
58	Fairly significant burden
60	Integral part of design anyway
62	None really
63	Main problem is knowing what legislation are on the horizon
65	A very big burden
73	Not too bad
77	Does place a significant burden on the business
79	It is necessary burden
84	Does place some burden
97	Places a heavy burden compared with the competition
101	Yes, and has not really changed the machinery significantly
112	Little really
117	May not be extreme
128	Not a great deal
179	Very high burden
181	Yes but it is necessary
182	Essential part of the design process
183	Difficult to segregate out the expense because the risk assessment is very integrated
186	Documentation is the main burden
187	Necessary part of the design process not a separate issue
191	It does place a high burden but it is an essential part of the process

Table 20: Obstacles to risk assessment

Question 14: What do you find are the greatest obstacles to carrying out a thorough risk assessment on your machinery?

ID	Comments
9	Time and money and not being able to apply legislation to our machinery very easily
20	This respondent does not use the legislation enough or do enough risk assessment to suffer many obstacles! Lack of information is his greatest obstacle
29	Doing paperwork
37	Interpretation is main problem, difficult to know when a suitable assessment has been done. Safety gives no market advantage
40	Time to understand the legislation and document the process.
42	Lack of knowledge of the whole area
49	Economy of design time
58	Time constraints and interpretation
60	Time constraints, need to rush to market. Lack of information
62	No great obstacles, but recording the risk assessment is difficult because they use their expert knowledge and common sense to do assessments
63	Time scales
65	Not knowing when a suitable assessment has been achieved. Not being up to date on legislation or guidance
73	Grey areas of the legislation make most problems
77	Interpretation is biggest problem plus dealing with huge number of regulations
79	No main problems
84	Dealing with grey areas, trying to predict cost when doing assessments
97	Interpretation is main problem
100	Lack of knowledge
101	Interpretation
112	Lack of knowledge
117	None really
128	Time
179	Interpretation
181	Knowing whether you have covered everything
182	Confidence in the risk assessment which has been done, i.e. need to know that it is sufficient
183	Proper interpretation of legislation to a suitable level
186	Time and expectations of the market, interpretation
187	Knowing when the risk assessment has been done to a high enough degree
191	Time and commercial pressures

Eight of the 29 responding to Question 14 mention interpretation specifically as a problem and another 12 raise the same issue using differing terms, e.g. grey areas, need to know it is sufficient, covered everything, and knowledge. Therefore at least 20 (two thirds) are unsure about what is required to carry out a thorough risk assessment to meet legislation. This highlights a fundamental problem, in that designers are carrying out risk assessments to meet legislation, when what should be happening is that they need to be identifying the potential for risk. The issue of recording and paperwork is also raised. These comments emphasise that the perceived objective of carrying out risk assessment is to meet legal requirements, this is inevitable since the driver is most likely to be the need to mitigate the risk of litigation arising from accidents. This is understandable but is likely to be to the detriment of designing safety into machinery.

In discussion a number of issues arose reinforcing the recorded comments, but also adding to the debate:

- Several designers complained of grey areas in the legislation which caused them problems, and they did not know where to go to get a definite answer. It would be useful for them to know the kinds of problems which had led to accidents and court actions i.e. case studies.
- Customers are not interested in safety features. This means that the designers do not recoup the expense of the risk assessments, so there is little incentive to do them. If customers actively looked for safety features in the product then the fact that this creates a competitive advantage would fuel better risk assessments. This is an example of the safety culture of the farming industry affecting the safety culture of the agricultural engineering design industry.
- Interpretation is a major problem which can mean some manufacturers going much further than others. The extra effort does not pay back however, because buyers are only interested in how long the machine will last.
- There is often a lack of knowledge of testing and approval procedures for various pieces of equipment, even in larger Companies. A cross reference system of the standards and legislation should also include any relevant testing procedures.
- Interpretation of the legislation is often a problem. Outside consultants can greatly help a small Company which might not have the resources to cope with the need to train a person to deal with risk assessment, and keep up to date with legislation.

Table 21: Responsibility for resource allocation

Question 15: Who in your organisation, has the say over the amount of resources applied to risk assessment of the machinery, and designing for safety?

ID	Power
9	Managing Director
20	Partners in the Company/Managing Director
29	Chief engineer has major say but Managing Director has ultimate control
37	Managing Director, have to argue if more assessment needed
40	Managing Director/Designer
49	Project managers
58	Managing Director has ultimate say
60	Managing Director, but engineers have a say over input
62	Managing Director & Chief engineer, Managing Director ultimately
63	Managing Director
65	Engineer
73	Partner in the business
77	Managing Director
84	Owner
97	Partner with brother
100	Sales manager
101	The Managing Director (not interviewee)
112	Managing Director/owner
117	Self i.e. Managing Director
128	Self i.e. Managing Director
179	Lies with Managing Director. Time limits are main constraint. Customer can affect time scale
181	Managing Director
182	Managing Director
183	Managing Director and Design Manager
186	Chief Designer
187	Managing Director and quality controller
191	Technical Director

Table 21 shows that in over 80% of the Companies the final responsibility over the amount of resources applied to risk assessment lies with the owner or Managing Director. In four Companies it is an engineer, designer, project manager or technical director who takes the decision and in the other Company it is the sales manager. Engineers etc. are involved in the decision making process in most cases and can argue for more resources to be applied. However the application of resources to risk assessment is mostly a financial matter, not a safety issue.

Table 22: Attitude of management to health and safety

Question 16: What is the attitude to health and safety issues from the management?

ID	Comments
9	It is a bit of a nuisance
20	Good attitude, a necessary part of the design.
29	Chief Engineer & Managing Director share same attitude to health and safety, its a huge burden
37	'Expensive waste of time' - Managing Director
40	Want to make a safe machine but don't know what is considered safe
42	Do the minimum
49	Managers meet. Design must be sound before agreement will be given to develop, i.e. too much apparent risk will stop development
58	Very conscious of health and safety issues
60	Many managers don't understand health and safety and legislation, engineers understand better
62	Part of the design culture
63	Good attitude but not well informed
65	Very good, tolerant of engineer spending a lot of time on the risk issues
73	Good but fairly uniformed
77	Done to legal requirements
84	Issues OK but HSE not helpful
97	Good, but unfair competition from EU
100	Do the minimum necessary
101	Managing Director feels that Machinery Directive and health and safety assessment has not changed the products, but has created a large burden.
112	Very lax really
117	Very good but lack of knowledge
128	Must be done and HSE are molly-coddling users to some degree
179	Health and safety is part of a good design but can't control what a farmer does
181	In favour of health and safety but it is a burden
182	Positive attitude but lacking in information and techniques
183	Necessary part of the design process
186	Tolerated as something which has to be done
187	Very positive
191	Very positive, works to a very high health and safety standard

Table 22 shows that the full range of attitudes to health and safety by management exists. Some are very positive, working to a perceived high standard of health and safety (about 20%), whereas a similar percentage consider it is an expensive burden, achieving very little in terms of improved design. In between: there are indications of tolerance, but not much understanding, it is done because it is a legal requirement; and uncertainty about what is safe. One respondent considers the HSE are not helpful, and the unfair competition issue is raised again.

The overall impression is that risk assessment and health and safety is done because it has to be done and not because there is any great desire to design an inherently safe machine, or that it is related to designing an inherently safer machine. The fact that, risk assessment is a 'bolt on' process at the end of the design, identifies risk assessment in the eyes of managers as a burden, understood by some to be necessary, but by others at best tolerated, and at worst an expensive waste of time. There is no evidence that opinions are conditioned by the size of the Company or the products produced.

7.6 FACE TO FACE INTERVIEWS WITH MACHINERY DESIGNERS

This is a summary of the main points that emerged from the interviews with designers in 9 agricultural engineering manufacturers. Companies interviewed ranged from 11 employees to over 100, and from £1M to £70M turnover.

7.6.1 Structure of the interview

The design of these semi-structured interviews took into account the findings of the telephone interviews. One of the conclusions of the telephone interview was that questioning about health and safety was leading the response. It appeared that, because we were asking about health and safety, respondents were producing pre-conditioned responses. It was therefore decided that health and safety should be given a lower profile in these face to face interviews.

The interviews did not focus directly on health and safety or on legislation, but aimed at a general overview, discussion and analysis of the design process. In this way it was intended to avoid leading the interviewees into saying what they thought the interviewer wanted to hear. However, in order to obtain the interview the overall objective regarding health and safety in design had to be disclosed before the interview, so the interviewee did have some prior indication as to the overall theme of the discussion.

Discussing the whole design, development and marketing process also enabled an assessment of the overall prevailing attitude within the Companies to health and safety. It is expected that, the design culture prevalent within a Company will reflect the Company ethos, not only towards the technical excellence of it's products, but also towards the notion of conceptually safe designs.

Therefore the principal line of discussion was in the form of open questions such as; "In designing a new machine or item what are the main criteria you adopt?"; "What processes do you follow ?"; "How do you determine the design parameters or requirements and what would these normally be?". The aim was to obtain a true picture, or as true a picture as possible of the design process.

Our objective was to get them talking about how they design and what they take into account in design, with a little, but not too much prompting, to do with health and safety, but not to lead them to give the answers they think we want.

Following the initial discussion further open ended questions along the lines of: "What knowledge, better information, training would help you in the design process?; Are there any information gaps?; How could they be filled?"; If they did not mention human factors/ergonomics then further prompts along the lines of: "Do you have sufficient knowledge about people, anthropometrics, anatomy, bio-mechanics, psychology?; How do you design for different size people, strength, etc.?; What guidelines do you employ?"

All of the interviewees participated readily with this approach, and in itself this clearly increased the awareness of some of the designers in the notion of a more holistic approach to health and safety in design.

7.6.2 Summary of the interviews

The following points summarise the significant and re-occurring issues that were raised:

- In all case the main driver in the design process is the market place, although some designers were pre-occupied with engineering excellence.

- Historic design constrained development of improved systems, for example the Ferguson hitching and linkage system.

- Most designers are very aware of the need, moral and legal obligations to design inherently safe machinery, but many expressed doubts that customers would pay for inherently safe designs if it made the machinery more expensive than that of competitors. This view was particularly associated with smaller Companies where product pricing and survival is a very important issue at present. Larger Companies with substantial corporate support and strong quality branding were less concerned about this factor.

- In no instances are health and safety factors considered until well into the prototype stage. This confirms that generally agricultural machinery is not conceptually designed with safety as a principal concern. Surprisingly this situation also prevails with machines where operator conditions, in respect of ergonomics, lead to significant exposure to health risks. For example jobs that involve long periods of repetitive operation, such as tractor and fork lift driving, and work on vegetable processing lines.

- Homologation is a design safety issue that pre-occupies vehicle manufacturers supplying the German and French markets. This appears to divert the attention of these designers away from a more rounded overview of safety in design. Homologation principally concerns highly regulated and policed safe design of chassis, axles, wheels, braking systems and lighting. It is not directly operator safety related, being more about general and third party safety.

- Psychological aspects of safety in design is not considered by any of the Companies, e.g. analysis of why operators make mistakes, or forget operating procedures. There was little evidence of beginning with a design objective that is inherently safe, or designs that make mistakes less likely. Only one Company professed to design out safety risks.

- The most common method to meet safety legislation is to rely on adding guarding at the end of the design process, usually immediately pre-manufacture.

- It is significant that the one Company employing a retained health and safety consultant mainly used the capability in a reactive way rather than at a conceptual level.

- Larger Companies subscribed to databases and specialist suppliers of Euro legislation for access and supply of information. AEA was the most common source, but one Company uses an EU wide information service.

- All the Companies would like easier and more comprehensive hands-on access to legislation, and good health and safety design practice would be useful. The most popular format would be in either CD ROM, or possibly on the World Wide Web, but certainly incorporating an effective search capability.

- Several designers mentioned the need for a procedure to give them access to new and revised legislation sooner than at present. The lead time for many new products can typically be 5 years, and even if new legislation is not yet framed it would be very helpful to have at least established a two way dialogue with HSE .

- Taken overall there was an apparent openness to the concept of having better knowledge on human factors. The opportunity exists to build better human factors knowledge into design from first principles i.e. from the concept stage. The strength of this openness/willingness did vary considerably however. There was an indication that to achieve this introduction of human factors would also require some education of the market place. Farmers/growers needed to understand the benefit.

- Most Companies would potentially be interested in health and safety training for in service staff, although in the main the decision about paying for such training would be taken at a higher level within the Company.

- Smaller Companies clearly suffer from a lack of resources to seek and obtain health and safety information and legislation. Any developments for the industry must address this issue as small manufacturers supply a significant proportion of the working implements and attachments to tractors. Many accidents involve the machine rather than the tractor, since inside the cab of a modern tractor is, in general, an inherently safe environment.

- Some other specific safety issues which were discussed with particular relevance to mechanised farming in the UK were:

    - Singleton operation of large arable machines, i.e. no other staff near to help in emergencies (could be mitigated by use of latest emergency communications devices and panic/alarm devices linked to GPS etc.,)

    - Seasonal unfamiliarity with controls and settings of new technology and advanced engineering, e.g. computer controls on sprayers, combines etc.

    - Safety in design and operation of the tractor/implement interface.

    - Potential for improving the vision and control of machine processes by using “head up” displays and CCTV, particularly relevant to the increasingly long operating hours needed to properly utilise capital intensive seasonal machinery, e.g. combines and root harvesters.

7.6.3 Interview 1

Introduction and Summary

This is a specialised crop sprayer manufacturer employing a workforce of approximately 100. The Company designs and manufactures large high quality crop sprayers for the UK and increasingly the EU market. This is a product area where the UK is more advanced than all of the rest of Europe, due to our larger farm size and the advanced nature of our arable farming technology. The same type of products, particularly self-propelled sprayers, do not exist in the United States, so the Company are probably world market leaders in international terms.

The interview was conducted with the most senior member of the design staff. In terms of the Company hierarchy he did not hold a senior position.

The designer was mostly concerned (pre-occupied) with structural safety of the machines, i.e. avoiding chassis and boom breakages, and in meeting German and French road safety homologation requirements. In relation to operator safety the main reaction was to respond to customer and legal requirements, and in the main he stated that the product set the standard for the rest of the market, the most significant drivers being, "not getting sued", and "no complaints", and keeping costs down in a competitive market. In terms of structured inclusion of human factors in design or of designing a product to be safe in use, at best these took second place to mechanical design. That is a generous conclusion.

Main Design Criteria

Good engineering and practice, e.g. does it meet customer expectations, and is it fit for the purpose. He stressed good use of materials. When he started at the Company they only used 3, 6 and 10 mm steel, he introduced 4 mm which is 30% stronger than 3 mm.

Processes, e.g. designing an axle mounting sub-assembly. Mostly, they draw the design and there are very few calculations. Has to meet TUV (German) and Cemagraf (French) homologation legislation. He uses a circular design process, not linear, i.e. after the first design solution looks at minus points and corrects, and then repeats whole process. e.g. what is not right i.e. axle ground clearance, is it user friendly, i.e. servicing brakes, will it fail safety, does it meet specification, can I improve it?

Uses a mental form of FEMA "Future Mode Failure Analysis", this weights the effect of a failure relative to costs of repair and safety implications.

Other Issues

All through the interview there was plenty of reference to 'user needs in an operational sense', i.e. what was expected of the machine in performance, but virtually no reference to the physical and psychological needs of the operator.

In response to probing human factors issues, a fringe discussion centred on relatively peripheral factors, these included the engine bonnet access handles, cab steps, access to the tank filling cap. "Management say that proper access is not required because on a modern sprayer there isn't a need to look in the top of the tank, when actually all operators always want or need to do this when cleaning it out to ensure it is fully clean". It appeared that if an issue was identified then it would receive attention, therefore recognition of human factors, it if occurred, would be reactive.

The chemical filling system is a particular health hazard which has received significant improvements in the last 10 years. The designer stated that he could improve it still further, but it would just shift the chemical hazard one stage. If the system isolated the operator from neat chemical it would then expose pump engineers to it, and they may not be fully aware of the variety of chemical hazards. This could be interpreted as a form of risk analysis on this specific aspect of the machine design, but there was no evidence of any overall or formal risk analysis of the machine. This also suggested that this designer was capable of fully addressing human factors in design, but a change in culture was required to release this potential.

The Company do their own cab design, but it does not need to be tested like tractors (even in Germany and France) because it is an "Agricultural Machine", not a "Tractor". On probing, it was clear that no human/ergonomic factors were considered except in response to the new machinery operations directive which concerns the spatial layout and marking of levers,

switches etc. He stated that the cab was the best in the sprayer market and that he considered it to be, "well designed ergonomically".

In respect of seasonality, and problems that this might cause to operators because of lack of continuous familiarity with equipment, this was considered to be minimal in respect of their machines, since high specification arable sprayers are now in use for upto 40 weeks per year. He acknowledged that instruction books and procedures were getting ever more specialist, but said that some farmers simply didn't employ good enough technicians for modern sprayer technology. It was apparent that he placed the responsibility for using the machine safety squarely on the shoulders of the user. Their sprayers are individually specified, such that no two machines are ever the same, and therefore writing instruction books that included the full and correct safety procedures (in German and French as well as English) was a major problem. Therefore initial training, including safety briefing, was at the individual farm level, and provided by the manufacturer or by the dealer.

Information Gaps

The designer was quite complacent about any gaps in his knowledge. In respect of human factors the Company always reacted to customer needs, but stated that the Company policy in this area was "if it ain't broke don't fix it". Reacting to customer needs is clearly important, but it is not in itself embracing human factors which this designer did not understand. This attitude is symptomatic of a mechanical design engineer whose training will always tend towards functional machine design with the operator considered later. The perception about designing for people was limited to such things as altering step heights for small people, i.e. anthropometrics. He stated that if the Germans thought the cab was OK then it was OK!

He considered that the biggest problem was management attitude, not information availability. Information is required to educate management as to the risks to the Company arising from designs not being safe. However, his concerns did not relate to the broad issue of human factors, but to engineering specifics. The understandable preoccupation with meeting market requirements surfaced again, since the only identified information was related to homologation, e.g. lighting requirements for the French market.

When pressed on an information data base he eventually agreed that it would be nice to have "a simple bible", a full handbook , e.g. on CD ROM, with all health and safety issues identified, but it would only find favour if was free. A good quality overview document should also be issued free to all engineering students.

Final discussion concerned Company policy on the Machinery Directive (CE mark), which notably had not surfaced in the discussion before this point. Remarkably it was stated that although all machines had a CE mark on them, documentation was not collated by the Company to support the CE mark. It was acknowledged that the self certification system for CE required technical files supporting and justifying the mark to be kept by the Company. If this is true the Company is in a very risky position if anyone, particularly following a personal injury, or pollution case, were to take action against them and the lawyers subsequently delved into these Machinery Directive issue.

Other comments by Interviewer

This was a strange reactive type interview:

1. He was not prepared to be interviewed on the Company premises because he might be accused of wasting time. Hence the interview was after working hours in a local pub. This

prevented the possibility of taping the discussion. The interview lasted about 2 hours and there was a lot of opinionated background comment, supporting the attitudes detailed above, but this was not captured.

2. The whole design process was conditioned by the attitude of senior management which limited the freedom of the designer.

3. It is clear that this is a good mechanical design engineer, but he has poor appreciation of human factors in design, and his Company's policy does nothing to alter this perception. This attitude might be tenable if there was no human interaction in the use of this machine.

7.6.4 Interview 2

Introduction and Summary

This is a specialised materials handling manufacturer of telescopic boom rough terrain pallet and fork handling machines. All manufacture, design and development is in the UK. Turnover is £30 M with 85 employees. Annual production is 800 machines, of which 75% is exported, mainly to Germany and France, but UK is the biggest single market, and the market is solely agricultural.

The interview was with the Chief Engineer covering all design, development and testing with a staff of 18. The design office has 8 staff and is fully equipped with state of the art 3D CAD. All components are out sourced, i.e. the Company specifies and assembles these components.

The Company appears to be very responsible in respect of health and safety issues, employing professional consultancy design support and a specialist information service to keep up to date. However, they would welcome a more proactive relationship with HSE particularly in respect of future legislation. There appeared to be an open door for the introduction of human factors.

Main Design Criteria

For a new product the main driver is market place demand using feed back from market sources. The first step is to develop a product profile, which is a large document mainly drafted by the marketing department. Specific headings would include projected sales volumes, requirement for product (i.e. user need for the product), market specification, application related requirements, service requirements, and finally sales features ("whistles and bells") such as seat colour etc.

With an existing product the above process is much shorter and the main criteria is whether specific areas of detail can be improved, particularly in relation to user comments and competitor analysis.

Processes

The main health and safety issues, that the Company recognise with this product, involve the physical safety and occupational health of the operator whilst in the cab, although it was agreed that the most physically dangerous activities would be when the operator leaves the cab to change attachments or make external adjustments.

As the Company are presently designing a new cab it was convenient to use this process as an example.

The ergonomic design for the new cab comes from associated Companies already working with the parent Company. However structural design is in the UK and the ROPS (roll over) and FOPS (falling object) tests are carried out by a specialist UK Company. Despite the stringent French and German homologation legislation, throughout EU this type of agricultural machine does not have to be tested to the standard OECD/ISO tractor cab test.

The seat is designed to conform with the ISO standards on vibration, and anthropometric information is sourced from the Henry Dreyfuss reach and comfort zone data. Also they make use of the SAMMI computer model from Cranfield Institute to assess and improve the operator visibility spectrum. A significant occupational health issue with this type of product is "neck craning" upwards to overhead loads as the FOPS legislation preclude any roof glass.

Other Issues

We discussed singleton working, particularly in respect of out of cab operations such as changing the handling attachments. As much as possible these now have automatic hydraulic connections. The possibility of developing an industry standard GPS based panic button system was discussed as a possible solution to the generic risks associated with singleton working in agriculture.

The Company are well organised in respect of Machinery Directive documentation, maintenance and audits. In particular the TUV homolgation legislation in Germany requires a risk audit every 3 months.

Information/Training Gaps

The main health and safety information gap is in anticipating new or amended legislation. Information currently obtained from BSI and AEA is mainly reactive. The Company currently subscribe to a specialist information consultancy, "InterRegs" who scan all European sectors, but it is not forward looking.

As a result of informal contact the Company became aware recently that HSE were using one of their older models for vibration research, and used this as an example of inadequate liaison with HSE.

The Chief Engineer's background training was in vibration, no one in the engineering team had any formal health and safety or human factors training either at higher education or in service level. Any improvement in access to safety training and information would be welcomed.

Other comments by Interviewer

This Company demonstrated a very positive attitude to health and safety issues in general and appear determined to offer a product that is of a very high quality. They appear to be amongst the best in respect of good practice in health and safety in design, but nevertheless still want to improve. If any further development of support is implemented as a result of this project, this would be a good Company to use as a benchmarking measure.

7.6.5 Interview 3

Introduction and Summary

This is a typical, small agricultural equipment manufacturer, having developed from a family farming diversification workshop through repair and service into manufacture. The main

product is tractor pulled and tractor mounted sugar beet harvesters, but they also import and distribute self propelled harvesters and precision spacing drills from Germany.

The Company employs 14 staff and has a turnover of £1 M. Most of the production is for the UK, but recently machines have been exported to Hungary, Japan and Chile.

Main Design Criteria

Functionality is the main design criteria, making sure the machine does what is needed.

Next is looks, does the design look right both aesthetically and engineering wise, does it look strong enough?

Weight is also a major issue as their machines work mainly over the winter period.

Safety is acknowledged to come at the bottom of the list with the majority of effort going into guarding. They acknowledged that 'if there is more than one way of making something work, go for the one that is easiest to guard'. Besides being at the bottom of the list, safety is therefore also reactive. In their culture there is no perception of designing safe from the outset.

Design Process

Mainly design is by incorporating existing basic components to satisfy customer needs. A recent example is the development of a 'bulking tanker option' because the market is going that way to reduce labour. Only the bulking hopper and elevator will be designed from scratch, but where it connects to the existing machine there will be modifications to strengthen and accommodate the new component.

There is no systematic risk assessment of the whole machine, just assessment of the individual components with HSE help. They don't have the training to do a complete risk assessment. At the end of the prototype stage HSE look at the whole machine, but this mainly concerns HSE opinion on physical risks of where people can reach. They feel that as their machines are basically fully mechanised, the greatest risk occurs when the tractor driver leaves the cab to clean, repair or adjust mechanisms. Clearing jammed machines while they are running is probably the most common operator error. But, even though this is recognised it would appear that in the design no thought is given as to how this can be avoided.

Specific Issues

Operator posture and comfort in the cab during long cold days was discussed. As their machines are built around tractors the driver spends a lot of time half turned, looking back at the lifting mechanism compared to a self propelled type. CCTV cameras and screens are now cheap technology (less than £100) and the market is being tested to see if users will pay for this refinement. They are also working with SRI Silsoe to develop a vision system. In the longer term automatic steering is thought to be achievable at economic cost. This is available now on some self propelled machines with automatic manual override as soon as the driver makes a steering input.

Information/Training Gaps

They openly admitted that they do not have the resources to access all of the legislation which is published. This is a small Company with one designer, and a small design capability. They would welcome direct access to legislation by CD ROM or on the Internet. However, the information must be visual not just the wording of the legislation. Also source books would be

favoured, as it is difficult to get an overview on CD ROM or on Internet compared to flicking through a book.

The designer does not have any formal professional or in service training.

Comments by Interviewer

Although this Company clearly suffers from limited resources to tackle safety in design effectively, they are very positive about the need to improve the situation, and overall they display a positive attitude to the subject. It is also quite likely that they do not fully recognise their responsibilities due to lack of training and briefing. This was confirmed by the "CE situation" where they have put stickers on their machines but have no back up documentation to support their self certification that the equipment conforms to the Machinery Directive..

7.6.6 Interview 4

Introduction and Summary

This is a specialist sprayer manufacturer of self propelled machines. All machines are built to order and to the individual specification of the user. Annual production is 50/60 machines with 20% sold to the EU market. They also supply to Japan and Australia. There are 40 employees.

The design team is 3 strong. The design engineer is self taught and his 2 assistants were apprenticeship trained. There were no specific health and safety training opportunities for them.

This is typical agricultural machinery manufacturer with a positive and responsible attitude to health and safety, but with insufficient knowledge and resources to be fully capable of considering safety as an inherent component of good design.

Main Design Criteria

Marketing and requests for new product development is handled directly by the Managing Director based on feed back from clients.

Operator comfort and visibility are main objectives and are always measured against the same criteria for tractor mounted machines.

Basic features are constantly reviewed with particular emphasis on comparison with competitors. It is an overdriving objective to offer the best specification available to keep the machines at the top end of the market. Given the nature of the team this is mechanical specification and function.

Design Process

It is very unusual for them to start with a clean sheet of paper, because of the specialist single product nature of the machines. The components are continually upgraded, and it is only the chassis and transmission system which potentially could be completely new, and this only if a customer asked for something that is not possible with present designs.

At present they are working on a new generation cab that will be positioned in the middle of the chassis to improve comfort and visibility. These are human factors issues.

Other items currently under review and development are in cab hand washing, boom washing systems and clean water tanks to supply these items.

Specific Issues

The designer was of the view that spectators and third parties are more at risk than the operator due to chemical risks. A further risk is from low power lines on sloping fields due to the extreme width of modern spray booms. Also the stability of high clearance models on a narrow track width is of concern. Seasonality of working is not an issue with such specialised machines as they are generally in use, by the same highly trained operators, for 40 + weeks per year.

Cab design is an area where the Company are keen to excel, but they admitted that they only use their own in house experience, common sense and user feedback. They would certainly be interested in more science and information in this area. Cab access is one of the key issues.

No overall risk assessment is carried out on the complete machine. A particular area which they presently omit is to consider all the possible ways the machines could be misused.

Information/Training Gaps

EU standards are the main ones consulted, and AEA information is also very important. Accessing all of the legislation is a problem, but they are familiar with the most important for their product. A comprehensive list of legislation with a summary of the content of each would be useful. They would also value information on projected standards, training courses, Internet site, source books etc.

Comments by Interviewer

This was an honest analysis of their position by this Company, and the interview certainly increased their awareness of the part design can probably play in improving the inherent safety in machinery. Appreciating the gaps in their knowledge made them realise what could be achieved if they had better knowledge.

7.6.7 Interview 5

Introduction and Summary

This is a specialised manufacturer of high speed tractors, which manufactures around 1000 units per year. The tractor is a fundamentally different design to the conventional agricultural tractor and as such the Company probably represents the most fundamental and objective design capability in Agricultural Engineering in the UK.

The interview was conducted with the most senior member of the engineering staff, who is also one of the senior management team in the Company. Two engineering managers support the Chief Designers, both of these previously worked in the automobile industry.

The Company has a very well defined design process, but this is almost entirely market reactive, rather than safety or health proactive. Surprisingly, considering the overall level of sophistication and the type of product, human factors, ergonomics, anatomy, anthropometrics et al, do not feature strongly or professionally in the design process. The tractor is a market leader in suspension and transmission design but appears to be similar to conventional tractors in respect of operator cabin environment, probably on the assumption that solving the suspension and ride problems is sufficient to maintain the technical lead.

Main Design Criteria

"Have to start with a product that someone will pay for", "All design work starts with a marketing brief produced by the marketing department", are the two most significant quotes that characterise the design process.

The order of priority in a typical 'Marketing Brief' indicates the relative importance of some of the health and safety issues:

- Homologation requirements
- Nomenclature
- Physical dimensions (of the machine)
- Engines
- Exhaust/Engine Silencer Unit
- Transmission
- Main drive coupling
- Speed splitter
- Speed gearbox
- Speed and reverse range gearbox
- Axles
- Brakes
- Steering
- Suspension
- Fenders
- Hydraulics
- Trailer hitches
- Operators cab
- Forward visibility
- Electrics and instrumentation
- Capacities
- General
- Serviceability

Health and safety issues are not specifically identified, but clearly some of the factors listed can embrace these. It should be remembered that an overall aim of this product was to address the issue of poor 'ride' and vibration.

The next stage is to produce a design brief. This process translates the marketing brief into engineering requirements to check that it is feasible to provide what the market requires. In essence the design brief is a detailed component system specification to enable selection from standard components or specified manufacture.

The following are typical main headings in a component system specification:

- Attachments
  - Trailer hitches
  - Ballast weights
  - Point linkages
  - Implement control box harness
- Structures/Cab
  - Fenders
  - Bonnet
  - Hydraulic oil tank
  - Fuel tank
- Electrics and Instrumentation
- Controls
  - Transmission controls
  - Hand throttle
  - Slip control
- Hydraulics
- Transmissions
  - PTO
  - Front axle
  - Rear axle
  - Speed powershift
  - Differential lock control
- Brakes
- Engine
- Complete machine
  - Homologation requirements
  - Nomenclature
  - Physical dimensions
  - Serviceability

Processes

The similarity of the design brief to the market brief indicates that the designers are mostly responding to marketing requirements, i.e. the design process is market led. Given the nature of

this product, especially in respect of the comfort and environment of the operator, it is surprising that ergonomic processes and design requirements are not specifically addressed.

Although serviceability is listed last, the whole process is implemented by a "Simultaneous Engineering Team" which includes a service engineer, (others being, design, manufacturing, marketing, sales).

Other Issues

In the initial design there was some input from a specialist German Company in connection with homologation requirements for the TUV legislation. However since then the human interface has been covered using very basic data e.g. the 75 kg guideline for a typical body and then testing at extremes with large and small people, e.g. "a 7ft shepherd and a 5 ft 2 in pregnant secretary". This exercise resulted in lengthening the cab by 3 in to allow a lower seat height with a car style driving wheel position.

To indicate how market orientated the design process remains, the tractor is still fitted with a suspension seat as standard, because marketing indicate that their will be customer resistance if a purely sprung seat such as in a truck or car was fitted. A suspension seat is not needed on a vehicle with a suspension system that already isolates the driver from terrain induced vibration and shock. In fact a suspension seat makes the operator environment more difficult at high travel speeds, because there is greater movement of the seat relative to the controls.

Seasonality of operation is not an issue specific to this product, and no particular areas of the product were identified as being difficult for operators in this respect.

Singleton operation was acknowledged as an issue. There has been continuing development of controls that enable the operator to make adjustments to the tractor in order to connect implements whilst standing beside the tractor. The main concession to safety being a remote engine stop. The interviewee was very critical of the whole concept of the industry standard three point linkage system (Ferguson System) in this respect. It is a paradox that one of the main reasons the Ferguson system was developed was as a safety solution to another tractor/implement hitching problem. This high lights the problem of historic design, but it is important that in this case the Chief Designer of a prestige product acknowledges this problem.

Information Gaps

The interviewee was enthusiastic about improving access to all information that would improve product design in safety and health. As the product is a vehicle with very stringent homologation safety requirements in Germany and France in particular, the Company are very well briefed in all safety legislation. Nevertheless it was acknowledged that there was probably a lot more advanced health and safety information available which could help them to further improve the product.

Other comments by Interviewer

1. This Company has a very positive attitude to health and safety

2. As market leaders the Company would be prepared to develop and evaluate any product improvements that might be identified by improved knowledge and information

3. The Company is likely to respond positively to training, briefing, seminars and information packages for their product area.

Health and safety information for designers would be most useful if it was supported by a search engine capability in either www or by CD ROM.

7.6.8 Interview 6

Introduction and Summary

This Company manufacture systems for preparation, processing and packaging of all types of food and vegetables. The Company employs 62 staff with a turnover of £3.5 M. Essentially the equipment is supplied for use in a factory type environment and the operators are characterised by lowly paid repetitive type work and skills.

Although the Company appears to be very diligent in respect of legislation, e.g. full understanding and compliance with the Machinery Directive, (possibly because of the high element of electrical and magnetic interference equipment in their product), overall their attitude was the most negative experienced in this study. In particular they felt that there was too little consistency about implementation of the legislation across the industry both domestically and internationally. For example, safety precautions that HSE had insisted on for their box fillers were not enforced on competitors.

It was disappointing, considering the product type and the substantial amount of human interaction, that the Company had little interest in training or information on ergonomics, even at the lowest level of anthropometrics. This attitude confirms the reality in the industry in respect of human factors in the design of this type of equipment.

Main Design Criteria

Main criteria is always functionality, followed by reliability and serviceability. Although the range of products would suggest that ergonomics would be important in practice it is not a customer issue. In reality this is an untenable approach since function is so closely related to human factors, but knowledge of these products in the market place confirm this situation.

The next stage is to look at the finer detail to ensure that it will do the job. Detailed design then follows, and finally the method of operation including safety is considered.

Design Process

The process either starts as a customer requirement or an idea in the designers mind. They then evaluate the market potential, is it a one off or will there be further business?.

Ninety nine percent of design work begins with an existing machine which needs modifying for a new function e.g. a new crop or food product. This highlights part of the problem, in that the existing weaknesses and problems in design are carried forward into the new.

Specific Issues

Seasonal operator familiarity is not an issue with most of the products as they are in use all year round, but low skill operators doing highly repetitive work is a significant problem in terms of designing for safe operation, and also in respect of occupational health, e.g. repetitive strain injury.

Ergonomic and anthropometric information is not used in the design of the working environment at all, but mainly they use their own experience and user comments and requirements. “We try our best to do it right for the man rather than the task”. However, the only significant information used in recent years has been lighting colour research, but this is

not always followed up in use in the factories when lighting tubes are subsequently replaced. Lighting is only one part of the human factors associated with grading, the ability of the eye to trace faults is a greater problem.

There is considerable variation in the management of the factories which affects the safety risks. Medium skill operators, i.e. processing line chargehands/foremen, are OK. High tech equipment such as programmable logic and microprocessor controllers is generally operated effectively and safely by middle management.

The Company are very conscious about safety in servicing, and in particular the electrical safety risks, e.g. supply isolation and isolation of individual machine and components in a production line. However this matter is usually only considered at the end of the design process.

Information/Training Gaps

Main shortcomings in the design process relate to lack of time to research all the information, not lack of information itself. Recognised that there was significant lack of information and training in respect of occupational health but not sure if others in the industry would work to the same standards, and would the customers pay for better conditions for their staff?

There was no interest in any training. There would be interest in a self help CD ROM. An HSE helpline would be useful but the interviewee was again skeptical about the consistency of interpretation between different people and Companies.

Comments by Interviewer

Overall this was a rather negative interview with a disappointing reluctance to consider anything beyond that which legislation requires. Nevertheless the Company claims to fully meet the requirements of the Machinery Directive. In terms of physical safety they are probably as advanced as any of their contemporaries. This interview highlights the need for better understanding of the role of human factors by the market place.

7.6.9 Interview 7

Introduction and Summary

This is a specialist manufacturer of potato harvester and potato cultivation equipment. Present turnover is £5 M with 35 employees.

The Company has been innovative, and by obtaining a technical lead over most other manufactures has been able to achieve about 30% of the market for 2 row unmanned harvesters.

The Chief Engineer has 2 designers and 1 parts/manuals specialist. He was previously an engineering apprentice working on fork lift design.

Main Design Criteria

The approach to design criteria is heavily dependent on whether the design work is aimed at a complete new machine or, as is more common in this Company, the detailed design of modules that can be slotted into a variety of machine configurations. A recent machine development was aimed at entirely eliminating the haulm extraction rollers because of potato damage and some safety risks. However the development process was unable to achieve this completely and after prototype testing one haulm roller module had to be re-introduced into the otherwise totally new machine to make it sufficiently functional to be marketed.

With modular design the main criteria are:

- Serviceability
- Interchangeability
- Adjustably.

In an unmanned potato harvester the modules are typically:

- Drawbar
- Main chassis and wheels
- Digging share assembly
- Main elevating web
- Second elevating web
- Separator
- Cart elevator.
- Hydraulics and control services.

These are essentially considered as separate elements in design. In this approach serviceability suffers the most, getting to all the nuts and bolts and having access to them for repair without having to completely remove the element from the machine. In designing a new machine existing satisfactory modules have to be integrated with new modules.

Processes

- Design from a marketing discussion
- Rely heavily on service engineers to feed back to designers where there are problems, although it was accepted that the engineers possibly know the machines too well and miss some problems that seasonal users have
- Risk analysis is carried out, but is based on intended or normally expected operations, rather than perhaps some of the unexpected or erroneous ones that may occur.

Specific Issues

Demonstrators use the machines in a much wider range of conditions than most other operators due to the wider range of crops and soils across the country. Many settings and adjustments are only made once by normal operators.

They have to assume a reasonable level of operator capability in using £100,000 + machines, e.g. settings, but also basically simple operation is needed, hour to hour, to minimise operator fatigue and hence errors.

Operator fatigue, in relation to position of control boxes and the possibility of using CCTV to achieve “head up” type working so that the driver is looking forward all the time was discussed. The problem as to whether the market would pay for this was raised.

Information/Training Gaps

There was never enough information on ergonomics/anthropometrics.

Use AEA for health and safety information.

Better access to health and safety documentation would be very helpful and welcome.

Would like a single book listing all matters related to health and safety in AEA, could then arrange to supply the actual legislation as required.

Comments by Interviewer

A very co-operative designer, and although mainly sticking to the rules there is a positive attitude towards any information that would help them to design more safely.

7.6.10 Interview 8

Introduction and Summary

This Company manufacture cultivation and seed drilling equipment specialising in high capacity, top of the range, heavy duty machines for very large tractors, and large arable farms. The Company is owned by the management and so the Design Director, with whom the interview was conducted, is very closely allied to the " mentality" of the Company. There are 85 staff, 4 full time engineers/designers and the turnover is £9M.

The Company have a retained safety consultant who visits the factory and the design office every week. The designers tend to delegate safety issues to this consultant. Nevertheless there was enthusiastic support for a comprehensive package of safety information, and some in service training.

Main Design Criteria

The market is the main design criteria, and when a market need is identified they then analyse if there is a profitable solution, i.e. cost of design, development and tooling versus the likely sales volume and selling price. Also consider if the product fits with the Company product profile and image, i.e. they are well known for non-ploughing cultivation techniques and would not lightly develop into ploughs or power harrows.

New product development begins with a 'Product Development Request' which is a formalised procedure involving:

- Market projection
- Machine specification
- Development cost
- Production cost
- Financial analysis (project cash flow)
- If all Directors approve the above then it will move to a detailed design stage.

Design Process

They claim to have an 'instilled safety philosophy' beginning at the concept stage. Hence it is unusual to have to make late changes, especially as the health and safety consultant is regularly on site.

The following motto is instilled in the design office staff:

1. “Design it out”

2. “Guard it out”

3. “Warn it out !”

Nevertheless the designer went on to give an example of the problems of, ‘safely folding up a wide cultivator for transport’, that rather contradicted this position. In this case an elegantly simple and cheap folding method was retained for economic reasons despite some inherent safety risks. In general safe folding of wide implements is the most common design problem they meet.

Specific Issues

Standard tractor/implement coupling systems remain a significant problem area. The very wide range of clevis connecting pin dimensions means that drawbars have to be separately specified for individual tractors, and this leads to many compromises. They have endeavoured to standardise hitch systems on higher power tractors, but with no success.

Information/Training Gaps

The outside health and safety consultant is responsible for keeping the Company up to date with all relevant rules and legislation.

The legislation could be more user friendly and they would welcome an easier methodology for searching and reading the documents, Internet would be good, but also source books. The Company also uses the AEA “Update” publication.

Designers at this Company were either Silsoe or Harper Adams trained but have not had health and safety or human factors training. It was agreed that some form of in service training in the psychology of safety in design would be useful to improve the basic approach.

Comments by Interviewer

The use of an independent safety consultant is both unusual and interesting in the Agricultural Engineering sector. In this study this was the only example of this form of delegation. Superficially this appears to be a highly responsible approach, but perhaps it may lead to a degree of complacency in respect of thinking of safety fundamentally within the Company. It was also pointed out that legally the Company cannot divest itself of health and safety responsibility for it’s products just by employing a consultant.

7.6.11 Interview 9

Introduction and Summary

This Company manufactured potato harvesters, planters and specialist potato cultivation equipment. The Company employ 65 people and has a turnover of £5 M.

This interview was with the Technical Director in charge of all engineering development with a small design team of 5 staff employing traditional design and drawing office methods and some use of CAD. The Company is a very enthusiastic member of the AEA and it’s Technical Committee including health and safety matters. Therefore they rely on AEA for much of their health and safety information.

The Company have a very conventional and traditional approach to safety in design which relies on the legislation, retrospective guarding, and HSE approval.

Main Design Criteria

A new design project is entirely market led. Initially the marketing department draw up a marketing specification from which a basic machine specification is developed. The next stage is a feasibility study to establish if the overall scheme for the machine can be produced. e.g. if the specification calls for 4 separating webs, is it possible to fit them into a machine of practical size.

Processes

The next important process is to do a 'ball park' costing to check that the machine price is reasonable. Others processes are:

- Design review meeting
- Schematic proposal to Marketing
- Time scale for product development, testing and manufacture
- Board decision on project
- Finalise schedule
- Detailed design
- Function is examined - does it still meet marketing specification ?
- Safety - informal risk assessment based on previous experience, e.g. nip points on haulm rollers and webs - no direct human access allowed
- Monthly/bi-monthly design reviews including Marketing, Purchasing, Production, Sales and Design staff
- Final meeting at first prototype stage
- During prototype build continually review for improvements to parts and manufacturing methods
- HSE invited to comment on guarding and general safety
- Prototype testing to coincide with start of potato harvesting season
- Post build task force meeting involves users, development engineers and produces a design modification list
- Drawing office do modifications on drawings.

Decision On Production

After first year of production another task force meeting

First production machine

HSE invited to comment on guarding and general safety.

Information/Training Gaps

The draft standard on potato harvesting, EN 13118 was obtained through the AEA. Also use the BSI "Update" publication but have to scan for anything under the "AGE"(Agricultural Engineering) committee, or "AU"(Agriculture) general committee.

Would welcome electronic sourcing of all relevant information, but are worried about whether all small Agricultural Engineering Companies would be able to access this.

The Company engineers are mostly ex local apprentices, as opposed to degree or HND trained. HSE should talk to all engineering Colleges about safety in design.

Comments by Interviewer

Seasonality of operation has never been thought about particularly. They try to label all controls and ensure instruction manual is adequate.

Effect of singleton working is not considered, suggested specific designs to prevent singleton from undertaking dangerous procedures without assistance, and specific instructions not to do certain things single handed, mainly settings/adjustments/transporting.

The designers have no knowledge about the psychology of people and how they are likely to react in certain situations. Records required by the Machinery Directive are fully mainland.

The Company appear to be very diligent about safety in design but within a very traditional approach. This considers mainly conventional physical safety at a relatively late stage in the development process. Access to information on legislation is sufficient to ensure that machines are fully compliant**.**

7.7 INVESTIGATION OF AGRICULTURAL COURSES

7.7.1 Objective

The objective of this part of the study was to determine:

- In respect of health and safety what is currently included in the courses/training on offer
- What scope there is for increasing the content of health and safety in the courses/training offered.

The introduction to the interview comprised advising interviewees that we were interested:

- In their attitude to health and safety
- The health and safety content in the courses currently being offered
- Problems they foresaw in changing the content and material used in their courses
- What health and safety issues could be included in future courses.

The full results of the five interviews undertaken are set out below. For ease of reading the question is presented followed by the response. These interviews are summarised below in 7.7.2.

7.7.2 Summary of the interviews

Health and safety content in courses

The level of content was variable between the five Colleges interviewed, but all included some health and safety awareness and risk assessment training. Only one of the five interviewed had a compulsory design module addressing the legislation. In this case the emphasis was on health and safety and risk assessment, human factors was not mentioned. In contrast, one of the others had a greater emphasis on human factors rather than the narrow approach of health and safety. In the other three Colleges health and safety had limited cover and was seen as something that had to be done and tolerated rather than essential.

Scope for increasing the content of health and safety

Generally all were open to the proposal. Problems lay in funding, to be successful it would need to be a compulsory module, the subject needed to "dressed up" to be more attractive. There was a need for support in developing and servicing such a module. Equally it appears likely that human factors training or course modules would find favour. Indeed it is possible that approaching the problem through human factors could resolve the image problems associated with health and safety.

To address the issues of funding and to ensure inclusion of health and safety, risk assessment and human factors modules within course content would require planned and concerted effort to achieve success.

There was interest in running discrete short courses covering the whole issue of safety in design. In this again support was required, funding was a problem, but willingness and recognition of the value of such courses was not in short supply.

Taken overall the concept of increasing the health and safety, risk assessment and human factors in agricultural engineering and other similar courses was well received. There was a commitment to support and help in the construction of these, but external help and funding would be essential.

7.7.3 Interview 1: Peter Crossley - Cranfield

1. **What courses, if any, include some H&S awareness training, e.g. dealing with legislation and the risk assessment process**

   Health and safety and human factors is taught in all courses where it is appropriate i.e. where there is a legal requirement to meet health and safety issues e.g. for CE marking under Machinery Directive.

2. **What is the extent of H&S awareness training in the course currently i.e. time and content**

   Abide by Machinery Directive rating system, and so they train in methods to meet these.

   EA1 (Engineering Accreditation requirement) system, they provide practical training. Workshop training done at RMCS Shrivenham.

   Training done on own farm at the college. This involves machinery operation and use.

Sprayer training - GNVQ qualification.

   Final year project includes a lecture on health and safety. A risk assessment form is produced as part of the project. HSE pamphlets are provided as part of the course material. Human factors training is a part of the process of design i.e. it is a design constraint. Human factors are taken more seriously than health and safety.

3. **Do you see any need for an increase in the H&S content?**

   Courses currently represent ergonomics issues quite well, but an alternative point of view is always beneficial. Occasional seminars on the design issues in health and safety would be beneficial.

4. **What obstacles would there be to providing more H&S content, health and safety e.g. shortage of course time, expense of producing the course**

   Approvals are not a problem, the flexibility is there. Attitude to H&S is one of it being a bug-bear.

5. **Who has to approve the course content?**

   This is the responsibility of the lecturers and College jointly.

6. **Are any of your courses approved by the Engineering Associations (Which?)**

   EA1 system.

7. **If the HSE were to produce an education pack, would you consider using it?**

   Yes, would use it as part of an overall method for imbuing a user-centered design and health and safety approach.

8. **In what format would you like an education pack to be presented e.g.: physical items such as overheads, guidance notes for producing own material**

   Case studies would be more beneficial than a prescriptive methodology for design, e.g. examples of bad design followed by suggestions for how it could have been done better, and

how it could have been identified at an earlier stage. This would help to create the right culture and attitude rather than telling people what to do.

Would like to have the support material but would prefer to have an outside speaker. This would add weight to the credibility of the message.

9. **Would you be willing to comment on a draft education package some time in the future**

   Yes.

10. **Collaboration**

    Would be willing to take part. The issue is becoming increasingly important from a moral, legal and financial point of view as product liability claims increase.

7.7.4 Interview 2: Dave Kynaston - Reaseheath

1. **What courses, if any, include some H&S awareness training, e.g. dealing with legislation and the risk assessment process**

   Diploma level course - Design module. Consortium of Reaseheath, Lackham, Askham Brian, Rycote Wood, Kaythorpe DeMontfort.

2. **What is the extent of H&S awareness training in the course currently i.e. time and content**

   Compulsory design module - have to investigate all legislation affecting machinery, e.g. Machinery Directive.

3. **Do you see any need for an increase in the H&S content?**

   No scope unless it is funded. Colleges funded to do so many hours and doing any time in excess of this is not considered efficient.

   Need for a simplified package especially for approvals under the Machinery Directive. Currently students and teachers have to go out and do their own research, an up to date reference list would be useful. Easy to use interpretation of the relevant legislation would be useful.

4. **What obstacles would there be to providing more H&S content, e.g. shortage of course time, expense of producing the course, approving material**

   No time in excess of course time. Needs to be made part of education policy to work.

5. **Who has to approve the course content?**

   The courses are a mix of BTEC etc., so are difficult to change.

6. **Are any of your courses approved by the Engineering Associations (Which?)**

   No, or not sure.

7. **If the HSE were to produce an education pack, would you consider using it?**

   Yes

8. **What format would you like an education pack to be in, e.g.: physical items such as overheads, guidance notes for producing own material**

   No thoughts on this at the moment.

9. **Would you be willing to comment on a draft education package some time in the future**

Definitely willing to help

10. Comments

There is an association called ALAM (Assoc. of Lecturers in Agricultural Machinery). Active body useful for disseminating information to people in the Colleges that are involved with Agricultural/Horticultural Machinery. Sec. Phil Hurrell based at Reaseheath (01270 613 230).

Summary of interview points

- Reaseheath, Lackham, Askham Brian, Rycote Wood, Kaythorpe DeMontfort are likely to cover 80% of students going into design.
- Short course would be very useful especially for providing the most up to date information on Machinery Directive approvals for various types of machinery.

Relevant courses/modules

Module/Course Title	Content
Diploma in Ag. Eng. BTEC Advanced GVNQ in Engineering	Deals with most powered and non-powered machinery, fault diagnosis, fabrication and computing. Graduates go into design and development, manufacture, installation and management.
Introduction to engineering - 1 year course BTEC Intermediate GNVQ in Engineering	Prepares students for basic level entry into the industry.

7.7.5 Interview 3: Nigel Warner - Royal Agricultural College

1. **What courses, if any, include some H&S awareness training, e.g. dealing with legislation and the risk assessment process**

   Main course has been suspended because of lack of interest, but is on the books and ready to run. Other courses touch on agricultural engineering, but do have individual modules on agricultural engineering and machinery development.

   Time input relatively small because of time constraints.

2. **What is the extent of H&S awareness training in the course currently i.e. time and content**

   Provide information on risk assessment, sources of information on health and safety and BSI

3. **Do you see any need for an increase in the H&S content?**

   Feel there should be more health and safety in the courses but student level of interest and appreciation of health and safety issues is very low (‘not a sexy subject’).

4. **What obstacles would there be to providing more H&S content, e.g. shortage of course time, expense of producing the course, approving material**

   There is a shortage of time in existing modules, but there is definite scope for a 1-2 day course run separately from the degree/MSc. They would want to run it as a course to outside designers etc., presumably free for their students.

   Would be prepared to run course provided that HSE supported the course development.

Did produce a half module on health and safety management, but this was rejected by the accreditation board. However, stand-alone courses are not such a problem.

5. **Who has to approve the course content?**

   Accreditation board, also applies to short course?

6. **Are any of your courses approved by the Engineering Associations (Which?)**

   Not currently, but may in future.

7. **If the HSE were to produce an education pack, would you consider using it?**

   Would definitely use any support material

8. **What format would you like an education pack to be in, e.g.: physical items such as overheads, guidance notes for producing own material**

   Reference lists

   Actual paper material

9. **Would you be willing to comment on a draft education package some time in the future**

   Yes

10. **How does image of H&S in the department affect the attitude to H&S of course lecturers and organisers.**

Done for the legislation rather than for the principle of good design.

Relevant courses/modules

Module Title	**Content**
Mechanised Crop Production	Develops the student's abilities to analyse the requirements and alternatives for machine systems used in crop production and post harvest produce care.
Mechanised Livestock Production	Students analyse requirements for machinery and equipment in relation to various livestock, housing and production systems
Tractor Design and Development	Review tractor/machine technology; the UK/EU legislation affecting its design and use in European agriculture
Agricultural Engineering	Students develop a detailed knowledge of various aspects of farm mechanisation and further develop an understanding of the agricultural engineering industry.
Agricultural Machine Technology	Provides a sound understanding of farm machinery development, the use of new technologies and safety implications, requirements of farm machinery use.

7.7.6 Interview 4: Len Foreman - Rycorte College

1. **What courses, if any, include some H&S awareness training, e.g. dealing with legislation and the risk assessment process**

   GNVQ Advanced students do risk assessments

2. **What is the extent of H&S awareness training in the course currently i.e. time and content**

   Do workshops and risk assessments methods. Do assessments to Machinery Directive standards.

   HND students do the ergonomics of design and consider noise levels, vibration and safety etc., but don't cover foreseeable miss-use of a product as such.

3. **Course material provided**

   HSE freebies. Individual projects given a reference list, but no definitive list available. Normally sent to the Information library.

4. **Do you see any need for an increase in the H&S content?**

   They do risk assessment courses for Companies already, this is normal risk assessment though given by the Professional Training Services Department in the College.

   What obstacles would there be to providing more H&S content, e.g. shortage of course time, expense of producing the course, approving material, H&S culture

   Obstacles - instructed to run on minimum hours so extra time requirements would not be acceptable. Always trying to keep to the minimum! Difficult to fit extra things in.

   Deliver the minimum that is set by the approvals board (BAGMA?)

5. **Who has to approve the course content?**

   Through Course Co-ordinator, the Head of curriculum and through the Academic board. This is a long process that is not easy to change.

6. **Are any of your courses approved by the Engineering Associations (Which?)**

   HND approved by IAgE, Institute of Motor industries. NVQ BAGMA. TEC approve on some modern apprentiships.

7. **If the HSE were to produce an education pack, would you consider using it?**

   Yes - depends on cost. Can spare some time but must be zero expense. Can provide facilities for running the seminar or whatever.

8. **What format would you like an education pack to be in, e.g.: physical items such as overheads, guidance notes for producing own material visiting speakers?**

   Case studies would be most useful.

   Combination of guidance and material.

   Material for use in the library for self-study, especially as teaching time is limited.

9. **Would you be willing to comment on a draft education package some time in the future**

Yes.

Relevant courses/modules

Module/Course Title	**Content**
Agricultural Mechanic (NVQ)	Provides skills necessary to service, maintain and repair agricultural. machinery.
Agricultural Engineering	Fundamentals of engineering as applied to Ag. machinery &

(GVNQ Advanced)	equipment.
Engineering for agriculture and the environment (HND)	Mainly management and application of technology to land based industry.
Engineering (GVNQ)	General engineering.

7.7.7 Interview 5: Malcolm Carr-West - Writtle College

1. **What courses, if any, include some H&S awareness training, e.g. dealing with legislation and the risk assessment process**

   All their engineering courses do include some health and safety teaching, but it was not formally listed in the courses until recently.

   Validation panel requested formal statement on the health and safety content

2. **What is the extent of H&S awareness training in the course currently, i.e. time and content**

   Risk assessment is included. All student projects need to have a proper risk assessment done. Workshops incorporate health and safety issues.

   Legislation dealt with when appropriate, but not thoroughly. Students will not necessarily know all the legalities inside-out.

   Aware of need to consider the expense of, and moral duty to produce safe machinery.

   Students made aware of standards etc. from BSI.

   They provide as much HSE information as possible, if it is free, e.g. the free advice sheets.

3. **Do you see any need for an increase in the H&S content?**

   There is scope for increasing health and safety in design, but not in the standard course modules. A separate mini-course would be very attractive.

4. **What obstacles would there be to providing more H&S content, e.g. shortage of course time, expense of producing the course approving material**

   Attitudes - own health and safety responsibilities are a bug-bear. Affects attitude and image of health and safety in other areas.

   Most suitable solution for Writtle would be to have an extra ‘Safety by Design’ 1 - 2 day course, certificated and validated separately from the main course.

   They see this as a way of offering the students more for their money.

5. **Who has to approve the course content?**

   Courses approved by own validation panel at the College. Consists of couple of external academics, two internal academics and two from industry. Purely specific to this College.

6. **Are any of your courses approved by the Engineering Associations (Which?)**

   BEng Courses are accredited to Engineering Council standards. Students become Chartered Engineers - rules are changing at end of year.

   Engineering Council not likely to approve a short course, they would see it as a Continuing Professional Development programme. Quality standard would have to be provided by an educational body or HSE itself.

7. **If the HSE were to produce an education pack, would you consider using it?**

   Definitely yes. Would be willing to help develop a short course and trial it.

8. **What format would you like an education pack to be in e.g.: physical items such as overheads, guidance notes for producing own material**

   Want the entire package ready to deliver.

9. **Would you be willing to comment on a draft education package some time in the future**

   Yes

10. **Comments**

- Health and safety has on image problem because of their own H&S responsibilities getting in the way of day-to-day work. This could be affecting the profile of health and safety in the teaching process.
- Poor health and safety image may be affecting prevention of more serious injuries, i.e. too much of the minutia could be blinding people to the major issues.
- Source books of accidents would be useful.
- Source book of good ideas which have improved human factors issues.
- Writtle use accident reports as examples of poor design work.
- Ref: 'Agricultural tyres' By Dunlop. (Innes & Kilgower) shows result of exploding agriculture tyre. This is very effective in getting over the message. The energy in a tyre can accelerate a 60Kg man to a speed of 100kph.

7.8 HUMAN FACTORS IN AGRICULTURAL ENGINEERING DESIGN

A brief review of the ergonomic, human factors issues will highlight the factors which agricultural engineers should be considering and adopting as part of their standard procedures in developing and proving designs for agricultural equipment and machinery. In the context of this report this can only highlight the issues since to cover these in depth is outside of the scope of this project.

7.8.1 Human error

It seems appropriate to begin this review with the subject of human error. Human error is often the reason that is given for the cause of accidents, the finger of guilt is pointed at the person using the equipment at the time of the accident. Fundamental to all that is being investigated in this study is what is described in the "catch-all" phrase as human error. Virtually all problems in safety arise from human error either to anticipate or to accommodate the problem.

The recognition that human beings make errors came well before the 21st Century. In 'An essay in criticism', Pope (1688-1744), offered the view "To err is human, to forgive is divine", and Bolinbroke (1678-1751) offered : "Truth lies within a little and certain compass, but error is immense". Perhaps more pithily, Locke (1632-1704) wrote: "All men are liable to error; and most men are, in many points, by passion or interest, under temptation to it".

In view of the above it is perhaps surprising that more is not done by design to accommodate the human propensity to make mistakes. However, it explains why, that in today's highly

sophisticated and mechanised world, the problem of human error has exercised much attention. This is generally because of the spectacular, sometimes fatal and often extremely expensive consequences of failure arising from 'human error'.

Human error in the use of machinery and equipment and at work, will call forward, varying responses from different sectors of the population. On the one hand, there will be the sympathetic view of the ergonomist, but the designer, the engineer, the manufacturer, management, the insurers and even the judiciary tend to look for a scapegoat. It is often convenient to put the blame on the final, easily perceived, human error rather than on design failure. Design failure is human error one stage removed from the accident, but it is easier to apportion blame to the user, by virtue of an operating error, even though the design was at fault. Recently there has been greater recognition of this, at least in major disasters, such as at the Paddington rail crash and greater sympathy for the person making the final error which might have been outside of their capacity to avoid.

Human error is the end result of bad interface design, poor working environment and a general lack of appreciation of the physical and psychological constraints of human beings. The worker is often the last protection against bad design and is used to produce correct operation from design chaos. Agriculture is no less a victim of this malaise than any other sector of industry. Indeed because of the multiplicity of tasks, machines and environments with which the agricultural worker has to cope, the problems may well be greater. Singleton operation, in particular of machinery, can exacerbate the potential for error.

Classically all errors conform to four types: commission and omission, either of which can be reversible or irreversible. This means that errors are produced either by taking incorrect action or not taking action when action is required. In either of these situations it may be possible to either halt (reverse) the resulting reaction in which case the system returns to normal or if not then there is failure (irreversible).

Another approach to the classification of human error comprises: incorrect diagnosis; insufficient caution or attention; wrong procedure; and wrong instruction. Therefore we can see that engineers, including agricultural engineers should be: correctly diagnosing; ensuring sufficient caution in design; designing correct procedures; making sure that only correct procedures can be undertaken; and providing adequate and clear instruction for use.

It is contended that the need to understand man's limitation is itself not fully understood by most engineers nor given sufficient weight in design. By nature engineers are interested/motivated by the mechanics of their design, by its design elegance, e.g. the simplicity of the gearing, leaving human factors and safety to benefit, if at all, only by default.

Errors can occur as a consequence of 'man's' adaptability. Adaptability is one of 'man's' great assets and is a strong argument for inclusion of the man in the system, but adaptability is also a cause of his error potential. Since human beings are essentially goal orientated, they are adaptable and flexible. If the conditions under which a particular goal can be achieved are changed, then human strategy also changes, and so, human beings are not always successful at performing a sequence of actions.

Error potential exists in the operator but the error will not be realised until the situation and idiosyncratic factors co-exist. Situational factors will include poor design, poor environment, an overloaded work situation or complex tasks. Idiosyncratic factors might include lack of motivation, lack of skill and training and lack of physical capability. Conversely too much motivation and an extreme desire to get the job done may be an important factor leading to an error occurring.

Organisational factors are not always recognised or accepted as safety factors. In many production systems there are two different parties with different interests, on the one hand management and on the other workers. Both parties are trying to maximise their benefits and minimise their costs and effort. Management provides a production system, within which safety is an element, and which is supposed to comply with legislation. Moreover, workers may disregard instructions or directions for use of the system and take risks in order to reduce the amount of effort required to operate the system to gain some personal benefit, or increase in pay. The result is that the system is less safe and accidents occur. To improve the safety record; understanding and application of the human factors involved must be promoted.

Another important issue is the fact that people do not read or understand instructions. The conclusions of researchers are that it is a design problem. Instructions are often not read and so machines should be designed for instruction free operation, but where instructions are essential, cannot be avoided, they must be properly designed. Designers should recognise that instructions for the operation of their machine will not be read and design the machine accordingly.

Classifying, analysing and understanding why errors occur and their implication is essential for fitting the job or machine to the man. Generally the concept of applying human factors/ergonomics to the design process in agriculture is now fairly well understood but not always well established.

7.8.2 Human error in agriculture

That human error is prevalent in agriculture is certain, general indicators can be found in Health and Safety Executive (HSE) accident statistics. But, errors occur daily, for example, when cowmen identify the wrong cow for insemination, and crop sprays are diluted in the incorrect proportions. Poor machine design associated errors are legion, but fortuitously very few lead to a major accident, but many cause minor injury or poor performance. These will not be recorded.

There is no doubt that farm workers/operators can increase the chances of an accident occurring by their actions or lack of action, they may also quite deliberately increase the risk of an accident taking place, (Locke - by passion or interest (motivation) under temptation to it). When operators are on piecework, in the interest of getting the job done, they discount the risk and take a chance. Farmers on small farms, not employing labour are in a similar situation to the piecework employee, as are those workers working alone in the field with machinery - singleton operation.

The HSE approach to recording accidents is important in that it directs attention to those situations where accidents are occurring and injuries are being incurred. Recording the type of injury gives a measure of the human cost involved. Therefore judgments can be made as to which areas should be investigated and where efforts need to be made to reduce the number of accidents and therefore injury. However, unless information is available to explain why the accident occurred then the solution is likely to be mis-directed.

Typical of this concerns the situation regarding tractor overturns. Farm workers have been killed by tractors overturning. The negative solution to the problem was to fit tractors with safety cabs to reduce the chances of the driver being killed when the tractor overturned. A more positive or proactive approach to the problem would be to isolate the reasons why tractors overturn and to set about preventing them overturning. The result of the chosen solution was, not only the fact that tractors still overturn, but that this reactive “solution” to the problem increased the noise level on the tractor and resulted in increased occurrence of occupational

deafness. Subsequently other negative, reactive, but expedient, measures to quieten the cabs were taken to reduce the incidence of occupational deafness. This is not to suggest that this was not required.

The evidence is that the traditional approach in agriculture is to define the work, design the machine to carry out the work, and then deal with any problems involving man, the machine and work as they arise. Whereas, the human factors/ergonomics approach is to define the work and see how best man and machine working together can carry out the work, ensuring that the design of the task and the machine fully understand the limitations of the worker. There is no reason why ergonomics should not be post-hoc, but this could lead to radical redesign rather than palliative measures.

It is considered that the key to safety in agriculture is to obtain a good understanding of why accidents actually occur. This requires investigation into the causes until the human factors or ergonomic reason for the accident occurring is discovered. It is argued in the previous discussion that the cause of accidents lies in human error, but that the accident itself is more often than not, only the manifestation of a series of preceding errors in the design process.

Farmers and agricultural workers are multi-disciplined, work in many varied environments and diverse locations using a variety of tools and machines, and there are many opportunities for human error and accidents are frequent. There is an urgent need to look beyond the accident to establish the root cause that is, the human error in design and where it did not take account of the situational and human factors.

7.8.3 Physical and psychological factors

The above has concentrated on the issue of human error in the agricultural work environment and the implications of poor design factors that need to be embedded in the design process. This does include both physical and psychological factors, but some discussion of these in their own right is required in that they are human factors.

Physical factors will include human anthropometry (body size), anatomy and bio-mechanics. In respect of anthropometry ergonomists will point out ‘the fallacy of the so called average person’ since no such person actually exists. Closer examination of any number of people who are at the mean height of the population will show that they do not weigh the same, their arm and leg length will vary and even the below and above knee and fore and upper arm lengths, will be different within the group. Head and facial measurements are also subject to great variation. Designing for the average therefore will mean that the design is unlikely to fit anyone. Designers need to fully understand anthropometrics in order to design to meet the needs of the people using their designs. Typical situations concern reach envelopes and work table working heights. In agriculture and horticulture very little effort, outside of the cab environment, is made to enable workers to vary their working environment to suit their anthropometric characteristics. For example 6 feet tall men and 5 feet tall women are often expected to work alongside one another on a standard height grading line, designed for the average women of 5 feet 4 inches. The consequences are that many suffer from early fatigue and low back pain. Another problem is in the design of protective clothing where the acknowledgment of anthropometric variation is an essential requirement.

There is also considerable variation between people both anatomically and bio-mechanically. These are well known, but often forgotten in agricultural design. The key recognition required is that human performance degrades slowly as the body muscles and physiology tires, this compares to sudden breakdown associated with machines and equipment. Design needs to embrace what people do well and what machines do well.

As mentioned earlier people have a great asset in that they are able to adapt and make do, change their methods to fit new situations, make the best of poor design and overcome difficulties because they are so flexible in their approach. This is a great strength when used properly in design and taken advantage of to add value. For example, when the task in continuously and unpredictably varied. However, it is too often used to make poor design work. A simple example is that unless a machine is designed with tolerances that enable it to do its job it fails, but if it is required that the worker has to reach a handle that is outside of their sitting reach envelope, they will stand up or reach forward or both to reach the handle. They will continue to do so until, and after, their performance degrades and they cause themselves harm.

The potential result of this adaptability can become much more serious when design is such that in order to achieve design objectives workers are drawn into highly dangerous situations. An example is where design determines that workers have to stand or work between items of equipment, e.g. a tractor and trailer or cultivation equipment, in order to couple the items together, often compounded by providing tractor control equipment which can be operated from that position. Some legislation specifies that they should not do this, but in practice it is not possible to do the job unless they do.

The psychological issues include, not only motivation mentioned earlier, but also the perceptual skills. Often design demands perceptual skills which are outside of the capability of the worker. An example of this is where operators are asked to grade produce, the grade of the produce is determined by factors of blemish, size and colour, among other attributes, and the operator is asked to select the produce that fails the grade criteria from a moving belt. Experience indicates, that the task is most likely to be outside of the capability of the operator in terms of the number of observations the human eye can make in the time allowed and the selection parameters to be applied. What tends to happen is that, in order to be seen to be doing the job, the operator chooses produce to take off the grading line at random, because they are unable to invoke the selection criteria within the design provided.

Good knowledge of the human senses of sight, hearing, smell, taste and touch are essential. The interaction and application of these in safe design is an important requirement.

The writing of instructions often fails to take account of basic facts in presenting information that need to be understood. Researches have demonstrated that text line length of between 8 and 14 words, text size of 12 point, line heights 10% greater than point size and unjustified text are easiest to read and understand. However, instructional text often ignores this, favouring the styles of advertising or marketing literature. Often the contrast rendering between text and its background are driven by ‘pretty, graphical’ rather than functional design.

Recognition of human factors by engineering designers will provide a better fit between man and machine, a better choice of which is best fitted to the particular job, leading to improved performance and a safer environment.

7.8.4 Assessment techniques

Critical to integrating human factors into design are techniques for understanding the job to be done. The term ‘task analysis’ embraces any method that can be applied to understand fully the component parts of a task. In this case a task means part of a job. A task can be broken down into elements and this is part of the process of task analysis. In terms of human performance task analysis identifies redundant and repetitive elements which can by design be removed from the task thereby improving performance.

The role of task analysis in machinery design is two fold:

- Full understanding of the tasks that make up a job is an essential pre-requisite of allocating functions to man or machine on the basis of which functions are best performed by man and which by machine. Human factors knowledge and expertise provides the basis upon which this allocation of tasks between man and machine should be made. Agricultural machinery designers need exposure to this knowledge and expertise.
- Having determined which tasks are to be done by man or where man has an integral involvement, the analysis of the task carried out by man becomes essential to the risk assessment process.

It is difficult to understand how full risk assessment can be carried out without task analysis. Each task or component in the use of a machine where there is a human involvement requires to be analysed. If this is done then the opportunity will be realised for: correct diagnosis; ensuring caution in design; designing correct procedures; making sure that only correct procedures can be undertaken; and providing adequate and clear instruction for use. Risk in normal use and in miss-use, will have been assessed as will both the psychological limitations and physical abilities of the users.

8. CONCLUSIONS

8.1 DESIGNERS

8.1.1 Health and safety and risk assessment

- In agricultural engineering design, health and safety is not an integral part of the design process. Some designers do consider health and safety at an early stage in the design process, even at the concept stage, but it appears that it is still seen as a separate entity. For others it is clearly a bolt on process, taking place after the functional design is complete. These designers will resolve safety problems by guarding the equipment. This is a deliberate policy in the treatment of health and safety. Risk assessment is done because there is a legal requirement to do it not because it is seen as adding value by identifying and resolving risk.
- Risk assessments appear to be of variable quality. Many designers have not received formal training, these carry out risk assessments based on experience developed in the narrow confines of their own design environment. There was uncertainty about what was required in a risk assessment.
- There are a number of machinery designers who have developed their business from perceiving an opportunity as farmers. These have not had formal training in machinery design. The emphasis and basis of their design is to meet the needs of the activity, e.g. planting, cultivating, harvesting. These practical functions they need to do well, and clearly do do well, since they survive in a highly competitive market. Taking full account of health and safety factors is not essential to achieving success in the market place and consequently is not given the attention it requires. These designers present a particular problem in addressing the health and safety issue.
- Documenting risk assessments is acknowledged to be less than adequate by nearly all designers. Recognised formal systems appear to be infrequently used, if at all.

- Assessing risk early in the design process did appear to reduce safety problems arising later and at production. This leads to the conclusion that improving human factors knowledge so that the risk assessment process was also improved would pay dividends in safer design.
- Designers did recognise that it was predominantly the role of the designer to design safe equipment. The burden was on them not the users.

8.1.2 Human factors

- Human factors knowledge, in the few design environments where it exists, is limited to anthropometrics and knobs and dials ergonomics. This is typically limited to the driving cab environment.
- Detailed knowledge of the whole area of human error, physical and in particular psychological applications rarely exists, certainly not as described in this study.
- Formal allocation of tasks to machine and man does not appear to take place. There was no evidence of task analysis being used to assess risk where there was either direct or indirect human involvement in the process.

8.1.3 Legislation

- The use and knowledge of legislation and support materials was both patchy and poor. It would appear that designers had made a big effort to become conversant with legislation and its design needs when the Machinery Directive and it's requirement were first put in place. Subsequently there had been little effort to keep up to date.
- Keeping up to date, having good knowledge of legislation and knowing specific requirements was clearly a problem for all. This problem is likely to be greater for the smaller Companies where the burden falls on one or two designers. Not knowing what was needed was an escape from the burden of finding out
- Designers recognised the problem of not knowing the legislation sufficiently well and would welcome measures to address these problems. Suggestions for referring and sourcing both paper based and electronic via internet were welcomed.
- There was concern over varying standards between EU and International and also because of varied interpretation by Countries. Designers complained that standards and legislation was biased in favour of the French and German. It is likely that this was their own fault since designers have not represented their views in the formation of EU legislation and therefore have not influenced the legislation. By contrast the French and Germans have represented their views which have become embedded in the Machinery Directive. By default it is French and German based and biased. UK designers need to play an active role in the formation of legislation.

8.1.4 The market place

- Design is driven by the demands of the market place, this is not suprising, indeed it would be very suprising if this were not so. The market place may not recognise sufficiently the advantage of safer designs or at least does not attach a premium to safer design. In terms of the utility of acquisition of health and safety this is often non existent. There is no pressure and no premium for designers to seek and offer safer designs. The main driver for safer designs is legislation, not the market place, therefore designers do only what is required to satisfy legislation, they do this with the minimum of effort and expense.

8.1.5 Management attitude to health and safety

- For the most part management make the decisions on the resources committed to health and safety. In some cases management and designers are one and the same. In all cases designers have a role and a say in the resources that are committed.
- The burden of health and safety and risk assessment is considered by many to be substantial, by some to be much too great with little benefit, by others to be substantial but an important part of the design process and another group do not see it as a burden. It is quite possible this latter group do not commit sufficient resource to the activity.
- The main objective of management is to meet the needs of the market and to produce and sell profitably.

8.1.6 The potential for better addressing the issues

- The options that were presented were well received, although in some cases with caution.
- Most favoured were a "detailed reference list of relevant material" either on paper, CD-ROM or Internet. Also highly favoured were regular updates and a help contact at HSE. Training courses also found favoured. A problem exists in that those Companies with few employees and a small design team did not have sufficient critical mass and therefore time to make use of these support ideas. This is a considerable problem since they are likely to be in need of most support. A help contact at HSE was considered essential.

8.1.7 Formal training

- Formal training prior to employment was mostly at Agricultural Colleges or Universities. However, many designers had gained their knowledge and experience from working in agriculture, using the equipment, and from doing the design job. Continuing professional development appeared to be confined to "on the job training". None had had formal training in risk assessment. Out of those interviewed none had had formal human factors training.

8.1.8 Overall

- There was acknowledgement that improvement was required and there was a willingness to embrace change. In some cases there was enthusiasm for better knowledge of human factors, improved risk assessment capability and to the concept of incorporating health and safety into design from first principles. There was caution because of cost, time and whether the market would pay for safer designs. In general designers recognise it is their role to provide safer designs and they would welcome efforts to help them in achieving this. Their attitude was positive towards this.

8.2 THE TRAINING COURSES/MODULES

- The training available from those offering agricultural engineering design training was varied. Some courses included and emphasised human factors training, others offered health and safety and risk assessment, but not from a human factors background and yet others offered little of either. These latter concentrating on the function of treating the crop.
- There was considerable willingness to embrace human factors, health and safety and risk assessment. Concern was expressed because health and safety is not perceived as a

stimulating or interesting subject. Approaching health and safety through human factors might address this.

- It was clear that there were barriers to the introduction of such courses/modules. They would need to be formally accepted by those determining course content and would have to be obligatory modules for students. They would not be taken up by students unless they were obligatory modules. The cost of working up these modules would require support.
- External help in the development of human factors, health and safety and risk assessment modules would be welcomed.

9. RECOMMENDATIONS

- A detailed reference list of all legislation, standards and support material relevant to promoting safer design in agricultural engineering should be prepared.
- This reference list to be available as a paper based system, on CD-ROM and Internet. It is expected that in the fullness of time the Internet site would satisfy most needs and would provide an easier route for amendment. There will be a need for a robust search engine.
- Such a reference list would need to be supported by notification of change to legislation and availability of new standards and guidance.
- Advanced warning of changes to legislation should be given.
- To support the reference list case studies concerning problems, and accidents together with recommendations for solutions should also be made available and referenced.
- Pressure to be brought on agricultural engineers in the UK to take a more active part in the setting of standards and the formulation of legislation.
- Formal training modules for human factors, health and safety and risk assessment should be prepared and implemented. These modules to be a formal, required part of the education of those training to become agricultural engineering designers.
- Training in human factors, health and safety and risk assessment must become part of the ongoing professional development of agricultural engineers. As such, a case exists for it to be formally recommended by the Association or other professional bodies.
- These modules need careful planing to ensure that their content meets the needs of the industry, leading to safer designs. There is a need to bring about a change in philosophy and in culture.
- The HSE and others (DTI) will need to consider how they can prime the development of the improved training with both active and financial support.
- It is expected that these activities will require underpinning by a legislative requirement that they will be used, observed and undertaken. There needs to be both carrot and stick.
- Further efforts are required to improve the safety culture in agriculture. Concerted action needs to be taken to increase farmers utility for safer designs.
- To implement these recommendations more detailed study is required. A specification for the reference list and support material will be required. Detailed study will be required to develop the training modules and the support material required for these. The involvement of human factors expertise in this is essential and will require to be related to the processes

of agricultural design. Those approving these education modules will require persuading of the essential need for such training.

Appendix 1: Questionnaire structure: Agricultural engineers (Telephone interview)

Type: Semi-structured telephone interview

Time: Nominally 30 mins or at the convenience of the interviewee

Format: CATI system, data into MS Access database

- **Start CATI**
    - Enter Co details onto database if not entered.
    - Call interviewee.
        - Available = Start
        - Unavailable = Ask if OK to call back
            - If OK to call back = record callback time
            - Not OK to call back = Thank and exit interview
- **Introduction points to cover**
    - "On behalf of the HSE I am collecting feedback from designers and producers of agricultural machinery in order to understand the difficulties experienced in conducting risk assessments on machinery, in meeting British and European legislation and in designing machinery which is as free of risk as possible."
    - "Would you be interested in discussing these topics?"
        - Yes = Continue
        - No = Try to find out why they do not wish to talk. Thank and exit interview
    - All comments you make will remain anonymous unless you wish otherwise.
    - Do you mind if we record this interview for reference, it will be erased after the main points have been transcribed?
        - Don't mind = start recording
        - Do mind = "I will just make some notes as we go along"
    - Start question 1
- **Questions**

Levels of consideration for H&S in current working practices

- **Q1.**
  Do you adopt any systematic methods for evaluating the risks and hazards of a piece of machinery you are designing or modifying? (open)

- **Q2.**
  At what stages in the design process does an assessment of potential risks to people generally occur?

(0/1) Concept stages/sketches (0/1) Modeling/detailed drafting stage (0/1) Prototypes stage (0/1) Final product stage (0/1) During production

- **Q3.**
  Do you find that you are having to make modifications to the design of machinery at a late stage in the design process because of needing to satisfy BSI, European or HSE requirements? (1) Yes (2) No (open) comments

- **Q4.**
  In the design process or risk assessment, Do you think about: (1/2) all the possible ways in which people might get hurt with the machinery when doing normal tasks (1/2) all the possible ways in which people might miss-use the machinery, carry out dangerous actions with the machinery or disobey instructions. (1/2) the psychological state of the persons using the machinery (1/2) the physical abilities of the persons using the machinery

Support systems and material

- **Q5.**
  What information sources do you actually use during the design and risk assessment process e.g. guidelines, standards, own skills, etc.

(Find awareness of the following items)

Ref.	Title	(1) use	(2) aware of
HSG89	HSE Book - Safeguarding agricultural. machinery (big-92/small-98)		
5304	BSI standards 5304 'Safety of machinery'		
BS EN 1050	European/BSI 'The Safety of Machinery' standard - Principles of risk assessment		
BS EN 292-1/2	European/BSI 'The Safety of Machinery' standard - Basic concepts		
BS EN 294 & 811	European/BSI 'The Safety of Machinery' standard - Safety distances upper/lower		
BS EN 349	European/BSI 'The Safety of Machinery' standard - Gaps to avoid crushing		
BS EN 953	European/BSI 'The Safety of Machinery' standard - design & construction of guards		
BS EN 1088	European/BSI 'The Safety of Machinery' standard - interlocking devices		
BS EN 418	European/BSI 'The Safety of Machinery' standard - Emergency stop equipment		
	CEN Safety of Machinery standards under development		
	CEN Ergonomics in Safety of Machinery standards under development		
PM41	HSE book - Application of photo-electric safety systems		
BS EN 1037	European/BSI - Prevention of unexpected start-up		
BS EN ISO 3767	European/BSI/ISO - Symbols Standards for operator controls and displays		
EN 50099-1	European - Visual, audible and tactile signals		
EN 60204-1	European - Electrical equipment		
BS 5861	BS PTOs on tractors (5861)		
BS 1841	BS for 3 point linkage on tractors		
L22	Safe use of work equipment (PUWER Guidance) 1992		
PUWER	Provision & use of work equipment legislation (PUWER) 1992/1998		
SI 3073	Supply of machinery safety Regulations(1992)		
SI 2063	Supply of machinery safety Regulations (1992) + amendments of 1994		
95/650	DTI Blue book Guidance notes on the UK Regulations (1995)		
	HSE Free Information sheets (any)		
	Safe use of combines		
	Safe use of rotary flail hedge cutters		
	Safe use of big round balers		
	Working safely near overhead power lines		
IND(G) 241L	No second chances - A farm machinery safety guide		
IND(G) 270	Supplying new machinery		

- **Q6.**
  Which of the following would you find useful in helping you to design safer machinery, and do a more thorough risk assessment?

1. Detailed reference list of all relevant material to help implement legislation, standards etc.	(1)
2. Regular updates on the current and projected legislation and standards	(1)
3. Short 1-2 day training courses on designing out risk from machinery	(1)
4. An internet site which lists all current available information and research	(1)
5. A source book of case studies where certain designs have led to injury	(1)
6. A source book of design ideas for dealing with different risks, to stimulate invention	(1)
7. A source book of components for safety and their specifications for use	(1)
8. A help contact at HSE for dealing with specific design issues as they arise	(1)
9. Interpretation of the legislation for their specific machinery	(1)
10. Other	(1)
(open) Comments on any of above	

- **Q7.**
  Which of the above would be of most value to you? (1-10) first preference (1-10) second preference (1-10) third preference (open) comments

- **Q8.**
  Would you prefer to be working to an EU or International set of standards? (1) EU (2) International (open) Comments

Training of the design team members

- **Q9.**
  Where did members of the design team get their training, and what courses did they do if any?

place	course
(open) Code later	(open) Code later

- **Q10.**
  What training have they had whilst in employment? (open)

Personal and organisational attitudes to H&S and risk assessment

- **Q11.**
  Do you feel it is the responsibility of the user to use the machinery carefully, or the responsibility of the designers to make it impossible to use the machinery unsafely. (open)

- **Q12.**
  Do you believe it is more effective to train people to use machinery safely than to try and design out all the risks? (1) Yes (2) No

- **Q13.**
  To what extent do you feel that dealing with risk assessment of your products places a burden on your business (open)

- **Q14.**
  What do you find are the greatest obstacles to carrying out a thorough risk assessment on your machinery (open)

- **Q15.**
  Who, in your organisation, has the say over the amount of resources applied to risk assessment of the machinery, and designing for safety? (open)

- **Q16.**
  What is the attitude to H&S issues from the management? (open)

Company background

- **Q17.** .(If not previously known) No employees (0-1000) Details of product lines (open)

  Proportion of customers in: (0-100%) UK
  (0-100%) EU
  (0-100%) Worldwide

  No. machines produced each year (0-1000)

Exit dialogue

- **Q18.**
  Would you like to receive a summary of the results of this study? (1) Yes (2) No

- **Q19.**
  Would you like to discuss these issues in more detail with a visit to your Company? (1) Yes (2) No

    - If Yes = Arrange a possible visit date and send details of what the visit would involve.

- Thank and exit interview.

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