Department of Transport and Regional Services

Australian Transport Safety Bureau

Aircraft Maintenance Safety Survey – Results

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Introduction

There is a growing recognition that human factors exert a powerful influence on the quality of work and the safety of workplaces. In recent decades, 'pilot error' has been the focus of much aviation human factors research. However, human factors affect the work of maintenance personnel as well as pilots. Worldwide, maintenance deficiencies are estimated to be involved in approximately 12% of major aircraft accidents and 50% of engine-related flight delays and cancellations.[1]

As an ongoing safety program, the Australian Transport Safety Bureau (formerly BASI) is investigating the human factors which affect maintenance personnel. In September 1998, BASI distributed a safety survey to Licensed Aircraft Maintenance Engineers (LAMEs) in Australia. The survey was designed to identify safety issues in maintenance, with a particular emphasis on human factors.

This report has been prepared to provide maintenance personnel with factual information on the results of the survey. Analysis of survey results, conclusions and recommendations will be published separately.

Respondents

Of the 4,600 surveys distributed, 1,359 were returned, representing a response rate of approximately 29%.

Sixty per cent of respondents worked on high-capacity airline aircraft, 9% worked on regional airline aircraft, 13% on charter aircraft, 9% percent on general aviation aircraft, while 3% performed 'other' maintenance work[2].

Ninety-four per cent of those who responded were LAMEs. The remaining respondents were Aircraft Maintenance Engineers (AMEs) and other maintenance personnel.

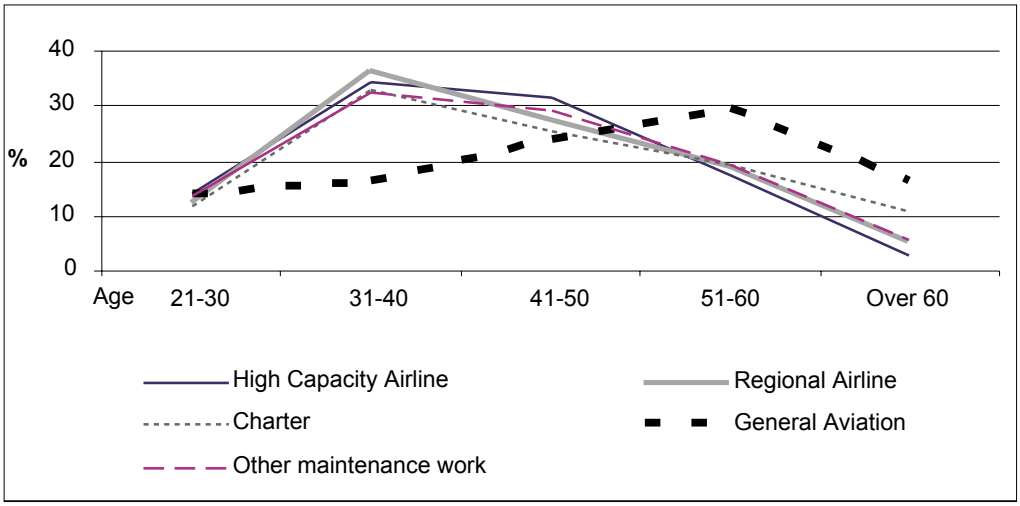
Age distribution of LAMEs

Respondents were asked to indicate their age, using 10-year groupings. LAMEs who worked on airline or charter aircraft, or who performed 'other' maintenance work were most commonly in the 31 – 40 year age group (see fig. 1). However, the age distribution for LAMEs working on general aviation aircraft was significantly different. Approximately 30% of those LAMEs were in the 51 – 60 year age group and approximately 70% were over 40 years of age.

[1] Marx D. A. & Graeber R. C. Human error in aircraft maintenance, in N. Johnston, N. McDonald & R. Fuller (eds), *Aviation Psychology in Practice*, Aldershot, Avebury (1994)

[2] High-capacity airline aircraft are those with more than 38 passenger seats; regional airline aircraft are those with 38 or fewer passenger seats. Personnel who maintained aircraft from more than one category were assigned to the category characterised by the larger aircraft type.

FIGURE 1. Age group by employment type. *

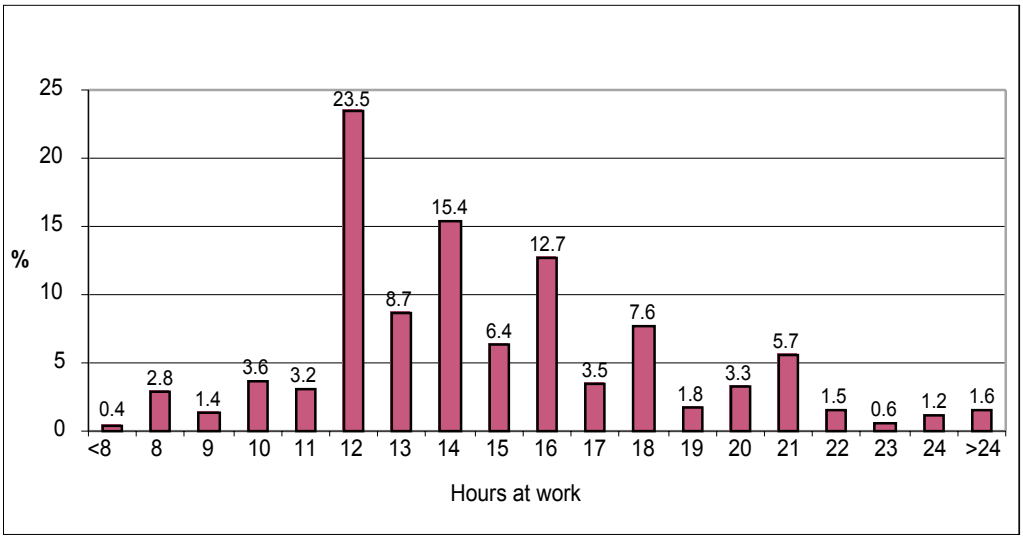


* AMEs are not included in this figure. Where a LAME reported that they worked on more than one category of aircraft, they were assigned to the group represented by the largest aircraft type.

Work duration

Respondents were asked to report the longest period they had been at work in the last 12 months. The most commonly reported duration was 12 hours, reported by over 23% of respondents (see fig. 2). Over 10% of respondents indicated that they had worked for over 20 hours at a stretch at least once in the last year.

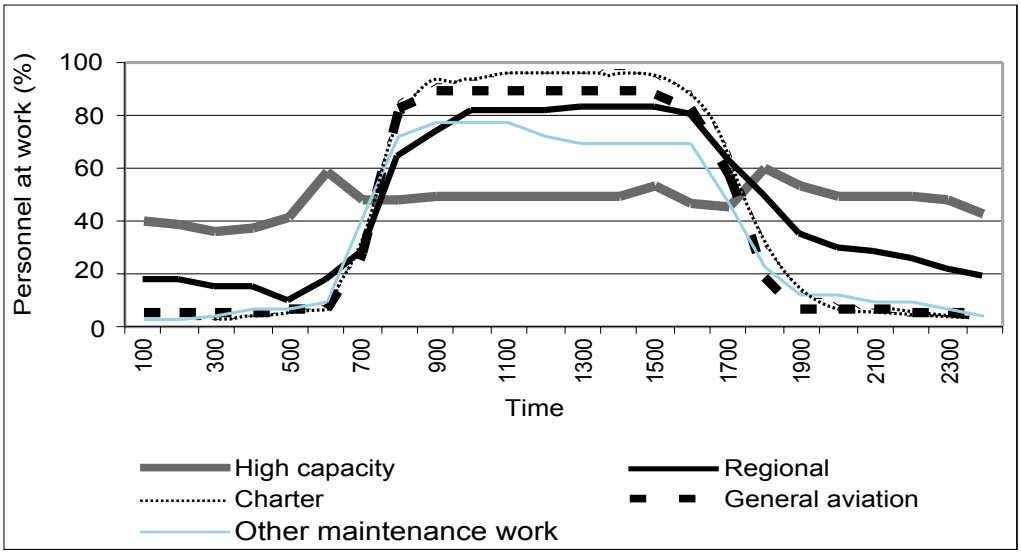
FIGURE 2. Longest shift worked in last year



Hours of Work

Respondents were asked to report the hours they had worked during their most recent work period. As can be seen from fig. 3, the work attendance pattern reported by those working on high-capacity airline aircraft was significantly different to that reported by workers in other sectors of the industry. High-capacity maintenance work was being performed continuously throughout the 24-hour day. However, those who worked on general aviation and/or charter aircraft, or who performed 'other maintenance work', were at work mostly during daylight hours. Workers in the regional airline industry also attended work mostly during the day, but reported more night work than those in general aviation.

FIGURE 3. Work attendance pattern by industry group



The peaks evident on fig. 3 for high-capacity airline workers at 0600 and 1800 reflect shift changeovers.

Types of Safety Occurrences

Six hundred and ten respondents used the survey to report a safety occurrence. Occurrence reports were not linked with particular organisations or individuals.

Occurrence outcomes

As table 1 indicates, the most common outcomes for airline-related maintenance occurrences were systems operated unsafely during maintenance, towing events and incomplete installation. 'Systems operated unsafely during maintenance' refers to cases where aircraft systems such as thrust reversers were activated during maintenance when it was not safe to do so, in some cases because personnel or equipment were not clear of the area.

The most common outcomes of non-airline occurrences were incorrect assembly or orientation, incomplete installation and persons contacting hazards. Definitions of the outcome categories can be found at attachment A.

Table 1. Outcome of safety occurrences*

	Airline	Non-airline
System operated unsafely during maintenance	18%	7%
Towing event	9%	3%
Incomplete installation, all parts present	8%	9%
Person contacted hazard	7%	9%
Vehicle or equipment contacted aircraft	7%	1%
Incorrect assembly or orientation	6%	11%
Material left in aircraft	4%	5%
Part damaged during repair	4%	2%
Panel or cap not closed	3%	3%
Incorrect equipment/part installed	3%	4%
Part not installed	3%	6%
Required servicing not performed	3%	4%
Degradation not found	1%	5%
Other	24%	31%

*Figures are rounded to nearest per cent

Personnel involvement in occurrences

Over 95% of the occurrences involved the actions of personnel. Table 2 indicates that memory lapses, procedure shortcuts and knowledge-based errors were the most common unsafe acts reported. Some occurrences involved more than one type of action: for example, a memory lapse (such as forgetting to tighten a connection) may have been followed by a procedure shortcut, (such as deciding not to perform a functional check due to time constraints).

Table 2. Unsafe acts in occurrences

	Airline	Non-airline
Memory lapse	21%	20 %
Procedure shortcut	16%	21 %
Knowledge-based error	11%	18 %
Trip or fumble	9%	11 %
Failure to check	6%	2 %
Unintended action	3%	6 %
Failure to see	5%	6 %

Occurrence factors

Respondents were asked to suggest why the occurrence had occurred. The most commonly nominated factors are shown in table 3. As can be seen, pressure, fatigue and co-ordination problems were the most commonly mentioned factors for airline and non-airline occurrences.

Table 3. Occurrence factors

	Airline	Non-airline
Pressure	21%	23%
Fatigue	13%	14%
Coordination	10%	11%
Training	10%	16%
Supervision	9%	10%
Lack of equipment	8%	3%
Environment	5%	1%
Poor documentation	5%	4%
Poor procedure	4%	4%

Respondents frequently attributed memory lapses to pressure and/or fatigue. Procedure shortcuts were associated with pressure or a lack of equipment. ‘Failures to check’ frequently involved poor coordination with other workers. ‘Failures to see’ tended to occur when the person was fatigued or when the environment made the job difficult, such as when access was difficult or light levels were low.

Time of occurrences

As can be seen from fig. 4, the number of occurrences involving the maintenance of high-capacity aircraft varied throughout the day, even though the number of workers present at work did not vary significantly.

FIGURE 4. Personnel at work and occurrences throughout the 24-hour day for high-capacity airline maintenance

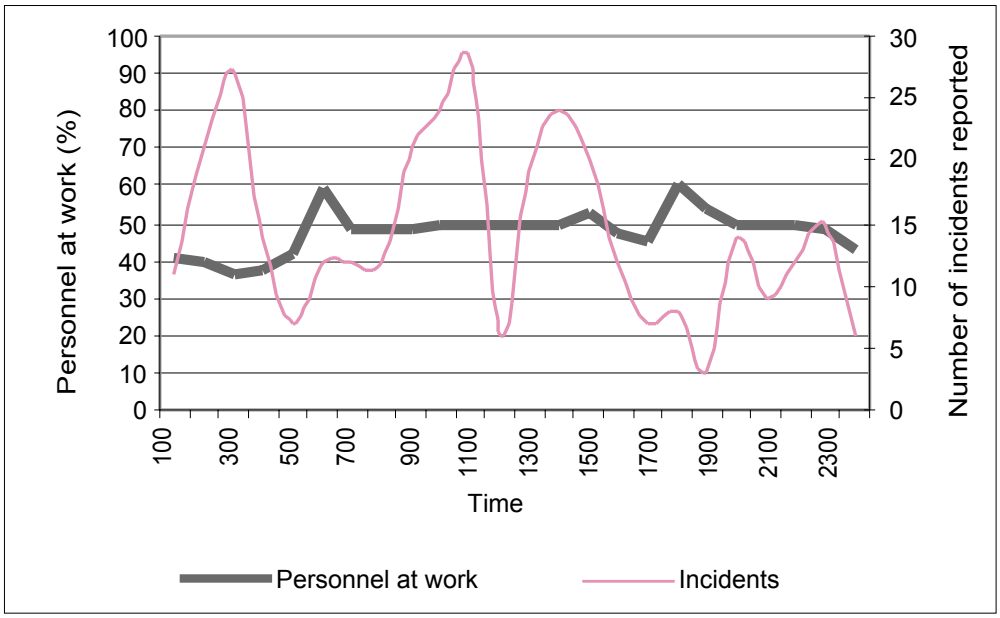
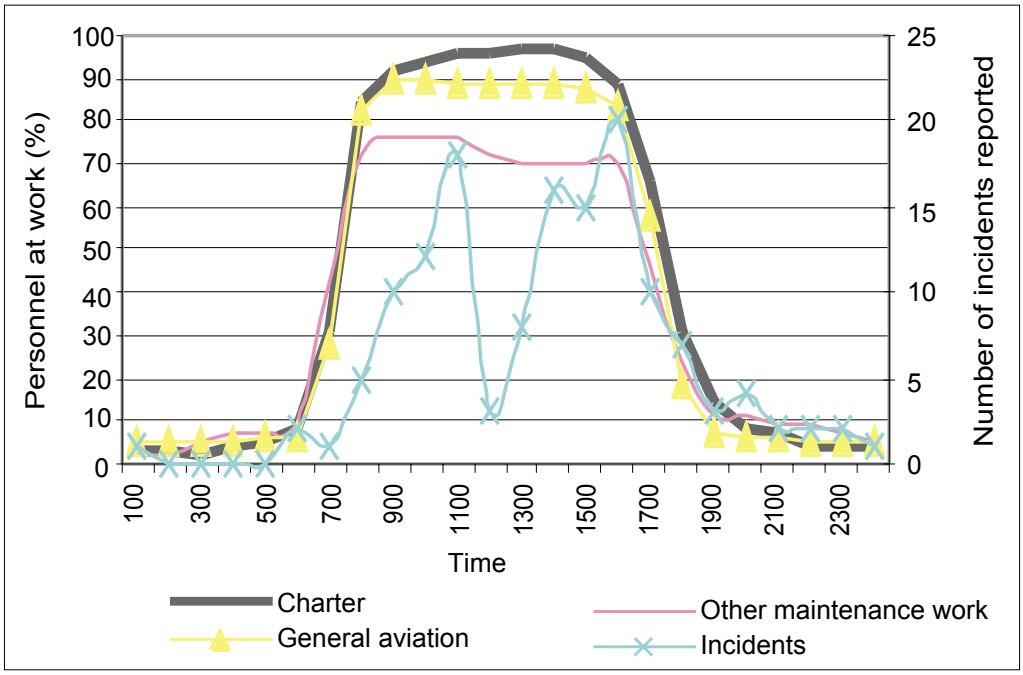


FIGURE 5. Personnel at work and occurrences throughout the 24-hour day for non-airline maintenance



The occurrence times for non-airline related maintenance show two peaks, one at around 1000 – 1100 hours, the second at around 1600 hours (see fig. 5).

Data for regional airlines are not presented here as there were relatively few occurrences for which time information was available.

Frequency of injuries and quality occurrences

In addition to the opportunity to describe an occurrence, respondents were also able to indicate in a multiple choice question, whether they had been involved personally in a health and safety or airworthiness occurrence within the previous 12 months.

The majority of respondents reported that they had not been injured at work in the last 12 months. However, just over 30% had been injured once, or more than once (see table 4). Approximately-two thirds of respondents reported that they had been involved in an airworthiness-related problem in the previous 12 months.

Table 4. Percentage of respondents who had been involved in work-place injuries and airworthiness-related problems in the previous year

	None	One	More than one
Airworthiness-related problems*	32.9%	17.3%	49.8%
Injuries at work**	67.9%	21.7%	10.4%

* Excludes 74 respondents who did not answer this question

** Excludes 25 respondents who did not answer this question

Unsafe acts in aircraft maintenance

The questionnaire contained a 48-item checklist of 'shortcuts and mistakes' that have contributed to maintenance occurrences in the past. Respondents were asked to indicate on a five-point scale the extent to which they had carried out (or failed to carry out) each of those actions in the last 12 months. The scale was designed to gather general judgments rather than specific assessments of frequency.

The full results for this checklist can be found at attachment B.

The most commonly reported acts involved not referring to the maintenance manual or other approved documentation on a familiar job, and being misled by confusing documentation. The most infrequent actions were accidentally starting an engine and adding the wrong fluid to a system.

Responses were analysed using a statistical procedure which identified clusters of related items.[3] Three key clusters emerged – procedure shortcuts, memory lapses and misunderstandings.

Typical procedure shortcuts were not referring to the maintenance manual, or turning a 'blind eye' to a minor defect. Memory lapses included being interrupted part way through a job and forgetting to return to it, and leaving a connection 'finger tight'. Misunderstandings included being misled by confusing documentation or as a result of inadequate communication with other personnel.

Younger respondents tended to report more shortcuts than older respondents. The reported frequency of memory lapses and misunderstandings, however, did not change significantly with age.

[3] SPSS principal components analysis with varimax rotation.

Respondents were asked about their attitude towards procedure shortcuts. Sixty-nine per cent felt that it was sometimes necessary to ‘bend the rules’ to get the job done. While 38% of respondents believed that their management discouraged shortcuts, the remaining respondents considered that management either did not know about shortcuts, or tolerated them.

Respondents reporting that they had been involved in an airworthiness occurrence during the previous year, also tended to report an above average level of procedure shortcuts. Such respondents however, reported an average level of memory lapses and mistakes.

The respondents who reported that they had been injured at work in the previous year tended to suffer from a slightly higher level of memory lapses but were not more likely to take shortcuts or make mistakes.

Summary of Findings

- Respondents who work in the general aviation industry tended to be older than other survey respondents.
- Over 10% of respondents indicated that they had worked for longer than 20 hours at a stretch at least once in the previous 12 months.
- For airline maintenance, the most common forms of occurrences involved systems operated unsafely during maintenance and aircraft towing events.
- For non-airline maintenance, the most common forms of occurrences were incorrect assembly or orientation of components, incomplete installation and the contact of workers with hazards.
- Aircraft maintenance personnel are most likely to refer to issues of pressure, fatigue, coordination and training when describing why occurrences have occurred.
- Memory lapses were the most common form of unsafe act preceding the reported maintenance occurrences.
- Procedure shortcuts were the second most common form of unsafe act preceding the reported maintenance occurrences.
- Statistical analysis of the unsafe act checklist data suggests that the three main forms of unsafe acts in maintenance, are procedure shortcuts, misunderstandings and memory lapses.
- Most respondents considered that it was sometimes necessary to ‘bend the rules’ to get the job done.
- Younger LAMEs report a higher rate of procedure shortcuts than their older colleagues.
- The rate of procedure shortcuts is statistically associated with involvement in airworthiness-related occurrences.

Attachment A.
Definitions of Occurrence Outcomes

Several of these categories are based on those of Boeing's Maintenance Error Decision Aid system.

System operated unsafely during maintenance

Activating an aircraft system such as flaps or thrust reversers when it was not safe to do so, either because personnel or equipment were in the vicinity, or the system was not properly prepared for activation.

Towing event

A safety occurrence which occurred while an aircraft was under tow.

Incomplete installation, all parts present

Although all necessary parts were present, the installation procedure had not been completed. For example, a connection may have been left 'finger tight' rather than correctly tightened.

Person contacted hazard

A worker came into contact with a hazard which caused, or had the potential to cause injury. Includes electric shocks, falls and exposure to aircraft fluids or other chemicals.

Vehicle or equipment contacted aircraft

A stationary aircraft was contacted by a vehicle or maintenance equipment such as stairs or moveable stands.

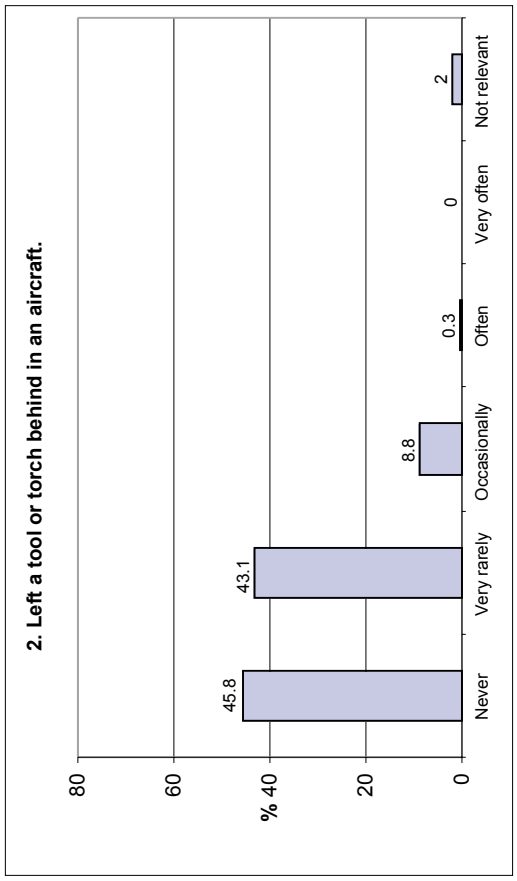
Incorrect assembly or orientation

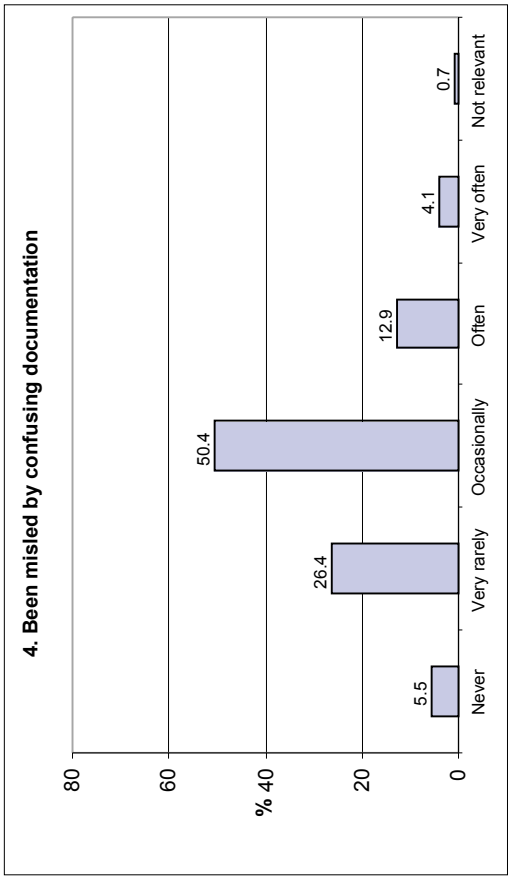
A component was installed or assembled incorrectly.

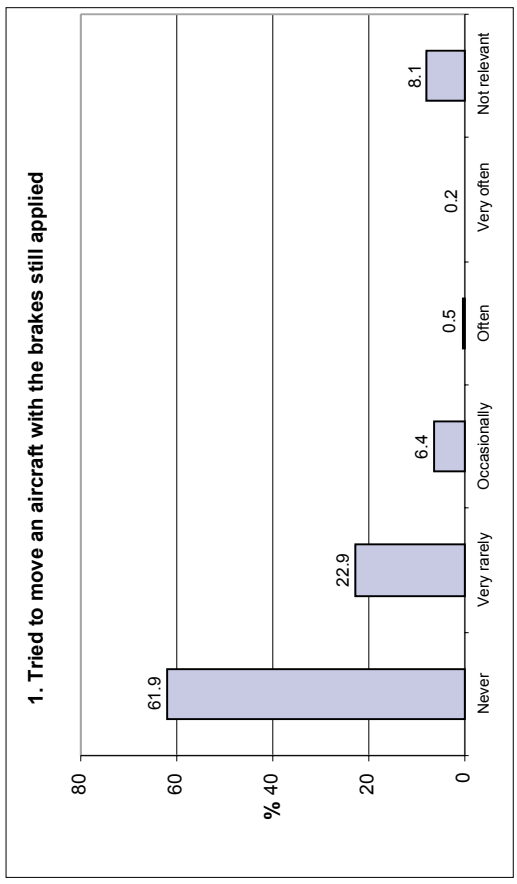
Material left in aircraft

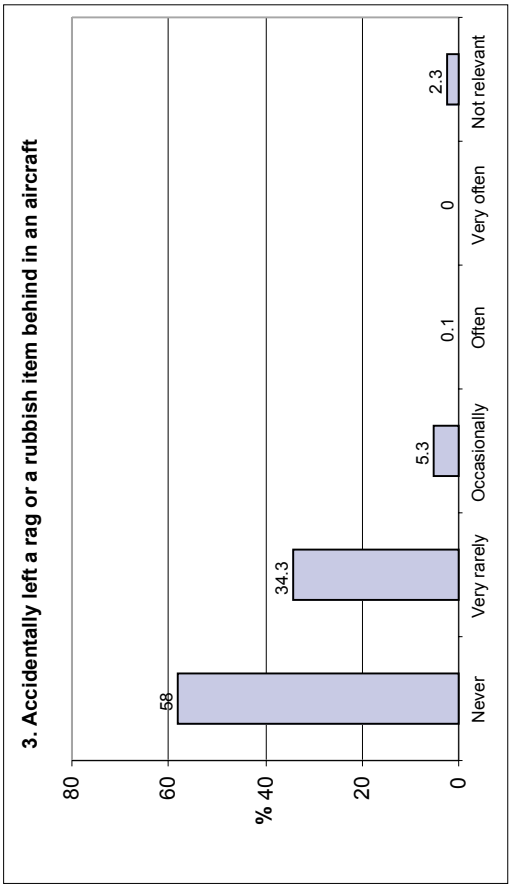
A maintenance related item such as a tool was inadvertently left behind by a maintenance worker.

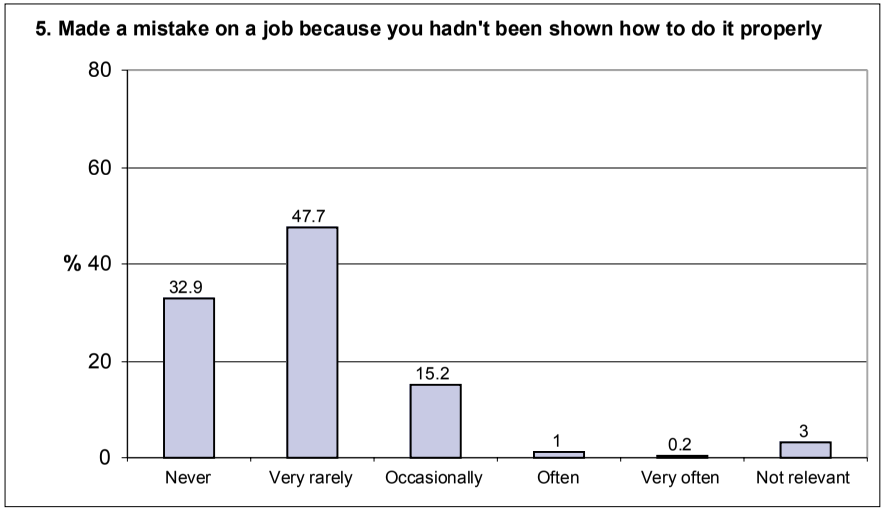
Attachment B. At work in the last year or so, how often have you:

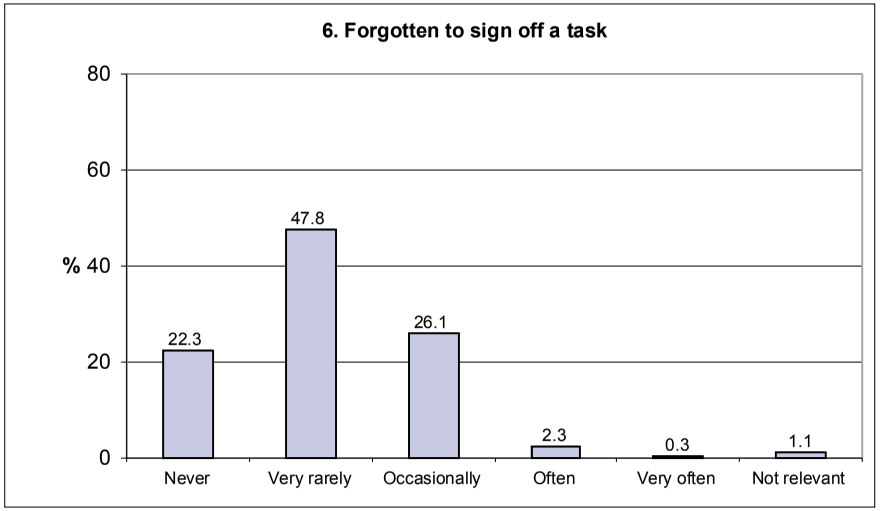


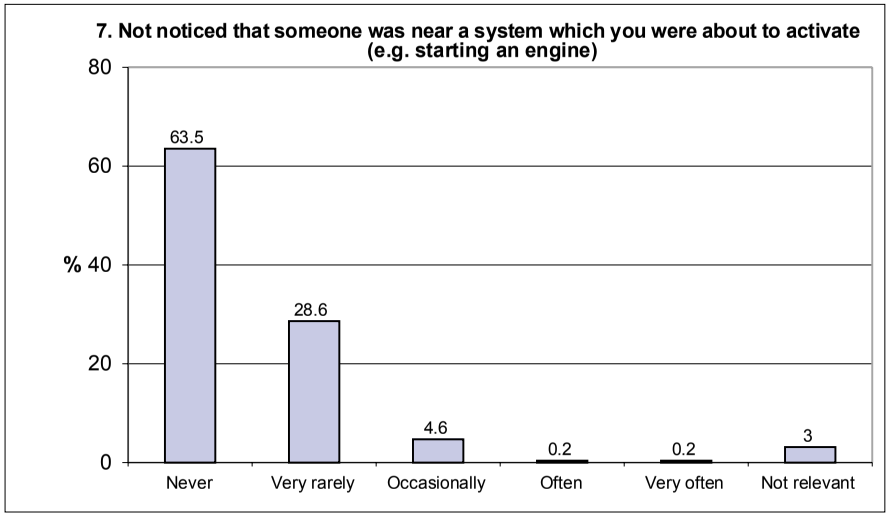


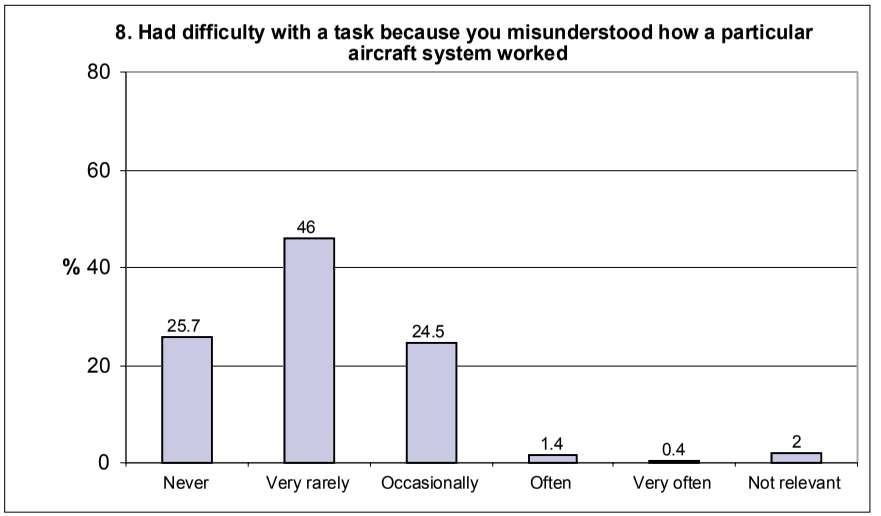


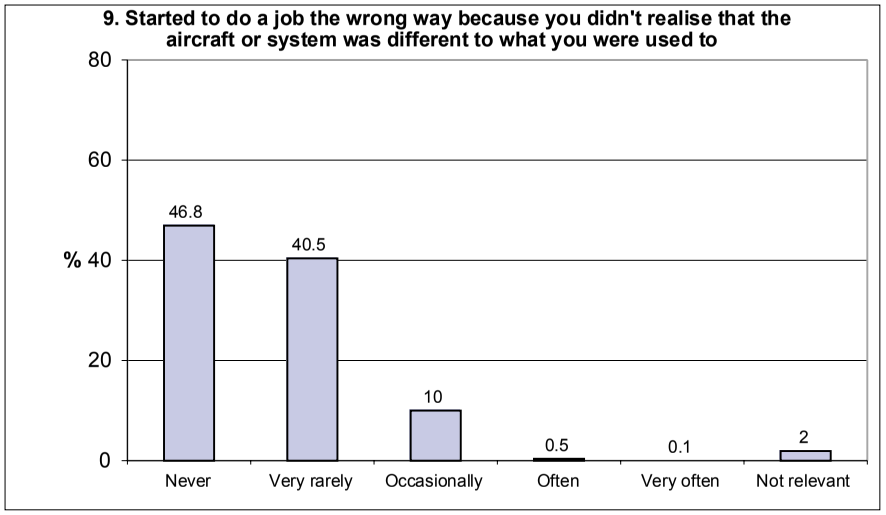


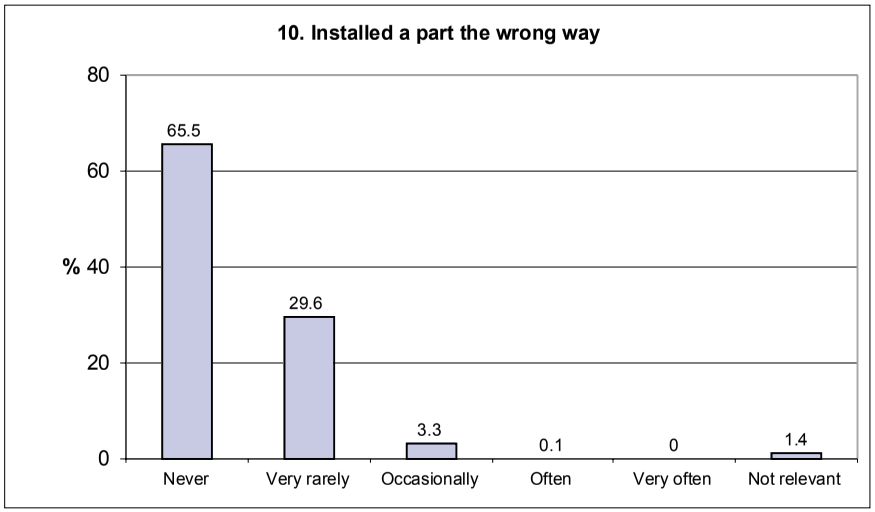

5. Made a mistake on a job because you hadn't been shown how to do it properly
80
60
% 40
20
0
32.9
47.7
15.2
1
0.2
3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

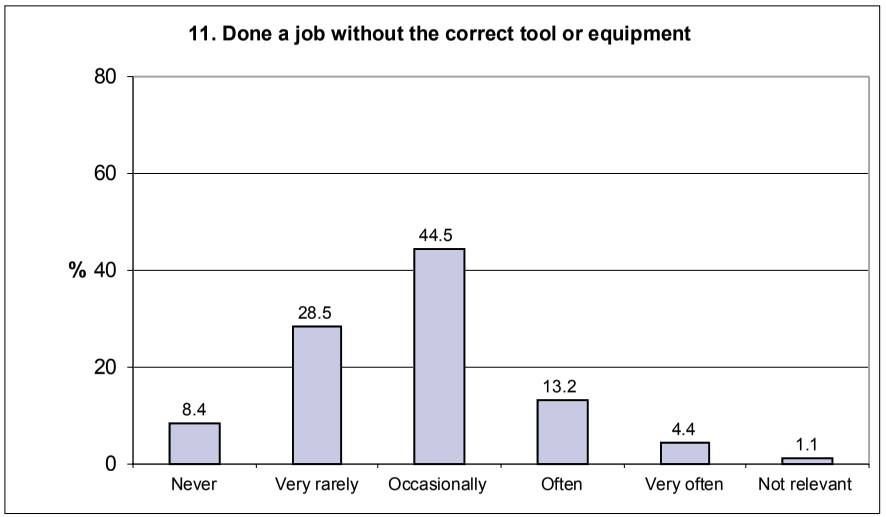

6. Forgotten to sign off a task
80
60
% 40
20
0
22.3
47.8
26.1
2.3
0.3
1.1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

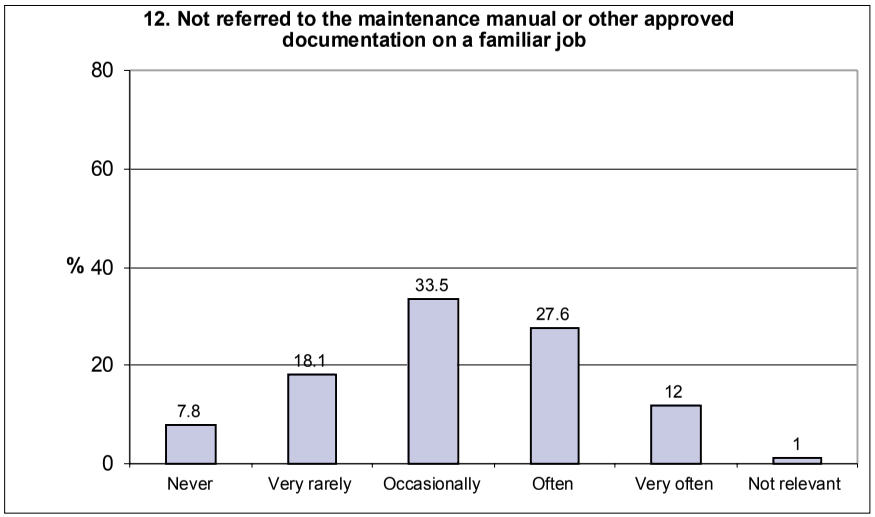

7. Not noticed that someone was near a system which you were about to activate (e.g. starting an engine)
80
60
% 40
20
0
63.5
28.6
4.6
0.2
0.2
3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

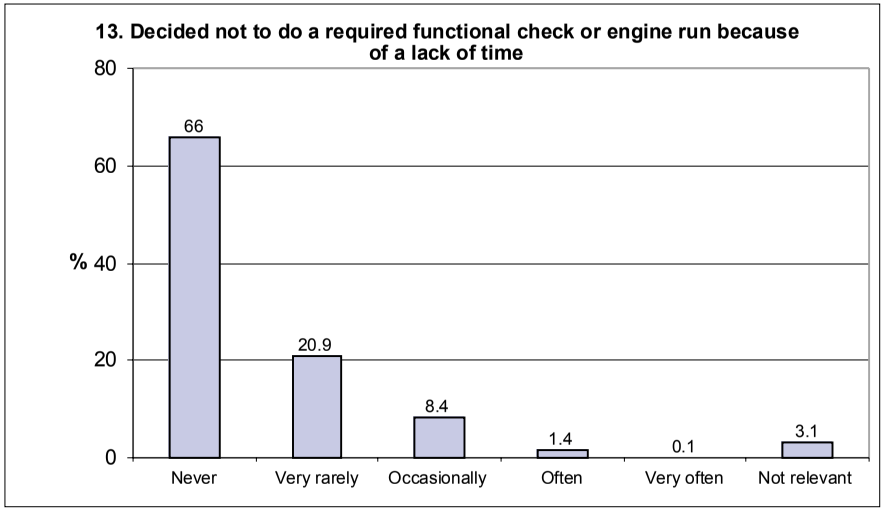

8. Had difficulty with a task because you misunderstood how a particular aircraft system worked
80
60
% 40
20
0
25.7
46
24.5
1.4
0.4
2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

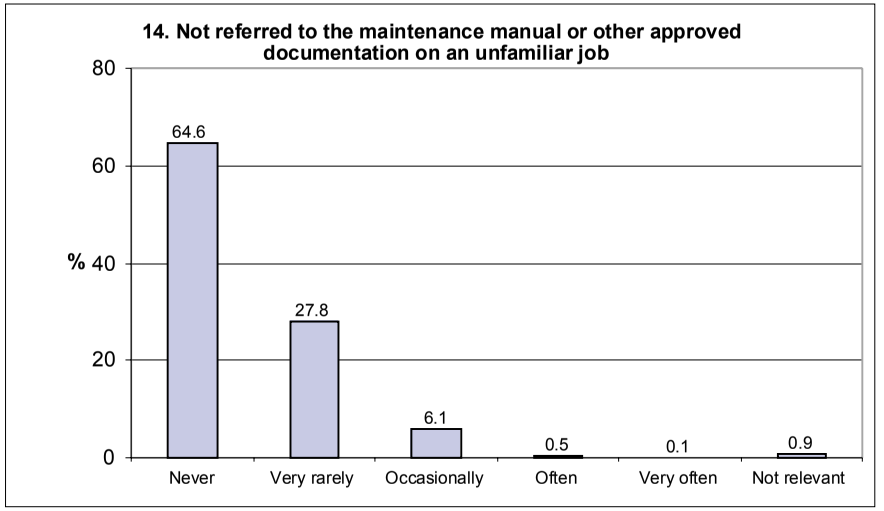

9. Started to do a job the wrong way because you didn't realise that the aircraft or system was different to what you were used to
80
60
40
20
0
%
46.8
40.5
10
0.5
0.1
2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

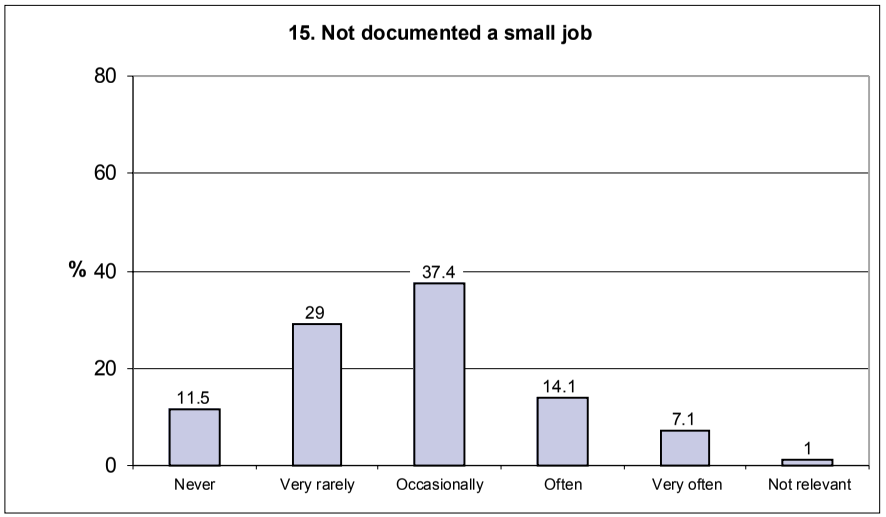

10. Installed a part the wrong way
80
60
40
20
0
%
65.5
29.6
3.3
0.1
0
1.4
Never
Very rarely
Occasionally
Often
Very often
Not relevant

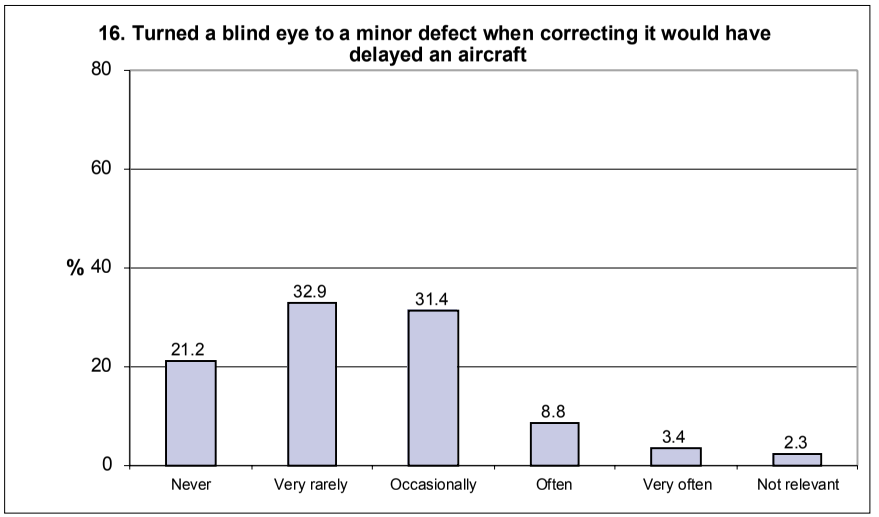

11. Done a job without the correct tool or equipment
80
60
40
20
0
%
8.4
28.5
44.5
13.2
4.4
1.1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

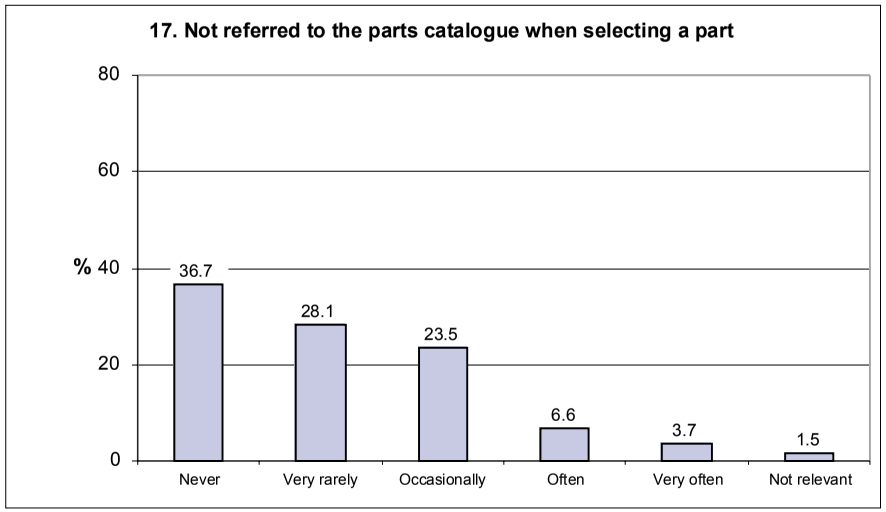

12. Not referred to the maintenance manual or other approved documentation on a familiar job
80
60
40
20
0
%
7.8
18.1
33.5
27.6
12
1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

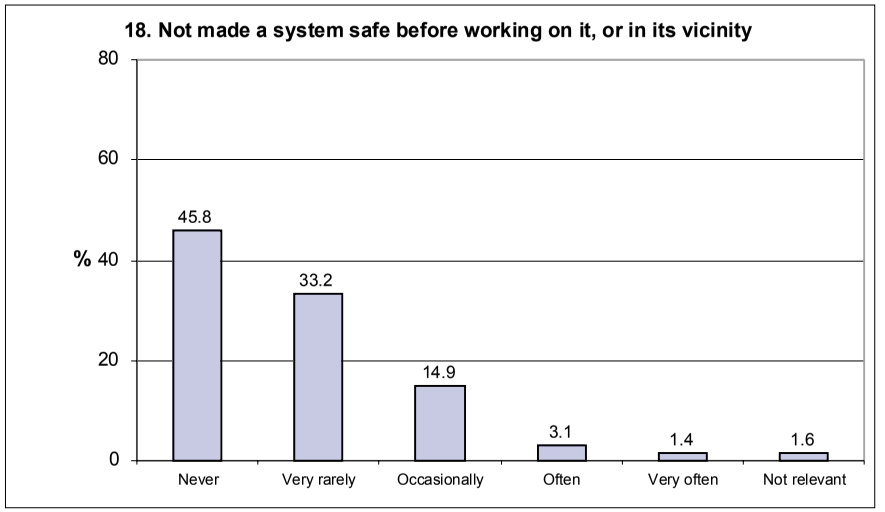

13. Decided not to do a required functional check or engine run because of a lack of time
80
60
% 40
20
0
66
20.9
8.4
1.4
0.1
3.1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

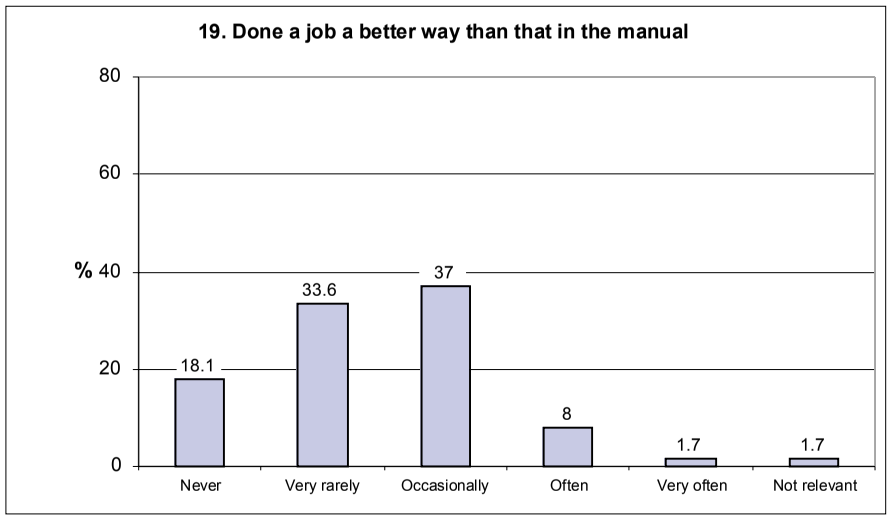

14. Not referred to the maintenance manual or other approved documentation on an unfamiliar job
80
60
% 40
20
0
64.6
27.8
6.1
0.5
0.1
0.9
Never
Very rarely
Occasionally
Often
Very often
Not relevant

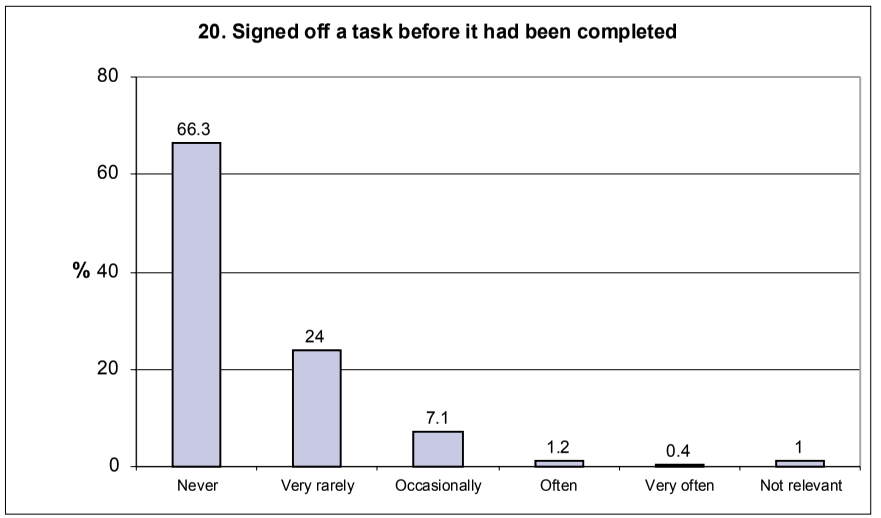

15. Not documented a small job
80
60
% 40
20
0
11.5
29
37.4
14.1
7.1
1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

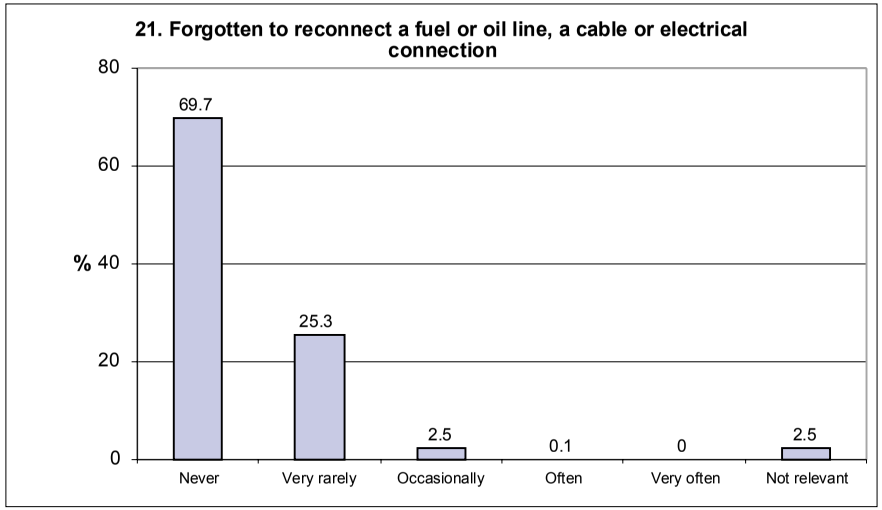

16. Turned a blind eye to a minor defect when correcting it would have delayed an aircraft
80
60
% 40
20
0
21.2
32.9
31.4
8.8
3.4
2.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

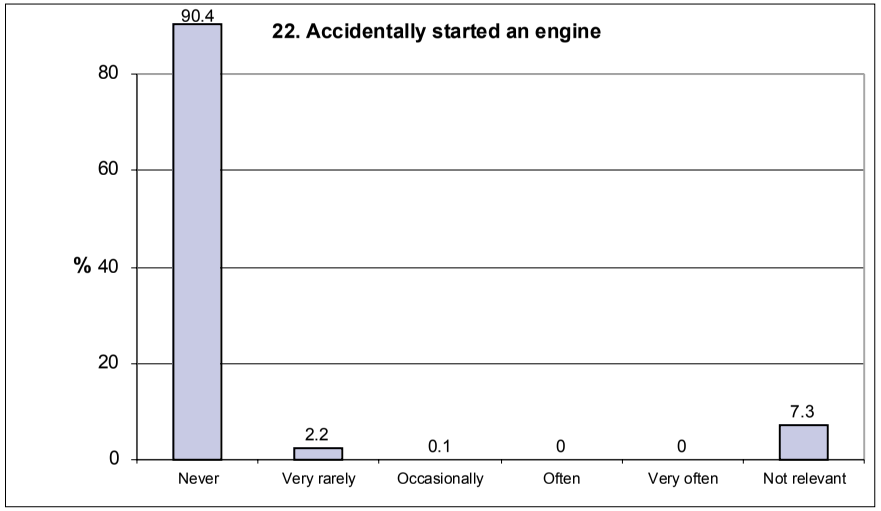

17. Not referred to the parts catalogue when selecting a part
80
60
% 40
20
0
36.7
28.1
23.5
6.6
3.7
1.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant

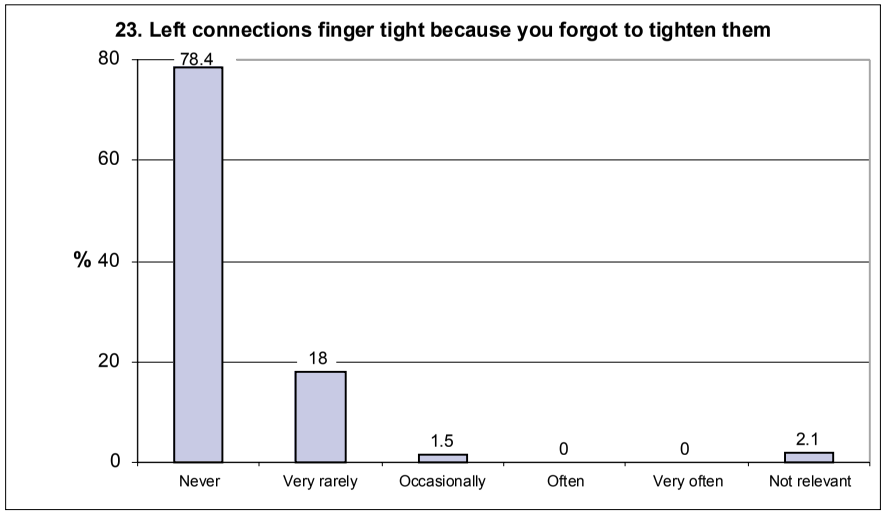

18. Not made a system safe before working on it, or in its vicinity
80
60
% 40
20
0
45.8
33.2
14.9
3.1
1.4
1.6
Never
Very rarely
Occasionally
Often
Very often
Not relevant

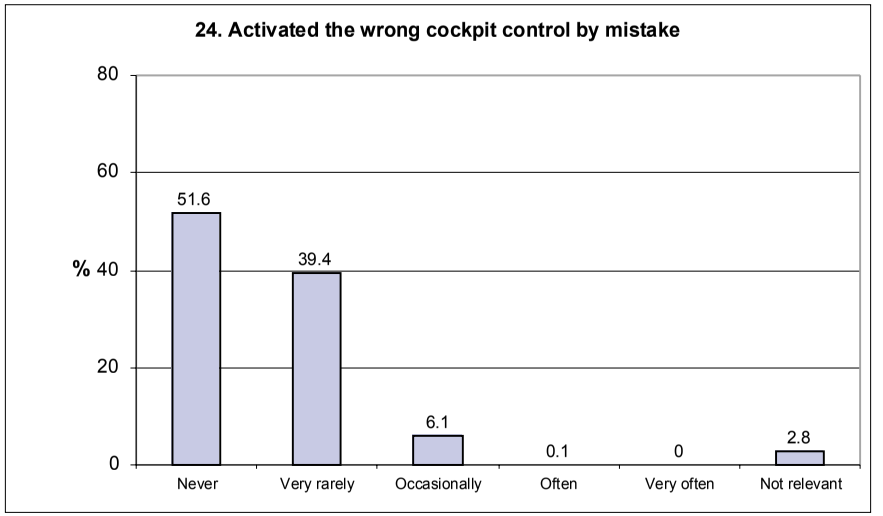

19. Done a job a better way than that in the manual
80
60
% 40
20
0
18.1
33.6
37
8
1.7
1.7
Never
Very rarely
Occasionally
Often
Very often
Not relevant

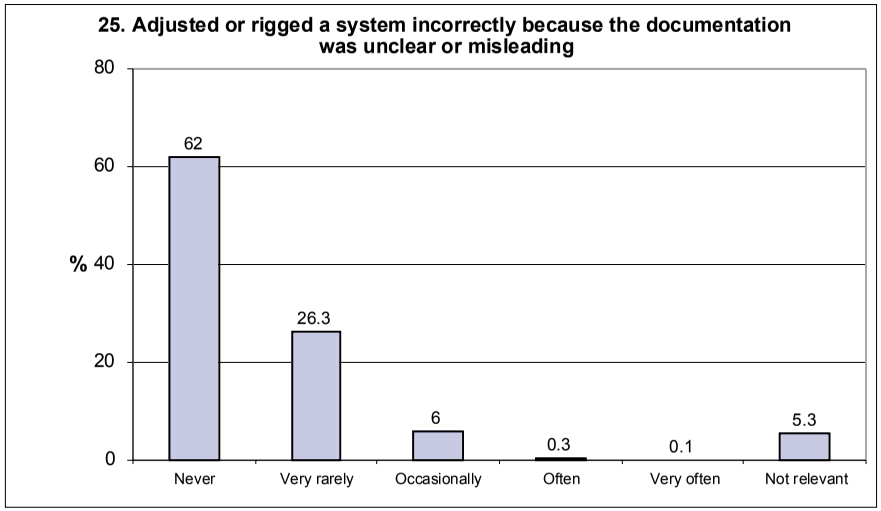

20. Signed off a task before it had been completed
80
60
% 40
20
0
66.3
24
7.1
1.2
0.4
1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

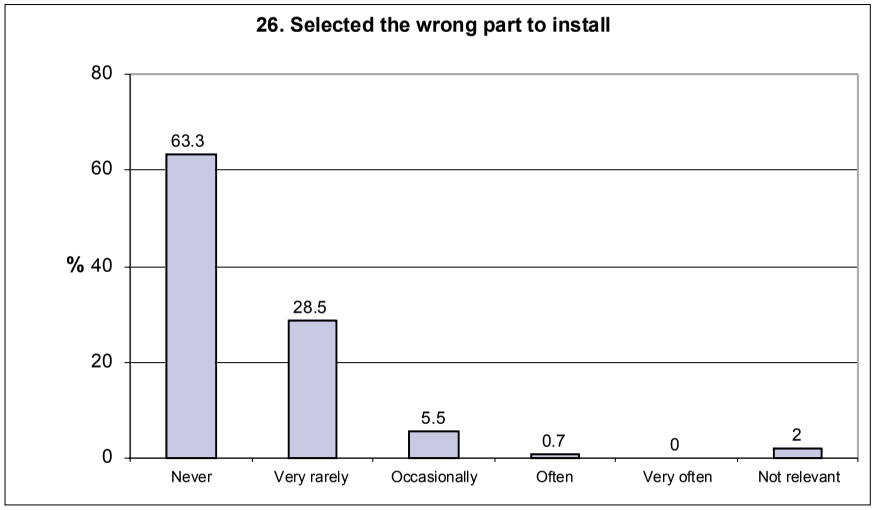

21. Forgotten to reconnect a fuel or oil line, a cable or electrical connection
%
80
60
40
20
0
69.7
25.3
2.5
0.1
0
2.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant

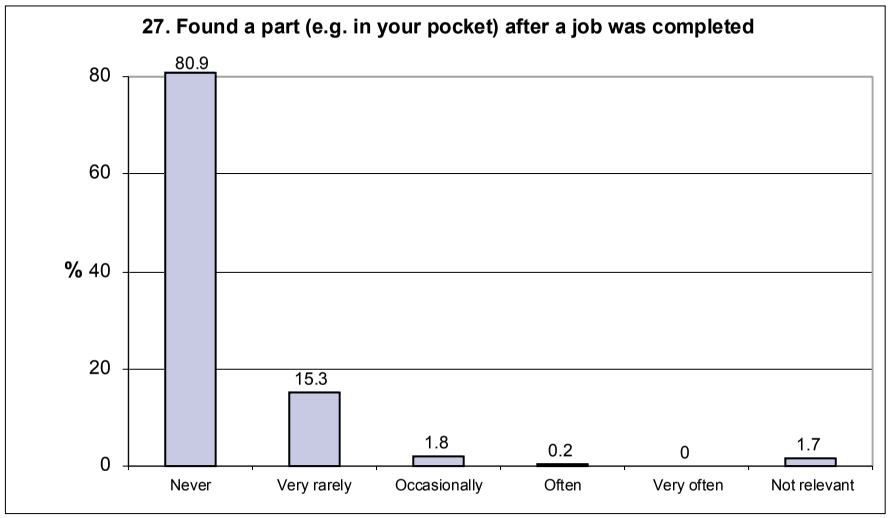

22. Accidentally started an engine
%
80
60
40
20
0
90.4
2.2
0.1
0
0
7.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

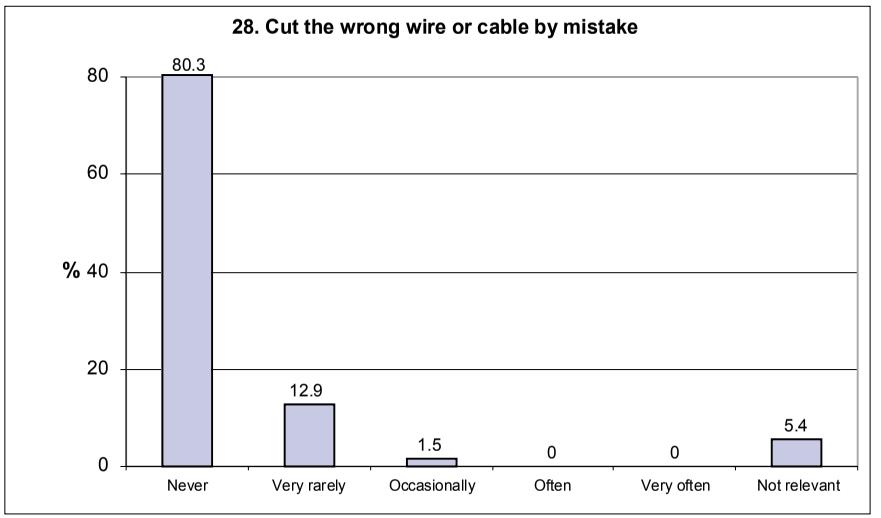

23. Left connections finger tight because you forgot to tighten them
%
80
60
40
20
0
78.4
18
1.5
0
0
2.1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

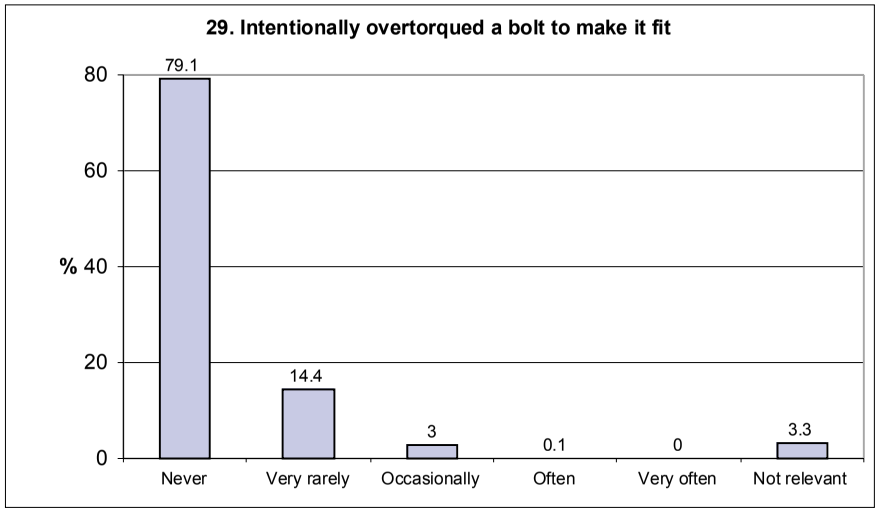

24. Activated the wrong cockpit control by mistake
%
80
60
40
20
0
51.6
39.4
6.1
0.1
0
2.8
Never
Very rarely
Occasionally
Often
Very often
Not relevant

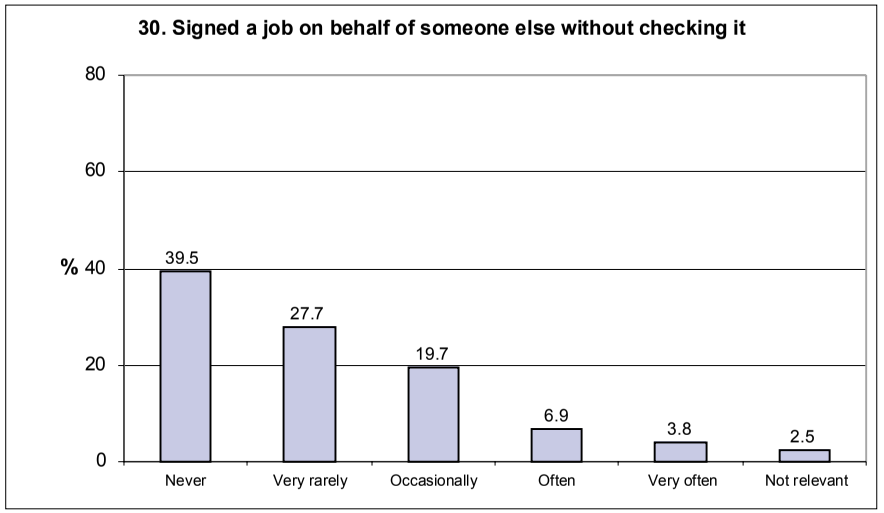

25. Adjusted or rigged a system incorrectly because the documentation was unclear or misleading
80
60
40
20
0
%
62
26.3
6
0.3
0.1
5.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

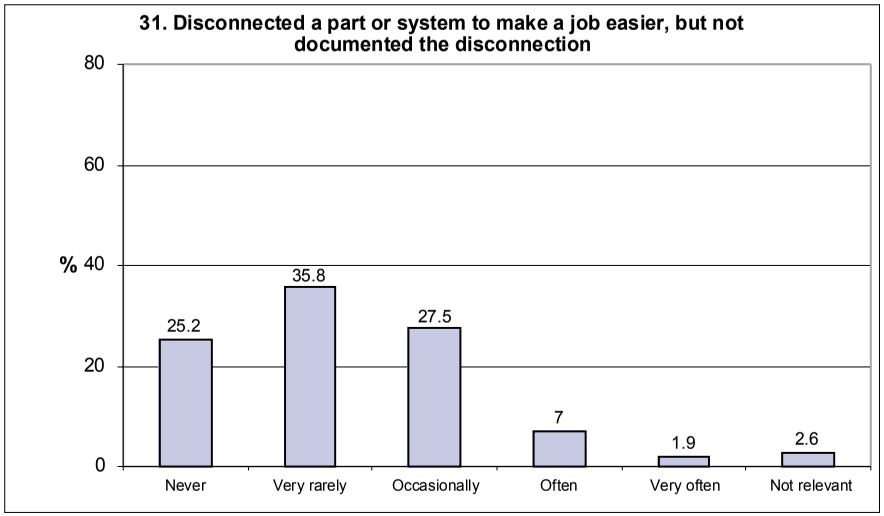

26. Selected the wrong part to install
80
60
40
20
0
%
63.3
28.5
5.5
0.7
0
2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

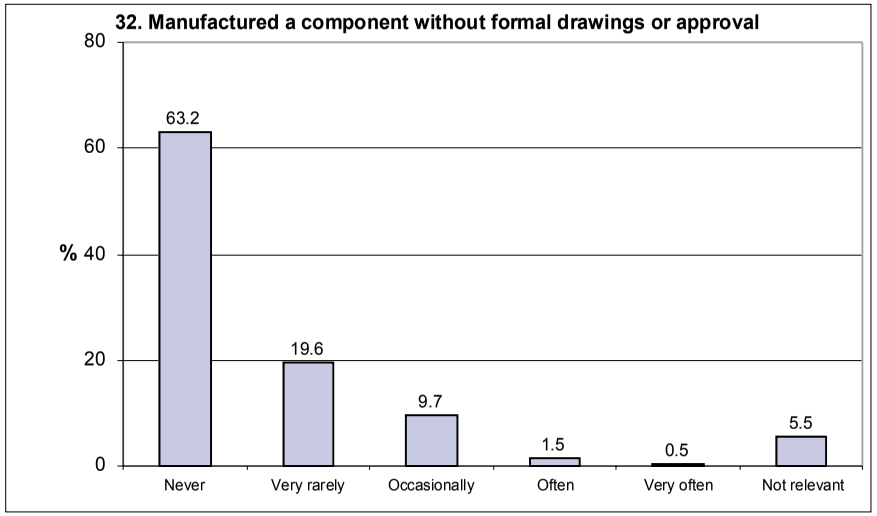

27. Found a part (e.g. in your pocket) after a job was completed
80
60
40
20
0
%
80.9
15.3
1.8
0.2
0
1.7
Never
Very rarely
Occasionally
Often
Very often
Not relevant

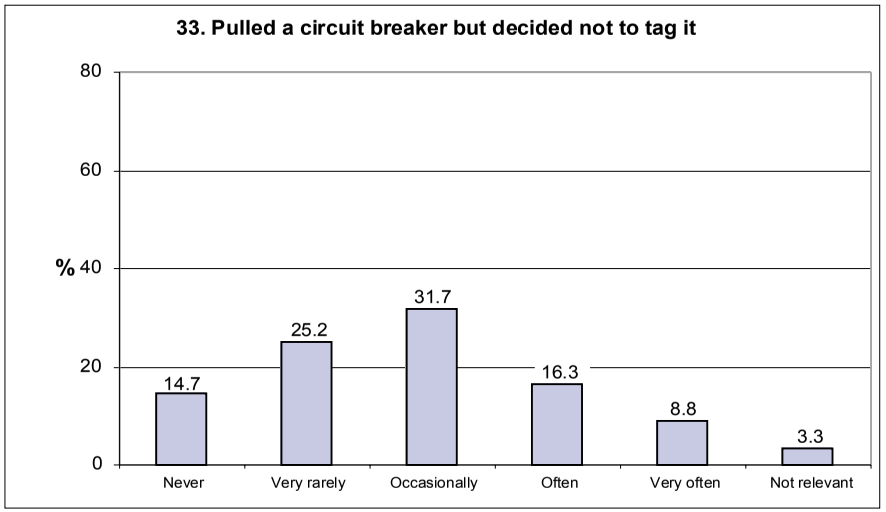

28. Cut the wrong wire or cable by mistake
80
60
40
20
0
%
80.3
12.9
1.5
0
0
5.4
Never
Very rarely
Occasionally
Often
Very often
Not relevant

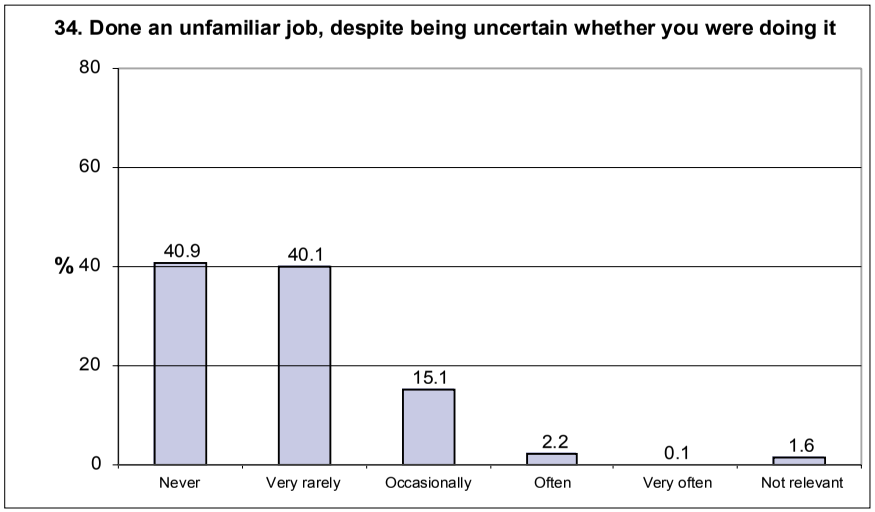

29. Intentionally overtorqued a bolt to make it fit
80
60
% 40
20
0
79.1
14.4
3
0.1
0
3.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

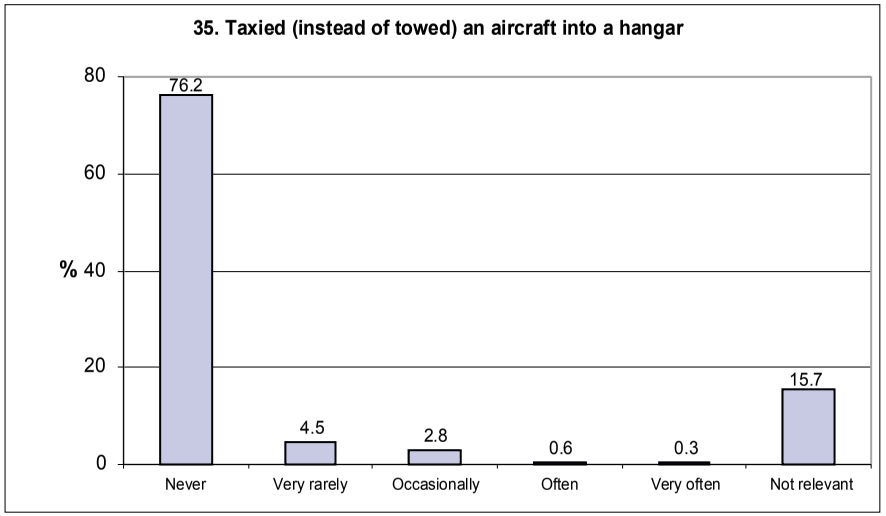

30. Signed a job on behalf of someone else without checking it
80
60
% 40
20
0
39.5
27.7
19.7
6.9
3.8
2.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant

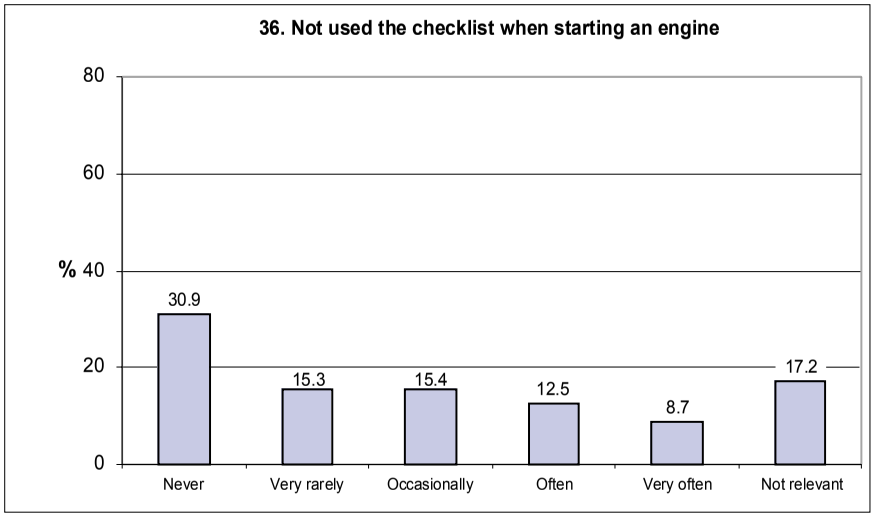

31. Disconnected a part or system to make a job easier, but not documented the disconnection
80
60
% 40
20
0
25.2
35.8
27.5
7
1.9
2.6
Never
Very rarely
Occasionally
Often
Very often
Not relevant

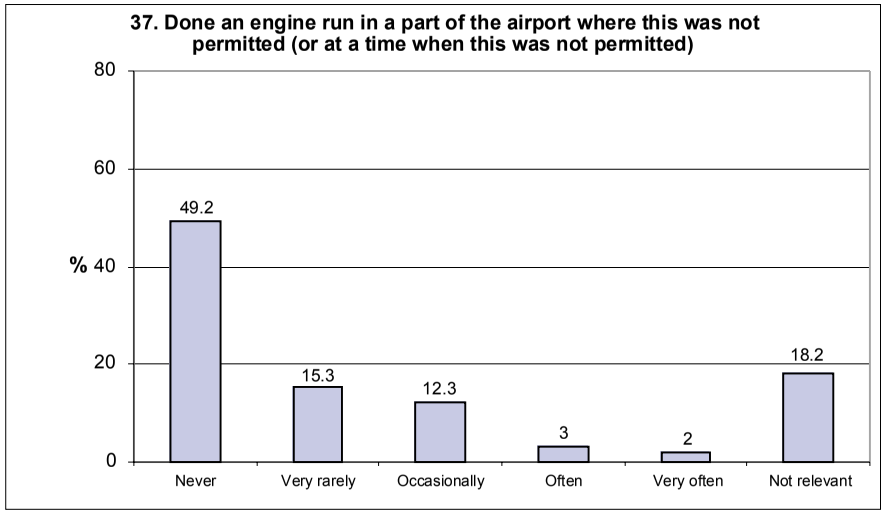

32. Manufactured a component without formal drawings or approval
80
60
% 40
20
0
63.2
19.6
9.7
1.5
0.5
5.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant

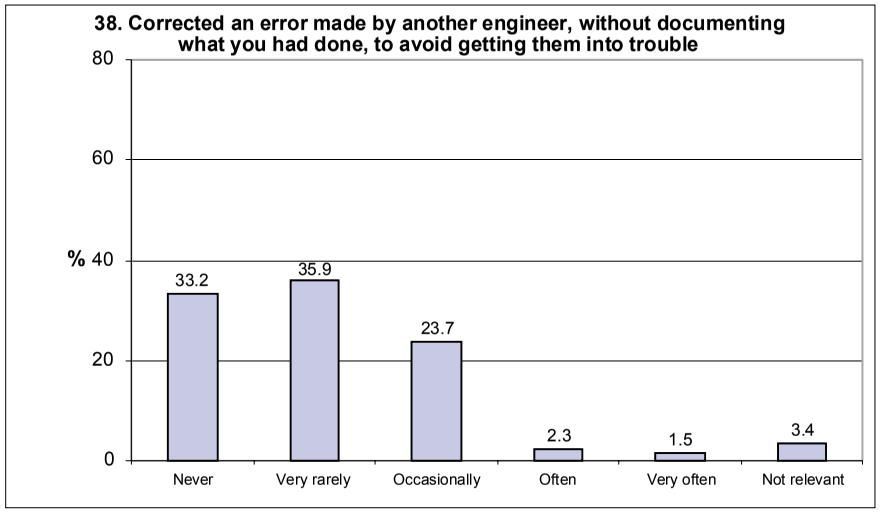

33. Pulled a circuit breaker but decided not to tag it
80
60
% 40
20
0
14.7
25.2
31.7
16.3
8.8
3.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

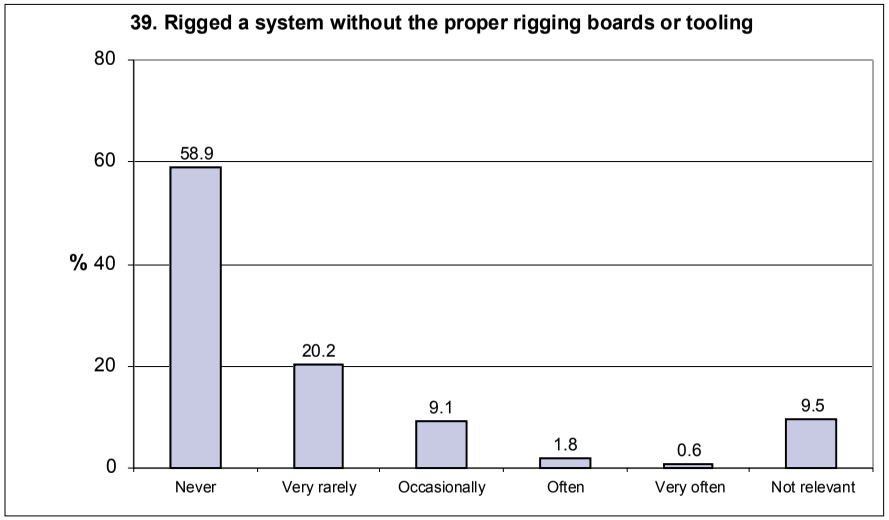

34. Done an unfamiliar job, despite being uncertain whether you were doing it
80
60
% 40
20
0
40.9
40.1
15.1
2.2
0.1
1.6
Never
Very rarely
Occasionally
Often
Very often
Not relevant

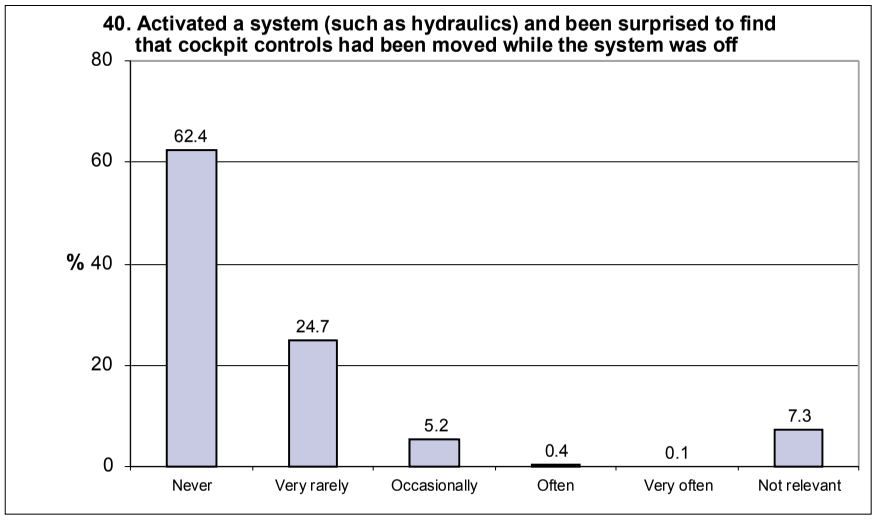

35. Taxied (instead of towed) an aircraft into a hangar
80
60
% 40
20
0
76.2
4.5
2.8
0.6
0.3
15.7
Never
Very rarely
Occasionally
Often
Very often
Not relevant

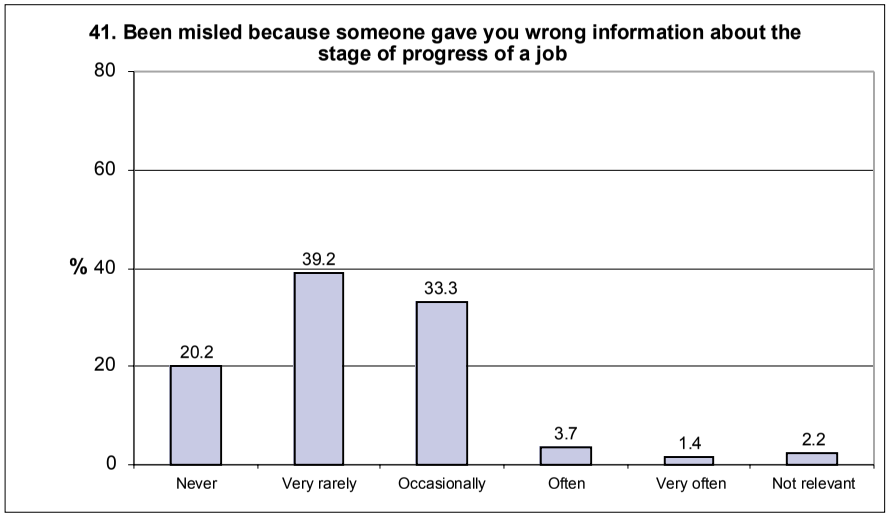

36. Not used the checklist when starting an engine
80
60
% 40
20
0
30.9
15.3
15.4
12.5
8.7
17.2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

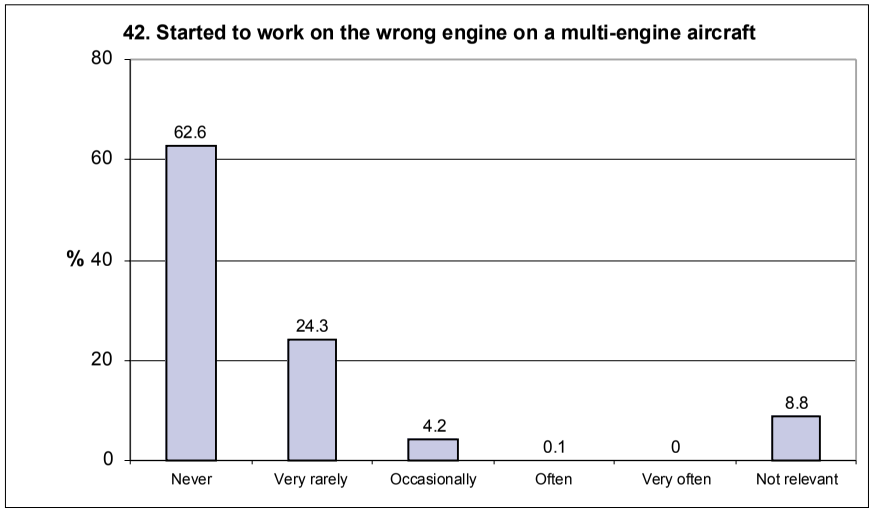

37. Done an engine run in a part of the airport where this was not permitted (or at a time when this was not permitted)
80
60
% 40
20
0
49.2
15.3
12.3
3
2
18.2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

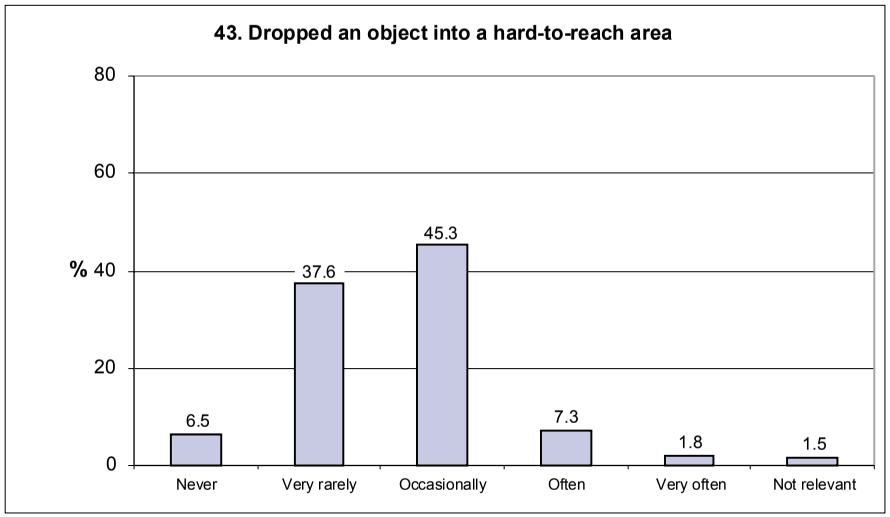

38. Corrected an error made by another engineer, without documenting what you had done, to avoid getting them into trouble
80
60
% 40
20
0
33.2
35.9
23.7
2.3
1.5
3.4
Never
Very rarely
Occasionally
Often
Very often
Not relevant

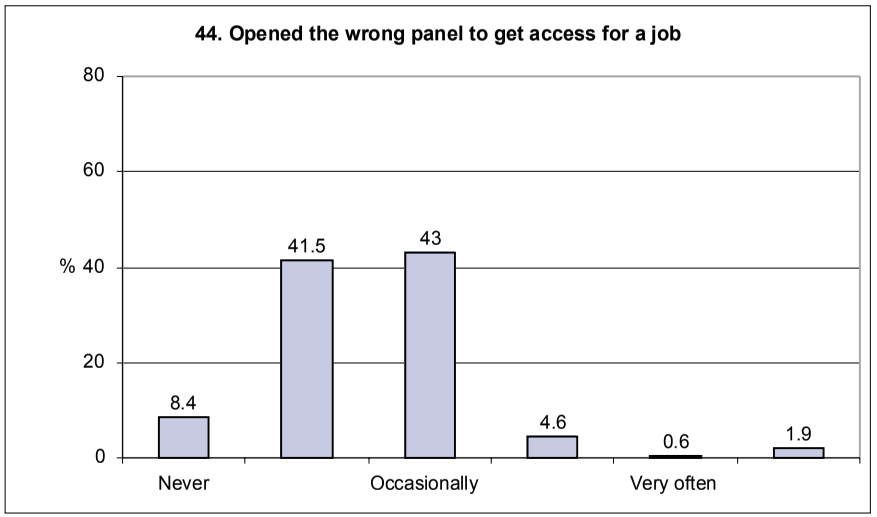

39. Rigged a system without the proper rigging boards or tooling
80
60
% 40
20
0
58.9
20.2
9.1
1.8
0.6
9.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant

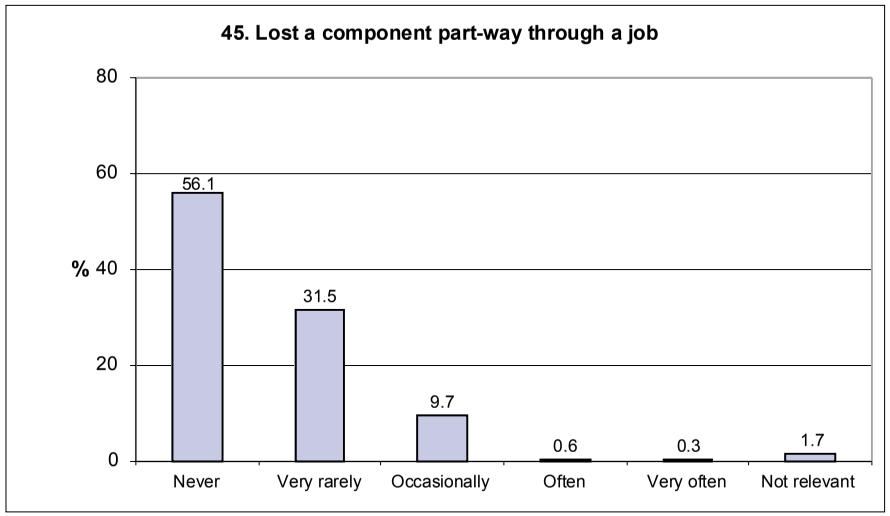

40. Activated a system (such as hydraulics) and been surprised to find that cockpit controls had been moved while the system was off
80
60
% 40
20
0
62.4
24.7
5.2
0.4
0.1
7.3
Never
Very rarely
Occasionally
Often
Very often
Not relevant

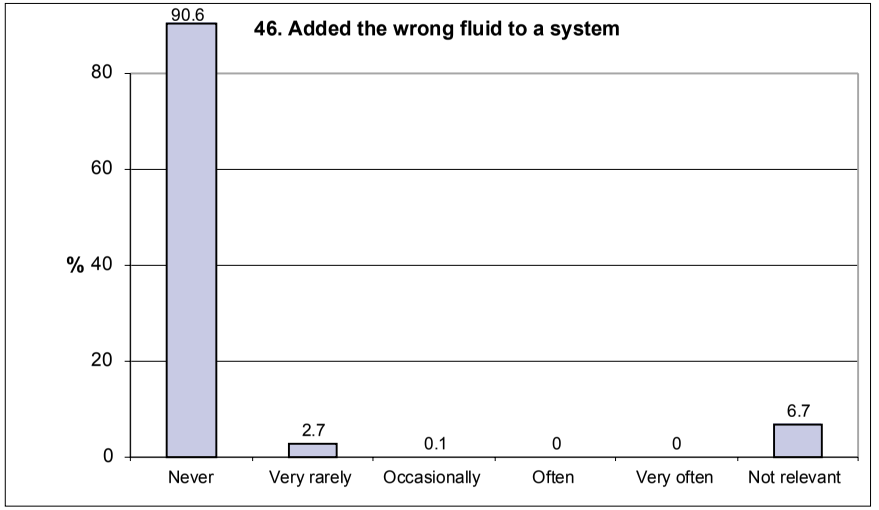

41. Been misled because someone gave you wrong information about the stage of progress of a job
80
60
% 40
20
0
20.2
39.2
33.3
3.7
1.4
2.2
Never
Very rarely
Occasionally
Often
Very often
Not relevant

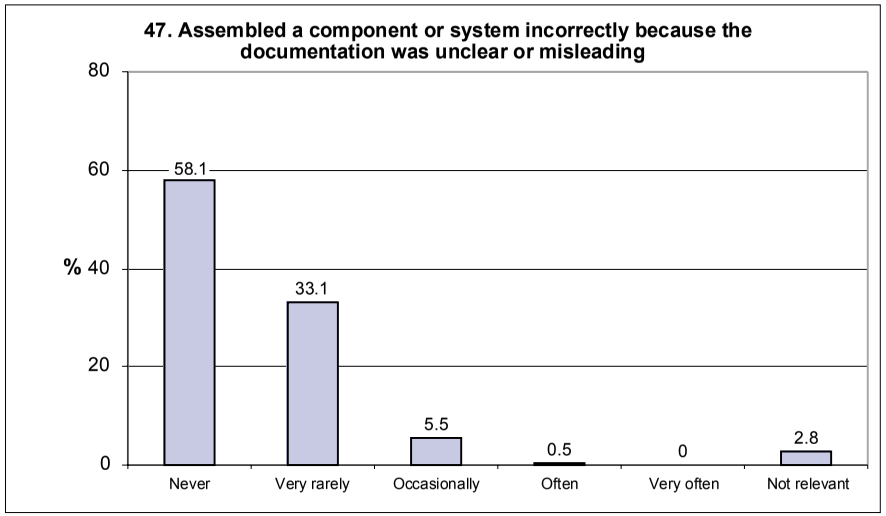

42. Started to work on the wrong engine on a multi-engine aircraft
80
60
% 40
20
0
62.6
24.3
4.2
0.1
0
8.8
Never
Very rarely
Occasionally
Often
Very often
Not relevant

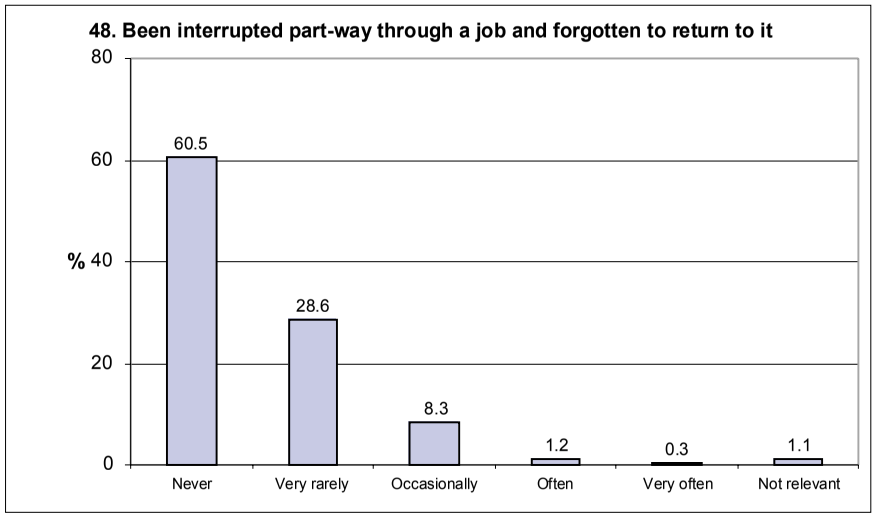

43. Dropped an object into a hard-to-reach area
80
60
% 40
20
0
6.5
37.6
45.3
7.3
1.8
1.5
Never
Very rarely
Occasionally
Often
Very often
Not relevant


44. Opened the wrong panel to get access for a job
80
60
% 40
20
0
8.4
41.5
43
4.6
0.6
1.9
Never
Occasionally
Very often


45. Lost a component part-way through a job
80
60
40
20
0
%
56.1
31.5
9.7
0.6
0.3
1.7
Never
Very rarely
Occasionally
Often
Very often
Not relevant


46. Added the wrong fluid to a system
80
60
40
20
0
%
90.6
2.7
0.1
0
0
6.7
Never
Very rarely
Occasionally
Often
Very often
Not relevant


47. Assembled a component or system incorrectly because the documentation was unclear or misleading
80
60
40
20
0
%
58.1
33.1
5.5
0.5
0
2.8
Never
Very rarely
Occasionally
Often
Very often
Not relevant


48. Been interrupted part-way through a job and forgotten to return to it
80
60
40
20
0
%
60.5
28.6
8.3
1.2
0.3
1.1
Never
Very rarely
Occasionally
Often
Very often
Not relevant

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