

Reducing Equipment Downtime

A New Line of Attack

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Not surprisingly, most—if not all—healthcare organizations look upon unscheduled equipment downtime as a significant impediment to providing excellent patient care. Equipment failures are encountered virtually every day wherever medical devices are in use, and each and every one of the subsequent repair calls starts the equipment downtime clock running. Although it is not strictly logical, it has been a longstanding tradition to use equipment downtime as a measure of the effectiveness of the facility's equipment maintenance program. This article discusses "a new line of attack" for reducing equipment downtime.

There are a number of things besides the effectiveness of the facility's equipment maintenance program that trigger repair calls and thus contribute to equipment downtime. Every one of those additional factors involves something that is usually beyond the control of the maintenance team. The biggest of these is the inherent reliability of the equipment itself.

The equipment's inherent reliability is determined by the quality built into the equipment in 3 ways:

- the quality of the design used by the equipment manufacturer,
- the quality of the components used in the construction of the equipment, and
- the quality of the workmanship used to construct and assemble the equipment.

Generally speaking, the higher the quality of the equipment, the greater its inherent reliability. However, the quality of the equipment is determined by purchasing decisions in which the equipment maintenance team usually has, at best, only a minority voice.

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It is the inherent reliability of the equipment that establishes the lowest achievable failure rate and therefore the lowest achievable level of repair calls. And the minimum achievable downtime corresponding to the built-in device failure rate is obtained when the maintenance team achieves its lowest aggregate "elapsed time to repair" or ETTR rate.

$$\text{Total equipment downtime} = \text{device failure rate} \times \text{average time to repair}$$

Because it is the only component of the equation above that is substantially within its control, the effectiveness of the maintenance team should be judged by its time-to-repair performance, rather than by total equipment downtime.

In addition to the inherent reliability of each piece of equipment, there are a number of other factors that contribute to equipment downtime, some of which have more to do with how well the equipment is managed than with how well it is maintained. These factors include:

- the training of the equipment users on how to care for the equipment and how to operate it properly,
- providing the utilities and other environmental support services required to allow the equipment to operate properly, and
- purchasing the proper accessories for the equipment.

The lowest achievable level of repair calls for any particular piece of equipment (corresponding to the device's inherent reliability) is experienced only after all of these equipment management-related factors have been reduced to zero, or to the lowest practical level.

Why Equipment Repair Calls Are Made

Devices with nondurable parts (ie, parts that are known to be vulnerable to progressive wear or deterioration) will eventually fail if those parts are not replaced or restored.

This is the basic rationale for a preventive maintenance program. However, there is a quite long list of *other reasons* why devices fail (and repair calls are made), including the following:

- subjecting the device to physical stress beyond its design tolerances, usually through accidents such as dropping the device to the floor;
- exposing the device to environmental conditions beyond its design tolerances, for example, by subjecting the device to a below-normal supply voltage or providing inadequate cooling;
- poor or incomplete initial installation of the device;
- someone tampering with an internal control within the device;
- disturbing the device by performing intrusive preventive maintenance, for example, as a result of someone not replacing a connector properly after a test;
- a “run-on” problem resulting from an incomplete or poor-quality previous repair;
- poor design of the hardware;
- poor fabrication or assembly of the hardware;
- general wear and tear;
- and, of course, the random failure of a component part.

It is worth noting that one of these reasons, disturbing the device by performing intrusive preventive maintenance, is an adverse consequence of well-intentioned preventive maintenance (PM).

Apparent Device Failures

In addition to the real causes of equipment failures listed above, there are 3 categories of *apparent failure* where the device is actually working but the user *believes* that the device has failed. Apparent or perceived failures occur when,

- the user has not set up the device correctly or does not know how to operate it,
- the device is being used with a defective accessory, and
- there is a malfunction within a data network connected to the device’s output.

Capturing Information on Reasons for Equipment Repair Calls

Keeping track of the various reasons why repair calls are made can provide useful information on the development of adverse trends that can be reversed by taking appropriate remedial measures. For example, a higher than usual number of use errors, either across the entire facility or in certain departments, could be indicative of a need for some further in-service instruction to be sure that the clinical staff knows how to operate the equipment properly. This might follow the purchase of some new equipment or the increased use of temporary clinical help in certain departments.

Similarly, an increase in the number of repair calls due to problems with accessories might result from a change to lower quality accessories from an alternative supplier. An increased level of repairs due to equipment being dropped or otherwise abused might suggest the need for an investigation to track down the reason for this new, adverse trend.

Because of our clients’ consuming interest in minimizing equipment downtime — *irrespective of the cause* — Masterplan has begun systematically coding each repair call to track the development of any adverse trends so that they can be investigated, managed, and, hopefully, minimized. We have developed and standardized the repair call coding procedure described below. Its basic format is a 9-item questionnaire. The resulting “Repair Call Category” coding is now a mandatory reporting field in our computerized maintenance documentation system.

Category

- 1) Are the device and its accessories still working properly and safely?

Calls that fall into this category are generally described as a *use error* or *operator error* resulting from the user either setting the device up incorrectly or not operating it properly.

These calls are also labeled as a “no fault found” or “unable to duplicate.”

Typical evidence includes controls such as switches in the wrong position, power cords either not plugged in or disconnected at the equipment end.

Include in this category problems due to the following:

- a user error that resulted in a discharged battery,
- user-related accidents such as beverage spills, and
- loose connections that the user should have noticed.

Include in this category problems caused by lack of user-level maintenance (such as topping up the circulating water level in a hyperthermia/hypothermia unit).

It is also *possible* that these calls could be the result of an *intermittent problem*.

If yes; the underlying cause for this call is user-related (Category 1)

If no; go on to...

- 2) Is there evidence that the problem is due to the use of a wrong or defective accessory or to a problem within a data network connected to the device’s output?

Include in this category printer problems (such as paper jams) unless the printer is built into the device itself—in which case put it in Category 9.

Include in this category also any problems due to *missing* accessories.

Exception: code the call to Category 8 (as evidence of poor user care) if the problem is due to a missing part, such as a battery door.

If yes; the underlying cause for this call is accessory or connectivity-related (Category 2)

If no; go on to...

- 3) Is there evidence that the device has been damaged by exposure to excessive physical stress?

Obvious examples would be if the device appears to have been dropped or the power cord or cord cap has been damaged.

Include in this category also situations where there is evidence of deliberate abuse (such as tool marks).

If yes; the underlying cause for this call is physical stress-related (Category 3)

If no; go on to...

- 4) Is there evidence that the problem could be a run-on result of a prior event such as a poor or incomplete initial setup or installation or an incomplete previous repair?

Include in this category deficiencies such as missing segments of software libraries for smart pumps.

If the problem is attributable to poor prior service, remember to check for possible warranty coverage.

If yes; the underlying cause for this call is run-on-related (Category 4)

If no; go on to...

- 5) Is there evidence that the device has been damaged by exposure to excessive environmental stress?

Include in this category problems caused by exposure to out-of-spec electrical power caused by routine transfers to an emergency generator or local brownouts, or

- an excessively hot or cold environment,
- exposure to fluids such as water or another cleaning fluid,
- exposure to a harmful chemical such as a potent disinfectant or sterilant,
- exposure to electromagnetic or some other kind of interference,
- or to a faulty facility service such as central vacuum, gas supply, water supply, and so forth.

Exception: code the call to Category 1 if the problem is due to a beverage spill by a user.

If yes; the underlying cause for this call is environmental-stress-related (Category 5)

If no; go on to...

- 6) Is there evidence that the failure was due to a battery problem?

Include in this category problems caused by worn-out batteries (beyond the manufacturer-recommended end-of-life date),

- leaking batteries,
- defective battery chargers, or
- completely discharged primary cells.

Exception: code the call to Category 1 if the battery is simply discharged because of a user error (such as the device not being plugged in).

If yes; the underlying cause for this call is battery-related (Category 6)

If no; go on to...

- 7) Is there evidence that the problem is due to a lack of preventive maintenance?

Does it look as though the problem is due to the deterioration of a part (other than a battery) that would normally be replaced or restored during periodic PM? Examples include corroded contacts, worn brushes, or a frayed line cord.

Or did fixing the problem only require simple *internal* cleaning or lubrication that would normally occur during a periodic PM?

Exception: code to Category 1 problems due to a lack of user-level maintenance.

If yes; the underlying cause for this call is inadequate-PM-related (Category 7)

If no; go on to...

- 8) Is there evidence indicating that the problem was due to some kind of human interference with the device?

Include in this category problems that seem to have been caused by some kind of tampering (such as switches or other controls that are not intended to be user-accessible in the wrong position)

Or was it due to some apparently well-intended human interference? An example is if the failure could be attributed as the result of the device having been disturbed during earlier invasive inspection or PM.

Include in this category also problems attributable to a lack of user care (such as removable doors or panels being missing).

If yes; the underlying cause for this call is human interference related (Category 8)

If no; go on to...

- 9) Does the problem seem to be due to a random, unpredictable failure of a component, to poor design or construction, or to simple wear and tear?

In addition to the usual random failures, include in this category problems caused by the following:

- false alarms in the form of erroneous error messages or false error indications,
- software errors (where the device only required rebooting),
- printer problems (unless the printer is a separate accessory—see Category 2), and
- problems requiring only minor fixes (such as loose or missing screws or loose connections).

Include in this category also problems related to normal wear and tear (such as a clogged line in a sterilizer).

If yes; the underlying cause for this call was an unpredictable failure (Category 9)

If it was not possible to answer “yes” to any of the above questions or if the work order was for something other than an apparent equipment failure, then this is an uncategorized repair call (Category 0).

What Are the Most Common Causes of Medical Equipment Problems?

Table 1 shows some of our findings. The statistics shown are typical although they do, of course, change according to the number of calls analyzed, the nature of the facility, and 1 or 2 other factors. We have found that before any corrective programs are initiated, it is quite common to find situations in which the level of repair calls caused by random, unpredictable failures of the device’s components (Category 9 repair calls) can be as low as 50% or even lower.

With respect to the overall repair call statistics, our findings to date are that Category 1 user-related calls typically represent 10% to 20% of all of the calls. They are usually not evenly distributed throughout the various departments—tending to be most numerous in areas where smaller bedside units such as infusion devices are in use. When we began collecting these statistics, there was very little reliable information on the most common causes of reported equipment failures available in the literature. There is in the literature evidence for the related, fairly widespread belief that user-related problems are associated with many of the documented equipment-related patient injuries. For example, the information in the various patient incident/injury databases suggests that many of the burns associated with the use of electrosurgical units are the result

of users failing to position the electrodes properly or using poor-quality or damaged electrodes.

There is some evidence from other industries that unnecessary intrusive PM (Category 8 repair calls) resulting from the apparently common human tendency to “open and inspect” is a non-negligible cause of equipment failures. For example, it is well known in the power generation industry that the number of unexpected power plant failures peaks during the period shortly after routine maintenance has been performed. Our findings to date are that Category 8 calls are relatively rare. This may be reasonably representative of the real world of medical equipment, or it may be a function of a need to refine the diagnostic skills of the reporting technicians.

There are 5 categories that correspond to the equipment management issues we mentioned earlier, rather than to maintenance issues or the device’s inherent reliability. They are as follows:

- Category 1. User-related calls
- Category 2. Accessory- or connectivity-related calls
- Category 3. Physical-stress-related calls
- Category 5. Environmental-stress-related calls
- Category 8. Human-interference-related calls

Collectively, these 5 categories can account for 20% to 45% of the facility’s total repair calls, and thus, they represent a significant opportunity to reduce overall equipment downtime. We have begun experimenting at some selected accounts by exploring the hospital’s interest in setting up remedial programs to try to reduce the incidence of these calls. So far, perhaps not surprisingly, the level of interest has been mixed, and we have not yet managed to formulate a single compelling approach. User training programs can be seen as difficult to arrange, and they are often given relatively low priority. There is similar resistance to remedial programs focused on reducing episodes of equipment being damaged by careless handling.

Table 1. Typical findings from Masterplan’s ongoing repair call cause coding

Category	Cause of repair call	A.	B.	C.
1	User related	14.0	20.1	13.0
2	Accessory or connectivity related	3.0	3.3	8.7
3	Physical stress related	25.0	6.6	7.1
4	Set up/ run-on related	1.0	3.3	1.1
5	Environmental stress related	1.0	7.0	2.4
6	Battery related	NA	7.5	7.8
7	Inadequate PM related	1.0	4.2	2.2
8	Human interference related	0.0	0.0	1.0
9	Random, unpredictable failures	52.0	47.9	46.3
0	(Uncategorized repair calls)			
	Number of repair calls analyzed	850	213	2598

A. One 450 bed facility - Analysis of 6 month’s calls made during 2007.

B. Three facilities - Analysis of 1 month’s calls made in May 2008.

C. Fourteen facilities - Analysis of 3 month’s calls made during 2009.

As managers of the facility's equipment maintenance program, we have a strong interest in tracking the 3 maintenance-related categories.

- Category 4. Setup/run-on-related calls
- Category 6. Battery-related calls
- Category 7. Inadequate-PM-related calls

We are finding that the number of Category 4 calls is typically less than 3%. Again this may be attributable to relatively unsophisticated reporting skills. It is also quite rare to find a report of a failure that the reporting technician attributes to a poor or incomplete prior repair, and some have suggested that technicians may not be inclined to make reports that seem to be self-incriminating. We do find relatively high levels of calls (typically between 5% and 10%) that are Category 6—battery related. This seems to be an opportunity for us to improve the battery replacement programs in some facilities. We have been a little surprised to find levels of Category 7, inadequate-PM-related calls, as high as 5%. At a time when there is widespread interest in reducing unproductive PM work, we expected to find very few calls attributed to the failure of parts that should have been replaced or restored during routine PM. However, further investigation of these calls tends to reflect poor formulation of the PM procedures rather than poor execution. As we move more toward adopting the reliability-centered maintenance (RCM) approach and a run-to-failure strategy for devices where we have determined that it is acceptable and less costly to allow the device's nondurable parts to simply wear out, we will expect to see a higher level of Category 7 repairs. This regular monitoring will provide us with a useful check and balance on deliberately chosen maintenance strategies such as run to failure.

The last area to consider is the Category 9 calls that are random, unpredictable failures associated with the devices inherent reliability. This area promises to provide a wealth of valuable data. For example, it will be interesting to see

Potential Collaborative Remedial Measures for Downtime Reduction
• Ensuring that all users receive adequate training on how to operate the equipment properly. (Category 1 calls; potential to reduce number of repair calls by 10-20%)
• Having a well managed battery care program. (Category 6 calls; potential to reduce number of repair calls by 7-8%)
• Encouraging the users to treat the equipment with more care. (Category 3 calls; potential to reduce no. of repair calls by 6-8%)
• Having the proper accessories available. (Category 2 calls; potential to reduce number of repair calls by 3-9%)
• Maintaining the environmental conditions specified by the equipment manufacturer. (Category 5 calls; potential to ... 2-7%)

What is RCM?
It's a very powerful tool with its own specialized terminology that was developed in the 1970s in the civil aviation industry
• Found too much PM can be counterproductive
• Less PM lowered costs and improved reliability
It uses a systems approach and precise methodology based on modern reliability theory
• including Failure Modes and Effectiveness Analysis
It has been widely adopted throughout all segments of the equipment maintenance industry, except healthcare
Introduced to healthcare by the Joint Commission in 2009
• Still not well understood by many maintenance managers in healthcare
Uses precise metrics and criteria to determine whether or not preventive maintenance (PM) is cost-effective
It strips away the fuzzy mystique surrounding "PM"
• PM schedules will be based on RCM PM risk analyses
• More equipment will be allowed to run-to-failure

whether any correlations can be made on the typical level of Category 1—user-related calls associated with specific manufacturer-model versions of different types of device—and whether this can be considered an indicator of a particularly good or particularly bad user interface design.

There is a lot of interest in tracking the level of Category 9 calls for specific pieces of equipment (ie, different manufacturer-model combinations) because this provides a good measure of the device's inherent reliability relative to other manufacturer-model versions of the same type of device. We know that some institutions already use the annual repair call count as an indicator of equipment reliability in their equipment replacement planning programs. Our experience with repair call coding has been that, unless the logged numbers of repair calls have been "purified" by separating out only those calls attributable to the design and manufacture of the device, using the number of repair calls for replacement planning purposes can be quite misleading. Since these inherent reliability-related failures are basically random, there is a need to aggregate the data over a reasonably large number of device-years or to collect data from a reasonably large number of similar devices (same manufacturer-model and similar vintage).

There are many other possibilities for interesting analyses that could be made once we have created a substantial, well-standardized data collection. By publishing this standardized methodology, we are hoping that others will adopt compatible data collection methodologies that will facilitate establishment of an open clinical engineering community data depository.