NFPA Disclaimer

- Although the speaker is Chairman of the NFPA Technical Committee on Emergency Power Supplies, which is responsible for NFPA 110 and 111, the views and opinions expressed in this presentation are purely those of the speaker and shall not be considered the official position of NFPA or any of its Technical Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation. Readers are encouraged to refer to the entire texts of all referenced documents.

- NFPA members can obtain staff interpretations of NFPA standards at www.nfpa.org.
Content: a lot to cover

- EP gap analyses, vulnerability analyses & risk assessments,
- EP maintenance & reliability
- Failure contingency planning
- Changes to NFPA 110 and 111
- Changes to NFPA 99’s EP requirements.
- NEC requirements for Critical Operations Power Systems

Some Learning Objectives

1. Describe current NEC® requirements for determining existing loading
2. Identify the top causes of EPSS failures
3. Name power system equipment predictive and preventive maintenance options
4. List several proactive methods for improving power system reliability
5. Describe design goals for power system risk reduction
6. Name major changes in NFPA 110-2010 and major anticipated changes for NFPA 110-2013
6 Critical Areas of EP Management

- EP System Reliability
- Maintenance & Shutdowns
- Circuit Breaker Testing
- Fuel Oil Maintenance
- Planning for Failures
- Construction & Modifications

Emergency Power Reliability

- Designed for Reliability
- Full System Commissioning
- Installation Acceptance Testing
- Comprehensive Testing Program
- Strong Maintenance Program
- Continuous Quality Improvement
- Accurate Useful Documentation
- Failure Contingency Planning
- Emergency Power Reliability
- Infrastructure Master Planning

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NFPA Disclaimer
Managing Hospital EP Systems

69 page 2009 ASHE Management Monograph
www.ashe.org/ashe/products/pubs/mg2009stymiest.html

Managing Hospital Emergency
Power Systems — Testing, Operation,
Maintenance and Power Failure Planning

2012 Update is in process now

Managing Hospital Electrical Shutdowns

• 56 page 2012 ASHE Management Monograph available to ASHE members at
www.ashe.org under the RESOURCES tab or
http://www.ashe.org/resources/management_monographs/mg2012stymiest.html

• Hard copies (cat # 055954) are available at
www.ashestore.com

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NFPA Disclaimer
### NP & EP Risk Reduction Designs

- Location of equipment and feeders
- Protection from hazards; common-mode
- Facilitate maintenance
- Facilitate shutdowns
- Provide operating flexibility
- Redundancy and internal backups
- More & smaller ATS’s / closer to loads
- Effective selective [protective] coordination

### Commissioning Power Systems

- Punch lists are not commissioning
  - What the engineer observed
  - Proving it is correct
- Commissioning ensures design intent is realized in final installation.
- Commissioning authority needs input from electrical testing
- COPS EPSS must be commissioned
EP System Testing Program

- Installation acceptance testing
- Weekly EPSS inspections
- Monthly EP System load & transfer tests
- Monthly review & analysis of test results
- Trend analysis of results and problems
- Investigate & resolve systemic issues
- Annual load bank test if required
- Extended run load test every 36 months

Periodic testing might not show

- Generator set auxiliary equipment on NP (fuel oil transfer pump, remote radiator fan)
- Other critical equipment that is not on EP but perhaps should be on it.
- NFPA 110 Installation Acceptance Test will show these **if NP is turned off**.
- Restricted generator set cooling airflow path that is a problem only near full rated load or on high ambient design days
Proactive EP System testing

- EP system needs to power what it should, when it should, for as long as required.
- Functional test of generation and distribution equipment – make it real
- Dealing with power transfers
  - Train maintenance personnel
  - Train user personnel
  - Mechanical & process system responses
  - Other building system responses

EPSS Failures During Testing

- Why? Because equipment is operating.
  - That is when MEP failures occur.
  - We want to force incipient failures while NP is available.
- Benefits of testing failures
  - Controlled conditions, already paying attention
  - Normal power is still available
  - The failures would have occurred anyway during the next unanticipated NP outage.
- They are not “problems.” This is why we test.
### TJC 2012 Standard EC.02.05.07

**DIR (Direct Impact Requirements) apply**

<table>
<thead>
<tr>
<th>Elements of Performance for EC.02.05.07</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP-1 Test battery lights (req’d egress) for 30 sec every 30 days</td>
</tr>
<tr>
<td>EP-2 Test battery lights (req’d for egress) for 90 min every 12 months or replace all batteries annually with 10% testing</td>
</tr>
<tr>
<td>EP-4 Operate generators for 30 minutes every 20-40 days</td>
</tr>
<tr>
<td>EP-5 Load tests above 30% or ≥ exhaust gas temp; annual 2-hr load bank tests if 30% or minimum temps are not satisfied</td>
</tr>
<tr>
<td>EP-6 Operate all ATS’s every 20-40 days</td>
</tr>
<tr>
<td>EP-7 36-month 4-hour load test</td>
</tr>
<tr>
<td>EP-8 36-month load test above 30%, static or dynamic loads</td>
</tr>
<tr>
<td>EP-9 <strong>EP test failure requires measures</strong></td>
</tr>
<tr>
<td>EP-10 <strong>EP test failure requires retest after repairs / corrections</strong></td>
</tr>
</tbody>
</table>

### EC.02.05.07 Common Issues

- EP’s not having **sufficient documentation** to show compliance with the specific requirements.
- EP 3: Not understanding what constitutes a SEPSS.
- EP 4: Not documenting test duration meets the 30 min requirement.
- EP 6: Not operating all ATS’s every time.
- EP 7/EP 8: Just accepting and filing a testing company’s 4-hour test report without looking at it, and then finding that the first 30 minutes is below 30%. (this invalidates the entire test!) Many testing companies tell hospitals they know what they are doing, but they DO NOT know the requirements of this standard.
- EP 9: Not doing (or documenting) consideration of “measures” if a test has failed. Not doing the ILSM assessment if a generator or LS ATS fails a test and is down for some period of time.
- EP 10: Not doing the **retest** after a problem is fixed.
In a nutshell …

Refer to NFPA Disclaimer

- **WEEKLY** inspections per manufacturer’s recommendations and NFPA 110-1999, paragraphs 6-3.6 and 6-4.1. Also refer to NFPA 110-2010 and 2013 paragraphs 8.3.7 and 8.4.1 for recent thinking. 110 Annex FIGURE A.8.3.1(a) also recommends weekly checks for water in fuel oil system.
- **WEEKLY** starts are NOT required by TJC, CMS, or NFPA. However you might have to do them if your state or local AHJ requires them (some do). If your engine manufacturer recommends weekly starts for Level 1 units (some do) then you would need to address that recommendation, perhaps with a risk assessment, when you set up your EC.02.05.01 EP-3 O&M program for those units.
- **MONTHLY** inspections and maintenance per manufacturer’s recommendations and NFPA 110-1999, sections 6-3 and 6-4. Also refer to NFPA 110-2010 and 2013 paragraphs 8.3 and 8.4 for recent thinking.
- **MONTHLY (20-40 DAYS)** load tests per EC.02.05.07 EP-4 and EP-5. The requirement is not less than 30 minutes at not less than the engine manufacturer’s recommended minimum exhaust gas temperature to avoid wet stacking. If you do not measure exhaust gas temperature, then you need to use the alternate requirement for not less than 30% of nameplate rating AT NOT LESS THAN 30 MINUTES AT OPERATING TEMPERATURE [per NFPA 110-2010, 8.4.2(2) and 2013 edition]. Many hospitals get this wrong because they do not allow for engine warm-up time to get to operating temperature before they start taking their load readings. Also, in my opinion one reading does not document 30 minutes. I recommend at least 3 sets of readings, one set at ~5 minutes (after warm-up), one set at 20 minutes, and one set at 35 minutes before you transfer back the ATS’s. This provides, again in my opinion, 30 minutes at operating temperature.
- **MONTHLY (20-40 DAYS)** documented operation of ALL ATS’s per EC.02.05.07 EP-6. You should list all ATS’s and require initials that they were in fact transferred on a specific date.
- **QUARTERLY** inspections and maintenance per manufacturer’s recommendations and NFPA 110-1999, section 6-3. Also refer to NFPA 110-2010 and 2013 section 8.3 for recent thinking.
- **ANNUAL LOAD TEST** only if required per EC.02.05.07 EP-5. The annual load test is only required if you do not satisfy the exhaust gas temperature requirement and also do not satisfy the minimum 30% loading requirement on any of the monthly tests. Satisfying either requirement for all 12 monthly tests eliminates the need for an annual load test for that year.
- **ANNUAL** inspections and maintenance per manufacturer’s recommendations and NFPA 110-1999, section 6-3. Also refer to NFPA 110-2010 and 2013 section 8.3 for more recent thinking. Don’t overlook the ANNUAL fuel quality test per NFPA 110-2010 and 2013, paragraph 8.3.8.
- **ANNUAL** operation of low voltage (<600V) EPSS Level 1 circuit breakers per NFPA 110-1999, section 6-4.6. Also refer to NFPA 110-2010 and 2013 section 8.4.7 for more recent thinking. This applies to most hospital EPSS systems. The EPSS is your generators and transfer switches and the equipment and wiring between them. The EPSS does not extend out to the LS, CB and EB branch panels, so this requirement does NOT involve operating CB, LS, EB branch panel breakers. [Note that medium voltage circuit breakers (rated in excess of 600 volts) for Level 1 system usage shall be exercised every 6 months and shall be tested under simulated overload conditions every 2 years.]
- **LESS FREQUENT** inspections and maintenance per manufacturer’s recommendations and NFPA 110-1999, section 6-3. Also refer to NFPA 110-2010 and 2013 section 8.3 for more recent thinking.
- **AT LEAST EVERY 36 MONTHS**: 4-hour load test per EC.02.05.07 EP-7 and EP-8. Also refer to NFPA 110-2010 and 2013, section 8.4.9. I recommend these editions rather than previous editions because we substantially improved the wording for this test in 2010.
- **Measures and retests** as required by EC.02.05.07 EP-9 and EP-10.
- **Installation Acceptance Test** on all new units and modifications per NFPA 110-2010 and 2013, section 7.13. I recommend these editions rather than previous editions because we substantially improved the wording for this test in 2010.
NFPA 110 & 111 Changes

- **2000 LSC**: 1999 NFPA 110; 1996 NFPA 111
- **2012 LSC**: 2010 NFPA 110 & 111
- A lot of changes since 1999 and 1996
- Start reviewing soon to get ready
- ASHE white paper summaries available

- **2013 NFPA 110**: fuel recommendations

Example of Major Change in NFPA 110 1999 to 2010

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly testing duration if using % loading criteria</td>
<td>30 minutes minimum under operating temperature conditions or at not less than 30 % of the EPS nameplate rating</td>
<td>30 minutes minimum under operating temperature conditions and at not less than 30 % of the EPS nameplate kW rating</td>
<td>Annex clarification on prime vs. standby ratings</td>
</tr>
</tbody>
</table>
### Example of Major Change in NFPA 110

**1999 to 2010**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stipulated parallel gear maintenance</td>
<td>None stated. All EPSS per manufacturer.</td>
<td>Similar to ATS stipulated maintenance</td>
<td>SAME, but also references NFPA 70B for info</td>
</tr>
<tr>
<td>Stipulated battery maintenance</td>
<td>Weekly inspections; follow manufacturer’s specs</td>
<td>Also permits battery conductance testing in lieu of specific gravity</td>
<td>SAME, but also references NFPA 70B for info</td>
</tr>
</tbody>
</table>

### Example of Major Change in NFPA 111

**1996 to 2010**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SEPSS design and equipment</td>
<td>1990’s era technology, now obsolete</td>
<td>Updated for modern technology, including fuel cells, flywheel systems, close-coupled hybrid rotary systems, ultracapacitor systems</td>
<td>Adds DC rectifier plants</td>
</tr>
</tbody>
</table>
### Example of Major Change in NFPA 111
1996 to 2010

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing after repairs</td>
<td>Not discussed</td>
<td>After any repair or replacement, including battery replacement</td>
<td>SAME</td>
</tr>
<tr>
<td>Installation Acceptance Test</td>
<td>Time-sequenced, includes full load test</td>
<td>More detailed than previously, still includes full load test</td>
<td>SAME</td>
</tr>
<tr>
<td>First routine test</td>
<td>Immediately after acceptance test</td>
<td>SAME</td>
<td>SAME</td>
</tr>
</tbody>
</table>

### NFPA 99-2012
Some electrical changes

- MedGas alarms may be on CB or LS
- Generator testing – 10 sec not required during monthly testing – annual confirmation
  - 6.4.4.1.1.2 The 10-second criterion shall not apply during the monthly testing of an essential electrical system. If the 10-second criterion is not met during the monthly test, a process shall be provided to annually confirm the capability of the life safety and critical branches to comply with 6.4.3.1.
  - 6.4.4.1.1.3 Maintenance shall be performed in accordance with NFPA 110, Standard for Emergency and Standby Power Systems, Chapter 8. [2010 Edition]
“Previous editions of NFPA 99, as well as NFPA 70, defined the essential electrical system as a set of subsystems and branches. This distinction led to some confusion, particularly with respect to the number and arrangement of transfer switches. This edition eliminates the confusion by replacing the definition of the essential distribution systems with three simple branches.”
- NFPA 99-2012 Handbook p.311

Second Order Consequences

- Wide-ranging consequences beyond the primary intent of the testing
  - Pump set control panel resets after ATS transfers
  - VFD misoperates while on generator
- May signify problem with the next NP outage
- Analyze system failures and surprises that coincide with or follow the tests
- Follow up on lessons learned
- Determine causes and effects
- Take corrective action
- Fix the problem; not the symptom
Power System Documentation (EC.02.05.01)

- Main one line diagram – accurate, updated regularly to incorporate construction / renovation (C/R) projects.
  - “As found” better than “as built” or “as remembered”
  - Changes cause surprises when NP fails.
- C/R project riser diagrams okay if no changes since C/R project was completed.
  - Multiple project riser diagrams create complexity and confusion when NP fails.
  - Lots of info on drawing – less likely to stay current
- Accurate main one line diagrams are better than riser diagrams for internal disaster E.M.
- NFPA 70E requires updated one line diagrams.

Documenting EP System Demand Load

- EP peak demand load must be known
  - Due diligence
  - AHJ’s may require it
- EP load growth surprised some facilities after disasters occurred.
- Monthly load test readings do not usually represent real demand load (tests usually occur at low activity times)
NEC® 220.87
Determining Existing Loads

- Use maximum demand data for 1 year
- OR; if you do not have a power monitoring system, and 1 year of demand data are not available:
  - Recording ammeter or power meter for 30 days
  - 15-minute demands
  - Include seasonal & periodic loads by calculation

- (NOT hand-held or ATS-mounted ammeters)
- (NOT a couple days of data logging)

Actual EP System Demand Loading

- During a simple normal power outage
  - Will reflect type of day and time of outage
  - May reflect season / ambient weather

- During an emergency
  - May include extra fire alarm load
  - May include smoke control systems
  - May include fire pump
  - May include EXTRA loading due to nature of exterior emergency and ED surge

- Lessons learned from outages, disasters
Sample ATS daily load profiles

Same chart, same data, different format shows EPSS loading
Impact of Fire Alarm on LS ATS loading

This building experienced a fire alarm condition during the recording period. The recorded value is for 15 minute demands, therefore the actual peak demand may have been higher depending upon the duration of the event.

Generator Failures

- Generators can fail to start or shut down
- Procedures to acquire portable genset
  - Emergency connection panels
  - Connect portable unit into existing EPSS
  - Engine fuel oil, start wiring, spill issues
  - Avoid engine exhaust issues at air intakes
  - Verify short circuit capability of system
  - Structural adequacy of planned location

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EPSS Failures

• Lack of maintenance and testing of:
  ○ Batteries
  ○ Battery cables
  ○ Other starting system components
• Considered to be #1 cause of EPSS failures.

Other Types of EPSS failures

• Fuel oil condition, age, contamination, air, leaks, hot
• Installation error and lack of acceptance testing
  ○ Generator auxiliaries on normal power (fans, FO pumps)
• Lack of maintenance
• Mechanical or electrical failures
• Engine overheating – inadequate cooling air
• Overloads – generators, breakers, fuses
• Load shed not working – multiple generators fail
• Lightning – power surge affects generator controls
• Generator breaker trip: poor protective coordination
Generator service contractor observations during Hurricanes Ivan & Katrina

- Monthly testing work-arounds (VFD issues) came back to haunt those facilities
- Single spin-on fuel filters clogged when
  - Dirty fuel was delivered
  - Fuel delivered to nearly empty tank stirred up sediment
  - Filters had extremely small micron level
- Put multiple filter assembly with isolating valves and bypass valves in main fuel tank header or at each generator set

Paralleling Switchgear

- All generator outputs connected together
- Potential for common-mode failure
  - Control power failure
  - Internal short circuit (no GF protection)
  - Low probability but very high impact
- Failure may become apparent when EPSS next becomes energized.
Proactive planning for power failures (EC.02.05.01)

- Recognize that failures will occur
- Plan appropriate responses ahead of time
- Response will be different for each failure
- It is too late to formulate a response after the failure occurs
- Input to Emergency Operations Plan (EM.02.02.09, EP2)

Utility system risk assessments

- Help determine operational reliability
- Identify and respond to risks
- Must have contingency plans that address risks associated with potential utility failures - TJC EC News

- EC.02.01.01, EP 3: “... hospital takes action to minimize or eliminate identified safety and security risks in the physical environment.”
TJC risk assessments
7-step process

1. Identify the issue
2. Develop arguments for that issue
3. Develop arguments against that issue
4. Objectively evaluate both sets of arguments
5. Reach a conclusion
7. Monitor and reassess the conclusion to ensure it is the best decision

Shutdown Risk Assessments

• HFM 8/2012 article about conducting electrical shutdown risk assessments

• Copies available from speaker upon request [RISK]
# Utility Failure Contingency Plans (EC.02.05.01)

“The whole thing about utilities management in my mind is contingency plans”
- George Mills, 10/07 NEHES Conference

- Practice EC.02.05.01 Utility Failure Contingency Plans with Emerg Mgmt exercises
  - George Mills, 8/22/08 JCR Audio Conference
  - George Mills, 10/08 NEHES Conference

- “Contingency plans address at least two issues
  - Equipment failure or disruption
  - Emergency related failures or disruption”
  - George Mills, 10/08 NEHES Conference

- Test Your utility contingencies
  - Don’t just rely on MOU’s
  - Only drills (EM exercises) can expose potential flaws
  - George Mills, 4/10 JCR webcast

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Contingency planning is critical.
Solutions are always obvious afterwards.
Reliability requires smart O&M

- “Reliability and facility infrastructure health are not guaranteed simply by investing in and installing new equipment. Unexpected failures can compromise even the most robust facility infrastructure if appropriate testing, maintenance and due diligence techniques are not employed.”


Proactive EP System maintenance (EC.02.05.01)

- Preventive Maintenance (PM)
  ○ Calendar-based
- Predictive Maintenance (PdM)
  ○ Condition-based
- Reliability-Centered Maintenance (RCM)
  ○ Based on system analyses, logic, statistical input, and criticality of equipment to be maintained
  ○ Optimum mix of reactive, time-interval-based, condition-based, and proactive maintenance practices
Designing for infrared thermography

- Pinhole lens technology can see through ½” viewport

Other PdM examples

- Transformer oil testing
  - Widely used for decades
- Emergency engine generator fluid testing
  - Not widely used, but growing
  - Lubricating oil
  - Fuel oil
  - Cooling water
- Vibration analysis of rotating equipment
- Ultrasonic analysis
When is maintenance needed?

- End of construction (conductive dust)
- Preventive maintenance schedules
  - NFPA 70B
  - NETA Maintenance Testing Specifications
  - IEEE Yellow Book
- Predictive maintenance (IR scanning) shows hot spots – impending failure
- Other predictive maintenance triggers

EP Vulnerability Analyses

- Infrastructure
- Power Sources
- Areas
- Clinical Preparation
- ASHE white paper available
### EP Vulnerability Analysis: Infrastructure

**EP system vulnerabilities: examples**

- Common-mode failure potential
- ATS's not maintained regularly
  - Because not bypass-isolation type
- ATS’s not transferred every month
- Lack of branch maintenance
  - Life Safety Branch
  - Critical Branch
  - Equipment System

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**Emergency Power Challenges in 2012 & Beyond; Copyright(c) 2012 SSR, Inc., All Rights Reserved**
Arc Flash Hazards …
The risks of working LIVE

- Lots of requirements, can be confusing
- Circuit breaker PM or the lack of it can affect fault clearing times and available incident energy
- Infeasible ≠ Inconvenient
- 2009 HFM article available: 15 references
- 2012 NFPA 70E tougher

SEA-37 Gap Analysis – a process for change

Source of Graphic: The University of Queensland, Australia

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Outline of Gap Analysis Strategy

1. Define the concerns, policies, urgency, data needed, metrics
2. Assess current situation
3. Analyze data; summarize gaps
4. Develop recommended actions
5. Brainstorm strategies to bridge gaps and recommendations
6. Determine best options (short and long term)
7. Develop action plans
8. Implement action plans

Power System Gap Analysis

FOR POWER SOURCES

• What is on EP now?
• What else needs to be on EP?
• How do we get there?

• Could also apply lessons learned from previous shutdowns (temporary wiring, contingency plans, surprises, etc.)
Power System Gap Analysis
FOR VULNERABILITIES

• Gap Analysis can also address results of Vulnerability Analysis
• How vulnerable is EP System to failures?
• How vulnerable is NP System to failures?
• Where are the common-mode failure vulnerabilities?
• What can we do to mitigate these vulnerabilities: short term; long term?

Gap analysis of supplied services

• Examples: fuel oil supplier, generator or ATS service company, spare parts supplier
• Understand any vulnerability or over-commitment with the service provider.
• Systematically identify gaps between where the supplier’s crisis management capabilities end and your contingency plans begin. (EM.02.02.09)
• Fix them.
### Utility failure incident reports

- Review all utility failures (internal also)
- Fix the immediate cause
- Consider generic relevance
- Improve policies and procedures
- Avoid similar future failures
- Improve overall utility reliability
- Use lessons learned for competency training

### Competency training for maintainers

- Responses to various internal failures
- Responses to simultaneous multiple utility failures
- Operation of different equipment, not just the same equipment every month
- Understand and look for second order consequences
Critical Operations Power Systems
Article 708 first seen in 2008 NEC®

- Risk assessment: ID hazards, mitigation strategies
- Documented load testing & maintenance
- Commissioning
- Surge protection, selective coordination, bypass-isolation ATS’s, selective load pickup & shedding, 2 levels GF if required
- 72 hours onsite fuel, means to connect portable genset
- Physical security, physical protection, separation, 1 hr & 2 hr FRR, location limitations, 100 year floodplain considered, labeling, fire protection
- Many other requirements

NFPA 111:
UPS supplied by EPSS is not SEPSS

NFPA Disclaimer
Tracers on Preparing for Power Failures

• Test your own readiness
  ○ Clinical equipment & personnel responses
  ○ Reliance on UPS’s
  ○ Power shutdowns
  ○ Maintenance
  ○ EP loading
  ○ Equipment failures
  ○ Documentation

• ASHE paper with power failure tracers available upon request

Thank you. Questions anyone?

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(References follow this slide.)
### References 1


### References 2

- “Tier Classifications Define Site Infrastructure Performance”, W. Pitt Turner IV, John H. Seader, and Kenneth G. Brill; copyrighted by © The Uptime Institute, [www.uptimeinstitute.org](http://www.uptimeinstitute.org)
References 3