LIBERTY™

免维护阀控式铅酸蓄电池（26至200安培小时容量）
Valve Regulated Lead Acid Battery (26 To 200 AMPERE-HOURS CAPACITY)

MPS12-XXX系列
UPS12-XXX系列

用 户 手 册
Maintenance Instructions

（原 大力神）

LIBERTY™
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阀 控 铅 酸 电 池
26至200安培小时容量

MPS 及 UPS电池定期保养说明书

目 录

总资料......1
电池系统说明......1
电池串联......1
电池并联......1
VRLA电池安全问题......1
电气事故......1
处理回收......2
化学事故......2
火灾,爆炸和热事故......2
告诫......2
VRLA电池定期保养指导......3
要求的保养工具和设备......3
定期保养的工作和日程......3
季度保养......4
半年保养......4
年度保养......4
两年保养......4
数据分析和纠正行动......5
环境及电池温度......5
电池目检指导......5
电池系统浮充电压......5
电池系统接地故障探测......6
电池系统浮充电流......6
电池的浮充电压......7
高倍率瞬时负载放电测试......7
阻抗测试......8
单体电池间连接电阻......8
电池性能和容量测试......8

表格
表 1 --- --- ---电池系统故障类型及解决方法......10
表 2 --- --- ---按型号的电池参数......32
SC&D LIBERTY 蓄电池运行保养记录表......封三
附录
附录1 --- --- --- VRLA电池定期保养数据记录表......封底

VRLA 电池系统

定期保养及检修指南

总 资 料

本手册系为26至200安时容量Liberty VRLA电池的定期保养和故障检修提供指南。

其他可和本指南结合应用的说明手册有:

1. 综合测试 41-7264
2. 阻抗和电导测试 41-7271
3. 容量测试 41-7135

C&D LIBERTY 系列阀控式铅酸蓄电池（VRLA）电池系统总括

VRLA电池系统通常是由一组2V，6V, 10V或12V电池串联而组成一个能够提供较高电压的电源系统。例如，如图1所示,4只标称12伏的电池（24个单格）可以通过串联而组成标称电压为48V电源系统。

多组串联的电池可以并联成为一个容量等于各串联电池组容量总和的电源系统。例如图2所示，2个各为48V 90安时容量的串联电池组能够通过并联组成48V 180安时的电池组。 Liberty 品牌的MPS及UPS系列电池是一种依据电池内部“氧化合循环”机理来设计的铅酸电池。该设计使得电池在正常使用时减少或避免了因电解液分解生成气体而造成电池失水、干枯这一缺陷，而且电池电解液是吸附在AGM隔板中。这样设计的结果是电池在使用过程中不需要添加水或电解质，也不需要测量电解液比重。

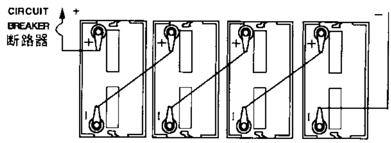


Figure 1-Series Connected String of Batteries
图1 --电池的串联

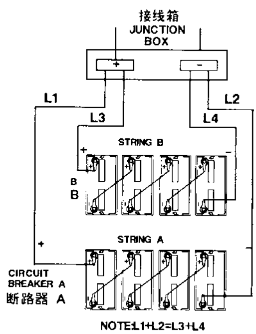
VRLA电池安全问题

VRLA电池的保养和服务需要熟悉铅酸电池知识、人身安全要求和设备安全知识的人员进行实施和监督。非专职人员必须远离电池和保养活动。

电气事故

电池系统产生电击和高短路电流的危险。保养VRLA电池的必须注意下列告诫:

1、 去除一切个人金属物件 （手表，戒指等）。



Figue 2-Parallel Strings of Batteries
图2-- 一电池组的并联

2、应用绝缘工具。

3、穿戴全套眼镜和橡皮手套。

4、注意电路极性。

5、不要随意连接或中断带电电路。

6、在把电池搬上金属架上之前，先用接地故障探测指示器检查，确保电池没有接地危险。没有此指示器时，可测量电池与架之间的电压是否为零。若不是，则必须在进行其他操作前查明原因并予以解决。

7、避免在电池上面放置金属工具。

8、在进行电池保养时，应尽可能避免接触电池系统带电的裸露部分。

用于VRLA电池充电的某些充电机电路可能没有隔离变压器，因此，在这种系统上对电池进行保养和收集数据时便必须特别小心。

VRLA电池有时安装在一些不方便接触电池的电池箱中，此时，在对电池系统进行保养和收集数据时也须特别小心。

处理回收

用过的铅酸电池是要回收利用的。电池里装有铅和稀硫酸。处理时必须按照当地政府的规定。不要置于地面、湖泊或其他非特许的地方。

化学事故

VRLA电池里溢出的任何液体都是含有稀硫酸的电解液，会伤害皮肤和眼睛，能导电、有腐蚀性。

皮肤如果接触了电解液，应立即用水彻底冲洗。电解液如果进入眼睛须用清水彻底清洗至少10分钟或专用的中性洗眼液进行清洗，并立刻就医。

任何溅出的电解液用弱碱性的溶液（例如碳酸钠溶液）予以中和。

火灾、爆炸和热事故

铅酸电池处于过充电状态时可能会释放出含有氢气的爆炸性气体。

电池安装区域禁止吸烟、带入火星。

搬动电池之前先触碰一下一个接地的金属物体，释放掉可能在人身上存在的静电荷。

不要在密闭的环境中给电池充电。安装电池时，电池之间要保留1.5cm以上的空间供对流冷却。如果是装在箱里的，木箱和房间必须进行适当通风防止爆炸性气体累积产生危险。

告诫

不可拆卸Liberty VRLA电池的排气阀或给电池加水，这很不安全并将使质保失效。

VRLA电池定期保养指导

为了获得电池最佳的可靠性 ，推荐每季度检查一次电池系统。如果电池系统已含有收集电子及环境数据的自动监控系统，那么季度检查可只限于评价记录数据和目视检查电池。

一般，定期保养中须检查的项目有：

系统充电电压

环境温度

电池外壳温度

电池间连接件的电阻和松紧度

电池的浮充电压

瞬间高倍率放电负载试验

电池容量试验

对各只电池的电阻/阻抗或导电性的实验，尽管是任选的但仍然值得推荐的作为定期保养的基本要求。这些数据及其发展趋势对系统的故障检修有很大帮助，还可确定是否需要进行系统容量测试。

开始定期保养活动之前保证所有要求的保养工具、设备和安全措施齐全无缺和功能正常，并告知每一个将参与保养或维修活动的人员。还要给电池里所有单元都编号以便进行专对该单元的记录和数据分析。

必备的电池系统保养工具和仪器

VRLA电池的维护和故障检修至少要求有下列工具和设备：

1、 数字伏特计或万用表

2、 绝缘套筒扳手

3、 绝缘活络扳手

4、 扭矩扳手

5、 橡皮手套

6、 全套面罩

7、 塑料围裙

8、 眼药水

9、 灭火器

下列为根据进行保养类型而选用的设备。

1、 毫欧计

2、 电池电阻，阻抗或导电率试验组件

3、 100安培瞬时负载试验组件

4、 系统负载组（直流负载在电池上进行，交流负载用一个UPS输出进行）

季度保养

每季度必须完成下列检查。

1、 确保电池安装处清洁及光照良好

2、 确保所有安全设备具备并功能正常

3、 测量和记录电池房内空气温度

4、 目视检查电池：

a、 清洁度

b、 端子是否有损坏或发热痕迹

c、 外壳或盖的是否损坏

d、 过热痕迹

5、 测量并记录电池系统上直流浮充电压，也可测量和记录交流纹波电压。

6、 测量电池每个极性对地的直流电压以探测接地故障。

7、 若有可能，测量和记录电池系统直流和交流浮充电流。

8、 测量和记录电池控制设备的温度。探测电池侧面中心部位或电池负极端子的温度。

9、 测量和记录各电池直流浮充电压。

10、 测量和记录系统均充电压。

半年度保养

1、 重复各项季度保养检查的检查项目。

2、 随机测量和记录各电池的电阻/阻抗或电导以分析个别电池发展趋势，同时可判断个别电池与正常电池之间异常情况。

年度保养

1、 重复半年度保养的所有检查项目。

2、 重新拧紧所有电池间的连接件至表2上的所列的值。如果已进行连接电阻测量并没有发现超过原始安装时值20%，这项可以省略。

两年保养

电池每两年必须进行一次根据负载要求的电池容量测试，或进行服务设备要求的放电倍率进行测试，最理想的测试结果是和原始安装时验收试验的结果相同。一旦发现电池已降至额定容量的85%时须每年进行电池容量测试。容量测试要求可参考《容量试验》手册。

数据分析和纠正行动

定期保养活动中累积的数据可记录在附表1所示的表格里。下文说明如何解释数据和采取纠正行动，但本说明并不是包罗无遗的，分析和纠正行动的决策须由熟悉VRLA电池及其操作和故障情况的人员来做。

环境及电池温度

VRLA电池虽在极端温度下也能工作，但标准数据是在温度为77˚F（25˚C）时的测量结果。电池理想的工作温度范围是70˚F（21˚C）至80˚F（27˚C）。在温度较低的环境中工作，电池期望的工作时间会减少，在温度较高的环境下工作，则会缩短电池的服务寿命及增加电池发生热失控的危险。

高出77˚F（25˚C）每18˚F（10˚C）就会缩短电池50%的寿命。因此，电池存放处的室温过高须使用适当的通风设备或空调机来降温。

在超过122˚F（50˚）的温度的环境下VRLA电池切不可充电，这很容易造成电池热失控。

一组电池中各单个电池温度都不得高于环境温度18˚F（10˚C）以上。如果一组电池中有个别电池的温度特别高，该电池会有发生热失控的危险。在这种情况下，应该立即停止给电池充电并找出问题所在并予以解决。

如果发生了热失控，需对电池进行容量测试，必要时需更换电池。

电池目检指导

电池清洁

每只电池的清洁和电池间适当的距离是非常重要的。电池盖上有污垢、尘埃或水分能形成导电途径而使得电池两极之间发生短路或电极发生接地故障。

在进行电池清洁时，应该使电池处于开路状态。清洁电池表面可用蘸有碳酸钠水溶液的抹布，不可用清洗窗子或玻璃的清洁剂。因为某些石油类清洁剂可能与电池塑料外壳发生反应而造成电池外壳破碎或龟裂。

端子

弯曲或损坏的端子会产生较高的连接电阻，因此损坏了端子的电池必须更换。

如果电池两电极端子（正/负极端子）周围塑料有熔化或软化现象，这是连接发热的症状。可能是由于连接不好造成的电阻过高引起的，这时就须拆下连接件，检查损坏情况，问题解决后重新正确安装上去，如需更换必需更换。

电池系统浮充电电压

电解液比重为1.280至1.300的VRLA电池，我们推荐对电池使用浮充电电压在77˚F（25˚）时

为2.25V/C~2.30V/C。例如，对于一个由30只每只12V(6单格/电池)的电池串联组成电池系统，我们推荐在77°F（25°）时浮动充电压为405~414VDC。

当电池在较高或较低温度下工作时，需要对电池充电的浮充电电压进行温度补偿。温度补偿系数是华氏每度为-0.0028V/F°（摄氏每度为-0.005V/C°）。

例如，当电池工作时温度为90°F时，那么平均浮充电压应该为2.21V/C~2.26V/C。在由30只电池组成电池组中则降为电压397.8-408.6VDC。由于充电电压降低，所以能够有效的降低因电池工作温度升高而导致热失控的危险。

当电池工作时温度为60°F，充电电压需有所提高。例如对于由30只电池组成电池组来说，此温度下我们推荐的充电电压为413.6至422.6VDC。

对于一只经过多次放电而每次充电都不足的电池，它的额定容量会逐步降低。如果发生这种情况可用通过对电池进行均充充电予以补救。但是这情况不能经常发生，否则电池极板可能出现不可逆转的硫酸化而导致电池失效。

对电池进行长时间的较高电压的充电会造成过高的浮充电流，会加速电池板栅腐蚀和一定数量电解液损失而变干涸，容易缩短电池的使用寿命。

严重的过充电会引起电池发生热失控，此时需要更换换电池。

在测量直流浮充电压时可同时测量电池系统两端的交流纹波电压。如果交流纹波是正弦波形，其最大读数应是小于直流浮电压0.5%Vrms。例如,直流浮充电压为414VDC的180单元串列便是2.07Vrms。用示波器测量纹波时，若浮充电压是在414VDC，那么最大P--P值应是浮充电压的1.5%,即6.2V(P—P)。

过高的交流纹波电压会造成电池产生气体和发热，同时会缩短使用寿命。

电池系统接地故障探测

如果电池充电用的充电机具备接地故障探测能力，应经常留意其指示器以确保系统安全。一旦指示器显示故障出现，应在电池系统作进一步保养之前，先予以查明并解决。

如果充电机没有接地故障探测能力，可以用数字伏特计测量电池电极和地线（接地架或房间）间的电压。若有电压则说明电池至地线有短路或有漏电，有接地故障的电池大约位置可从系统输出端起测量得的电压除以平均每一单体电池充电电压的值得到。例如，测得某一电池组至地的电压为135VDC，且已知电池充电电压为2.25V/C。那么，接地故障发生大约在从电池系统输出端起的第10只电池处（10个12伏电池）。

电池系统浮充电流

如果能够测得直流浮充电流，那么就能够知道电池系统的正常充电接受能力的大小。图3所示的是浮充电流与充电电压和温度变化关系曲线。在25°C时，温度每升10°C，浮充电流大约增

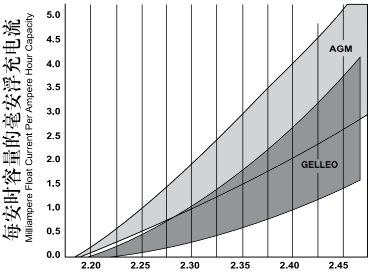


Figure 3 – Float Current Vs. Voltage

图 3——浮充电压与电流的关系

大一倍。

如果发现电池的浮充电流为0，

则电池组中有电池发生了开路。如果浮充电流高出预期值，则可能是电池温度升高或电池组中有电池发生短路。无论是那一种情况，均应予以查明并解决，因为温度升高和单个电池短路都会导致热失控。

单体电池的浮充电压

当电池系统的浮充电压设定为2.25--2.30V/C之间的某一个值时，这并不能保证所有的单体电池的浮充电压都会是这个设定值。因为每个单体电池的阻抗和“内部氧循环”均略有不同，所以即使在同样的浮充电流下也会出现稍有不同的浮充电压。例如，给12V的单体电池以2.30V/C的电压进行充电，电池的电压并不一定正好是13.9V，而可能会在13.3--14.5之间变动，但仍属于正常的现象。一个电池系统如果在安装前给电池均充了24小时，或电池系统服务时间较长，那么浮电压的变化范围会有所减小。

表2中提到的直流浮充电压是指在一个串联电池组中电池的两端测得的最大和最小直流浮充电压。如有个别电池测得值过低，可能电池中发生了短路现象。如果有个别电池测得值过高，这可能是电池内部电阻增加的指示。如果测量显示有个别电池浮充电压极高而该串联电池组中其他电池电压接近电池的开路电压值，那么此高电压的单体电池可能已经发生开路现象。

串联电池组中如果有发生短路的电池存在，那么就会导致整个电池组的充电电流升高。例如，给一个4由个单体（24个单格）电池的串联的电池组以55.2VDC充电，其中有2个单格发生短路，那么对于剩下的22个单格来说，他们的充电电压就会变为2.5V/C（55.2VDC/22单格）。这样，整个电池组的充电电流就增加了，最终会造成热失控。

对于电池组中有短路或开路的单体电池，一般可以通过比较各个单体电池的阻抗，或比较各个单体电池二端测得的交流纹波电压来予以确定。

不要对怀疑有短路或开路单元的电池进行高倍率负载放电试验，这是很危险的。会导致单体电池内部产生火花并引燃内部气体。

对怀疑有短路或开路的室的电池只有立即拆下更换。

有关单只电池浮充电压测量和说明的其他资料，请参阅手册《综合试验》。

高倍率瞬时负载放电试验

高倍率瞬时负载放电试验是对串联电池组中单体电池进行的电池性能的试验。这不能替代电池容量测试，但能够表明电池能否达到所要求的负载的容量。对于20至200AH范围里的电池的来说，典型负载为100安培。施加试验负载后10秒钟，单元的电压应该是平均至少1.7V/C（在12、10、6伏电池上分别为10.2、8.5、和5.1VDC）,否则电池即应被怀疑为有短路，开路，已放电或者极高电阻及低容量。

对怀疑有短路或开路单元的电池切不可进行高倍率瞬时负载放电试验。进行这项测试必须戴全套面罩，因为单体电池内部的一个火花就会引燃或引爆电池内的可燃气体。

有关本试验及按电池型号期望的最低电压的其他资料均在手册《综合试验》内。

阻抗试验

VRLA电池一般失效模式有极板格栅腐蚀，极板活性材料劣化和电解液部分干涸等。不正常的失效模式是导电途径劣化和电解液过度干涸。这些情况都会影响或增加单体电池的电阻。定期测量电池的阻抗及电导的数据，能够有助于了解电池失效发展趋势（参考图4）。个别单体电池电阻的急剧变化表明电池内有短路、开路，干涸和导电途径不好等现象发生。

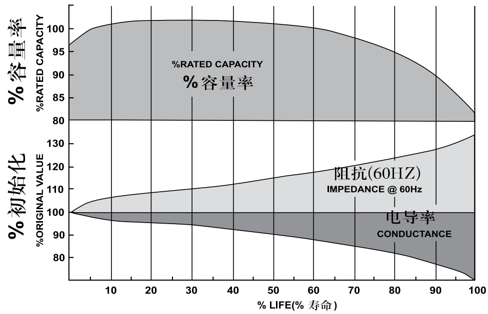


图 4　VRLA 电池的阻抗

如果电池电阻比新的时候增加了30%，则需要对该电池进行试验以确定其原因。必要时，可对该电池进行容量试验以确保其可靠性。

有关这一问题更详细的信息请参阅《阻抗和导电试验》手册。

单元间连接电阻

如果各单体电池间连接电阻过高或连接件发生松动，则放电时由于产生过大的电压降以致减少供电时间，严重时造成电池端子熔化和火灾发生。

所有连接的接触面必须刷干净，去除一切氧化铅和污物，再用特种防氧化油脂保护和拧紧。

连接硬件可能因时间和电池系统重复循环而有些松动。所以要重新拧紧达到有关数据表所载，用于该型号电池的数据，表2列具电池端子类型和推荐扭矩值。

性能和容量试验

当电池放电容量降低到电池额定容量的80%时电池必须换掉，也就是说如果一个电池系统在新的时候能够供电100安时的容量，到后来同样1只电池只能供电80安时容量时便必须更换电池。如果100安培是实际负载而且必须供电至少一个小时，那么电池新的时候必须是原设计能供电125安培一个小时的。在原先设计电池时这个1.25的因子就称为老化因子。

当电池容量降到额定容量的80%时，此时电池板栅已经开始腐蚀并发生膨胀，极板活性材料已老化，电解液已经开始干涸，此时，电池应该被替换。

当然，替换电池可能还有其他原因。譬如，不再支持负载最小的要求时间——即使电池仍有大于80%的额定容量。

一般的VRLA电池各项数据是在77°F（25°C）的值。但需要知道在较低温度下工作电池不会被损坏，但工作时间会减少。温度对电池性能的影响可参考小册子《容量试验》。

在较高温度下连续工作会使加速电池的老化。比77°F（25°C）每高出18°F（10°C）电池老化速率就会比正常快一倍。这一问题的详细资料备载小册《预期寿命和温度》。

VRLA电池定期保养摘要

VRLA电池仅电解液方面不需要保养。但为了保证电池的可靠性，进行厂商推荐的定期保养仍十分重要。推荐的定期保养无论是通过手工操作抑或自动监控系统都是旨在确定系统容量的劣化程度、探测能影响系统可靠性的其他因素或个别电池的出现任何异常情况。

表1　VRLA电池的症候和解决

症候	可能原因	可能后果	纠正行动
容量测试结果			
服务时间减少、电压逐步下降	正常老化	不能支持负载，随后有单格短路危险	容量降至80%额定容量或以前更换电池
电池服务时间减少、电压分步下降或出现电压平台	有个别低容量电池（存有单格反向电池）	单格反向的电池会变得极烫、难以充满电	换掉隔离出的低容量电池
开始放电时电压下跌过快,甚至在起初的几秒钟内电压已降到终止电压值	电池太冷		提高电池工作环境温度
	电缆太细	电压降过大	更换或添加并联电缆
	连接电阻过高	电压降过大	清洁连接电缆、螺丝及重新安装连接
	电池额定容量过低，不能满足负载要求		增加电池或更换高容量电池
	短路单元	单元变热，会发展至热失控；内部火花会导致爆炸	换掉短路故障单元并评价整个串列
温度检查			
室温过高	电池安装处通风不足或无空调设备	电池使用寿命降低	降低电池温度或认可电池使用寿命降低
电池温度过高	室温过高	寿命降低、可能导致热失控	改善室内温度控制设备
	电池箱通风不良	寿命降低、可能导致热失控	改善电池箱通风系统
	放电/充电循环	若不超过18°F (10°C)则正常	降低充电电流
高电流充电	充电电压过高	导致热失控	降低充电电流
	有短路电池		更换电池、检查整组电池
电池外观检查			
电池槽/盖开裂	撞击引起	单格电池干枯、引起接地故障	替换电池
电池槽/盖的爆裂	电池内部短路、产生的火花引燃气体。电池存放处不通风，积累可燃性气体引起	爆炸时造成人员伤害和设备损坏；不能支持负载	替换电池、检查整组电池

症候	可能原因	可能后果	纠正行动
电池外观检查(续)			
外壳烧焦	容器碎裂会导致电解液泄漏，产生接地故障	由于电池架带电可能会造成人体伤害；能造成冒烟或电池着火；能造成热失控	解决接地故障、替换失效电池、检查整组电池
外壳永久性变形（膨胀)	环境温度过高、过充电、充电电流过大、有短路电池或存在接地故障等	可能释放臭鸡蛋味的硫化氢气体、电池着火及不能支持负载	替换失效电池、降低电池工作处温度 检查整组电池
臭鸡蛋味	环境温度过高、过充电、充电电流过大、有短路电池或存在接地故障等	臭味是热失控的产物	替换电池,解决导致热失控的问题
端子上有熔化的油脂	连接松动、接触面过脏、连接处腐蚀发生腐蚀等造成的高电阻	过高电压降可能会降低电池运行时间、损坏端子；严重时会使端子熔融和融化盖子	如果连接损坏,清洁和重新组装；换掉任何端子损坏的电池
正负极端子腐蚀	制造过程中的残留电解液、电池端子密封漏出的电解液	增加连接电阻使高倍率放电时连接头发热及增大电压降	拆下连接，清洁连接面、端子区并密封涂上抗氧化油再妥善安装.如果端子区渗漏明显,则必须换掉电池
直流电压检查			
浮充电压高于2.3V/C(25度)	充电机输出设置不当	会导致电解过早干枯及潜在的热失控危险	重新设定充电机输出值到推荐值
浮充电压小于2.25V/C(25度)	充电机输出设置不当	工作时间减少、容量逐衰减；时间过长会导致极板上便会生成非活性的硫酸铅，从而造成电池容量永远性丧失	重新设定充电机输出值到推荐值；将电池系统均充48至72小时并进行容量试验；如果容量丧失是永久性的,即须替换电池

症候	可能原因	可能后果	纠正行动
直流电压检查(续)			
均充电压大于2.4V/C(25度)	充电机输出设置不当	过度充电会导致产气过多和电解液干涸以至发生热失控	重新设定充电机输出值到推荐值
系均充电压小于2.4V/C(25度)	充电机输出设置不当	均充和补充电效率不高需要延长充电时间	重新设定充电机输出值到推荐值，适当提高均充时间
个别电池浮充电压小于2.2V/C	可能有个别电池短路，这可用检查阻抗或电导来证实	电池运行时间缩短、浮充电流增加、放电时电池发热及可能会导致潜在热失控危机	替换问题电池
个别电池浮充电压高于2.42V/C	可能个别电池存在开路单元.这可凭检查(零)浮充电电流或检查电池的电阻(很高)来证实	无法支持负载，能造成引燃室内气体的内部电弧	替换问题电池
动监控设备接地故障指示有故障	电池槽损坏使电解液泄漏	人员电击事故；可造成严重伤害或致命	查明接地故障的源头及替换问题电池
交流纹波电压检查			
系统上的交流纹波(峰-峰)电压大于直流浮充电压值4%	充电机输出滤波不良	产生热量及对极板活性材料有害	改进充电机滤波能力
电池组中个别电池出现交流纹波电压二倍于组中其他电池	电池阻抗较高，电池可能干涸、短路或开路单格存在	降低电池运行时间；存在导致热失控的潜在危机	检验电池并按要求替换
浮充电流检查			
浮充电流为0	电池或连接断开； 检查浮充电压或交流纹波电压或检查 电池阻抗	无法支持负载	检验电池及连接并按要求替换
浮充电流过高，超过额定容量每安培小时3.0毫安（25°C）	电池没有充满	电池容量不足	确定各项原因并采取必要行动
	电池温度过高 有短路单格	导致热失控	
10秒高放电负载测试			
端子电压略低于10秒点规定的最小电压	电池可能没有充足电电池服务时间过长	会降低电池运行时间	完全充电

症候	可能原因	可能后果	纠正行动
10秒高放电负载测试(续)			
端子电压明显低于10秒点规定的最小电压	电池已经放电或导电回路、极板格栅、活性材料或电解液劣化	会降低电池运行时间	充电及再测试电池或按要求调换
	单格短路	导致热失控	
	单格开路	不能支持负载	
电池阻抗/电导试验			
阻抗/电阻比原始值高50%或导电性值比原始值低50%	电池已放电或电流回路、板栅、活性材料,电解液恶化	不能支持负载	充电及再测试电池或按要求调换
	单格短路	导致热失控	
	单元开路	不能支持负载	
连接件松紧度及其电阻检查			
连接电阻较原阻值（安装初始值）增加20%及以上	连接外忽冷忽热以致扭矩松脱及连接电阻增加	连接件松脱会导致端柱过热并易熔融	重新扭紧连接件
	连接里的污染会导致腐蚀和高电阻	大电流放电时过大的电压降会缩短电池工作时间	清除污染源,清洁连接区域,用抗氧化油脂涂覆接触面再安装
连接件（螺丝）的紧密度小于规定的“扭矩”值	反复充放电循环造成连接的忽冷忽热使连接松脱,电阻增大	在高放电时,松动的连接能使端子发热损坏甚至溶解	按要求再拧紧连接

Table of Contents

General Information
Battery System General Description
Series string 15
Parallel string 15

VRLA Battery Safety Concerns
Electrical Hazards 16
Disposal 16
Chemical Hazards 16
Fire, Explosion and Heat Hazards 16
Handling Hazards 17

Preparation for VRLA Battery Periodic Maintenance
Required Maintenance Tools and Equipment 17

Periodic Maintenance Tasks and Schedule
Quarterly Checks 18
Semi-Annual Checks 18
Annual Checks 18
Bi-Annual Checks 18

Data Analysis and Corrective Actions
Ambiant and Battery Temperature 19
Battery Visual Inspection 19
System Float Voltage 20
Ground Fault Check 20
Float Charging Current 21
Individual Battery Float Voltage 21
High Rate Momentary Load Test 22
Battery Impedance 22
Connection Resistance 22
Performance Testing 23

Tables
Table 1-Battery System Symptoms and Solutions 24
Table 2-Battery Parameters by Model Number 31

Figures
Figure 1-Series String of VRLA Batteries 15
Figure 2-Parallel Strings of VRLA Batteries 15
Figure 3-Float Current VS. Float Voltage 21
Figure 4-VRLA Battery Impedance VS. Capacity and Age 22

SC&D LIBERTY BATTERY MAINTENANCE AND APPLICATION RECORDER .... Cover-three
Appendices
Appendix 1-VRLA Battery Periodic Maintenance Data Recording Form .... cover

VRLA Battery

DYNASTY VRLA BATTERY SYSTEM

PERIODIC MAINTENANCE AND TROUBLESHOOTING GUIDE

General Information

This pamphlet provides a guide for use during periodic maintenance and troubleshooting of the LIBERTY VRLA batteries of 20 through 200 ampere hours capacity.

Other instructional pamphlets which can be used in conjunction with this guide include:
1.Integrity Testing 41—7264
2.Impedance and Conductance Testing 41--7271
3.Acceptance and Capacity Testing 41—7135

C&D LIBERTY VRLA
Battery System General Description

In general the battery system is a group of 2 bolt cells of 6, 10 of 12 volt batteries connected in a series string to provide a total system of higher voltage. For example , as shown in Figure 1, four of the nominal 12 volt batteries may be connected in series to provide a 24 cell system with a nominal voltage of 48 volts.

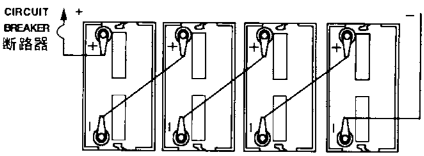


Figure 1–Series Connected String of Batteries
图 1——电池的串联

Multiple strings of the series connected batteries may be connected in parallel to provide a total system with a capacity of the sum of the capacities of the individual strings. For example , as shown in Figure 2 , two each 48 volt 90 ampere hour capacity strings can be connected in

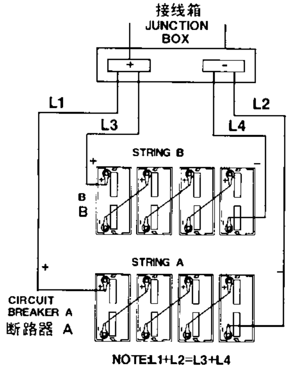


Figure 2-Parad **Stings** of Batteries

The LIBERTY VRLA battery is a lead acid battery which facilitates an oxygen recombination cycle. The net result is that under normal conditions there is minimal gas emission and loss of water from the electrolyte is immobilized in either a gel form or is absorbed separator between the plates. Consequently , the battery is maintenance free in terms of electrolyte maintenance-that is, there is no requirement nor capacity to add water to the cells or to measure the electrolyte specific gravity.

VRLA Battery Safety Concerns

Maintenance and servicing of the LIBERTY VRLA battery should only be performed and supervised by personnel knowledgeable of lead acid batteries and required personal safety and equipment safety precautions. Keep unauthorized personnel away from the batteries and maintenance activities.

VRLA Battery

Electrical hazards

Battery systems present a risk of electrical shock and high short circuit currents. The following precautions should be observed when maintaining VRLA batteries:

1. Remove all personal metal objects (watches, strings, etc.)
2. Use insulated tools

3. Wear full eye protection and rubber gloves.

4. Observe circuit polarities.

5. Do not make or break live circuits.

6. Prior to handling batteries on a metal rack, assure the battery is not inadvertently grounded by observing the ground fault detector indicator. In its absence, measure the voltage between the battery and the rack. It should be zero. If not, determine the cause and correct prior to proceeding.

7. Do Not lay metal tools and hardware on top of the batteries.

8. As appropriate, use an insulating blanket to cover exposed portions of the battery system when performing extended maintenance that could result in personal or equipment contact with the energized conductors.

Certain types of rectifier circuits used in charging the VRLA battery may not include a line isolating transformer. In these cases extreme caution should be exercised when maintaining and collecting data on the battery system.

The VRLA battery is sometimes enclosed in cabinets with very limited access. Again ,extreme caution must be exercised when maintaining and collecting data on the battery system.

Disposa

Lead acid batteries are to be recycled. Batteries contain lead and dilute sulfuric acid. Dispose of in accordance with Federal , State and local regulations. Do not dispose of in a landfill, lake or other unauthorized location.

Chemical Hazards

Any gelled or liquid emissions from a VRLA battery is electrolyte which contains dilute sulfuric acid which is harmful to the skin and eyes; is electrically conductive; and is corrosive.

If electrolyte contacts the skin ,wash immediately and thoroughly with water. If electrolyte enters the eyes, wash thoroughly for 10 minutes with clean water or a special neutralizing eye wash solution and seek immediate medical attention.

Neutralize any spilled electrolyte with the special solutions contained in a “pill kit” or with a solution of 1 lb. bicarbonate of soda to 1 gallon of water.

Fire ,Explosion and Heat Hazards

Lead acid batteries can contain an explosive mixture of hydrogen gas which can vent under overcharging conditions.

Do not smoke or introduce sparks in the vicinity of the battery.

Prior to handling the batteries ,touch a grounded metal object, such as the rack ,to dissipate any static charge that may have developed on your body.

Do not charge batteries in a sealed container. The individual batteries should have 0. 5 inches of space between the batteries to allow for convection cooling. If contained, assure the container or cabinet and room have adequate ventilation to prevent an accumulation of potentially vented gas.

VRLA Battery

Caution

Do not attempt to remove the vents(valves) from the LIBERTY VRLA battery or add water. This presents a safety hazard and voids the warranty.

Handling Hazards

The individual batteries may weigh from 25 to 100 pounds depending on part number. Exercise care when handling and moving batteries. Assure the use of appropriate handling equipment.

Preparation for VRLA Battery Periodic Maintenance

There is little difference between the periodic maintenance associated with a VRLA battery and a vented (wet) cell battery with the exception of that related to the liquid electrolyte. Naturally, it is not required to measure electrolyte specific gravity or add water to the VRLA cells.

For optimum reliability, it is recommended that the battery system be monitored quarterly. If the battery system incorporates an automatic monitoring system to gather the electrical and environmental data, the quarterly checks are limited to the evaluation of the recorded data and a visual check of the battery.

In general the types of checks to be made during the periodic maintenance include:

1. System charging voltage
2. Ambient temperature
3. Battery pilot unit temperatures
4. Interunit connection hardware resistance or tightness
5. Individual battery float voltage
6. Momentary high rate load test
7. Battery system capacity test

A test of the individual unit resistance, impedance or conductance, while optional, is also recommended on a periodic basis. This data and its trend can be a valuable aid in troubleshooting the system and predicting the need for a system capacity test.

Prior to starting the periodic maintenance activity assure that all required maintenance tools and equipment and safety equipment is available and functional. Notify anyone who will be affected by the intended maintenance or troubleshooting activity.

Also,all units in the battery should be numbered so as to facilitate the recording and analysis of data unique to each unit.

Required Maintenance Tools and Equipment

At a minimum, the following tools and equipment are required to maintain and troubleshoot the LIBERTY VRLA battery.

1. digital voltmeter
2. socket wrenches, insulated
3. box end wrenches ,insulated
4. torque wrench calibrated in in.-lbs.
5. rubber gloves
6. full face shield
7. plastic apron
8. potable eyewash
9. spill kit
10. fire extinguisher (class C)

The following equipment is optional depending on the type of maintenance to be performed.

1. micro-ohm meter
2. battery resistance, impedance or conductance test set
3. 100 amp momentary load test set
4. system load bank (DC if to be performed at the battery and AC if to be performed by loading a UPS output)

VRLA Battery

Quarterly Maintenance

The following checks should be completed quarterly.

1. Assure the battery room is clean, free of debris and well lighted.

2. Assure that all facility safety equipment is available and functional.

3. Measure and record the air temperature within the battery room.

4. Visually inspect the battery for:
   a. cleanliness.
   b. terminal damage or evidence of heating.
   c. container or cover damage.
   d. evidence of overheating.

5. Measure and record the battery system DC float charging voltage at the battery. Optionally measure and record the AC ripple voltage at this time also.

6. Measure the DC voltage from each polarity of the battery to ground to detect any ground faults.

7. If possible, measure and record the battery system DC and AC float charging current.

8. Measure and record the temperature of the battery pilot unit. Sense the temperature on the side of the unit in the center or at the negative terminal of the unit.

9. Measure and record the individual unit DC float charging voltage.

10. Measure and record the System Equalization Voltage.

Semi- Annual Maintenance

1.Repeat the quarterly checks.
2.Optionally perform the 10 sec. high rate (e. g.100 amp) load test to assure the individual batteries are functional.
3. Optionally measure and record the resistance/ impedance/conductance of the individual units to trend the condition of the individual units over time and to detect dramatic differences between individual units and the norm.

Annual Maintenance

1. Repeat the semi-annual checks.
2. Retorque all the interunit connecting hardware to the values noted in Table 2. This can be omitted if the connection resistance is measured and found to have not increased more than 200o from the value at installation.

Bi - Annual Maintenance

The battery should be capacity tested every two years at the service load or at the battery rating related to the service requirements. Ldeally , this will be the same rate at which it was acceptance tested when originally installed. Once the battery is found to be at 85% of rating, it should be capacity tested annually. Capacity testing instructions are found in the bulletin “Acceptance and Capacity Testing” # 4141-7135.

Data Analysis and Corrective Actions

The data accumulated during the periodic maintenance activities should be recorded on a form such as shown in Appendix One.
Following is an explanation of how the data would be interpreted and the correction action to be taken. However, it must be recognized that this explanation is not all inclusive and the analysis and corrective action decision must be made by personnel familiar with VRLA batteries and their operation and failure modes.

VRLA Battery

Environment Ambient and Battery Temperature

While the VRLA battery wil function at extremes of temperature, it is rated at 77°F (25°C)and the ideal operating temperature range for the VRLA battery is 70 (2JfC) to 80°F (27°C). Operation at cooler temperatures will reduce the anticipated standby operating time while operation at warmer temperatures will detract from the battery life and will increase the potential of a thermal runaway condition.

The battery will experience a 500o reduction of life for each 18°F (10°C) above 77°F (25°C). High ambient room temperature should be corrected through the use of appropriate ventilation and air conditioning.

The VRLA battery should not be charged at temperatures exceeding 122°F (50°C). A thermal runaway condition could result.

The individual batteries within the string should not exceed the ambient temperature by more than 18°F (10°C). If the entire battery or individual units temperatures are excessively high, the respective units may be experiencing thermal runaway. In this situation the charging current should be terminated and the cause of the situation should be determined and corrected.

If thermal runaway has occurred, the battery system should be capacity tested and replaced if necessary.

Battery Visual Inspection Container Cleanliness

It is important that the individual batteries be clean and properly spaced. An accumulation of dirt or dust and moisture on the covers can produce a conductive path between the terminals or to ground which could result in short circuits or ground faults.

When batteries are cleaned, they should be on open circuit. For cleaning, use a cloth moistened in a solution of bicarbonate of soda and water. Do not use cleaners of unknown solutions such as window or glass cleaners and solvents. Use of certain petroleum based cleaners will damage the battery plastic containers and could cause them to crack and craze.

Container and Cover Damage

Should a crack or other penetration of the container or cover of a battery be noted, it should be replaced. A crack in the container could allow conductive electrolyte to wick from the battery and create a ground fault. A ground fault could lead to melting and burning of the container.

A hole in the cover, even without wicking of the electrolyte, can also be a serious situation. The hole will allow drying of the electrolyte in the subject cell resulting in an eventual high resistance and heating of the subject cell.

Containers which are severely swollen and permanently deformed have been overheated and experienced thermal runaway. Thermal runaway will also cause the batteries to gas and dry out and will damage the plates. In this case the entire battery string should be replaced.

Terminals

Bent or otherwise damaged terminals can produce high resistance connections or can hide a fracture that could fuse open under load. Batteries with damaged terminals should be replaced.

If the protective grease at a termination has melted and flowed onto the cover, it is an indication that the connection has been hot and this is, in all probability, the result of a loose or high resistance connection. In this situation the connection should be disassembled, inspected for damage, cleaned and properly reassembled.

VRLA Battery

Battery system Float Charging Voltage

The recommended battery system float charging voltage for the LIBERTY VRLA Batteries with a specific gravity of **1, 280** to **1, 300** is equal to the number of cells in the system multiplied by the range of **2. 25** to **2. 30** volts per cell at **77**°F (25°C). For example, a string of **30** each **12** volt (6 cell) batteries should be float charged within the range of **405** to **414** VDC(**180** cellsX**2. 25**V/C minimum and **180** cellsX**2.30**V/C maximum)at **77**°F(**25**°C).

When temperature extremes are encountered the float charging voltage should be temperature compensated. The temperature compensation coefficient is — 0.0028V/C per degree F (--0. 005V/C per degree C).

For example, if the battery normal temperature is **90** °F (**13**° above **77**°F) the average float charging voltage range should be reduced **0.036** V/C (**13~X0. 0028** V/C per F)to between **2. 21** and **2. 26** V/C. For a **180** cell battery this would be **397.8** to **408.6** VDC. This will help reduce the potential for thermal runaway at elevated temperatures.

If the battery operates at "cold" temperatures, for example 50°F (17° below 77°F) , the charging voltage can be increased to improve recharge time. For example, the charging voltage range could be increased by -17°X- 0. 0028 V/C per degree or 0.048 V/. For the 180 cell string this would be 413. 6 to 422.6 VDC.

If the battery is undercharged for a period during which there have been multiple discharges, the battery will not fully recharge following each discharge and it will provide progressively lower capacity. This condition may be correctable with an extended equalization charge (e g. 48 to 72 hours). However, if the situation has continued for too long a time, irreversable sulfation of the plates may have occurred and the battery may have to be replaced.

Extended overcharging will cause excessive float current, corrosion of the plate grids, gassing and drying of the limited amount of electrolyte. This constitutes premature aging of the battery and loss of capacity.

Severe overcharging for extended periods can induce a thermal runaway condition. This would also necessitate replacement of the battery system.

While measuring the battery system DC float charging voltage it may also be convenient to measure the AC ripple voltage appearing across the battery system. If the AC ripple voltage is a sinusoidal waveform the maximum reading should be less than 0.5% Vrms of the DC float voltage. In the case of 180 cell string floating at 414 VDC, this is 2. 07 Vrms. When measuring the ripple with an oscilloscope, the maximum p -p value should be 1.5% of the float voltage or 6. 2 Vp -p when floating at **414 VDC**.

Excessive AC ripple voltage across the battery could cause gassing and heating of the battery which would result in reduced life.

Battery System Ground Fault Detection

If the rectifier used to charge the battery has a ground fault detection capability, the indicator should be observed to determine the safety of the system. If a ground fault is indicated, it should be isolated and corrected prior to further maintenance on the battery system.

If the rectifier does not have a ground fault detection circuit, use the digital voltmeter and measure the voltage from each polarity of the battery to ground (the grounded rack or cabinet). A detected voltage would indicate a short or leakage current from the battery to ground. The approximate location of the cell with the ground fault ,from the battery system output terminal, would be the measured voltage divided by the average per cell charging voltage. For example, if the measured voltage to ground was 135 VDC and the charging voltage was 2. 25 V/C,the ground fault would be approximately 60 cells (ten 12 volt units) from the battery system output terminal.

Battery System
Float charging Current

If the DC float current can be measured,it can provide an indication of the proper current acceptance of the battery system. Depending on the charging voltage per string and the temperature, the float current per string should be approximately that shown in Figure 3. The float current will approximately double for each 18°F (10°C) above 77°F(25°C)

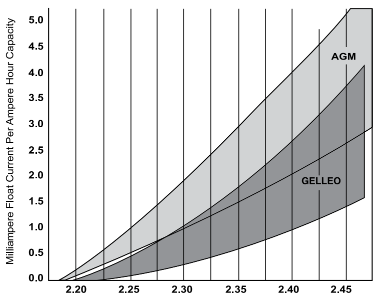


Figure 3 – Float Current Vs. Voltage

If the DC float current is zero there is an open circuit in the battery string. If the float current is higher than anticipated, it may be due to elevated termperature of the battery or shorted cells within the string. In either case the cause should be determined and corrected. Elevated temperatures and shorted cells are both situations which can lead to thermal runaway.

Individual Battery
Float Charging Voltage

While the battery string may be charged at an average of between 2. 25 and 2. 3 volts per cell ,not all cells will float at the exact average vlotage.

Each cell has a somewhat different impedance and rate of oxygen recombination and will therefore exhibit a slightly different float slightly different float voltage at the same float current. For example, all the 12 volt batteries in a string charged at 2. 3 volts per cell will not float at **13.9** VDC but may **vary from 13.3** to **14.5** and still be normal. If the system is equalized for 24 hours upon installation, or with an extended time in float service, this spread in float voltage will normally decrease.
Table 1 indicates the minimum and maximun DC float voltages to be measured across batteries in a series string. If an individual battery measures too low, it may be an indication of a shorted cell. If an individual unit measures too high. it may be an indication of increased resistance within the cell. If one unit measures very high while the balance of the units in the string indicate near the open circuit value, the high voltage cell may have an open circuit.

Shorted cells within the string will lead to increased voltage applied to the remaining good cells in the string and higher folat current. For example, A 24 cell string charging at 55. 2 VDC (2. 3V/C) which has 2 shorted cells will be charging the remaining 22 cells at 2. 5 V/C(55. 2VDC/22 cells)and the resulting increase in float current is sure to result in eventual thermal runaway.

A battery with a shorted or open cell can usually be confirmed by comparing the impedance of the individual units or by comparing the AC ripple voltage measured across the individual units.

Do Not perform a high rate load test on batteries that are suspected of having a shorted or open cell. This would be hazardous since a spark internal to the cell could ignite the internal gases.

A battery suspected of having a shorted or open cell should be removed and replaced immediately.

More information concerning the measurement and interpretation of individual battery float voltages is contained in the pamphlet "Integrity Testing" 4-41 -7264.

High Rate Momentary Load Test

The high rate momentary load test is a functional test of the individual battery within the series string. It does not replace a capacity test but it does indicate if the battery is functional at least up to the ampere capability of the test load. A typical load used for batteries in the 20 to 200 ampere range is 100 amperes. The voltage of the unit 10 seconds after application of the test load should be at least 1. 7 v/c average(10. 2,8.5 and 5.1 VDC for 12,10 and 6 volt batteries respectively) or the battery should be suspected of being open, shorted, discharged or of very high resistance and low capacity. Never perform the high rate momentary load test on a battery suspected of having a shorted or open cell. Full face protection should always be worn during this test, since a spark internal to a cell could ignite the residual gasses within the cell.

More information concerning this test and the minimum voltages to be expected by part number is contained in the pamphlet "Integrity Testing" #41-7664.

Impedance Testing

The normal wearout mode of the VRLA battery includes corrosion of the plate grids, deterioration of the plate active material and some drying of the electrolyte. Abnormal failure modes would include deterioration of the conductive path and excessive drying of the electrolyte. These processes will all increase the resistance of the affected cells and periodic measurement of the impedance,resistance or conductance of the cells and trending of this data can indicate string uniform gradual degradation and loss of capacity with time. This is shown in Figure 4.

Rapid changes in individual units may indicate shorted, open and drying cells and cells with deteriating conductive paths.

When an AC ripple voltage appears across a string of batteries it will be subdivided

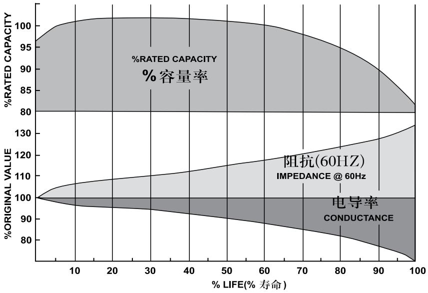


Figure 4-VRLA Battery Lmpedance and Conductance VS.Capacity and Age.

across the individual units in the string proportional to their relative resistance. Therefore in the absence of an impedance, resistance or conductance test set, the AC ripple voltage across the individual units can be measured with a DVM and compared to each other and the norm as an indication of their relative resistance and condition.

If the resistance of the batteries has increased by 300 over that when it was new, the battery should be further tested to determine the cause and if necessary the battery or system should be capacity tested to assure reliability.

More information on this topic is contained in the pamphle "Impedance and Conductance Testing" #41-7271.

Interunit Connecting Resistance

High resistance in the interunit connections and loose connecting hardware can cause excessive voltage drop during discharge resulting in reduced operating time and in the extreme case even cause melting of the battery terminals and potentially a fire.

VRLA Battery

The contacting surfaces of all connections should be brushed clean, removing all lead oxide and contamination, protected with a special antioxidation grease, and tight.

The connection hardware may loosen somewhat with time and repeated cycling of the battery system. The connection hardware should be retorqued to the value indicated for the battery part number as shown on the relevant data sheet. A summary of the battery terminal types an the recommended torque values is given in Table 2.

Performance and Capacity Testing

When the battery degrades to **8000** of its rating it should be replaced. That is ,if a battery system could support **100** amperes for 1 hour when new, it should be replaced when it can only support 80 amperes for the same 1 hour period. If 100 amperes is the actual load and this must be supported for a minimum of one hour, the battery should have been originally sized to provide 125 amperes for the one hour when new. This sizing factor of 1. 25 is referred to as the aging factor when originally sizing the battery.

When the battery capacity declines to 80% of rating is it an indication that the plate grids are corroded and expanded; that the plate active material has deteriated and that the drying of the electrolyte has occurred. The battery should be removed from service and replaced at this time.

Naturally, the other criteria for battery replacement is when it no longer supports the load for the minimum required time - even if the battery is still greater than 80% of rating. However, even at minimal load, the battery should not remain in service beyond that point when it is at 80% of rating.

The VRLA batteries are rated at 77°F (25°C). It is important to recognize that operation at lower temperatures, while it does not harm the battery, will reduce the operating time. Performance derating factors for reduced temperature are found in the pamphlet" Acceptance and Capacity Testing" # 41-7135.

Continuous operation at elevated temperatures will result in accelerated aging of the battery. For each 18°F(10°C)above 77°F(25°C)the battery will age at twice the normal rate. Additional information on this topic is found in the pamphlet "Life Expectancy and Temperature" #41-7329.

Summary of Periodic Maintenance for VRLA Batteries

The VRLA battery is maintenance free only as related to the electrolyte. For assurance of the battery reliability it is still important to perform the recommended periodic maintenance.
The recommended periodic maintenance ,whether performed manually or via automated monitoring systems, is designed to determine the gradual degradation of the system capacity and to detect any abnormal system or individual battery condition which could impact system reliability.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
CAPACITU TEST RESULTS			
Reduced operating time at 77F with smooth voltage decline,	Normal wear out	Eventual failure to support the load followed by potential for shorted cells.	Replace battery system when at 80% of rated capacity or before.
Reduced operating time at 77F with step voltage decline or voltage plateaus.	Individual low capacity cells.	Reversed cells during discharge_reversed cells will become very hot and will not fully recharge.	Replace the isolated low capacity batteries.
Excessive initial voltage drop even to the point of dropping load in the first several seconds.	Battery is cold.		Heat the battery.
	Cabling is too small. High resistance connections.	Excessive voltage drop.	Run parallel cables.
		Excessive voltage drop.	Clean and reassemble connections.
	Battery is undersized.		Add required parallel strings.
	Shorted cells.	Cells will become hot, could develop thermal runaway; internal arcing could result in explosion.	Replace isolated units with shorts and evaluate entire string.
TEMPERATURE CHECKS			
Elevated room temperature.	Lack of adequate air conditioning/ventilation.	Reduced battery life.	Cool the room or accept reduced battery life.
Elevated battery temperature.	Elevated room temperature.	Reduced life and potential thermal runaway.	Improve room air conditioning.
	Inadequate cabinet ventilation,	Reduced life and potential thermal runaway.	Improve cabinet ventilation and temperature.
	Discharge-Charge cycle	Can be normal if not exceeding 181F (10C) increase.	Limit recharge current.
	AC ripple current greater than 5 amperes rms/ lOOAh battery capacity.	Reduced life and potential thermal run away.	Determine cause of excessive AC ripple current and correct.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
High current recharge.	High charging voltage. Shorted cells	This combination can lead to thermal runaway.	Limit recharge current. Reduce to within specifications. Replace shorted cells and evaluate total string.
VISUAL BATTERY CHECKS			
Cover/container crack.	Handling or impact damage.	Cell dry out or ground fault. Potential internal gas ignition.	Replace damaged unit.
Cover/container explosion,	Ignition of cell internal gasses due to external source, fusing of internal conductive path, or internal spark due to shorting. This potential exists for batteries not maintained and continued in service beyond useful life.	Personal injury and equipment damage at time of explosion, Failure to support load.	Replace damaged unit and evaluate the balance of string.
Burned area on container.	Crack in container wicking electrolyte to grounded rack, etc. Ground fault.	Could result in personal hazard due conductive path to rack, etc. Could result in smoke or a battery fire. Could result in a thermal runaway.	Clear the ground fault and replace defective unit. Evaluate balance of the string.
Permanently deformed (swollen)container.	Thermal runaway possibly caused by high temperature environment, overcharging, excessively high recharge current, shorted cells or a ground fault or a combination of these items.	Could result in the emission of hydrogen sulfide which is detectable as a rotten egg odor, battery fire and inability to support the load.	Replace the battery system and correct the items leading to the themal runaway condition.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
VISUAL CHECKS (CONTINUED)			
Rotten egg odor.	Possibly caused by high temperature environment, overcharging , excessively high recharge current, shorted cells or a ground fault or a combination of these items.	Odor is a product of extended thermal runaway.	Replace the battery system and correct the items leading to the thermal runaway.
Melted grease at terminals.	Connections were hot probably due to excessive resistance caused by loose connection ,dirty contact surfaces or corrosion within the connection.	Excessive voltage drop perhaps leading to short operating time or damaged terminals.	Clean and reassemble the connection if undamaged. Replace any battery with damaged terminals.
		In extreme case could lead to melted terminal and ignition of the battery cover.	
Corrosion at terminals.	There is possibly either residual electrolyte from manufacturing or electrolyte leaking from the battery terminal seal that is attacking the interunit connector.	Increased connection resistance and resulting increase in the connection heating and voltage drop at high rate discharge.	Disassemble connection, clean ,coat connecting surfaces and terminal area and seal with antioxidation grease and appropriately reassemble the connection. If leakage about the terminal area is obvious ,the battery should be replaced.
DC VOLTAGE CHECKS			
System float voltage greater than 2. 3V/C average at 77V (25~C)	Charger output set incorrectly,	Overcharging will cause excessive gassing and drying of the electrolyte and will contribute to potential thermal runaway.	Reset the charger output voltage to the recommended value.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
DC VOLTAGE CHECKS (CONTINUED)			
System float voltage less than 2. 25V/O average at77TF(25C).	Charger output set incorrectly,	Undercharging will result in a gradual loss of operation time and capacity with successive discharge cycles. If allowed to persist, an irreversible level of lead sulfate will develop on the plates with the result of a permanent loss of capacity.	Reset the charger output voltage to the recommended value. Equalize the battery system for from 48 to 72 hours and perform a capacity test. If capacity loss is permanent. replace the total battery system.
System equalize voltage is greater than 2. 4V/C average.	Charger equalization voltage is set incorrectly,	Overcharging will cause excessive gassing and drying out the electrolyte and will contribute to potential thermal runaway.	Reset the charger output voltage to the recommended value.
System equalize voltage is less than 2. 4 v/c average.	Charger equalization voltage is set incorrectly,	Equalization and boost charging will be less effective and will require extended time.	If possible,reset the charger output voltage to the recommended value or accept longer equalization time.
Individual battery float voltage less then 2. 2V/C average, 13.3 VDC for 6 cell battery. 11. 1 VDC for 5 cell battery. 6.6 VDC for 3 cell battery.	Potentially the individual battery has a shorted cell. Could be verified with an impedance or conductance check.	Reduced operating time under load. Increased float current. Heating of cell during discharge. Contributes to potential thermal runaway.	Replace the individual battery.
Individual battery float voltage greater than 2.42 V/C average, 14.5 VDC for 6 cell battery. 12. 1 VDO for 5 cell battery. 7.3 VDO for 3 cell battery.	Potentially there may be open cell in the individual battery. This can be confirmed by checking for zero float current or checking for a very high impedance of the batter	Failure to support the load. Could result in an internal arc which could ignite the gasses within the cell.	Replace the individual battery.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
DC VOLTAGE CHECKS (CONTINUED)			
DC voltage measured between either of the battery system output terminals and ground (rack)or a ground fault indicated by automatic monitoring equipment.	Damaged battery container allowing electrolyte to wick out to the grounded surface (rack).	Personnel shock hazard which could result in serious injury or electrocution. Potential burning of the container at damaged area or battery fire.	Determine the source of the ground fault and replace battery.
AC RIPPLE VOLTAGE CHECKS			
AC ripple(p-p)voltage on the system is greater than 4% of the value of the DC float voltage,	Poor filtering of the charger output.	Excessive AC ripple could cause the battery to cycle at the ripple frequency and result in heating and deterioration of the plate active material.	Improve the charger output filtering.
Individual battery in string exhibits AC ripple voltage of twice that of the other typical batteries in string,	Battery with the high AC ripple voltage has a proportionately higher impedance and should be further evaluated for performance. Subject battery could have a deteriorating conductive path or a dry, shorted or open cell.	Reduced operating time. Potential conditions could be conducive to thermal runaway.	Verify the battery condition and replace as required.

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
FLOAT CHARGING CURRENT CHECKS			
Float current to the string is zero.	A battery or connection in the series string is open. This can be verified via the float voltage check or AC ripple voltage or impedance check of the individual batteries.	Failure to support the load. If an internal arc should occur during discharge ,it could ignite the gasses internal to the cell. If there is a open/loose connection in the external conductive path, it could damage the termination under load.	Replace the battery with the open cell or repair the open! loose external connection.
Float current exceeds 3.0 Millie amperes per ampere hour of rated capacity at 77F (25C)at float voltage.	Batteries are not yet fully recharged.	Not at 100% of capability.	Determine the specific cause and take necessary corrective action.
	Batteries are above 77F (25C).	Conducive to thermal runaway.	
	Potentially shorted cells in battery.	Conducive to thermal runaway.	
	Depending on the degree, the battery may be entering or in thermal runaway.	Thermal runaway results in eventual meltdown of the battery and the potential of hydrogen sulfide emissions and fire.	
AC ripple current exceeds 5 amperes per 100 Ah rated battery capacity.	Poor filtering of the charger.	Excessive AC ripple current will result in battery heating, reduced service life and potential thermal runaway.	Improve the charger output filtering.
HIGH RATE 10 SEC. LOAD TEST			
Terminal voltage is marginally below the minimum voltage specified for 10 sec. point,	Battery is perhaps not fully charged or is an older battery that has been in service and is of somewhat lower capacity.	Perhaps reduced operating time.	Fully recharge the battery.
Terminal voltage is significantly below the minimum voltage specified for 10 sec. point.	Battery is discharged or battery conductive path ,plate grid or active material or electrolyte volume deterioration.	Reduced operating time. Conducive to thermal runaway. Will not support load.	Charge and retest battery or replace as required.
	Shorted.		
	Open cells.		

TABLE 1-VRLA Battery Symptoms and Solutions (Cou't)

Symptom	Possilbe Causes	Possilbe Result	Corrective Actions
AITERY IMPEDANCE/ CONDUCTANCE TEST			
mpedance/resistance increase by 50% from original values when new or conductance decline to 50% or the value when new.	Battery is discharged or Battery conductive path, plate grid or active material or electrolyte volume deterioration.	Reduced operating time.	Charge and retest battery or replace as required.
	Shorted cells.	Conducive to thermal runaway	
	Open cells.	Will not support load.	
CONNECTION HARDWARE RESISTANCE/ TIGHTNESS CHECK			
Connection resistance increase of 20% or more from original value,	Repetitive cycles resulting in heating and cooling of connection can result in relaxation of torque and an increase in connection resistance.	Loose connections can result in heat damaged or melted terminals during high rate discharge.	Retorque the connection as required.
	Contamination within the connection can result in corrosion and high terminal resistance.	Excessive voltage drop during high rate discharge and resulting reduced operating time.	Correct the source of contamination ,clean the contact surface areas, grease the contact surfaces with antioxidant grease and reassemble.
Connection hardware tightness is less than the specified "retorque" value,	Repetitive cycles resulting in heating and cooling of connection can result in relaxation of torque and an increase in connection resistance.	Loose connections can result in heat damaged or melted terminals during high rate discharge.	Retorque the connection as required.