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Course Outline:
I. Introduction
II. Conventional battery design
III. AGM battery design
IV. Basic battery facts
V. Battery safety
VI. Common causes of battery failure
VII. Battery maintenance/management plan
   - Diagnostics
   - Corrective Maintenance
   - Preventive Maintenance
VIII. Conclusion
IX. Shop Level Program Outline

II. Conventional battery design

- (+) and (-) plates are connected to make a 2 volt cell.
- The case is filled with electrolyte (sulfuric acid & water)
- Electrolyte must always cover the battery plates (but don’t fill to top).

87,000 batteries in Kuwait
### Conventional Battery Design

- **Open top**
  - Wet Electrolyte
  - Deep cycle capabilities
  - Usually Antimony/Antimony
  - Greater plate density
  - Highest self-discharge rate up to 8% per month

- **Closed top**
  - Still have access to cells
  - Wet electrolyte
  - Calcium/Calcium plates
  - Reduced self-discharge rate

**Applications:** Cars, trucks, daily use vehicles

### Absorbed Glass Mat (AGM)

- Excellent SLI batteries
- Low self-discharge rate
- Higher initial costs
- Longer service life when properly maintained
- Cars, Trucks, Unique Orientation Installations

### III. AGM battery design

**Same basic design as conventional battery, except:**

- AGM batteries use an Absorbent Glass Mat to contain all the electrolyte.
  - The AGM holds all the electrolyte like a “super sponge”. Battery won’t leak or spill even if tipped over or accidentally cracked.
- Contains a one way safety valve to prevent out-gassing & loss of liquid during normal operation.
- High purity lead (not recycled) plus a little tin
- Plates are compressed into cell partition
  - Prevents plate to plate movement & shorting
  - Prevents loss of active paste material
  - Increases vibration resistance.

### Advantages of AGM batteries:

- **Longer life**
- **Less maintenance**
- **Safer**
  - No leaking acid
  - Eliminates corrosion to terminals & battery trays
  - No holes in your clothes, or burning skin
  - Reduced chance of battery explosion
- Battery will work temporarily after cracked open or taking a round.
- Lower internal resistance
  - Higher cranking power
  - More usable reserve capacity
  - Faster recharge

### IV. Basic battery facts

**A little voltage means a lot!**

- Only .7 volt difference
- 12.9 OCV
- 12.2 OCV

**Hawker/Optima state of charge versus OCV**

**The rate of self discharge increases as the temperature goes up**

For every 10°C rise in temperature the self discharge rate doubles!
Basic battery facts

Battery Storage Issues
- Climate controlled?
- HAZMAT restrictions?
- Prior to your purchasing them?
- Manufactured date verses your receipt date?

What can you do about these issues?

V. Battery Safety

Battery Safety

THIS PROGRAM DOES NOT TAKE PRECEDENCE OVER ANY LOCAL DIRECTIVE GOVERNING SAFETY.

Safety information provided by Battery Council International (BCI)

V. Battery Safety

Suggested Safety Equipment:
- Always wear proper eye, face, and hand protection.
- Keep all sparks, flames and cigarettes away from the battery.
- Never try to open a battery with non-removable vents.
- Keep vents tight and level except when servicing electrolyte.
- Make sure work area is well vented.
- Never lean over a battery when boosting, testing or charging.
- Exercise caution when working with metallic tools or conductors to prevent short circuits and sparks.

V. Battery Safety

Safe Charging:
- Follow all safety practices described previously.
- Never attempt to charge a battery without first reviewing the instructions for the charger being used.
- Turn chargers off before connecting leads to the battery to avoid dangerous sparks.
- Never try to charge a frozen or visibly damaged battery.
- Connect the charger leads to the appropriate battery terminals (red to positive and black to negative)

(This class deals only with batteries removed from the vehicle, so charging batteries when they are installed in vehicles will not be covered.)

V. Battery Safety

Handling Battery Acid:
- Battery acid or electrolyte is a solution of sulfuric acid and water that can destroy clothing and burn the skin.
- Use extreme caution when handling electrolyte and keep an acid neutralizing solution - such as baking soda or household ammonia mixed with water - readily available.
- When handling batteries or acid:
  - Always wear proper eye, face and hand protection.
  - If electrolyte is splashed into an eye, immediately force the eye open and flood it with clean, cool water for at least 15 minutes. Get prompt medical attention.
  - If electrolyte is taken internally, drink large quantities of water or milk. DO NOT induce vomiting. Get prompt medical attention.
  - Neutralize with baking soda any electrolyte that spills on a vehicle or a work area. After neutralizing, rinse contaminated area clean with water.

VI. Common causes of battery failure

Common causes of battery failure
BATTERY MAINTENANCE MANAGEMENT PROGRAM

VI. Common causes of battery failure

Deficit charging:
• When the vehicle cannot fully charge the battery during normal operation. Results in a decline in capacity (shorter run time of electronics) and reduced battery life.

Typical causes are:
• Engine alternator voltage and/or amperage is too low,
• Engine run time not long enough to recharge batteries.
• High accessory loads (lights, radios, etc)

Solutions:
• Install a higher amperage alternator
• Shut off accessories when possible (or leave engine running)
• Periodically use an external charger to fully charge the batteries.

12V Parallel or 24V Series Complications
Mixing different types of batteries together

Connecting different types of batteries together in the vehicle will lead to shorter battery pack life and possible overcharge or undercharge problems with individual batteries. Premature failure WILL happen.

Solutions:
• Only connect together batteries of identical make and model.
• NEVER mix different battery types.

VI. Common causes of battery failure - plate sulfation

Leaving (parking vehicle) batteries in a discharged condition:
Even a partial discharge will cause sulfation on the plates that reduces battery capacity and leads to premature battery failure.

Do not leave batteries discharged!
Damage can occur in a very short period.

Solutions:
• Check batteries before storing vehicle & recharge batteries if needed.
• If the vehicle or equipment is not used on a regular basis, periodically check the battery OCV and charge when necessary.
• Charge whenever the battery OCV is:
  • Wet/flooded: 12.5 or less
  • AGM: 12.7 or less
• When storing vehicles, use a maintenance charger such as those provided by PulseTech Products to prevent reoccurring battery discharge.

NEVER mix different battery types!

VI. Common causes of battery failure - plate sulfation

Cathode crystalline structures remaining after charging without pulsing
Cathode after charging and pulsing with SolarPulse

Battery Plate Cycle Comparison Chart
BATTERY MAINTENANCE MANAGEMENT PROGRAM

How do I create a complete Complete cradle to grave maintenance capability -

✓ DIAGNOSTIC
✓ CORRECTIVE
✓ PREVENTIVE

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Beginning SOC</th>
<th>Beginning SOH</th>
<th>Ending SOC</th>
<th>Ending SOH</th>
<th>Battery Status</th>
<th>Prior to Pulsing</th>
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<tbody>
<tr>
<td>GRP 31 Rated 650 CCA</td>
<td>11.4V</td>
<td>110 CCA</td>
<td>12.94V</td>
<td>690 CCA</td>
<td>Marked for Disposal</td>
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<td>12.97V</td>
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<td>122 CCA</td>
<td>13.05V</td>
<td>664 CCA</td>
<td>Marked for Disposal</td>
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<td>“NEW” Battery</td>
<td>Really?</td>
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<td>570 CCA</td>
<td>13.07V</td>
<td>754 CCA</td>
<td>“NEW” Battery</td>
<td>Really?</td>
</tr>
</tbody>
</table>

VII. BMMP - Diagnostics

If the engine starts, the battery must be good, right?

NOT NECESSARILY!

A borderline battery may start the engine, but fail shortly after.

Historically the three most common methods of battery testing have been:

• Multi-meter
• Load tester
• Specific gravity tester

VII. BMMP - Diagnostics

If a battery does not pass the diagnostics tests, it MUST be pulled from the vehicle and sent to the shop for corrective maintenance. If you don’t do this, your BMMP will not achieve it’s full potential results AND vehicle operation is jeopardized.

Not conducting the diagnostic portion of the BMMP and ensuring your batteries are in good condition as you implement your program is one of the biggest causes for a BMMP to fail.

Historically the three most common methods of battery testing have been:

• Multi-meter
• Load tester
• Specific gravity tester

Multi-meter – A first glance tool to check out a battery.

Voltage and a battery’s capability to operate may have little to do with one another. This is especially true with flooded conventional batteries.

An excellent example of this is the occasional battery that won’t start a vehicle shortly after being taken off of a battery charger. When the battery is just off charge, a multi-meter will often give you a reading of over 13 volts. Yet when you try to start a vehicle or power radios, it immediately fails and the voltage drops to 12 volts or less. The battery had voltage (surface voltage) but no capacity.

OCV readings alone on flooded batteries are not suitable for determining battery condition or capacity.

AGM: OCV < 12.7 (25.4 on a 24 volt battery pack) recharge immediately.

Flooded: OCV < 12.5 (25.0 on a 24 volt battery pack) recharge immediately.
Load Testing – An effective “old school” way to test a battery’s condition.

A battery shop procedure

Creates a dead short across the battery’s terminals with a gauge that indicates how the battery handles the load.

Battery MUST first be fully charged which makes load testing impractical anywhere except in a battery shop.

Load test battery per the equipment's instructions.

If tester is not automatic, set for ½ the battery CCA rating. (700 CCA Battery Tested at 350A)

Discharge for 15 seconds.

To pass the test the battery voltage during load must stay above 9.6 volts

Passing batteries should be recharged again after load test.

Load Testing

Works on both Flooded & AGM batteries

OK for battery shop. Impractical in the field.

Use of Load testers takes time and requires caution. Enormous heat and mishandling can cause burns.

Tester must be allowed to cool after every couple of batteries.

It is a time-consuming process that presents some genuine training and safety issues to users.

Specific Gravity Testers

In the past, Specific Gravity Testers were considered to be the standard for testing most batteries.

Can identify state of charge and bad cells.

Requires that each battery cap must be opened individually and each cell must be tested individually.

Associated safety issues from exposure to battery acid (ruined uniforms, chemical burns, etc.)

Time consuming - opening and closing each cap on a 4-battery set means that at a minimum, properly testing four batteries will take over 30 minutes per set. At today’s manning levels, that is too many man-hours.

Specific Gravity tests are not applicable to sealed AGM or maintenance free batteries

RESISTANCE TESTING -

Examples of Resistance Testers

390 PT 777P-PT

Corrective maintenance is intended to reverse or correct a problem that has already occurred.

You found a dead or questionable battery, what’s the next step?

The first question that must be asked when batteries are dead is “Why?”
VII. BMMP - Corrective Maintenance

Lights or other electrical devices left on

• Short engine run times
  (“can’t refill the bucket” without running the engine longer)

• Key off loads
  (loads that are still drawing current from the batteries even with the switch in
  the off position) newer vehicles have many microprocessors that often add to
  this problem.

• Parasitic drain
  Small shorts in the wires of one or more pieces of equipment on the vehicle.
  These are generally not large loads or they would trip a fuse or breaker. They
  pull batteries down over time. These loads must be found and fixed. See
  Appendix 2 – Parasitic Loads for how to test to see if you have this problem

VII. BMMP - Preventive Maintenance

Lack of use or - Battery Self Discharge

• Antimony batteries have approximately a 4.5% self-discharge rate
  rate

• AGM batteries monthly self-discharge rate of about 1%

• Batteries will self-discharge faster in higher temperatures.

• Discharged & partially discharged batteries will suffer from plate
  sulfation.

• Often a standard charger or alternator cannot break up plate
  sulfation and fully recharge the battery.

• The only way to prevent self-discharge & sulfation is with frequent
  charging or by adding hardware.

VII. BMMP - Preventive Maintenance

Terminal and Battery Box Corrosion

Flooded Cell Batteries

• Corrode at the posts.
• Grease or corrosion inhibiting spray properly applied delays but doesn’t
  eliminate corrosion.
• Acid, vented at the caps, induces battery box corrosion.

AGM Batteries

• Do not produce terminal or vent cap corrosion under normal circumstances.

VII. BMMP - Preventive Maintenance

Corrosion

AGM – Unnecessary Treatment
Flooded Cell - Required Corrosion Control

VII. BMMP - Preventive Maintenance

Flooded Cell - Required Corrosion Control

- Acid on the outside of the battery case

VII. BMMP - Corrective Maintenance

- Place one probe of a multi-meter (set to DC volts) on either post of a battery and place the other probe on the “non-conductive” plastic case. With a dirty, shiny, or oily top (acid film), you will often see voltage on the meter. That means that the debris on the case has created an electric path and is drawing the battery down. To stop this, the case must be washed with soap and water to remove the oil. Baking soda must also be used to neutralize the acid (DO not allow baking soda to get into the battery cells). They can all be mixed together to make it easier.

- Once you have identified and hopefully corrected the cause of the problem -

The dead batteries are sent to the battery shop for testing and attempted recovery.

- If not sufficiently recovered,

replace them with known good batteries!

VII. BMMP - Corrective Maintenance

Chargers

- Must be designed for the specific battery type!

Flooded lead acid batteries use conventional automotive type chargers.

- When possible the charger should be an automatic type as to not accidentally overcharge the battery if it’s left connected.

AGM batteries need a high quality charger

- Voltage needs to be properly controlled

(some automotive chargers can have a very wide voltage swing)

- If it does NOT have an AGM or sealed battery setting:

Voltage should be regulated between 14.25 and 14.9 volts.

- All Chargers should be built for rough treatment:

Heavy Duty power supply

Tough clamps for good electrical connection.

Pulse Chargers

- The XCR-20 is four products in one.

- ICE cord compatible for use within the United States or abroad.

- Automatically adjusts for unique requirements of flooded lead-acid batteries and AGM batteries.

- Pulse & Charge, which simultaneously pulses the battery while it is being charged.

- Continues pulsing after charge complete.

It’s also a “smart charger” that constantly tests the battery to insure a proper charge. Once the battery is fully charged, the charger switches to a Pulse Only mode to continue to clean and maintain the battery.
BATTERY MAINTENANCE MANAGEMENT PROGRAM

VII. BMMP - Corrective Maintenance

Pulse Charger

- The SC Pallet Charger is for use on all 12-volt batteries
  - Senses battery condition and provides appropriate charge current per channel.
  - Charges all conventional lead-acid battery types (flooded cell, AGM & gel).
  - Smart technology and pulsing prevents battery gassing, which allows charging with batteries sitting on the pallet.
  - Batteries can be left on pallets and not handled needlessly.
  - Very effective on deeply discharged AGM batteries that have been taken out of service in the past.
  - Charges and conditions up to 12 batteries at a time.
  - Batteries no longer need to be separated by type or state-of-charge.

VII. BMMP - Corrective Maintenance

Shop Equipment

VII. BMMP - Preventive Maintenance

Preventive Maintenance

After diagnosis and correction of your battery’s condition, the batteries are reinstalled in the vehicles and equipment.

PM also includes checking and charging batteries prior to installation. It is very common to get “NEW” batteries that have been sitting idle for months prior to your purchasing them. Not starting with a fully charged battery will reduce the battery’s life.

VII. BMMP - Preventive Maintenance

Common causes discussed previously:

- Dirty battery cases
- Parasitic loads
- Key off discharge
- Operator error (lights & switches left on)
- Self Discharge
- Insufficient engine run time

VII. BMMP - Preventive Maintenance

Solar Charge Maintenance Systems – Battery maintenance devices used on vehicles to prevent and break up large crystal sulfates on battery plates which occur in discharged batteries.

- Sulfate crystal formations slowly destroy the battery’s capacity.
- Solar charge systems can be powered by either sunlight (Solar panel) or an AC receptacle.
- New solar charge systems maintain and/or charge battery systems.

VII. BMMP - Preventive Maintenance

PM equipment:

Vehicles and equipment must have the battery tested and recharged as needed, so the solar maintenance system can work properly.
VII. BMMP - Preventive Maintenance

PM equipment:

Pro 12
Part No 746x915
Number of outputs: 12
12V 750 mA dc per output
High pulsing to desulfate

VII. BMMP - Preventive Maintenance

PM reminders:

• Use of PM equipment described above does not eliminate the requirement of checking electrolyte levels in flooded lead acid batteries.
• PM equipment will not keep dirt and grime off the batteries; they still need to be cleaned.
• The solar maintenance chargers discussed will overcome and maintain battery sets with very few exceptions for years at a time when they are not driven.

A properly administered PM program will reduce the requirement for Corrective Maintenance and create huge savings in man-hours and money

VIII. Conclusion

Conclusion:
The information and maintenance practices described today will provide direct benefits in terms of:

• Optimal vehicle electrical system performance
• Lower battery related maintenance expenses
• Fewer dead vehicles and jump starts
• The longest battery life possible

Any final questions?