Milestone 6 Report
Transmission System Operating Procedures
Section 6B – Transmission System Maintenance

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Initiative of Manitoba Hydro

CONTENT

APPENDICES

1.0 Executive Summary

1.1. Report Objectives

The overall objective of MD Report #6 is to identify plans, methods, and action items that if approved by the Supervisory Board, and properly funded, will improve the overall efficiency of the transmission system and operating equipment. As per the TOR (Terms of reference), the entire report has eight specific components to it as follows:

a) identifying system losses and ways of reducing these to levels comparable to losses on similar systems in emerging market countries

b) a plan to implement the computerized maintenance management system (IFS)

c) recommendations for a system to plan, schedule, and carry out routine maintenance activities

d) the results of a review of the current procurement system and recommendations for the implementation of an effective transparent procurement system

e) recommendations for the implementation of a Preventative Maintenance program for:
   - transmission lines
   - switching station apparatus and auxiliary equipment
   - protection equipment
   - vehicles and equipment

   The identification of administrative and technical facilities and equipment needed to support the overall transmission system operations, maintenance, and repair functions will also be addressed in this section. Wherever possible, the Preventative Maintenance program will include maintenance tasks, frequency, required tools and equipment, and procedures if applicable.

f) the results of a review of the emergency operations plan, along with recommendations for improvements to the emergency operations plan and associated training, mock drills, etc.

g) to identify actions to significantly reduce operational costs

h) to identify the basis and assumptions for the current transmission tariff, and if necessary, recommend changes to ensure the tariff is capable of financing transmission operations and capital expenditures

Because of the broad scope of this report, it has been broken down into four major sections or "sub-reports" namely:

Section 6A – Transmission System Loss Study (Item 5.6.6 a from the TOR)
Section 6B – Transmission System Maintenance (Items 5.6.6 b, c, e, f, g from the TOR)
Section 6C – Procurement (Item 5.6.6 d from the TOR)
Section 6D – Transmission Tariff (Item 5.6.6 i from the TOR)

This Section (6B – Transmission System Maintenance) will address the following from the TOR:

b) a plan to implement the computerized maintenance management system (IFS)

c) recommendations for a system to plan, schedule, and carry out routine maintenance activities

e) recommendations for the implementation of a Preventative Maintenance program for:
    i. transmission lines
    ii. switching station apparatus and auxiliary equipment
    iii. protection equipment
    iv. vehicles and equipment

   The identification of administrative and technical facilities and equipment needed to support the overall transmission system operations, maintenance, and repair functions will also be addressed in this section. Wherever possible, the PM program will include maintenance tasks, frequency, required tools and equipment, and procedures if applicable.

f) the results of a review of the emergency operations plan, along with recommendations for improvements to the emergency operations plan and associated training, mock drills, etc.

g) to identify actions to significantly reduce operational costs

1.2. Key Findings

The key findings by the subject matter specialists have been identified and categorized as shown below. The comments are in no way intended to be critical of TCN staff. It is MHI's observation that TCN staff are dedicated and have a true desire to do a good job, but are frustrated by the lack of funding and resources available to them.

A. Current State of the CMMS (IFS) System

TCN has no Computerized Maintenance Management System (CMMS) in place at this time. The IFS software that was purchased by TCN several years ago contained a maintenance management component, however, the implementation of the IFS system failed before any progress was made on this front. Milestone Deliverable Report #14 will contain a detailed plan to revitalize and implement the IFS system.

B. Current Maintenance Planning Process

To begin with, TCN has no comprehensive companywide maintenance standards. By default, it appears that all work is planned to be done on an "annual" basis. With no formal standards in place, or CMMS in use, the work that is being performed is not done consistently across TCN's asset base. The lack of formalized maintenance standards and procedures for field staff to follow continues to ensure that resources are not being used in the most effective manner. This creates inefficiency in staffing, resources, and available assets.

Under the current system, the identification of the work starts at the Work Centre / Regional Level, where the regional managers compile a list of maintenance tasks to be performed for the year ahead. This information is submitted to the National Control Centre for approval, and for coordination of required equipment outages. Once approved by NCC, the managers plan their resources accordingly to complete the work that was identified.

On a monthly basis, the managers will report on the tasks completed to the AGM of Performance Monitoring, who in turn compiles and develops reports as required (monthly and annual). Based on these reports, it appears that nearly 100 % of the maintenance and repair tasks are being completed. This seems somewhat unrealistic, especially in light of the number of equipment breakdowns and system interruptions.

C. Current Transmission Line Maintenance Program

The current Transmission Line Maintenance Program is unable to function effectively.
The utility has been tracking forced outages since January 2012, and has experienced a significant number of events; however, current processes do not facilitate proper investigations into the root causes of system outages. The response time to line faults is lengthy due to a lack of quick access (helicopter), lack of tools and equipment, and poor trouble shooting techniques. The preventative maintenance program is not functioning well to minimize these interruptions. There does not appear to be a corporate wide standardized approach to transmission line maintenance, and an absence of line

patroller check lists, procedures, etc. Transmission Line Maintenance staff have received no training for many years.

Staff levels in the office or non-technical areas appear to be excessive and outnumber field workers by a significant margin. This is exactly the opposite of what would occur in a high performing electrical utility. There is no central authority taking system wide ownership of the planning and prioritizing of transmission line maintenance activities.

Current funding for the maintenance program covers salaries, but there are no provisions for regular and routine minor capital maintenance requirements. This results in critical components being left unattended for lengthy periods of time (missing optical ground wire, poor vegetation control, for example). Also, the division of the budget to the regions does not appear to be driven by maintenance needs. This is due to a lack of knowledge of system wide requirements. If these were known, they could be used to justify the proper allocation of funds across the regions based on priorities. Reporting systems to aid in budget distribution are also poor to non-existent.

Historical data is stored locally, making system trending difficult. Inconsistencies were found in the data provided, making it unreliable. Documentation is poor and there is no central database to easily pull information from.

There is no master emergency response plan, nor localized response plans. There are no local emergency material caches. Everything must be retrieved from Lagos. This results in lengthy delays when attending to an emergency event. Emergency restoration is dependent upon the knowledge of the more experienced staff in the regions, with no documented plans in place.

D. Current Station Apparatus and Auxiliary Equipment Maintenance Program

The goal of a preventive maintenance program (PMP) is to detect potential failures in a timely, efficient, and effective manner, and to take corrective action prior to an actual failure occurring. In reviewing the maintenance activities presently being performed by TCN staff there is a large gap to meeting best practices. TCN's primary focus to date has been building, not maintaining the system. Current maintenance practices are best described as reactive, not proactive. The system is coming of age, and without a commitment to a Preventative Maintenance Program, valuable capital dollars will be diverted to replacing failed equipment, accompanied by a loss in revenue, reliability and reputation.

As with the transmission lines, there is no corporate wide standardized approach to high voltage switching station (sub-station) apparatus maintenance. Each region / area seems to have its own approach to maintaining the equipment. The present maintenance program does not make sufficient use of modern diagnostic testing techniques. Of particular concern is TCN's lack of ability to monitor HV insulation systems, or to take corrective actions with respect to same. The program could be described as run to failure.

The current TCN organizational structure does not accommodate efficient operation. Communication and decision making is hampered by poorly defined staff responsibilities, and cumbersome reporting relationships. The centralized engineering staff in Abuja should be playing a much more prominent role in developing maintenance standards and procedures, assisting with failure analysis, identifying trends across the company, standardizing equipment purchases, training, etc.

The entire program is under resourced. There is a notable shortage of technically trained staff, tools, equipment, materials, spare apparatus, engineering and administration support.

E. Current Protection Maintenance Program

Based on information provided, TCN over maintains their protection equipment. The TCN standard is to test all the protection equipment on an annual basis; however, industry best practices suggest that protection equipment should be tested every two to twelve years (see Appendix IV). TCN appears to have state of the art test equipment and good centralized engineering support; however, PC&M staff require training on certain protection schemes. In addition, TCN purchasing policy allows for too many makes and models of protection relays to be purchased, thereby making testing and training more difficult.

TCN appears to have a problem with nuisance trips. It is uncertain as to whether this is caused by incorrect relay settings due to inexperienced staff, or due to incorrect settings issued by the protection settings engineers. A comprehensive relay coordination study may be necessary. TCN does not appear to keep good records of relay test results / dates tested, inadvertent trip information, etc., so analysis of re-occurring trips may be difficult.

F. Current Vehicle Maintenance Program

There is no comprehensive maintenance program for the vehicles or equipment at TCN. Maintenance of the fleet is said to be approximately 60% outsourced, while 40% is conducted in-house, however, there was no data found to verify this. There are no procedures nor any written forms or maintenance inspection sheets. Operators conveyed that they conduct regular basic fluid level checks, but it is up to the discretion of each individual as to what is checked and how frequently. There are no log books or maintenance records that could be presented, thus the assumption was made that these do not exist or are in very poor shape.

The need for additional and better hand tools, shop equipment, supplies, secure facilities, training, and a scheduled updated maintenance program has hampered mechanics' ability to perform their duties effectively and efficiently. In addition, the repair facilities are in need of repair and organization.

Documentation revealed that there are approximately five-hundred and forty (540) cars, pick-up trucks, and lorry HIAB trucks located within all eight (8) regions, which includes the SNCC, NCC, and TCN Headquarters. Documentation of any other type of heavy equipment was not found. Two (2) non-useable cranes were seen, (one crane was said to be used last year, but MHIs' inspection indicated that it will need much repair). Numerous vehicles were found in disrepair and were left for scrap at various places.

G. Current State of the Emergency Response Process

There are no emergency response plans in place to review. This will be addressed in greater detail within Milestone Deliverable Report #11 – Emergency Response and Business Continuity Planning.

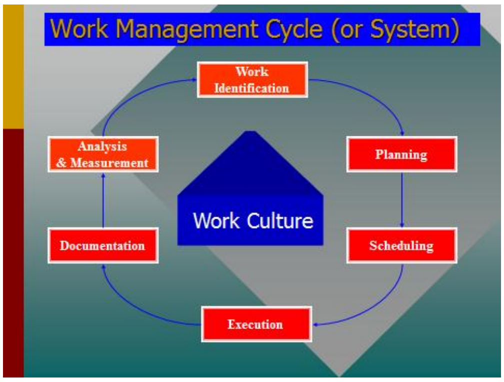
1.3. Key Recommendations

A. Implementation of the IFS Maintenance Management Function

A computerized maintenance management system is needed at TCN to assist in all aspects of a Work Management System. The implementation of a CMMS system (IFS in this case) will be covered in much greater detail in Milestone Deliverable #14 (MIS). The information contained in this report identifies the different phases of implementation, and also provides a high level overview of each phase. It is imperative to the TCN organization that the IFS is implemented as per the MD#14 Report.

B. Implementation of a Maintenance Planning Process

To begin with, TCN has to develop comprehensive companywide maintenance standards for all its assets in order to develop proper maintenance plans. Once the maintenance standards are developed (as per attached Appendices I to IV), and the resources required to carry out the maintenance are identified, then prioritization, scheduling and outage coordination can begin. The scheduling / coordination process that TCN currently uses, appears to be workable. Under the current system, the identification of the work starts at the Work Centre / Regional Level, where the regional managers compile a list of maintenance tasks to be performed for the year ahead. This information is submitted to the National Control Centre for approval and coordination of required equipment outages. This ensures that lines and equipment are not removed multiple times for different groups, and that the system can withstand the outages from a reliability standpoint. Although the TOR only calls for the development of a maintenance planning process, MHI recommends that TCN take this to the next level, and adopts a more formal Work Management System. This system consists of six interrelated processes that form a continuous loop as shown below:



The Work Management System process “boxes” are further defined to ensure that all involved understand their roles and responsibilities (See Appendix VI for more detail).

C. Implementation of a Transmission Line Maintenance Program

TCN must develop a formal Preventative Maintenance program, similar to the one outlined in Appendix I. Cycle times may vary with the region, and will need to be adjusted based on characteristics such as ease of access, vegetation growth rates, and line security concerns (vandalism). Introducing an aerial component can offset labour hours currently dedicated to ground patrols. Other cost saving opportunities may exist with a review of the current vegetation control program. Utilizing newer tools or methods (mechanical or herbicide control), and contracting out some of the work to local communities must be considered. Vehicles, tools and equipment need to be rationalized and should be purchased in appropriate quantities.

A full review of workloads and staffing levels should be completed. This includes the compiling of all outstanding work across the system. Once complete the following actions could be taken:

- *Relocate field staff on a temporary basis to the Regions with the largest backlog of outstanding work.*
- *Adjust the field staff capacity at each work centre with a goal to have patrolling activities only occupy 50% of their time, so that the remainder can be put towards repairing defects and performing vegetation control.*
- *Designated vehicle drivers should be trained to perform other basic tasks. It is an inefficient use of manpower to designate a person to drive the vehicles only, and not assist with other duties and tasks that do not require a high level of skill or training.*
- *If deemed necessary, increase the number of live line crews to meet the work demand.*
- *Reduce the number of management levels and make lines of reporting clearer and easier to deal with.*

TCN should create a centralized Transmission Line Asset Services (TLAS) group. This group will be responsible for the development of common standards for maintenance and inspection work, prioritization of work on outstanding defects, investigation of aging system components, and provide recommendations for action to the company executive. They will also build and manage all the information databases (GIS, etc.) associated with the transmission line infrastructure and participate in the development of the Transmission Line Emergency Response Program. The group should be comprised of:

- Supervisor/Manager (1)
- Engineering Support (2) - preferably Civil and/or Mechanical background
- Technical Support Staff (1) - Lineman or Technologist training. Construction background would be an asset.
- Accountant (1) - provides financial and business support by helping develop and track performance measures and financial targets.

- Environmental Officer/Engineer (1) - Forestry background and knowledge of local environmental laws and policies.
- Technology Specialist (1) - To maintain and manage the Geospatial Information System (GIS), and other required databases.
- Clerical Support (1) - Can be transferred from other work areas.

A proper budgeting process should be developed that allows maintenance dollars to be allocated as required by the defect tracking system and line performance statistics. TCN must provide stable and consistent funding for small capital maintenance projects to eliminate the lengthy delays in getting critical infrastructure repaired or replaced.

Training should be provided for line work, line patrolling, proper use of tools, computer training, and troubleshooting transmission line faults. This is covered in greater detail in MD#16. TLAS Engineers should take Project Management training and consider participating in industry peer groups similar to CEATI and EPRI, to keep current with the rest of the industry.

A formal emergency response plan must be created. This plan needs to deal with all aspects of emergency loss of transmission lines and how they will be effectively restored. This issue will be more fully addressed in MD#11.

D. Implementation of a Station and Auxiliary Equipment Maintenance Program

TCN must develop a corporate wide standardized approach to high voltage switching station (sub-station) apparatus maintenance. Each region / area must have the same approach to maintaining the equipment. (See Appendix III for recommended Maintenance Standards). To fully develop and implement a Preventative Maintenance Program will take three to five years. This is dependent on staff ability and capability, as well as budget. There is a significant shortage of technical staff. Hiring and training of staff will need to be aggressively pursued and diagnostic test equipment purchased to meet the requirements of a PM program.

A long term vision should be for the TSP reporting lines to be reorganized based on function (station apparatus maintenance, transmission line maintenance, PC&M, design and construction etc.), instead of along geographical areas or regions. This will ensure that at the levels of reporting below the ED of TSP, the “focus” will first be on the function, and not the region and then the function. The current system tends to promote “fenced in” visions for excellence, versus a vision that is company / country wide.

In the interim, similar to the recommendation in Sub-Section C above (Transmission Line Maintenance), TCN must create a specialized engineering support group, referred to herein as the Technical Support Services (TSS) group. The TSS group will become the station apparatus experts. They will develop, drive, control and support the preventative maintenance program. The journeyman technicians in the field will build and maintain the electrical and mechanical apparatus, supported by TSS specialists at the TCN headquarters. For the program to succeed staff must be well trained, and have a clear and direct reporting relationship.

Development and implementation of a preventative maintenance program will be in steps over a period of time with TSS determining priorities. The obvious priorities, which must be addressed as quickly as possible, include:

- A company-wide condition assessment of the HV insulation systems, particularly in the power transformers. The primary diagnostic/monitoring tools used to assess HV insulation systems are oil analysis and power factor (PF) measurements. Oil analysis can be implemented with little training and investment in equipment, and can be done without de-energizing the transformer; hence should be initiated immediately. On the other hand, PF measurements require the transformer to be de-energized, and require a significant development and training component. Recognizing the importance of PF measurements and the time needed to train staff, some early decisions should be made on how to proceed.
- An infrared scanning program for all sub-stations should be developed as soon as possible. IR scanning equipment has come down significantly in price and also in ease of use. See Appendix V for more information on pricing.
- A transformer contingency plan must be established. At present there are few or no spare power transformers. In many cases there is no built-in redundancy, which would result in an extended blackout, if a failure were to occur. Additionally, transformers cannot be de-energized to perform maintenance, or remedial work. It would be very prudent to acquire some spare power transformers as soon as possible.

E. Implementation of a Protection Maintenance Program

TCN should maintain their protection equipment as per the standards provided in APPENDIX IV. Since the frequency of maintenance testing will be cut back considerably under the recommended standards, TCN will have time to organize more "focussed training sessions". These sessions should consist of a competent engineer demonstrating the testing methodology to other less experienced engineers. This could be accomplished using existing staff and does not need a significant amount of additional resources. Pick a protection scheme / equipment, pick the expert on that scheme, and start training the others.

TCN should maintain better records of when the relays are tested as part of the maintenance program and also of any tests that are conducted as a follow-up to a suspected nuisance trip.

TCN should continue with its plan to introduce computerized relay testing. This will ensure standardized testing methodology and will automatically store results. Testing plans can be developed by a specialist for that particular relay type, and then shared across the entire PC&M organization. TCN should also standardize its protection equipment purchases (fewer makes / models), and its testing equipment purchases.

F. Implementation of a Vehicle Maintenance Program

Each vehicle and piece of equipment owned by TCN must be documented on a form and properly entered into the IFS database as part of the implementation of the IFS in MD#14.

There should be a plan to determine if there is a need for each vehicle or piece of equipment. If needed, a condition assessment should be completed and a cost analysis would have to be done for any repairs needed, and compared to procurement of a new or used vehicle or equipment.

Each regional office will require a head mechanic to track and repair vehicles in his area and be responsible to the manager to complete the job. However, maintenance standards should be developed and should be controlled by a centrally located specialist. (See Appendix II – Fleet Maintenance Inspection Sheets)

Support facilities and equipment will require updating, and replacing (See Appendix VII for Recommended Equipment Repair Facility Needs). This will insure TCN fleet mechanics will be able to keep up to the changes in technology and improve the working conditions for staff. A secure location and enclosed facility for repair, administration and storage will insure that the equipment and personnel will be able to do a more efficient and productive job.

A separate evaluation should be done on the helicopter(s). Cost of purchase, licensing, fuel, mandatory inspections, maintenance and included downtime for repairs should be compared to the cost of rental.

Light vehicles 3 years old or newer should have repairs and maintenance contracted to the selling dealer. Most of the repairs should be on warranty. Clauses in the purchase warranty can also include towing.

G. Implementation of an Emergency Response Process

Since there are no emergency response plans in place to review, there are no corresponding recommendations dealing with improvements of such. The development of site specific emergency response plans will be addressed in greater detail within Milestone Deliverable Report #11 – Emergency Response and Business Continuity Planning.

2.0 Key Acronyms

Acronym	Full Term
MO	Market Operations
TCN	Transmission Company of Nigeria
TSP	Transmission Services Provider
CMMS	Computerized Maintenance Management System
EAMS	Enterprise Asset Management System

3.0 Methodology

3.1. Understanding of MHI's Final Report Requirements

Because of the broad scope of this report, MHI has been broken down the reporting requirements into four major sections or "sub-reports" namely:

Section 6A – Transmission System Loss Study (Item 5.6.6 a from the TOR)
Section 6B – Transmission System Maintenance (Items 5.6.6 b, c, e, f, g from the TOR)
Section 6C – Procurement (Item 5.6.6 d from the TOR)
Section 6D – Transmission Tariff (Item 5.6.6 i from the TOR)

Section 6B – Transmission System Maintenance will address the following:

d) a plan to implement the computerized maintenance management system (IFS)

e) recommendations for a system to plan, schedule, and carry out routine maintenance activities

h) recommendations for the implementation of a Preventative Maintenance program for:
   i. transmission lines
   ii. switching station apparatus and auxiliary equipment
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   The identification of administrative and technical facilities and equipment needed to support the overall transmission system operations, maintenance, and repair functions will also be addressed in this section. Wherever possible, the PM program will include maintenance tasks, frequency, required tools and equipment, and procedures if applicable.

i) The results of a review of the emergency operations plan, along with recommendations for improvements to the emergency operations plan and associated training, mock drills, etc.

j) to identify actions to significantly reduce operational costs

3.2. Key Assumptions

MHI assumed that the sampling of written information it received and the information gathered from the limited site visits is reflective of the organization as a whole.

3.3. Approach Used to Gather Information

The information gathering process consisted of the following:

Preliminary information needs were identified by Milestone Deliverable Team Members, compiled by the MD Team Assistant Project Manager, and submitted to the Core Management Team HR director shortly after the mobilization of the CMT to Abuja. The document was referred to as the RFI (Request for Information). The CMT, along with existing TCN staff, submitted information in electronic format to the MD Team Assistant Project Manager. Although a commendable effort was made to gather information in response to the RFI, not all information requests were met. In addition, it appeared that some information was dated or appeared in different versions.

Upon arrival in Abuja, a series of meetings was set up to introduce the MD team members to those persons in the TCN organization that would be able to provide additional information and insights into the operation of TCN. The meetings consisted of presentations / explanations by the MD team, followed by questions and answers related to the information gathering process. Milestone 6 consisted of six initial information gathering kick-off meetings, followed up by many smaller one on one or small group meetings. In total, over 40 meetings were held to gather information for Milestone Deliverable #6.

To further assist in the initial information gathering and assessment process, site visits were conducted. These included site visits to:

- Katempe Station
- Apo Station
- Shiroro Station
- Benin Work Centre along with a transmission line in the vicinity of Benin Station
- National Control Centre
- Port Harcourt

A visit to a nearby equipment supplier was also conducted.

A visit to the Lagos Work Centre was called off at the entry gate to the station due to hostile union led activities. Similarly, a visit to the transformer repair facility was also stopped due to hostile activities.

The site visits were not as fruitful as the specialists had hoped, due to persistent crowds wanting to become engaged in the conversations, which often lead to disputes over the answers to questions, etc.

3.4. Reference Documents

Document Title	Version	Date Written	Written by	Document Overview
Assessment of Maintenance Programme of transmission Facilities				Financial analysis by region-PM and break down costs 2011
TRANSMISSION COMPANY OF NIGERIA (TCN). Technical Specifications – Power Auto Transformers and Shunt Reactors	TS 4200 Rev. A	APRIL 2008		
2012 Maintenance Management System for Benin Region				PM work plan for 2012
Maintenance of switchgears, Cables, Lightning Arresters and Station Auxilaries within TCN Network				Maintenance standard
Request for 132KV and 33KV isolators in Kaduna Region				
Laboratory Oil Tests		21/2/12	Olisa m. Okoli	330KV Reactor Benin
Meno – Installation of 3No. New Type 330KV CT on Circuit G3B		15/12/06	I. C. Okpe	Test results
Memo - Pre-Commissioning Tests' Results Report on the New 60MVA, 132/33KV "EMCO" Transformer in Ajaokuta-II Substation		9/02/12	Engr.O.A. Balogun	Test results/data
Resultsof Tests Carried out on 150MVA Transformer 6T2 in Benin		28/03/12	A.I.Initorufa	Tests after the failure of an associated primary CT
Memo – Report on 150MVA Power Transformer 6T1 Bemin		12/o4/12	Okungbowa Ota. Roland	Test results/data
12 - CT & CVT Test Reports				Ratio test data
Annual Maintenance Report (Circuit Breaker and Associated Isolators)		20/06/12		
Protection- Overcurrent Relay Report				Test data

4.0 Analysis of Findings

A. Current State of the CMMS (IFS) System

At present there is no CMMS system in place within TCN. An attempt was made to implement the IFS system, but it failed prior to implementation.

B. Current Maintenance Planning Process

Currently there is a crude planning process within each work centre. There is little actual planning that takes place as the same work is repeated each year on the equipment. It is a basic copy and paste from one year to another. The only planning or coordination that occurs happens at the National Control Centre where outages are attempted to be coordinated and matched.

All maintenance is done within 3 basic time frames:

- Annual
- Semi-Annual
- Quarterly

There may be additional checks or maintenance tasks assigned to a specific piece of equipment if there has been a history of problems. These only occur if someone recognizes a history of issues (usually from memory) and asks for maintenance records to determine if additional tasks are required.

Direction for maintenance is taken from manufactures recommendations and historical knowledge. There is little to no central discussion/coordination of annual maintenance between work centres, or regional work centres. Approval of programs is done by the National Control Centre when outages are coordinated. There are no maintenance standards or standardized instructions available to staff who are preforming the work. Very little instruction is recorded in the maintenance plans for each region for the identified tasks.

C. Current Transmission Line Maintenance Program

The current Transmission Line Maintenance Program is lacking funds, is poorly managed, inadequately supplied, and staff distribution is not optimized. Staff levels in the field are insufficient in numbers to be able to keep up with the current work load. Staff positions are wasted with onerous levels of management and non-technical staff which are drastically under employed. The staff are poorly trained or not trained at all.

There are two live line crews within the country. Although MHI did not have an opportunity to visit with the crews, we assume they are actively working as live line crews and that experienced staff on these crews have been passing knowledge down to newer staff through on the job training. In reviewing safety statistics there is no report of any accidents so again the assumption is made they are working safely. Condition of their equipment is not known, but as there is no stick refinishing facility they must be refinishing the tools themselves. Although not desirable this was and is still common in many companies.

The current funding of the department is inadequate. Present funding is essentially covering only wages and does not allow for essential repair or replacement of critical components such as missing optical ground wire, which has an impact on system performance. This is crucial to the system and should be responded to immediately for proper system performance. However, in many cases it is left in a state of disrepair for lengthy periods of time. The result is very poor system reliability. Dollars for capital maintenance projects to respond to transmission line maintenance issues are insufficient and therefore the system is negatively impacted.

The Regions each budget separately and get a share of limited available funds. Rationale as to the allocation of maintenance dollars is more an exercise in division, rather than allocation by need. This is primarily due to a lack of knowledge and a lack of maintenance systems documentation that could be used to justify expenditures.

The use vegetation control herbicides and other more productive types of vegetation control such as through mechanical clearing seems to be used sparingly if at all. It was difficult to determine if these types of vegetation control had even been considered. This may be due to lack of funding, environmental concern, or a lack of knowledge.

Management reports that are easily produced and give good decision making information for maintenance are not available. Processes and management systems to aid in decisions where maintenance dollars are to be spent are poor to non-existent.

Reports on line outages by cause are not available and TCN has only started tracking outages by line since January of 2012 (still not by cause). System Operations outage reports identify what equipment operated but do not tell management what caused the equipment to operate? These are critical types of information that management should be gathering and making available to all maintenance staff so efforts are directed in the right direction.

In the 8 months from January 2012 to August 2012, about one third of the lines have tripped at least once a month and some as many 45 times in that period. This is undoubtedly a combination of vegetation, lightning protection and other issues, that are a result of the current transmission line maintenance program. Due to the combination of poor vehicles, lack of helicopter availability, lack of tools and equipment and poor trouble shooting techniques line faults take unacceptable lengths of time to be located and repaired.

Engineering staff does not always review monthly work summaries. The work centres and regions store historical data locally. This makes it difficult to discover system wide trends. The facilities at TCN headquarters needs central data gathering capabilities and reporting systems so work issues can be examined for trends, average costs of maintenance per mile of line and effectiveness of various crews and their techniques.

The data MHI reviewed was quickly found to be incorrect or conflicting with other documentation. This type of incorrect reporting was found everywhere and therefore leads us to conclude that most of it is unreliable. Therefore establishing any kind of base line point is subject to a great plus/minus factor.

There is no inspection done on conductors, and defective or improperly installed vibration dampers appear to be of no concern. There is no direction from management to operate in a proactive fashion by determining where line problems are beginning to develop through various inspection processes.

Staff and management are ill prepared to respond to emergencies and there is no master emergency response plan. The regions do not possess the emergency equipment and materials locally to effectively attend to emergencies. They must retrieve them from central stores in Lagos.

D. Current Switching Station Apparatus and Auxiliary Equipment Maintenance

The goal of a preventive maintenance program (PMP) is to detect potential failures in a timely, efficient, and effective manner, and to take corrective action prior to an actual failure occurring. In reviewing the high voltage apparatus maintenance activities presently being performed, there is a large gap to meeting best practices. Current practices could almost be described as “run to failure”.

There is no corporate wide standardized approach to high voltage switching station (sub-station) apparatus maintenance. Each region / area seems to have its own approach to maintaining the equipment. The present maintenance program does not make sufficient use of modern diagnostic testing techniques. There is almost a complete lack of diagnostic testing of the high voltage insulation systems such as power factor testing, dissolved gas analysis (DGA), and standard oil testing. Other best practice testing such as transformer DC resistance measurements and battery continuity tests are also not employed.

Insulating oil has been described as the life blood of high voltage electrical apparatus. It is a critical component in maintaining high voltage electrical systems. Capacity and ability to test-analyze, handle, process, store and transport oil was observed to be very inadequate. Paper insulation systems (transformer windings) are another key component which must be maintained. This involves a process, such as hot oil spray-vacuum, to remove moisture from the winding’s paper insulation. No processing equipment was observed.

All current planned/scheduled maintenance work appears to be time based (i.e. 1 year, 1 month), as opposed to reliability centered maintenance (RCM). An RCM based program attempts to identify the right maintenance tasks, at the right time, and for the right reason. In a nutshell, equipment criticality is determined taking into consideration maintaining system functionality, equipment failure costs, safety, and environmental impact. Based on the equipment criticality, the RCM program then selects the most cost effective tasks aimed at preventing the failures. These tasks can be a combination of predictive tasks (ex: oil sampling), tasks based on the outcome of your predictive tests (ex: oil processing), or time based tasks (ex: protection tests / alarm checks). Overall, the TCN maintenance program is under-resourced in almost every conceivable area: staffing, tools, equipment, materials, training, vehicles, facilities, technical and administration support.

The preceding comments are in no way intended to be critical of TCN staff. It is MHI's observation that TCN staff are dedicated, but frustrated by the lack of funding and resources available to them. Staffs do not have clearly defined functional responsibilities. Reporting lines within the organization are cumbersome resulting in inefficient communication and decision making.

The maintenance program is neither efficient nor effective in identifying potential failures in a timely manner. Nor, does it have the ability to deal with potential failures. TCN's focus has been on building the transmission system with little attention to maintenance. The system is coming of age, and without a commitment to a PMP, valuable capital dollars will be diverted to replacing failed equipment. Revenue will be lost; reliability and reputation will suffer.

The assimilation and dissemination of information for the most part does not appear to happen. There is a marked absence of drawings and manuals in both TCN HQ and regional work centres. Apparatus history (test data, breakdown and corrective action reports, etc.) is stored locally in work centres and is minimal. There does not appear to be a verification process beyond the local work centre level. Test data is not reviewed, verified or analysed by another level unless the work centre chooses to forward the data.

Asset records are minimal containing little information beyond basic equipment ratings (KV, KVA), and are kept locally on paper or PCs. Tracking of spare apparatus and parts appears to be a paper system, which is not shared corporate wide. There is no computerized network, and use of PCs is minimal.

The absence of technical libraries and document storage filing systems/cabinets was conspicuously absent, even in TCN HQ. Piles of paper documents were noticed on tables and floors throughout the building. In general the facilities (office, electrical/mechanical shops, laboratories, oil processing and stores) which are vital to a functioning apparatus maintenance working group were sparse and inadequate. At no time did we observe a proper electrical or mechanical shop with even basic tools. In Abuja test equipment was locked in a metal shipping container. We were not able to visit an oil lab, but did see the test data produced by the labs. Data consisted of only dielectric and colour tests. Oil filtering trailers appear to be part of the tool inventory in most regions. The unit which we examined in Benin was new and appeared to have degasification capabilities. However, staff did not appear to be versed in the operation of the unit. Oil storage appears to be limited to 45 gallon drums. Hoses, which we observed, were not properly stored (no end fittings to prevent contamination). The stores facilities, which we observed, appeared disorganized and messy. At the work centres spare parts appear to be mostly salvage equipment kept for purposes of cannibalization.

Engineering support is the most critical component of a preventive maintenance program. These are the equipment specialists/experts. They should drive, control and support the maintenance program. The existing engineering support group at TCN HQ is not adequate (number & training of specialists). The functional relationship to field staff appears to be very limited, and the relationship also appears to be insulated through several layers of management.

E. Current Protection Maintenance Program

Based on information provided, and the site visit conducted, it appears that TCN has the staff and the equipment necessary for a good protection maintenance program, although some training is lacking on the more sophisticated equipment. TCN appears to have state of the art test equipment and good centralized engineering support, however, TCN does not keep good records of relay test results / dates tested, etc. In addition, TCN appears to have a problem with nuisance trips and a comprehensive relay coordination study may be necessary.

All protection equipment is included in their maintenance program, which consists of calibration tests and functional trip testing as per industry standards. However, findings also indicate that TCN over maintains their protection equipment. The TCN standard is to test the protection equipment on an annual basis. Industry best practices suggest that protection equipment should be tested every two years in the worst case scenario (poor environment, electro mechanical relays, no back-up protection provided in the scheme), and every 12 years under the best conditions (digital self-monitored relays in a clean environment with a A/B system). In addition, there are too many makes / models of protection equipment on the system, making testing and training that much more difficult.

TCN does not maintain its metering equipment on a routine basis, and will only check it if a problem is noted. This is acceptable in most cases.

F. Current Vehicle Maintenance Program

All information gathered was collated from documentation, discussions and observations. A few visual inspections of the available heavy equipment occurred. Photographs were also taken to assist in information-gathering. Based on the information found, there is no formal maintenance program for the vehicles or equipment. In addition, administrative and technical support facilities and the repair equipment will require updating or replacing. The need of additional and better hand tools, shop equipment, supplies, secure facilities, training and a scheduled updated maintenance program has hampered mechanics' ability to perform their duties effectively and efficiently. The security in the buildings is also of concern; some tools or shop equipment was left in the open. More secure storage for parts and tools will be needed. A general cleanup and organization of equipment, tools, and vehicles is greatly needed.

There was no evidence of a standardized fleet maintenance program. Field staff indicated that all required maintenance of equipment, and vehicle inspections, is the responsibility of the operator and/or driver. Pre-trip inspection sheets are not used and no regular maintenance had a set schedule (ie. oil changes). The operators conveyed that they conducted regular fluid level checks, but it is up to the discretion of each individual as to what is checked and how frequently. There were no written procedures nor any written forms or inspection sheets. A record book is kept in some, but not all, of the vehicles. All repairs needed are expected to be reported to the principal manager (PM) for approval and disbursement of funds. Repair follow-up is the responsibility of the mechanic in-charge, who also keeps a record of the repairs

Maintenance of the fleet is said to be approximately 60% outsourced, while 40% is conducted in-house, although there was no data found to verify this.

Staff indicated that equipment and vehicles were requested from the regions or work centers. The vehicles and equipment were purchased if funds were available and approved by the GM. There seemed to be no major budget for heavy equipment but it was indicated that any piece of equipment could be rented when needed (ie. swamp buggy, aerial, crane, etc.). When a large project is designed and tendered, the rental of heavy equipment is occasionally budgeted for. However, none of this equipment remains with the Transmission Company of Nigeria (TCN). The rental equipment is usually returned when the project concludes.

Documentation revealed that there are approximately five-hundred and forty (540) cars, pick-up trucks, and lorry HIAB trucks located within all eight (8) regions, which includes the SNCC, NCC, and TCN Headquarters. Documentation of any other type of heavy equipment was not found. Two (2) non-useable cranes were seen, (one crane was said to be used last year, but my short inspection indicated that it will need much repair, if it is at all feasible). Numerous vehicles were found in disrepair and were left for scrap at various places.

G. Current State of the Emergency Response Process

There was neither an Emergency Response Planning Process nor Emergency Response Procedures available to analyse.

5.0 Key Findings

A. Current State of the CMMS (IFS) System

There is no current Computerize Maintenance Management System in place in TCN. All Maintenance is driven by a manual inconsistent paper based system.

B. Maintenance Planning Process

Currently there is a rudimentary planning process within each work centre, although there is little actual planning that takes place as it appears that the same work is repeated each year on the equipment. It is a basic copy and paste from one year to another. The only planning or coordination that occurs happens at the National Control Centre where outages are attempted to be coordinated and matched.

C. Current Transmission Line Maintenance (TLM) Program

Itemized below are the Key Findings from MHI's review of the Transmission Line Maintenance Program. MHI's observation of TCN staff is that they are dedicated and want to do a good job, but are frustrated by the lack of training, funding and resources available to them.

1. In general, the transmission line maintenance groups are underfunded and lack a stable budget for minor defects / repairs.
2. There does not appear to be a corporate wide standardized approach to transmission line maintenance. Comprehensive procedures and check lists do not appear to be used.
3. There is no central group gathering pertinent data to support informed decision making related to the TLM Program.
4. There is a lack of system wide reporting that should drive higher level management decisions
5. There is no centralized proactive investigation into issues which may be indicators of larger problems arising on the transmission system.
6. There is no one responsible to ensure task frequencies are reviewed and potentially optimized in a work zone or across the entire system as a whole.
7. There is no central planning and therefore workloads and staffing requirements are not well understood. This results in missed opportunities to determine whether work load is evenly distributed among the work groups, or whether staff need to be re-assigned on a temporary or permanent basis to other work zones.
8. There are too few technical staff to deal with all the maintenance issues.
9. There are too many non-technical staff which are under-utilized, creating a drain on limited resources.
10. Technical and non-technical staff are poorly trained and therefore lack efficiency in their roles.
11. Management and technical staff need training in trouble shooting transmission line faults.

12. Vegetation clearing by hand and without the aid of herbicides and or mechanical clearing is a tremendously labour intensive practise. Contracting some of this work out may help TCN get a handle on this.
13. Completing ground patrols on a quarterly basis utilizes a significant portion of the available labour hours.
14. Air patrols are not used to support/enhance the ground patrols. This creates a problem as patrols must all be done on the ground which is part of the issue in the previous key finding, and some maintenance items are missed as they are more visible from above than below.
15. The time it takes to acquire materials from central stores, especially in emergencies, is unacceptable.
16. There is no formal emergency response plan.
17. There are no locally available caches of material for emergency response. The work centre having to send a truck to Lagos to get material in an emergency is very time consuming and counterproductive.
18. TCN has or had temporary emergency structures but MHI staff visiting stores in Lagos were told they didn't know where they were. Emergency response materials for transmission line maintenance needs to be held in the TLM department and they need to be held accountable for them.

D. Current Switching Station Apparatus and Auxiliary Equipment Maintenance Program

Itemized below are the Key Findings from MHI's review of the Station Apparatus and Auxiliary Equipment Maintenance Program. The comments are in no way intended to be critical of TCN staff. It is MHI's observation that TCNs TLM staff are dedicated, but frustrated by the lack of funding and resources available to them.

1. There is a large gap between industry best practices and the high voltage apparatus maintenance activities presently being performed. Current practices could almost be described as "run to failure".
2. The program is under-resourced in almost every conceivable area: staffing, tools, equipment, materials, training, vehicles, facilities, technical and administration support.
3. There is no corporate wide standardized approach to high voltage switching station (sub-station) apparatus maintenance. Each region / area seems to have its own approach to maintaining the equipment.
4. The present maintenance program does not make sufficient use of modern diagnostic testing techniques such as power factor testing, dissolved gas analysis (DGA), standard oil testing, transformer DC resistance measurements, and battery continuity tests.
5. TCNs capacity and ability to test-analyze, handle, process, store and transport oil was observed to be inadequate. No oil processing equipment was observed.
6. The maintenance program is neither efficient nor effective in identifying potential failures in a timely manner, nor, does it have the ability to deal with potential failures.

7. There is a marked absence of drawings and manuals in both TCN HQ and regional work centres. Apparatus history (test data, breakdown and corrective action reports, etc.) is stored locally in work centres and is minimal.
8. Asset records are minimal containing little information beyond basic equipment ratings (KV, KVA), and are kept locally on paper or PCs.
9. Tracking of spare apparatus and parts appears to be a paper system, which is not shared corporate wide. There is no computerized network, and use of PCs is minimal.
10. The absence of technical libraries and document storage filing systems/cabinets was conspicuously absent, even in TCN HQ. Piles of paper documents were noticed on tables and floors throughout the building.
11. In general the facilities (office, electrical/mechanical shops, laboratories, oil processing and stores) which are vital to a functioning apparatus maintenance working group were sparse and inadequate. At no time did we observe a proper electrical or mechanical shop with even basic tools.
12. Engineering support is the most critical component of a preventive maintenance program. These are the equipment specialists/experts. They should drive, control and support the maintenance program. The existing engineering support group at TCN HQ is not adequate (number & training of specialists). The functional relationship to field staff appears to be very limited, and the relationship also appears to be insulated through several layers of management.

E. Current Protection Maintenance Program

Itemized below are the Key Findings from MHI's review of the Protection Maintenance Program. MHI observed that the field staff that were interviewed and the staff at HQ are professional and dedicated to their work. They appear to be on the right track but a few improvements can be made with respect to the observations below:

1. TCN over maintains their protection equipment. The TCN standard is to test all the protection equipment on an annual basis. Industry best practices suggest that protection equipment should be tested every two years in the worst case scenario (poor environment, electro mechanical relays, no back-up protection provided in the scheme), and every 12 years under the best conditions (digital self-monitored relays in a clean environment with a A/B system).
2. TCN appears to have state of the art test equipment and good centralized engineering support; however, staff require training on certain protection schemes.
3. TCN does not keep good records of relay test results / dates tested, etc.
4. TCN appears to have a problem with nuisance trips and a comprehensive relay coordination study may be necessary.
5. TCN does not maintain the metering equipment on a routine basis.
6. TCN has too many makes / models of protection relays on the system

F. Current Vehicle Maintenance Program

Itemized below are the Key Findings from MHI's review of the Vehicle Maintenance Program.

1. There is no standardized maintenance program for the vehicles or equipment. All required maintenance of equipment and vehicle inspection is the responsibility of the operator and/or driver. A record book is kept in some, but not all, of the vehicles.
2. There are no procedures, written forms or inspection sheets.
3. Administrative and technical support facilities and the repair equipment will require updating or replacing. There is an acute need of additional and better hand tools, shop equipment, and supplies. More secure storage for parts and tools will be needed. A general cleanup and organization of equipment, tools, and vehicles should be a high priority.
4. Maintenance of the fleet is said to be approximately 60% outsourced, while 40% is conducted in-house. There was no data found to verify this.
5. There seems to be no major budget for the purchase of heavy equipment. Heavy equipment can be rented when needed (ie. swamp buggy, aerial, crane, etc.).
6. Documentation revealed that there are approximately five-hundred and forty (540) cars, pick-up trucks, and lorry HIAB trucks located within all eight (8) regions, which includes the SNCC, NCC, and TCN Headquarters. Documentation of any other type of heavy equipment was not found. Two (2) non-useable cranes were seen, however, one crane will need much repair. Numerous vehicles were found in disrepair and were left for scrap at various places.

G. Current State of the Emergency Response Process

There was neither an Emergency Response Planning Process nor Emergency Response Procedures available to analyse.

6.0 Proposed Recommendations

A. Implementation of the CMMS (IFS) System

The implementation of a CMMS system (IFS in this case) will be covered in much greater detail in Milestone Deliverable #14 (MIS). The information below identifies the different phases of implementation:

Phase 1

- Creation of network/backbone
    - Prior to the implementation of any CMMS system a network must be created linking all work centres, regional work centres, and TCN
- Purchase of required hardware
    - PC's will be required in all work centres, regional work centres and TCN. These assets will require setup and configuration to work within the new domain
- Training of All staff
    - All staff will be required to be trained in the basic usage of a computer. This is a key component to the implication of a CMMS. (If this is not completed the process will fail.)
    - This includes but is not limited to its basic operations and navigation, use of a 'office' application suite
- Purchase of and configuration of the CMMS application, c/w required licenses

Phase 2

- Input/normalization of asset data
    - A separate team will be required to gather, normalize and input all the required information into the new CMMS. This will require more than basic computer skills although including someone from each work centre, regional work centre is an advantage. This might be the person that may be in the planning role after the roll out

Phase 3

- Training
    - All staff that will be using the CMMS will require hands on training. Training will structured based on tasks
        - Planning & Assignment of work
        - Issuing of work
        - Completion of work, entering in of readings and test results
        - Reports - Reading of data and issuing if required
        - This can be looked at in the following manner
            - Field Staff
            - Supervisor/Managers
            - Planning
            - Technical Support

Phase 4

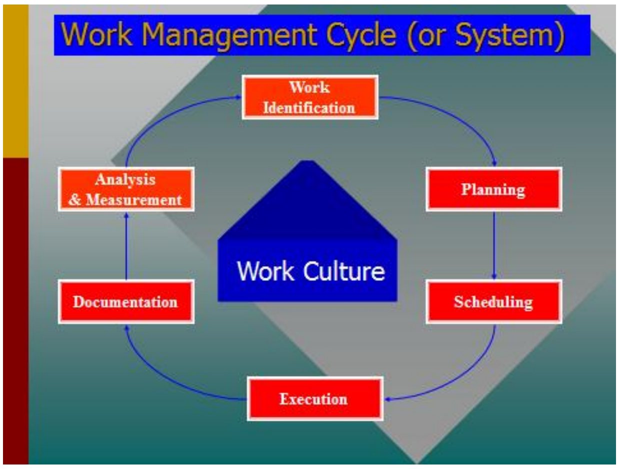
- Implementation/Release
    - The application is now configured with all required data; all staff has been trained in the applications use. Close monitoring will be required as well as additional hands on/over the shoulder support as each area begins using the application

Phase 5

- Periodic review
    - A structured review of the use of the application needs to be created. This review can be annual, quarterly, monthly. It will involve a user's group to gather input from each area on how the program is working and possible enhancements that may be identified that can be passed back to the parent company. Identification of metrics for reporting, tangible and intangible, Quantifiable as well as Qualifiable

B. Implementation of a formal Planning Process.

To begin with, TCN has to develop comprehensive companywide maintenance standards for all its assets in order to develop proper maintenance plans. Once the maintenance standards are developed (as per attached Appendices I - IV), and the resources required to carry out the maintenance are identified, then prioritization, scheduling and outage coordination can begin. The scheduling / coordination process that TCN currently uses, appears to be workable. Under the current system, the identification of the work starts at the Work Centre / Regional Level, where the regional managers compile a list of maintenance tasks to be performed for the year ahead. This information is submitted to the National Control Centre for approval and coordination of required equipment outages. This ensures that lines and equipment are not removed multiple times for different groups, and that the system can withstand the outages from a reliability standpoint. Although the TOR only calls for the development of a maintenance planning process, MHI recommends that TCN take this to the next level, and adopts a more formal Work Management System. This system consists of six interrelated processes that form a continuous loop as shown below:



The Work Management System process “boxes” are further defined to ensure that all involved understand their roles and responsibilities (See Appendix VI for more detail).

C. Implementation of a Formal Transmission Line Maintenance Program

New Human Resources

1. Create a centralized engineering support group that will function as the asset owner (Transmission Line Asset Services). The group will be comprised of and have the following responsibilities:

Engineering and Technical Support - Two (2) engineers, preferably with either a Civil (Structural) or Mechanical Engineering background, and one (1) extra support staff that could have a lineman background, but should be familiar with construction techniques and processes. They will have responsibility to:

- Evaluate patrol/inspection reports to be on top of all items of concern affecting the health of system components.
- Set the maintenance standards of practice for the inspection of components.
- Perform failure analysis and investigations into pre-mature component failures.
- Develop an Inspection tool that will function as a tracking system to log identified defects, classify them, and maintain an inventory of all outstanding defects on the transmission lines. It should also identify items that have been replaced and when, and should be readily available at the work centres to both upload and download information. The system can be spreadsheet based at the start, and will prioritize defects by area and type. Eventually the system can become more sophisticated and be installed on laptop computers with wireless upload and download capabilities.
- This group will also monitor the reliability performance of all transmission lines with regard to outage times and frequency.

Information Technology Specialist (1) - This individual will manage and maintain all data that is entered into a Geospatial Information System. The initial design and development of the system can be overseen by this person if they have the necessary experience. Off the shelf GIS systems can be purchased, but they will typically require modifications to address the specific business needs of the utility. The system can be used to provide a geospatial view of the utility’s transmission line assets, along with location and component information. Other information could eventually include tower location, access points, structure types, hardware components, and types of conductors, dampers, insulators. Another beneficial use is for vegetation management. It is possible to integrate the GIS with the Inspection tool discussed in the preceding section. Line history and corridor aspects can also be shown (cleared width, etc.)

Environmental Engineer (1) - This individual will be responsible for dealing with environmental issues and for setting the approach for the vegetation management program. This would include the application of herbicides to control certain types of rapid vegetation growth.

Business Support - Accountant (1) - The accountant would track spending on domestic capital expenditures and assisting in statistical information reporting and gathering. Initially there will be one or two technical staff inputting data and creating management reports.

TLAS should also play a significant role in the development of emergency response strategies, development of temporary structures and acquisitions of emergency materials.

1. Immediately develop a common reporting format for all maintenance activities. Defects should be categorized into three groups, those needing immediate attention, those that need to be repaired in the current year and those that can wait until there is other work at that structure or that need to be monitored.
2. On completion of recommendation #2, work should begin on building a GIS system for TLM (as per MD Report #12)
3. On completion of recommendation #2, all maintenance budgeting should be driven by data generated by reports from the maintenance reporting system.
4. Investigate and track all line outages by line and by cause.
5. Develop proactive random sample testing to ensure emerging problems are identified early. This would include unclamping conductor shoes, spacer and vibration dampers, and completing footing excavations.
6. As soon as possible, investigate opportunities to deal with vegetation in a more effective manner using herbicide, mechanical methods and contracted services to expedite the removal of trees.
7. TLAS must work to re-establish aerial patrols on a regular basis to free up valuable man hours.
8. TLAS and line management must review task frequencies to ensure optimum use of staff hours.
9. TLAS and line management as soon as basic reporting systems are in place need to review work allocation related to available staff and ensure available resources are assigned as effectively as possible, through temporary or permanent relocation.

Existing Human Resources

1. Management needs to review the work load associated with the two live line crews and if existing crews are not able to meet the work demand, create another live line crew.
2. Technical field staff numbers need to be increased to deal with workloads. This could include temporary re-assignment to different regions to help deal with local backlogs of work. An additional option is to reassign non-technical staff to technical positions and re-train where possible. Field staff need time to complete repairs as well as patrols. Consider staffing work centres with a goal to have 50% of their time to patrolling, and the remainder to repairs to the system and vegetation control activities.

3. Reduce non-technical positions which are not focused on core transmission line tasks
4. Management staff should be streamlined. There appear to be too many levels of management. There should be a line supervisor in each work centre where TLM is present, a manager for TLM in each of the 8 regions and 1 executive director under the CEO for TLM
5. Drivers on the crews need to become working members of the crew (retrain if needed).
6. Office and HR staff does not need to be a part of the work centre, with the exception of possibly a clerk or two that provides basic service to the technical group for time keeping etc. and should be relocated from other departments.

Budget

1. Create a proper operational budget for the department to cover operating costs, including purchase of the necessary small tools and equipment to run the day to day operation.
2. Provide consistent yearly blanket funding for maintenance capital which will allow for the purchase of materials and hiring of any necessary contractors to complete identified component replacement work identified and prioritized by the TLAS department.
3. Create a proper accounting system with order numbers to track labour and expense as related to the budget.

Training

1. Key TLAS Engineering and support staff should take Project Management courses to learn about resource allocation and tracking of key activities within a portfolio of projects.
2. Participation in industry peer groups such as EPRI and CEATI will provide on-going awareness of the industry state of the art. It will keep staff current with the way programs are run in more mature utilities.
3. A training program for technical staff needs to be developed for both patrolling and line work and all staff should receive this training. This is covered in part by the Line Patroller training program that will be delivered by MHI instructors in April. The program is being developed as a “Train the Trainer” program. TCN must make it sustainable. Further training is also addressed in Milestone Deliverable Report #14.
4. Clerical staff as well as technical staff will need basic skills taught to them in the use of computer spread sheets and word documents. This is also being addressed in the Critical Needs training developed by MHI and funded by the World Bank. As a GIS system is brought on board additional training will be required to input and download all necessary information (see MD#12)
5. Management and line staff need to receive training in order to have an improved skill set in the area of trouble shooting and sectionalizing line outages. (also part of MD#16)

Emergency Response

1. Create a formal corporate emergency response plan within TCN, including the requirements of TLM as per recommendations in MD#11.
2. TLM should create an emergency response plan including responsibilities during an event and material caches lists. The inventory should be kept separate from the company inventory. Emergency materials should be cached in strategic locations throughout the system to enhance the response time in event of an emergency.
3. Engineering work for temporary structures and designs should be identified and completed in advance, and filed electronically, so delays during emergencies are not encountered.
4. Emergency training exercises need to be developed and practiced on a regular basis.
5. All emergency materials that are required from Lagos should be shipped and delivered by Lagos staff to prevent long delays in going there to pick it up.

Preventative Maintenance Program

1. TCN must develop a formal Preventative Maintenance program, similar to the one outlined in Appendix I. Cycle times may vary with the region, and will need to be adjusted based on characteristics such as ease of access, vegetation growth rates, and line security concerns (vandalism). Introducing an aerial component can offset labour hours currently dedicated to ground patrols. Other cost saving opportunities may exist with a review of the current vegetation control program. Utilizing newer tools or methods (mechanical or herbicide control), and contracting out some of the work to local communities must be considered. Vehicles, tools and equipment need to be rationalized and should be purchased in appropriate quantities. One ground patrol per year should be sufficient to identify and record transmission line component concerns. Aerial patrols should be used to supplement the ground patrol. The frequency of an aerial patrol would be determined by the local conditions and the need to see the line on a regular basis. Regions that discover higher defect or vandalism levels may need to increase the frequency. Helicopter is the optimum tool for the aerial patrols, as they enable the patroller to find other defects not visible from the ground. The use of fixed wing aircraft could also be investigated.
2. Mechanical clearing of brush should be investigated to see if there are any suppliers that would be available locally to supply this service.
3. Vegetation control through broadcast spraying of herbicide should be investigated to more efficiently control some types of vegetation.

D. Implementation of a Formal Switching Station Apparatus and Auxiliary Equipment Maintenance Program

Prior to making specific recommendations for a preventative maintenance program (PMP), which incorporates reliability centred principles, we should recognize that it is an on-going process which is developed, monitored and revised to ensure that the goals of the program are being met. The program prescribes activities/tasks which are effective, efficient and timely in identifying potential failures. A general task template is developed for each type of apparatus (transformers, batteries, etc.) which identifies tasks/activities to be performed. However, the frequency of performing the tasks on any individual piece of apparatus is dependent on many factors: history, operating conditions, environmental conditions, risk to system, manufacture specific idiosyncrasies, as well as economic considerations. In addition to changing frequency, tasks and activities can be added or deferred. Hence, each piece of equipment has its own preventative maintenance program. See Appendix III for examples of task templates and maintenance activities. In making these recommendations the importance of developing a compliment of strong technical trained staff cannot be overstated. All recommendations depend on their abilities and capacity to perform the work.

Main Recommendations:

1. A philosophical and on-going monetary commitment by senior management is required if a PMP is going to succeed.
2. Create a “Technical Support Services Section”. This group will contain the apparatus specialists/experts, and will provide technical support for each and every piece of apparatus, and will be responsible for the development and monitoring of the PMP, as well as standards and procedures.
3. Regional/WorkCentre staff will report directly to the Regional Manager, but have a technical reporting relationship with the Technical Support Services (TSS) Section. Budgeting and work planning should remain in the Region/WC, coordinated centrally.
4. Review all positions from a functional perspective. Identify duties and skills needed to perform duties. Create job descriptions describing the same. This is also being addressed in MD#16.
5. Access optimal staffing levels and implement. Significant expansion of the technician and technical support groups is essential.
6. Develop and deliver training programs to provide the knowledge and skills needed by staff to perform their prescribed work functions. This is also being addressed in MD#16.
7. Procure the necessary diagnostic tools and equipment. See Appendix V for Recommended Tools and Equipment
8. As soon as practically possible, initiate an evaluation of all station apparatus using diagnostic test techniques. This includes Power Factor testing, detailed Oil Analysis and Dissolved Gas Analysis, and a thermal imaging program.
9. As soon as practically possible start the process of developing the PMP standards and procedures as per Appendix III.
10. Initiate a review of spare stock (apparatus) and spare parts required for the reliable operation of the TCN system. Updating the asset registry complete with nameplate data will be first step before commencing risk analysis. This information will also be required for the implementation of a CMMS system (see MD#14 for full details)
11. Develop a transformer contingency plan. Transformers are not only the most expensive assets; they also take the longest to procure, typically a year or

more. To offset financial impact consider early purchase of project transformers.

12. Excessive line faults result in excessive circuit breaker (fault) operations. Maintaining transmission lines will reduce breaker operations; hence, maintenance and corrective actions.

Additional Recommendations (Support Staff and Facilities)

1. Review and identify the information that is needed to perform work functions. Include: drawings, manuals, history (test data & reports), asset inventory, spare apparatus inventory, spare parts inventory, etc. Develop a plan to assimilate and disseminate information. Consider all users.
2. Review and determine the medium to be used for storage of information. Electronic storage incorporating a CMMS is highly recommended. Such a system would eliminate the bulky storage requirements of a paper system, and would significantly increase the productivity of all users. (The implementation of the CMMS is covered in MD Report #14)
3. Review, identify and procure the assets needed to support the information system: computers, software, systems/networks, scanners, printers, cameras, filing cabinets, desks, shelving, etc.
4. Review and identify office space requirements. Include TCN HQ and regional offices. Identify square footage and quality of office environment needed. Consider staffing numbers, interaction of staff, location of office support assets, security, etc. Procure and implement.
5. Review the requirements for a large multifaceted central service centre with capabilities to work on both large and small apparatus, process and test oil, test and repair HV apparatus, electronic equipment as well as protection and metering equipment. Identify the activities, space, tools and equipment needed to do the work. Abuja is strongly recommended as the preferred location, as it is central and would be close to the engineering support group.
6. Similarly, identify electrical/mechanical shop needs in the regions, identifying space, tools and equipment needed to perform work. Procure and implement.
7. Review and identify oil processing equipment, storage, transportation and handling requirements. Procure.
8. Review and identify oil laboratory requirements. Identify testing to be performed, test equipment, training and staff. Include standard oil and dissolved gas analysis. Consider incorporating the oil lab into a central service centre in Abuja. Procure and implement. It is our understanding that the WB may be funding a “National Oil Lab” to be located in Lagos
9. Review, identify and procure transformer processing equipment (trailer). Consider installation, maintenance and drying of transformers.
10. Review and identify storage requirements for spare station apparatus at a central store. Consider type of storage (indoor/outdoor, racks, shelves, environmental requirements, etc.), handling equipment, and space and maintenance requirements needed for each piece of spare apparatus. Include marshalling space/storage for new apparatus purchased for projects. Similarly, review storage requirements for spare small part. It is highly recommended that the central store be located in Abuja adjacent to the

service centre. Abuja is a central location, and the service centre can maintain the spare apparatus as well as perform acceptance tests on new apparatus.

11. Reorganize and increase staffing levels of the engineering support (TSS) groups as follows:
    - reactive equipment
    - interrupting equipment
    - auxiliary equipment
    - insulation test group
    - CMMS

    Each group would consist of approximately three to six specialists, and have a leader to coordinate activities.
12. Expand and define the responsibilities and roles of the engineering support group (TSS) as per the list below. This group is pivotal in ensuring the reliable operation of TCN's station assets
    - Review equipment performance and develop the maintenance standards, PMP.
    - Develop detailed maintenance procedures for all apparatus
    - Review and verify test data, and initiate action/recommendations as needed
    - Reviewing tool and equipment needs, make recommendations to purchase and standardize
    - Supporting field staff in both routine and breakdown work as required
    - Assimilate and dissimilate information (drawings, mfg. test reports, test data, procedures, etc. – essential all info needed by staff to perform work)
    - Identify and make recommendations for staff training.
    - Participate as a training instructor in the classroom or field as requested.
    - Lead root cause investigations of equipment failures/problems
    - Establish and maintain a working relationship with vital suppliers and contractors to ensure that needs of the corporation are met
    - Represent the corporations interests with respect to warranty claims
    - Perform studies and make recommendation for remedial work
    - Supervise/participate in the development and maintenance of the CMS
    - Develop commissioning procedures and provide technical support
    - Prepare specs and tenders for the repair or replacement of apparatus (batteries to transformers)
    - Evaluate tenders and administer contracts/purchase orders for the replacement of station equipment.
    - Perform risk analysis studies and make recommendation with respect to spare stock levels
    - Assign spare stock to meet the corporate needs
    - Developing and maintaining contingency plans (particularly for power transformers)
    - Establish and maintain working relationships with other departments to ensure that needs of the corporation are met

E. Implementation of a Formal Protection Maintenance Program

1. TCN should maintain their protection equipment as per the standards provided in APPENDIX IV.
2. TCN should organize more "training sessions", where a competent engineer demonstrates the testing methodology to other less experienced engineers. This could be done using existing staff, since the frequency of maintenance testing will be cut back considerably.
3. TCN should maintain better records of when the relays are tested and the results of those tests
4. TCN should maintain a record of any tests that are conducted as a follow-up to a suspected nuisance trip.
5. TCN should continue with its plan to introduce computerized relay testing.
6. TCN should reduce the number of makes and models of relays on the system by standardizing their purchasing.
7. TCN appears to have a problem with nuisance trips. It is uncertain as to whether this is caused by incorrect relay settings due to inexperienced staff, or due to incorrect settings issued by the protection settings engineers. A comprehensive relay coordination study may be necessary.

F. Implementation of a Formal Vehicle Maintenance Program

1. Each vehicle and piece of equipment owned by TCN must be documented on a form and properly entered into the IFS database as part of the implementation of the IFS in MD#14.
2. A needs analysis should be conducted for each vehicle or piece of equipment. If needed, a condition assessment should be completed and a cost analysis would have to be done for any repairs needed, and compared to procurement of a new or used vehicle or equipment.
3. Each regional office will require a head mechanic to track and repair vehicles in his area and be responsible to the manager to complete the job. However, maintenance standards should be developed and should be controlled by a centrally located specialist. (See Appendix II – Fleet Maintenance Inspection Sheets)
4. Support facilities and equipment will require updating, and replacing. This will insure fleet will be able to keep up to the changes in technology and improve the working conditions for staff. A secure location and enclosed facility for repair, administration and storage will insure that the equipment and personnel will be able to do a more efficient and productive job. (See Appendix VII for recommended tools and equipment)
5. A separate evaluation should be done on the helicopter(s). Cost of purchase, licensing, fuel, mandatory inspections, maintenance and included downtime for repairs should be compared to the cost of rental.
6. Light vehicles 3 years old or newer should have repairs and maintenance contracted to the selling dealer. Most of the repairs should be on warranty. Clauses in the purchase warranty can also include towing.

7. TCN may want to consider a few short-term purchases of equipment for testing and evaluating in the field to make crews more effective. These should include:
    a. A Swamp buggy or Flex Trac and trailer to be used by live line crew to access Transmission Line quickly and easily. The Flex Trac could be equipped to carry most necessary tools for line maintenance. Argo is one type of buggy available to be shipped and maintained with training of TCN staff. There is no Argo dealer in Nigeria but there is one in Egypt and South Africa.
    b. One Lorry truck with a Hiab or a suitable truck with a hitch to pull the flextrac on a trailer. One of the Lorry trucks could be used if it was equipped with a hitch.
    c. One Telehandler with accessories such as forks, bucket, bush cutter and a man basket. This unit could be used inside the stations for easier maintenance and also would be a more versatile tool. One caterpillar brand Telehandler was located in Abuja at one of the construction companies work yard. (procurement, repairs and parts should be available but further investigation is required) Bobcat is another brand sold worldwide but am still waiting for information back from our local dealer.

7.0 Proposed Implementation Programme

7.1. Implementation of a Maintenance Planning Process (Work Management System)

7.1.1. Programme Objectives

To develop a comprehensive Work Management System at TCN that will enable TCN to more effectively manage their work.

7.1.2. Programme Components

- Staff Training on the elements of the Work Management System (MHI to identify those to be trained)
- Process Mapping for each work area
- Assignment of responsibilities within each Process Box
- Implementation of new WMS

7.1.3. Programme Cost Projections

Approximately $50,000

7.1.4. Programme Implementation Schedule and Phases

Flexible

7.1.5. Programme Constraints and Requirements

Staff disinterest

7.2. Implementation of the CMMS (IFS) System

7.2.1. Programme Objectives

A computerized maintenance management system is needed at TCN to assist in all aspects of effectively maintaining the power grid and associated equipment. The implementation of a CMMS system (IFS in this case) will be covered in much greater detail in Milestone Deliverable #14 (MIS). The information below identifies the different phases of implementation

7.2.2. Programme Components

- **Phase 1** - Creation of network/backbone
- **Phase 2** - Input/normalization of asset data
- **Phase 3** - Training
- **Phase 4** - Implementation/Release
- **Phase 5** - Periodic review

7.2.3. Programme Cost Projections

Part of MD#14

7.2.4. Programme Implementation Schedule and Phases

Part of MD#14

7.2.5. Programme Constraints and Requirements

The purchase and Implementation of an IFS system is costly and complex, and requires a significant amount of human resources, time, and training.

7.3. Implementation of a Transmission Line Maintenance Program

7.3.1. Programme Objectives

- To enhance the overall capabilities of TSP to properly maintain the high voltage transmission lines

7.3.2. Programme Components

- Participate in the Line Patroller Training (April 2013) and identify ways of making this a sustainable program for delivery to other staff across the regions
- Create a Centralized Transmission Line Asset Services Group
- Rationalization of People and Resources
- Implement a maintenance program based on the suggested standards and inspection sheets provided in this document (Appendix I)
- Proceed with the development of emergency response plans as part of MD#11
- Proceed with properly allocated budgets based on need, not an equal division of funding.

7.3.3. Programme Cost Projections

- Participate in the Line Patroller Training (April 2013) – No cost other than local travel and accommodations.
- Create a Centralized Transmission Line Asset Services Group – This may require 5 additional staff to be hired over a 1-3 year period (estimated at $50,000 / year / person)
- Rationalization of People and Resources (no cost)
- Implement a maintenance program based on the suggested standards and inspection sheets provided in Appendix I of this document (no cost)
- Proceed with the development of emergency response plans as part of MD#11
- Proceed with properly allocated budgets based on need, not an equal division of funding

7.3.4. Programme Implementation Schedule and Phases

- Participate in the Line Patroller Training (April 2013)
- Create a Centralized Transmission Line Asset Services Group (3 - 12 months)
- Rationalization of People and Resources (6 – 12 months)
- Implement a maintenance program based on the suggested standards and inspection sheets provided in Appendix I of this document (immediate)
- Proceed with the development of emergency response plans as part of MD#11(12-18 months)
- Proceed with properly allocated budgets based on need, not an equal division of funding. (6 – 12 months)

7.3.5. Programme Constraints and Requirements

- Not enough highly skilled staff available to form the TLAS group and insufficient funding

7.4. Implementation of a Switching Station Apparatus Maintenance Program

7.4.1. Programme Objectives

To enhance the overall capabilities of TSP to properly maintain the high voltage sub-station equipment and the lower voltage auxiliary equipment

7.4.2. Programme Components

1. Reorganization (Develop TSS and Define Responsibilities)
   The TSP station apparatus reporting line is of paramount importance. All recommendations in this report are dependent on the TSS Department's ability to provide leadership, and the regional technician's ability to perform the required work. The first step is to define the reporting and working relationship between the two groups defining function and duties, and recording same in job descriptions. Determine optimum staffing levels in both groups. Then fill the TSS positions first with the best qualified staff. There is a huge shortfall of qualified and trained technical staff; hence an aggressive recruitment and training program will have to be implemented.

2. Training
   Staff selected for TSS positions will have sound theoretical and practical knowledge. Their training requirement will be for advanced specialty training. The main component should be self-education, supplemented by factory training, institutional courses, and related seminars. Mentorship/partnership training is an option which should be considered. Training needs for each specialist will have to be evaluated on an individual basis.

   The entry level technician/journeyman will typically not have sound theoretical or practical knowledge. Hence, a program to train entry level staff needs to be developed. See MD#16. Such a program takes time to fully develop, and is always under review. However, some immediate decisions on initial training and integration into the work force can be made.

3. IMS & CMMS
   Every TSS specialist and technician's capacity to perform work is dependent on ability to access and disseminate information. Each specialist will have to determine what information (drawings, manuals, data, reports, etc.) is needed to perform his work, and acquire same. Additionally, the specialist will forward same information to his customers, the regional technical staff, as needed.

   Most functional responsibilities within the TSS group depend on an accurate and complete asset registry. Regardless of how this information is to be stored the gathering process (collecting nameplate data) is the same. To ensure completeness and consistency the specialists should coordinate this activity. Digital nameplate photos are recommended to verify data accuracy.

4. Assessment of asset condition
   Assessing asset condition is dependent on acquisition of test equipment, staff training and budget. The time table for implementation is dependent on the TSS Department.

Coordination is up to the specialists. Priorities will have to be established. There are two areas of primary concern, transformers and batteries:

- Transformer condition can be quickly assessed with oil analysis. One litre cans samples, and 500 ml syringe samples from the BMT of all transformers can be taken and forwarded to an accredited lab for analysis. This can be done without de-energizing the transformer and with very little investment in equipment, and training. Standard oil analysis (expanded properties) and DGA are very effective in identifying problems with cores and windings.
- The reliability of the SCADA system is dependent on a reliable DC power supply, the batteries. Batteries can be quickly checked with a short discharge test. Defective or weak cells can be quickly identified by merely measuring their voltage. In addition to checking battery condition, information should be gathered and recorded for an engineering review (load, voltage drop from battery to load, physical parameters, and rectifier nameplate data).
- A comprehensive thermal scan should be conducted at all sub-stations.

5. Review Spare Apparatus and Parts Requirements:
   It is the responsibility of the TSS group to determine the number of spares to be held. This involves gathering information (population and failure history) to perform a risk analysis study. This may take some time, and initially be a lower priority for some apparatus. However, power transformers and SCADA DC power supplies should be considered a priority (See also MD#8 Report)

6. Standards, Procedures and Acquisition of Tools and Equipment:
   These items all go hand-in-hand. Test equipment without standards and procedures are of limited value. Identifying a potential failure without the ability to take corrective action is also of limited value. It will take time to put the entire program together. Priorities will have to be set. Depending on the abilities and capabilities of the TSS group, and budget, a goal of three to five years to have a functioning PMP should be attainable.

   In a PMP power factor measurements are the primary method of monitoring and verifying the serviceability of HV apparatus insulation systems. Considering the time required to train staff and to implement into the PMP (one year plus), an early planning initiative is needed for training and acquisition of Power Factor test equipment. The acquisition of transformer/oil processing equipment (trailer mounted) has to be a priority. The ability to pull vacuum, and to circulate hot oil in large transformers is paramount, to ensure the serviceability of the insulation system.

7.4.3. Programme Cost Projections

1. Reorganization (Setting up the Technical Support Services Group) - (part of MD#3)
2. Training - (Part of MD#16)
3. IMS & CMMS (Internal costs plus MD#14)
4. Assessment of asset condition (~ $1 M)
5. Review Spare Apparatus and Part Requirements (cost unknown… dependent on the number of spare transformers needed)
6. Standards, Procedures and Acquisition of Tools and Equipment (~ $1 M - $2 M per work centre)

7.4.4. Programme Implementation Schedule and Phases

1. Reorganization (Setting up the Technical Support Services Group) will be part of MD#3 schedule. This can likely start within a few months if the talent pool is large enough to draw from
2. Training is part of MD#16. Can start as soon as MD#16 is approved. Note that the longer term development of a formal and sustainable training program may takes several years to develop (NAPTIN)
3. Implementing the CMMS is a long range program (MD#14 - ~ 2 + years)
4. Condition Assessment can start immediately upon approved budget
5. Review of spare apparatus and parts requirement can start immediately. Purchasing these is money dependent
6. Application of new maintenance standards can start immediately, however, some tasks may require special tools & test equipment

7.4.5. Programme Constraints and Requirements

1. Small Pool of Trained Technical Staff:
   A functioning PMP is totally dependent on people to make it work. An aggressive recruitment and training program will be needed to fill the gap. The development and implementation of the PMP will depend on how quickly staff can be trained.

2. Financial:
   To this point in time maintenance has been a low priority. Financial resources have been directed towards building the grid. An on-going financial commitment to a PMP philosophy is needed.

3. Reorganization:
   Reporting relationships as they exist will not accommodate the development or operation of an efficient maintenance program. Roles, functions, and responsibilities of staff need to be defined, and the reporting relationships streamlined. An inventory of current technical staff identifying numbers and abilities (education & experience) will be required prior to implementing any organizational plan.

4. Culture:
   Hierarchy, one’s title and position within the hierarchy, appears to be the focus of the organization with lesser consideration given to need, function or value added. With the organizational changes proposed it is hoped that focus and attitude will shift, and that staff will take ownership of their job/function within the organization. Job titles should reflect function, and remuneration should be based on duties and responsibilities.

   The changes being proposed are a significant change from the status quo, and could lead to uncertainty, mistrust and unrest. It is natural for people to resist change; hence, effective and early communication should be part of the transition plan.

5. Facilities:
   As the PMP is developed the need for office space, shops, laboratories, stores and possibly a central service centre will become evident. Facilities are a significant investment and need careful on-going planning.

7.5. Implementation of a Protection Maintenance Program

7.5.1. Programme Objectives

- To enhance the overall capabilities of TSP to properly maintain the Protection equipment

7.5.2. Programme Components

- Adaptation of recommended maintenance standards
- Equipment specific training
- Standardization of protection equipment purchases

7.5.3. Programme Cost Projections

- Adaptation of recommended maintenance standards (no cost)
- Equipment specific training (use internal specialists to train others; some training will also be supplied as part of MD#16)
- Standardization of protection equipment purchases (no cost)

7.5.4. Programme Implementation Schedule and Phases

- Adaptation of recommended maintenance standards (immediate)
- Equipment specific training (once staff are freed up through the adoption of new standards, training can begin)
- Standardization of protection equipment purchases
    - Standards must be developed (1 year)
    - Implemented by Procurement group

7.5.5. Programme Constraints and Requirements

- none

7.6. Implementation of a Vehicle Maintenance Program

7.6.1. Programme Objectives

- To enhance the overall capabilities of TSP to properly maintain its fleet equipment

7.6.2. Programme Components

- Proper identification of all fleet vehicles
- Implementation of new maintenance standards
- Development of fleet maintenance program on the new IFS (MD#14)
- Purchase of proper equipment and tools

7.6.3. Programme Cost Projections

- Proper identification of all fleet vehicles (no cost)
- Implementation of new maintenance standards (no cost)
- Development of fleet maintenance program on the new IFS (MD#14)
- Purchase of proper equipment and tools ($55,000 per repair centre)
- Purchase of additional tow vehicle / service truck ($100,0000)
- Purchase of additional Hiab Lorry for transporting goods, craning, & towing ($190,000)
- Purchase of Telehandler machine for assessment by field crews ($150,000)

7.6.4. Programme Implementation Schedule and Phases

- Proper identification of all fleet vehicles(start immediately)
- Implementation of new maintenance standards(start immediately)
- Development of fleet maintenance program on the new IFS (MD#14)
- Purchase of proper equipment and tools(once budget is approved)
- Purchase of additional vehicles (once budget is approved)

7.6.5. Programme Constraints and Requirements

- Budget

Appendix I – Transmission Line Inspection Program

Note:

Manitoba Hydro International's E-submission includes an Excel file which outlines a general approach to a T-Line Maintenance program. The Excel file contains all 16 inspection sheets listed below.

1. Phase Hardware
2. Phase Conductor
3. Skywire (Included)
4. Skywire Hardware
5. Insulators (Included)
6. Aerial Markers Anchor
7. Guy Wire
8. Footing
9. Swamp Guy
10. Structures Steel (Included)
11. Structures Wood
12. Marker Lights
13. Grounding
14. Trees
15. Signs
16. ROW Maintenance Items

A. <u>Visual Inspections</u>

a. Ground Patrol

Each structure and span in the system shall be inspected from the ground, once per fiscal year.

- Items to be looking for include:
  - Bent or broken steel lattice members
  - Damaged insulators
  - Loose or missing cotter keys in the suspension hardware
  - Broken conductor strands at the suspension point or anywhere along the span
  - Damaged or missing dampers
  - Vegetation encroachments creating a hazard to the line
- Information can be logged on paper or entered immediately via laptop into an electronic Maintenance and Inspection Application. If spread sheets are used, paper checklists should be sent to the centralized inspection administrator.

b. Aerial Patrol

Used to supplement the ground patrol. Is understood to be a quick surveillance of the corridor and transmission line between the main Ground Patrol. Patroller is only looking for major defects.

- Frequency of the aerial patrol will be determined on need. If there are frequent incidents of vandalism or component failure, then these patrols will need to be increased. Rapidly growing vegetation may also necessitate increased frequency of aerial patrol.
- Under normal circumstances one additional patrol via helicopter or fixed wing is sufficient to manage the corridor. Ensure that the additional aerial patrol is completed during an opposite season from the Ground Patrol.

B. <u>Climbing Inspections</u>

Climbing inspections are labour intensive, and it needs to be evaluated if they are required. A full climbing inspection may be warranted if a number of defects have started to show up in a geographic area. They can also be completed when other activities are already occurring at a given structure. Crews may already be on the tower replacing or checking insulators, so a quick review of other components can be completed.

- Typical items looked for include:
  - Broken conductor strands under suspension conductor clamps
  - Loose or missing bolts on the tower
  - Broken conductor strands under damper clamps

C. <u>Component Inspections or Diagnostic Tests</u>

This again is typically completed on an as-needed basis, and is usually initiated following a discovery in a local area. Some of the types of Diagnostic/Component Inspections that can be completed include:

1. Guy tension readings on guyed towers to determine if there is tower movement.
2. Footing excavations on foundations to check for advanced corrosion.

3. Anchor Rod testing to ensure soundness of tower anchoring system.
4. Conductor samples can be removed and sent into a laboratory to evaluate the remaining life.
5. A representative sampling of insulator strings can be removed to determine the soundness of the population.
6. Vibration monitors can be installed on the conductors to determine if the dampening system on the line is working as required.
7. Readings can be taken to determine the remaining thickness of zinc on galvanized steel towers

Appendix II – Fleet Maintenance Inspection Sheets

PREVENTIVE MAINTENANCE REQUEST

GROUP 1 - CAR AND LIGHT TRUCK (UNDER 10,000 LB / 4500 KG GVWR)

Unit no.	Year	Make	Model	Licence no.	Kilometers / HRs
Work performed at			Signed by (Mechanic)	COMPLETED	yyyy mm dd
Operator name (print)	Phone no.	Cell. no.	Contact name	Phone no.	Cell. no.

ANY REPAIRS, OR REPLACEMENT OF ANY COMPONENT REQUIRES AN ESTIMATE AND AUTHORIZATION.	CONTACT FLEET

- [ ] Complete 'A' Service (70-PM-PMA)
- [ ] Vendor Service/Inspection equivalent to 'A' Service

CODES
✓ OK or completed
R Repairs required
A Advisement only

Service interval approx. 7,500 km or 12 months.

TASK	CODE
1. Change engine oil and filter, lubricate chassis and apply next service sticker.	
2. Inspect air and PCV filter.	
3. Check for oil leaks.	
4. Check radiator, hoses and connections for leaks.	
5. Check belt condition and adjust if required.	
6. Check power steering oil level.	
7. Check transmission and transfer case oil level.	
8. Check clutch adjustment and fluid level.	
9. Check transmission linkage and neutral safety switch.	
10. Check front and rear differential oil levels.	
11. Check constant velocity joint boots.	
12. Check drive shaft and components.	
13. Check brake system for leaks and damage.	
14. Check parking brake operation.	

TASK	CODE
15. Check tires and adjust air pressure (include spare).	
16. Check wheel nuts and torque to specs.	
17. Check springs, shocks and mounting hardware.	
18. Check steering and front end components for looseness.	
19. Check complete exhaust system.	
20. Check fuel tank, lines and connections for condition and leaks.	
21. Check operation of headlamps, tail, brake, signal, hazard, clearance, work and fog lights.	
22. Check pintle hitch for operation and lubricate.	
23. Check all hitch attachment points and safety chain eyes.	
24. Check and lubricate all door locks and hinges.	
25. Check wiper blades and motor.	
26. Check battery condition, hold down brackets cables and terminals. Clean as required.	
27. Check tow hooks for visible damage and if firmly fastened.	

Comments or request for additional repairs

PREVENTIVE MAINTENANCE REQUEST

GROUP 2 - MEDIUM TRUCK (chassis only)

MV unit no.	yyyy mm dd	Kilometers	Licence no.	Work performed at	
Mechanic certification no.			Signed by (Mechanic)		COMPLETED yyyy mm dd
Operator name (print clearly)				Operator phone no.	

ANY REPAIRS, OR REPLACEMENT OF ANY COMPONENT REQUIRES AN ESTIMATE AND AUTHORIZATION.	CONTACT - FLEET

- ☐ Complete 'A' service
- ☐ Complete 'A' service **except** items indicated by 'X'
- ☐ Vendor service/inspection package equivalent to 'A' service
- ☐ Complete 'B' service
- ☐ Complete 'B' service **except** items indicated by 'X'

CODES

- ✓ OK or completed
- R Repairs required within 21 days
- A Advisement only

	'A' SERVICE INTERNAL 70-PM-PMA 200 Engine Hours or 6 Months	CODE
☐	1. Change engine oil and filter, lubricate chassis and apply next service sticker.	
☐	2. Check operation of instruments, indicator lamps, dash lights, hourmeter and engine warning systems.	
☐	3. Check operation of headlamps, tail, brake, signal, hazard, clearance, work and fog lights.	
☐	4. Check operation of horns, heater, defroster, seats and seatbelts, windshield wipers, washer and fluid level.	
☐	5. Check air system build up time, governor operation and low pressure warning system.	
☐	6. Check clutch free travel and adjust as required.	
☐	7. Check coolant level, radiator hoses, all heater hoses and connections for damage or leaks.	
☐	8. Check all drive belts for condition; adjust as required.	
☐	9. Check air cleaner indicator operation. Replace elements as required.	
☐	10. Check transmission, differentials and auxiliary gear-box levels and for leaks.	
☐	11. Check drive shaft, u-joints, centre bearing and yokes.	
☐	12. Check tires and adjust air pressures.	
☐	13. Check wheels and nuts for damage, looseness, cracking and misalignment.	
☐	14. Check power steering system oil level.	
☐	15. Check front wheel bearing oil levels.	
☐	16. Inspect air brake system, hoses and tubing for leaks and chafing. Drain all air tanks.	
☐	17. Check air brake chambers for leaks and damage.	
☐	18. Check brake adjustment and parking brake operation.	
☐	19. Lubricate slack adjusters and clevis pins.	
☐	20. Hydraulic brakes: check master cylinder fluid level.	
☐	21. Check trailer pintle hook for operation and lubricate.	
☐	22. Check trailer safety chain eye condition and trailer electric/air connections.	
☐	23. Check body for damage, lubricate locks, latches and hinges.	
☐	24. Govt. inspection decal expiry date ____________.	
☐	25. Check tow hooks for visible damage and if firmly fastened.	

	'B' SERVICE INTERVAL 70-PM-PMC 12 Months (includes complete 'A' Service)	CODE
☐	1. Engine tune up as per Manufacturers Guidelines	
☐	2. Check turbo for noise, vibration and leaks.	
☐	3. Test antifreeze to -37ºC and check coolant conditioner.	
☐	4. Pressure test cooling system, rad cap and check thermostat operation.	
☐	5. Check block heater, battery blanket and interior warmer operation.	
☐	6. Check battery specific gravity, fluid level, holddown brackets, cables and terminals.	
☐	7. Load test battery, perform starter and charging system test.	
☐	8. Change fuel filters.	
☐	9. Check diesel fuel-water separator; service if required.	
☐	10. Change all powertrain external filters if applicable.	
☐	11. Perform Government Inspection.	
☐	12. Check operation of air dryer; service if required.	

Comments or request for additional repairs

PREVENTIVE MAINTENANCE REQUEST

GROUP 3 - HIGHWAY TRACTOR WITH MOUNTED EQUIPMENT

MV unit no.	yyyy mm dd	Kilometers	Licence no.	Work performed at
Mechanic certification no.			Signed by (Mechanic)	COMPLETED yyyy mm dd
Operator name (print clearly)				Operator phone no.

ANY REPAIRS, OR REPLACEMENT OF ANY COMPONENT REQUIRES AN ESTIMATE AND AUTHORIZATION.

CONTACT - FLEET

☐ Complete 'A' service
☐ Complete 'A' service **except** items indicated by 'X'
☐ Vendor service/inspection package equivalent to 'A' service
☐ Complete 'B' service
☐ Complete 'B' service **except** items indicated by 'X'

CODES
✓ OK or completed
R Repairs required within 21 days
A Advisement only

	'A' SERVICE INTERVAL 70-PM-PMA 15,000 km, 200 hrs or 6 Months	CODE
☐	1. Change engine oil and filter, lubricate chassis and apply next service sticker.	
☐	2. Check operation of instruments, indicator lamps, dash lights, hourmeter and engine warning systems.	
☐	3. Check operation of headlamps, tail lights, brake, signal, hazard and clearance, work and fog lights.	
☐	4. Check operation of horns, heater, defroster, seats and seatbelts, windshield wipers, washer and fluid level.	
☐	5. Check air system build up time, governor operation and low pressure warning system.	
☐	6. Check clutch free travel and adjust as required.	
☐	7. Check coolant level, radiator hoses, all heater hoses and connections for damage or leaks.	
☐	8. Check all drive belts for condition; adjust as required.	
☐	9. Check air cleaner indicator operation. Replace elements as required.	
☐	10. Check transmission, differentials and auxiliary gear-box levels and for leaks.	
☐	11. Check drive shaft, u-joints, centre bearing and yokes.	
☐	12. Check tires and adjust air pressures.	
☐	13. Check wheels and nuts for damage, looseness, cracking and misalignment.	
☐	14. Check power steering system oil level.	
☐	15. Check front wheel bearing oil levels.	
☐	16. Inspect air brake system, hoses and tubing for leaks and chafing. Drain all air tanks.	
☐	17. Check air brake chambers for leaks and damage.	
☐	18. Check brake adjustment and parking brake operation.	
☐	19. Lubricate slack adjusters and clevis pins.	
☐	20. Check trailer pintle hook for operation and lubricate.	
☐	21. Check trailer safety chain eye condition and trailer electric/air connections.	
☐	22. Check body for damage, lubricate locks, latches and hinges.	
☐	23. Govt. inspection decal expiry date ______________.	
☐	24. **Perform all mounted equipment logbook inspections and sign-off.**	
☐	25. Check tow hooks for visible damage and if firmly fastened.	

	'B' SERVICE INTERVAL 70-PM-PMB 12 Months (includes complete 'A' Service) Could include Mandatory Government Inspection	CODE
☐	1. Engine tune up as required.	
☐	2. Check turbo for noise, vibration and leaks.	
☐	3. Test antifreeze to -37ºC and check coolant conditioner.	
☐	4. Pressure test cooling system, rad cap, fluid level, and check thermostat operation.	
☐	5. Check block heater, battery blankets and interior warmer operation.	
☐	6. Check battery specific gravity, fluid level, holddown brackets, cables and terminals.	
☐	7. Load test battery, perform starter and charging system test.	
☐	8. Change fuel filters.	
☐	9. Check diesel fuel-water separator; service if required.	
☐	10. Change all powertrain external filters if applicable.	

Comments or request for additional repairs

PREVENTIVE MAINTENANCE REQUEST
GROUP 5 - TRACK VEHICLE

MV unit no.	yyyy mm dd	PTO hours	Engine hours	Licence no.	Work performed at
Mechanic certification no.		Signed by (Mechanic)			COMPLETED yyyy mm dd
Operator name (print clearly)					Operator phone no.

ANY REPAIRS, OR REPLACEMENT OF ANY COMPONENT REQUIRES AN ESTIMATE AND AUTHORIZATION.

CONTACT - FLEET

- ☐ Complete 'A' service
- ☐ Complete 'A' service **except** items indicated by 'X'
- ☐ Vendor service/inspection package equivalent to 'A' service
- ☐ Complete 'B' service
- ☐ Complete 'B' service **except** items indicated by 'X'

CODES

- ✓ OK or completed
- R Repairs required within 21 days
- A Advisement only

	'A' SERVICE INTERVAL 70-PM-PMA 200 Engine Hours or 6 Months	CODE
☐	1. Change engine oil and filter; service PCV system and lubricate chassis.	
☐	2. Check operation of instruments, indicator lamps, dash lights, hourmeter and engine warning systems.	
☐	3. Check headlamps, tail, brake, signal, hazard, clearance, work and fog lights.	
☐	4. Check operation of windshield wipers, heater, defroster, seats, seatbelts and escape hatch.	
☐	5. Check cab, glass and mirrors for damage.	
☐	6. Check coolant level, radiator hoses, heater hoses and connections for damage and leaks.	
☐	7. Check all drive belts for condition; adjust as required.	
☐	8. Check air cleaner indicator operation. Replace element as required.	
☐	9. Check air system build up time, governor operation and low pressure warning system.	
☐	10. Check exhaust system.	
☐	11. Check drivetrain gearboxes and final drives for operation and oil leaks.	
☐	12. Check all u-joints, centre bearing, yokes for looseness and wear.	
☐	13. Check steering differential and final drive bolts for looseness.	
☐	14. Check idlers and walking beam bushing/bearings for wear and alignment.	
☐	15. Check wheel bearings for lubricant and looseness.	
☐	16. Check drive sprockets for wear. Inspect tracks for adjustment and cuts.	
☐	17. Inspect air brake system, hoses and tubing leaks and chafing.	
☐	18. Inspect tire condition; check air pressure if applicable.	
☐	19. Inspect axle and wheel nuts for looseness.	
☐	20. Hydraulic brakes - check master cylinder fluid level, tubing and connections for leaks.	
☐	21. Check steering clutch/band adjustment; parking brake operation.	
☐	22. Check track frame alignment and weldments.	
☐	23. Check track rollers for oil and wear.	

	'A' SERVICE INTERVAL 200 Engine Hours or 6 Months	CODE
☐	24. Check condition of dozer/loader cutting edge, bucket and bucket teeth.	
☐	25. Check dozer/loader frame, pins and bushings for looseness, wear and cracks.	
☐	26. **Perform any mounted equipment service following manufacturer's recommendations.**	
☐	27. **Perform any mounted equipment logbook inspections and sign-off.**	

	'B' SERVICE INTERVAL 70-PM-PMB 12 Months ('B' service includes complete 'A' Service)	CODE
☐	1. Check throttle, PTO and winch operation.	
☐	2. Check glow plugs and engine starting aids.	
☐	3. Check engine and radiator supports.	
☐	4. Test anifreeze to -37ºC and check coolant conditioner.	
☐	5. Check block heater, battery blanket and interior warmer operation.	
☐	6. Fuel system; check tank, lines and connections for chafing and leaks.	
☐	7. Engine tune-up as required.	
☐	8. Change fuel filters.	
☐	9. Check diesel fuel-water separator; service if required.	
☐	10. Check air cleaner for loose mounting, hoses and connections; check elements.	
☐	11. Change all powertrain external filters if applicable.	
☐	12. Check turbo for noise, vibration and leaks.	
☐	13. Pressure test cooling system, rad cap and thermostat operation.	
☐	14. Check battery specific gravity, holddown brackets, cables and terminals.	
☐	15. Load test battery, perform starter and charging system test.	
☐	16. Check all drivetrain oil levels and change as required.	
☐	17. Service wheel bearings and replace seals as required.	

Comments or request for additional repairs

PREVENTIVE MAINTENANCE REQUEST
GROUP 4 - TRAILER WITH MOUNTED EQUIPMENT

MV unit no.	yyyy mm dd	PTO hours	Engine hours	Licence no.	Work performed at

Mechanic certification no.	Signed by (Mechanic)	COMPLETED yyyy mm dd

Operator name (print clearly)	Operator phone no.

ANY REPAIRS, OR REPLACEMENT OF ANY COMPONENT REQUIRES AN ESTIMATE AND AUTHORIZATION.	CONTACT - FLEET

- ☐ Complete annual service
- ☐ Complete annual service **except** items indicated by 'X'
- ☐ Vendor service/inspection package equivalent to 'A' service

CODES

✓	OK or completed
R	Repairs required within 21 days
A	Advisement only

	ANNUAL SERVICE INTERVAL 70-PM-PMA Trailer less than 4536 Kg (10,000 lbs) GTWR	CODE
☐	1. Check tongue, hitch, safety chains and hooks.	
☐	2. Check front and rear trailer jack.	
☐	3. Check deck and flooring.	
☐	4. Check bunks and supports.	
☐	5. Check trailer body sheet metal, doors, fenders and mudflaps.	
☐	6. Check load securement (include side rails, tie downs, webbing, winches and winchbar.)	
☐	7. Check loading ramps.	
☐	8. Check frame and crossmembers.	
☐	9. Check springs, hangers, shackles, pins and U-bolts.	
☐	10. Check wheels and nuts for damage, looseness, cracking and misalignment.	
☐	11. Check tires and adjust air pressures.	
☐	12. Check condition and operation of all lights and reflectors.	
☐	13. Check wiring, connections and electrical cord.	
☐	14. Inspect brakes and lubricate wheel bearings.	
☐	15. Check brake adjustment and parking brake operation.	
☐	16. Lubricate all grease points.	
☐	**17. Service any mounted equipment following manufacturer's recommendations.**	
☐	**18. Perform all mounted equipment logbook inspections and sign-off.**	

	ANNUAL SERVICE INTERVAL 70-PM-PMG Trailer 4536 Kg (10,000 lbs) GTWR and Greater	CODE
☐	1. Perform Government Inspection.	
☐	2. Check tongue, hitch, safety chains and hooks.	
☐	3. Check load securement (include side rails, tie downs, webbing, winches and winchbar.)	
☐	4. Check frame and crossmembers.	
☐	5. Check springs, hangers, shackles, pins and U-bolts.	
☐	6. Check wheels and nuts for damage, looseness, cracking and misalignment.	
☐	7. Check tires and adjust air pressures.	
☐	8. Check condition and operation of all lights and reflectors.	
☐	9. Lubricate all grease points.	
☐	**10. Perform any mounted equipment service following manufacturer's recommendations.**	
☐	**11. Perform any mounted equipment logbook inspections and sign-off.**	

Comments or request for additional repairs

DEFECTIVE EQUIPMENT REPORT

Report no.

Maintenance file no.	Originator		
	☐ S.C.C.	☐ B.C.C.	☐ STATION
	☐ W.C.C.	☐ E.M.D.	☐ OTHER

Station	Equipment

Type of trouble	DURATION	FROM		TO	
☐ Intermittent ☐ Continuous		yyyy mm dd	hh mm	yyyy mm dd	hh mm

Function(s) affected

Action taken by Reporting party

Evaluation or other comments by Reporting party

Reported by	Organization unit title	yyyy mm dd	hh mm
Verbally reported to	Organization unit title	yyyy mm dd	hh mm

ACTION TAKEN

Work performed

Recommendations from Technician's analysis of the occurrence

Material used

Work completed by	yyyy mm dd	hh mm	No. of man hours	
Prepared by	yyyy mm dd	Reviewed by		yyyy mm dd

EQUIPMENT RENTAL CONTRACT

☐ PAYMENT RECEIVED - DO NOT BILL ☐ PLEASE ISSUE A BILL AS FOLLOWS

Name	Transmittal
Street	

CITY OR TOWN	PROVINCE	POSTAL CODE

METHOD OF PAYMENT

☐ Cash ☐ Cheque This is customer's Cash Receipt. Mark "PAID" on all copies.	☐ By Misc. bill	Customer P.O. no.	Misc. Bill no.

ITEM NO.	DETAILS	COMMENCEMENT yyyy mm dd	RETURN yyyy mm dd	QTY	RATE	TOTAL AMOUNT
					PST 7%	
					GST 5%	
					TOTAL ($) ▶	

Customer Agrees:

- To pay for repairs other than ordinary wear and tear.
- To service equipment while on rent.
- That the terms and conditions on the reverse side hereof are acknowledged to form an integral part of this agreement.

I have read and agree to the terms on the back of this contract. The terms stated on the front and back of this document constitute the entire agreement between the parties. No one has made any oral or written representations not included in this contract.

I have received and been directed to read the equipment operating manuals and the safety procedure sheets.

I have the necessary safety equipment and undertake to operate the leased equipment in accordance with Workplace Safety and Health Regulations.

____
Initials

I acknowledge that I know how to connect the electric monitoring equipment that I have rented.

I hereby acknowledge receipt of a copy of this contract. I do not require any further equipment.

Lessee ______________________ Lessor ______________________

NOTE: IF YOU DO NOT UNDERSTAND HOW TO OPERATE THE EQUIPMENT YOU ARE RENTING, DO NOT HESITATE TO ASK ONE OF OUR STAFF FOR INSTRUCTIONS.

ACCOUNT DISTRIBUTION

Bus. Area	Cost Element or GL Account	Work Order (Enter Only One)	Cost Centre (Enter Only One)	Administrative Use Only	Amount

Prepared by	yyyy mm dd	Department
Checked by	yyyy mm dd	

TERMS AND CONDITIONS

1. In consideration of the rental payment set out herein, shall loan the equipment described herein to the Borrower for the agreed term and the Borrower shall return the said equipment at the end of the said term. Any software used for the analysis of the information obtained must be removed from the Lessee's computer upon return of the equipment.

2. All costs associated with delivery, installation and return of the equipment and any associated parts shall be borne by the Borrower.

3. shall not be held responsible for any damages, whether general, special, consequential or otherwise arising directly or indirectly from the use of the equipment including but not limited to damage arising from malfunctions of the equipment or applications of data obtained from the equipment. The Borrower shall indemnify its officers and employees from and against all demands, liabilities, costs and claims made against as a result of lending the equipment to the Borrower.

4. The Borrower shall use due care in the handling and use of the equipment to insure that the equipment is not damaged nor any person injured, property damaged or rights infringed. The Borrower shall indemnify officers and employees from and against all demands, liabilities, costs and claims made against

5. The Borrower shall grant access, at no charge, to all information and data derived as a result of the Borrower's use of the equipment.

6. Either party may terminate this Agreement at any time upon seven (7) days notice in writing to the other. Upon notice being given the Borrower shall return the equipment to within the aforesaid seven (7) days and no further obligations as between the parties shall thereafter immediately terminate, except clause 3 which shall in all cases survive termination. In the event terminates this Agreement, the Borrower shall be entitled to return of monies paid pursuant to clause 2 on a pro rata basis.

7. This Agreement shall be intrepreted, performed and enforced in accordance with the laws of

8. This Agreement shall enure and be binding upon the executors, administrators, heirs, successors and permitted assigns of the parties.

9. PAYMENT: Payment of rent to the Lessor shall be made promptly at the time specified herein and all amounts in arrears shall bear interest at the rate of 24% per annum until paid.

10. THE LESSOR shall have access to the place where the equipment is being used and to inspect same, and reserves the right, in its sole discretion, to cancel this contract at any time during the rental period, and to remove the equipment from the job without notice to the Lessee, who shall be liable for payment of rent pro rata from the time of such restoration is complete.

11. The Lessee shall operate the equipment according to manufacturers' instructions, with properly qualified operators, and shall return the equipment on the return date specified on the reverse side hereof in the same condition in which it was received, excepting reasonable wear and tear. Should the Lessee fail to do so, the Lessee shall pay any and all costs, charges, and expenses necessarily incurred by the Lessor to replace, repair, or restore the equipment to its original condition, and reasonable compensation for loss of rental until such replacement, repair or restoration is complete.

12. CONDITION OF EQUIPMENT: Lessee acknowledges he has examined said vehicle, machine or equipment and knows the condition thereof, and that same is in good condition and repair.

13. If the Lessee retains the Equipment for more than ten days beyond the end of the maximum estimated rental period, the Lessor may take appropriate measures for the prosecution of the Lessee for theft and/or conversion.

14. IMPORTANT: ACCEPTANCE OF THE EQUIPMENT SHALL CONSTITUTE ACCEPTANCE OF THE TERMS AND CONDITIONS HEREIN. FAILURE TO SIGN THIS AGREEMENT SHALL NOT RELEASE THE LESSEE FROM RESPONSIBILITY FOR LOSS OR DAMAGE IMPOSED UNDER THE TERMS AND CONDITIONS HEREIN.

TOOLS & EQUIPMENT EVALUATION

Return evaluation to Technical Authority	yyyy mm dd	Tool or equipment submitted for evaluation by *(please print)*	yyyy mm dd

EVALUATION UNDER THE DIRECTION OF T&D AND CS&M TOOL FORUM:

ITEM NO.	TOOL OR EQUIPMENT	CATALOGUE NO.	MODEL NO.	SERIAL NO.	CIIC NO.

Reason for evaluation

SUPPLIER OR MANUFACTURER

Name	Contact person	Telephone no.	Email

Description

EVALUATION:

Location of evaluation

Length of evaluation

Start date: ____________ yyyy mm dd End date: ____________ yyyy mm dd

Application

Frequency of use by evaluator: ☐ Daily ☐ Weekly ☐ Monthly ☐ Other

Evaluation Criteria (*rate the product, 1-10, with 10 being excellent)

Evaluation by Technical Authority:

Serviceability (parts & service readily available*): ________

Training required for use or repair: ☐ Yes ☐ No

Licensed / Certification required: ☐ Yes ☐ No

Evaluation by Field:

Ergonomics*: ________

Ease of use*: ________

Durability*: ________

How well did it perform its intended function*: ________

Safe for intended use*: ________

Training provided to field evaluator? ☐ Yes ☐ No ☐ Not Applicable

If training was provided, specify by whom?

Conformance to specifications & standards (identify non-conformance, if any)

Pros & cons

Comments

Tool or equipment evaluated by		yyyy mm dd
Signed by (Technical Authority)	☐ Approved ☐ Not approved	yyyy mm dd

Appendix III – Maintenance Standards for High Voltage Apparatus

Appendix III

Standards and Procedures

The following standards and procedures are taken from Manitoba Hydro's preventative maintenance practices. They are intended as examples, and are not recommendations. There are many equipment and operating differences between the two utilities, which must be considered when developing standards and practices for TCN.

- Appendix III BAT001 - Batteries - Station Flooded - Station Class
- Appendix III BAT002 - Batteries - Station Class - Valve Regulated Lead Acid
- Appendix III BKR001 - Breaker - Air Blast (Air Operator)
- Appendix III BKR007 - Circuit Breakers - Bulk Oil (Air Operator)
- Appendix III BKR011 – Circuit Breakers - Min Oil (Spring Operator)
- Appendix III BKR017 - Circuit Breakers - SF6 Live Tank (Hydraulic Operator)
- Appendix III Power Class Transformers - Bulletin #20, Scheduled and Unscheduled Inspections
- Appendix III TRF001 – Power Transformers

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
1	2012 07 05	Updated the task template and changed/added details throughout the document.	All	RWE	GV
0	2010 01 12	New Maintenance Standard	---	RWE	GV

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Batteries - Flooded - Station Class **Station Standby**				
Tasks	**Triggers**			
	Not Critical	**Low**	**Medium**	**High**
Integrity Check	6 months	6 months	3 months	3 months
Diagnostic Check	24 months	24 months	18 months	12 months

8	2012 06 20	Revise task frequency triggers, combine Specific Gravity check and Battery Ohmic into one task (Diagnostic check)	CM	RWE		GV	Original signed by G. A. Verch 2012 06 20
7	2010 01 12	Changed name of Conductance Check to Battery Ohmic Check	CM	RWE		GV	
6	2004 04 29	Split Diagnostic check into specific gravity and conductance checks. Trigger for conductance check < 13 years is reduced to 24 months.	CM	ARB		DW	
5	2002 08 21	Changed header	GW	ARB		DW	
4	2001 08 02	Infrared scan removed	GW	ARB		DW	
No.	Date	Revision	AMR Specialist	Tech Supp Services	Insul. Eng.	AMR Eng.	

A2 Integrity Check

The Integrity Check is done to ensure the integrity of the components and basic functions of the battery bank. This is mainly a visual inspection of the batteries along with some functional checks of associated equipment. The batteries will remain in service during an integrity check.

▲ WARNING ▲

- **Batteries give off explosive gasses. Keep open flames and sparks away from the batteries. Discharge to ground any possible static electricity.**
- **Use tools with insulated handles when working on batteries.**
- **Battery electrolyte is corrosive. Wear protective clothing while working on the batteries (including face shields, protective aprons and acid resistant gloves).**

While performing any battery maintenance, please observe the following:

– Only qualified personnel may work on the batteries.
– Ensure the availability of electrolyte neutralizing solution (Bicarbonate of Soda) prior to beginning work.
– Be aware of the presence and location of the nearest portable fire extinguisher.
– Perform a Job Plan prior and post near the work area.

A2.1 Integrity Check Task Description

Please contact the Auxiliary Equipment Section of TSS if any of the following conditions are excessive or questionable.

A2.1.1 Eyewash Station

An integrity check must first be performed on the eyewash station and the work must be recorded on the Job Plan. At conclusion of the check, the completed Job Plan must be handed in to meet the requirement of the Corporate Safety and Health document titled "*Emergency Eyewash Stations and Showers: Installation and Maintenance*".

A2.1.2 Visual Inspection - Jar Internal

A non-conductive flashlight is required to perform the following inspection.

1. Sulphation

   Check the plates for shiny crystals (sulphation). Some is normal but an excessive accumulation indicates undercharging.

2. Gassing

   Check level of gassing. Excessive gassing indicates overcharging. If gassing is excessive check the float voltage.

3. Mossing

   Check the top and sides of negative plates for an accumulation of spongy lead material. Mossing indicates overcharging.

4. Grid Cracking

   Check for cracks. Grid cracking indicates aging.

5. Sediment

   Check the bottom of the jar for sediment. An excess indicates aging.

   NOTE: *Some batteries are formed in their own jar and have sediment from new.*

6. Plate Expansion

   Check the plates. Expansion indicates aging.

7. Plate Discolouration

   Check the colour of the plates. Discoloured plates indicate contamination.

A2.1.3 Visual Inspection - Jar External

1. Cracked Jars, Electrolyte Leaks

   Check jars for cracks and/or leaking electrolyte. Clean up minor electrolyte leaks with a cloth soaked with distilled water. Stubborn stains can be carefully removed with a solution of 100 grams bicarbonate of soda to 1 litre of water and a cloth. When finished, rinse the area with a cloth soaked with distilled water.

2. Dirt

   Clean away dirt with a water dampened cloth.

3. Exposed Copper at Connections

   Check for corrosion at exposed copper connections. If signs of corrosion exist (blue-green colour), a thorough cleaning or replacement may be required.

4. Split or Bent Post Seals

   Check whether the post seals are split or bent. Such defects indicate internal corrosion.

5. Post Corrosion

   Check the posts. If they are black, the electrolyte is reacting with the lead creating a by-product that is a poor conductor. Clean and neutralize if severe. Post corrosion indicates poor design and/or assembly.

6. Battery Rack Corrosion

   Check the battery rack for corrosion. If severe, remedial action is required.

7. Flame Arrestor Caps

   The flame arrestor caps are in place to prevent the hydrogen inside the batteries from igniting. They are fragile and easily broken therefore removal/installation must be done by only grasping the plastic part of the cap (see Section C5.1.1). Note any that are damaged or missing. Clean those that are plugged by flushing using only clean, hot water. Shake out the majority of water and air dry before re-using.

A2.1.4 Visual Inspection - Electrolyte Level

1. Check Electrolyte Levels

   Determine the electrolyte level of each cell and apply the appropriate instruction when a level is:

   - *At or near high level mark*
     - No action required.
   - *At low level (min) mark (or will reach low level before next maintenance)*
     - Add distilled water to cell(s) and fill to high level (max) mark.
     - Record amount of water added (in litres) in RMS.
     - Use the reading type "Water Use (L)" attached to the battery nameplate.
     - Create a Incidental Failure report in RMS.
   - *Below bottom of filling funnel (plates exposed to air)*
     - Add distilled water to cell(s) and fill to high level (max) mark.
     - Notify the Auxiliary Equipment Section of TSS.
     - Record amount of water added in RMS.
     - Create a Functional Failure report in RMS.

2. Check Previous Water Consumption

   Review recent history of water consumption in RMS to look for any unusual water consumption increases that can indicate ageing (lead selenium batteries - occurs near battery end-of-life). High temperatures and contamination can also cause excessive water consumption. If found, enter as a Potential Failure.

A2.1.5 Visual Inspection - Battery Room

1. Battery Data Record

   Ensure the appropriate Battery Data Record is present and filled out properly.

2. On-site Hydrometer and Thermometer

   Ensure a separate bulb hydrometer and Celsius alcohol thermometer are available for each battery bank. These items must be in good condition and clearly labelled indicating to which bank they belong.

3. Battery Room Condition

   Ensure the battery room is clean and free of clutter.

4. Path to Eyewash Station

   Ensure there is a clear path to the eyewash station.

5. Fire Extinguisher

   Ensure there is a dedicated CO_2 fire extinguisher available for use in the battery room.

6. Signage/Labelling

   Ensure the following is adequately identified

   - Battery room - *identifying sign on the door (CIIC# 74-01-10)*
   - Battery bank - *labels on bank and associated hydrometer/thermometer*
   - Battery cells - *labels showing battery cell numbers*

A2.1.6 Functional Inspection

1. Battery Room Lights

   Ensure battery room lights (including applicable DC emergency lights) are working properly.

2. Battery Room Heat

   Ensure battery room heaters and thermostats are working properly.

3. Exhaust Fans and Timers

   Ensure exhaust fans and timers are in good condition and are working properly.

4. Float Voltage

   Measure the battery voltage at the terminals. It should be within -0% and +1% of the voltage stated on the appropriate battery data record ± the temperature compensation adjustment.

   NOTE: *Battery chargers with an active temperature compensation feature can skew the voltage on the battery data record by the parameters explained in Section C1 of this standard.*

   If the measurement is outside the above parameters, create an RMS failure report and take appropriate corrective action.

A2.2 Integrity Check List

Station: ________________ Battery Designation: ____________ Date: ____________

Other information: ____

1. Before entering any battery room, perform an integrity check on the eyewash station, and ensure the path to it is clear. Sign the tag and enter the inspection on the Job Plan.
2. Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

	Complete	Failed
A2.1.1 Eyewash Station	☐	☐
A2.1.2 Visual Inspection - Jar Internal		
1. Sulphation	☐	☐
2. Gassing	☐	☐
3. Mossing	☐	☐
4. Grid Cracking	☐	☐
5. Sediment	☐	☐
6. Plate Expansion	☐	☐
7. Plate Discolouration	☐	☐
A2.1.3 Visual Inspection - Jar External		
1. Cracked Jars, Electrolyte Leaks	☐	☐
2. Dirt	☐	☐
3. Exposed Copper at Connections	☐	☐
4. Split or Bent Post Seals	☐	☐
5. Post Corrosion	☐	☐
6. Battery Rack Corrosion	☐	☐
7. Flame Arrestor Caps	☐	☐
A2.1.4 Visual Inspection - Electrolyte Level	☐	☐
1. Check Electrolyte Levels	☐	☐
amount of water added (in litres):	*Record in RMS*	
2. Check Previous Water Consumption	☐	☐

	Complete	Failed
A2.1.5 Visual Inspection - Battery Room		
1. Battery Data Record	☐	☐
2. On-site Hydrometer and Thermometer	☐	☐
3. Battery Room Condition	☐	☐
4. Path to Eyewash Station	☐	☐
5. Fire Extinguisher	☐	☐
6. Signage/Labeling	☐	☐
A2.1.6 Functional Inspection		
1. Battery Room Lights	☐	☐
2. Battery Room Heat	☐	☐
3. Exhaust Fans and Timers	☐	☐
4. Float Voltage	☐	☐

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A3 Diagnostic Check

The diagnostic check includes the battery ohmic check and the specific gravity check. The battery ohmic check is performed to determine and monitor the state of charge of the battery bank and to determine its remaining capacity. Battery specific gravity check is performed to measure the battery bank state of charge. Remedial action may be initiated depending on the results of the complete diagnostic check.

The integrity checks for this equipment should be scheduled and performed at the same time as the Diagnostic Check.

▲ WARNING ▲

- **Batteries give off explosive gasses. Keep open flames and sparks away from the batteries. Discharge to ground any possible static electricity.**
- **Use tools with insulated handles when working on batteries.**
- **Battery electrolyte is corrosive. Wear protective clothing while working on the batteries (including face shields, protective aprons and acid resistant gloves).**

While performing any battery maintenance, please observe the following:

– Only qualified personnel may work on the batteries.
– Ensure the availability of electrolyte neutralizing solution (Bicarbonate of Soda) prior to beginning work.
– Be aware of the presence and location of the nearest portable fire extinguisher.
– Perform a Job Plan prior and post near the work area.

A3.1 Diagnostic Check Task Description

A3.1.1 Eyewash Station

An integrity check must first be performed on the eyewash station and the work must be recorded on the Job Plan. At conclusion of the check, the completed Job Plan must be handed in to meet the requirement of the Corporate Safety and Health document tilted "*Emergency Eyewash Stations and Showers: Installation and Maintenance*".

A3.1.2 Battery Ohmic Check

Measure and record the following readings using the Alber CRT-400 Cellcorder:

– Cell/jar internal resistance
– Intercell/interstep resistance
– Cell/jar voltage

Refer to the Manitoba Hydro Application Guide for Battery Ohmic Measurements to determine the appropriate method of testing and for pass/fail parameters. The document is supplied with the CRT-400 Cellcorder and is also available on the TSS website

The results of this check must be reviewed by the technician and when combined with the SG check, be attached to the appropriate nameplate in RMS (in ".cdf" file format). If any of the test results fall outside the threshold values, check that the results are valid before taking further action.

Any issues should be reported in RMS through a failure report and can be reported to the TSS Auxiliary Equipment section.

A3.1.3 Battery Specific Gravity Checks

The battery specific gravity check is performed to measure the state of charge of the battery bank and to identify whether remedial action (equalize charge) might be appropriate. Using the Anton Paar DMA 35N or DMA 35, this check will include specific gravity and temperature readings of each cell.

The results of this test must be reviewed by the technician and then downloaded into the CRT-400 Cellcorder. The resulting complete ".cdf" file can then be attached to the appropriate nameplate in RMS.

If any of the test results fall outside the threshold values, check that the results are valid before taking further action. The pass/fail parameters for this test are in the Manitoba Hydro Application Guide for Battery Ohmic Measurements.

Any issues should be reported in RMS via a failure report and can be reported to the TSS Auxiliary Equipment group.

B NON-REPETITIVE MAINTENANCE TASKS

B1 Non-Routine Task Template

BATTERIES - Flooded Lead Acid - Station Class		
Tasks	Triggers	
Installation Task	Upon installation	Upon installation
Capacity Load Test	When requested	When requested

B2 Installation Task

The installation task is a set of guidelines for the installation of station batteries to ensure work is done in a consistent and proper manner. Flooded, lead-acid, Station Class batteries generally have a life expectancy of twenty years. This is regularly achieved in Manitoba Hydro AMD station installations and the first step in achieving the expected life of a battery is applying the guidelines as written.

▲ WARNING ▲

- **Batteries give off explosive gasses. Keep open flames and sparks away from the batteries. Discharge to ground any possible static electricity.**
- **Use tools with insulated handles when working on batteries.**
- **Battery electrolyte is corrosive. Wear protective clothing while working on the batteries (including face shields, protective aprons and acid resistant gloves).**

While performing any battery maintenance, please observe the following:

- Only qualified personnel may work on the batteries.
- Ensure the availability of electrolyte neutralizing solution (Bicarbonate of Soda) prior to beginning work.
- Be aware of the presence and location of the nearest portable fire extinguisher.
- Have a battery room spill kit on site and readily available.
- Perform a Job Plan prior and post near the work area.

The eForm 0325A can be used to assist the installation of a battery bank.

B2.1 Battery Room Design

Any new battery room must be built according to the Manitoba Hydro Station Design Standard entitled "Battery Room Design c/w Fire Prevention and Protection Requirements" (drawing number: 1-01000-WO-55000-001). This document was written with reference to IEEE Standard 484-2002, the Manitoba Electrical Code and the Manitoba Hydro Fire Manual.

When performing a maintenance replacement of batteries in an existing battery room, practical efforts should be taken to achieve the design standard.

Additional design considerations:

- Avoid temperature differentials between cells. A maximum difference of 3ºC is acceptable.
- The battery room heat must be controlled independently from any other room of the building.

B2.2 Installation Task Guidelines

B2.2.1 Additional Safety Considerations

▲ WARNING ▲

Keep staff clear of battery/battery room when switching battery load (or turning the charger on or off) since a battery failure is most likely to occur during such an activity.

- Lighting and ventilation systems are operational prior to installing batteries.
- Because of the higher probability of an electrolyte spill during a battery installation, an acid spill kit and eyewash station must be operational prior to installing batteries.

B2.2.2 Battery Handling Requirements

- Handle batteries with care. Dropping, jarring or rough handling can cause problems that may only present themselves long after installation.
- Do not rest cells on hard irregular surfaces (e.g. concrete floor with sand or grit). Always rest the cells on a soft surface such as plastic, rubber or corrugated cardboard. Scratches will weaken the jar.
- Use proper lifting methods to avoid strained backs.
- Use the straps supplied and do not lift the batteries by the posts or lids.
- Dispose of the manufacturer supplied lifting straps after installation.
- Use additional lifting aids when required.

B2.2.3 Receiving Inspection

When the battery shipment arrives, check that the items on the packing slip match the project scope of work (if required confirm with AMD-TSS Auxiliary Equipment Section). Check for the following to help alleviate any delays during installation.

- Acid drip trays - ensure the battery drip trays and all the supports are present (if part of the installation).
- Battery rack - Ensure all components of the battery rack are present and in good condition (including: rails, uprights, rail covers, hardware, and instructions). Make sure the rack and trays are the proper size for the installation.
- Battery accessories - Ensure all battery accessories are present and in good condition. Accessories could include:
  - flame arrestor caps
  - intercell connectors with hardware
  - inter-step connectors with hardware
  - main terminal compression connectors
  - cell number decals
  - bulb type hydrometer and thermometer (per bank)
  - connection covers
  - bristle brush (plastic or brass)
  - lifting device (if applicable)

  - grease (if applicable)
  - papers (drawings, instructions, MSDS sheets)
- Batteries, physical condition - Check for manufacturer defects or shipping damage. Using a flashlight, inspect the inside of each cell (if possible) for signs of:
  - Cracking, buckling, or misalignment of the post and plate assembly
  - Excessive scaling of the plates
  - Excessive sediment
  - Excessive sulphation
  - Any other abnormalities

  Check the cell exterior for signs of:
  - Scratches or cracks
  - Damaged posts or post seals
  - Leaks at any other seal (e.g. lid-jar, etc.)

  Reject any cells that are defective and contact the TSS Auxiliary Equipment Section for further instructions.
- Batteries, electrolyte - Check the electrolyte level of each cell. It must cover the plates of the cell. Reject any cells with plates exposed to air. Adjust cells with electrolyte level below the minimum mark by borrowing from another cell that has a higher level. Do not add water at this time because the initial charge may cause the levels to rise. To prevent splashing of electrolyte do not install the flame arrester caps until the batteries are mounted on the battery rack.

If anything abnormal is noticed, contact the TSS Auxiliary Equipment Section

B2.2.4 Rack Installation

When installing a new rack or preparing an existing rack for new batteries, make sure the following items are considered.

- Thoroughly inspect the rack for any damage.
- Ensure the rack conforms to the Manitoba Electrical Code rule # 26-550.
- Make sure the rack is clean and painted. If new paint is required, neutralize first and then coat with a corrosion resistant epoxy or urethane based paint (e.g. Cloverdale "Clovamastic" 8310 epoxy mastic paint).
- Ensure the rail covers are present and in good condition.
- Ensure the battery rack is level and the mounting secure.
- Ensure the rail spacing is appropriate to support the batteries being installed.
- Attach the acid tray lift supports to the battery rack where possible.
- Ensure all metal rack parts are properly bonded to ground using a minimum #4 bare copper ground wire.

- Consider aisle spacing when placing multiple racks in the battery room.
- If acid drip trays are being used, ensure there is one tray support under each of the battery rack legs. Additional tray supports may be required at the junction of abutting trays.

B2.2.5 Battery Installation - Physical

When installing batteries on a rack, make sure the following items are considered.

- Mount cells according to the Manitoba Electrical Code rule # 26-550.
- Space cells according to the manufacturer’s instructions to allow for air flow.
- Where possible, place cells on the rack with the plates perpendicular to the rack to allow for visible inspection of the plate edges.
- Place cells on the smooth part of the rails. Deformities such as dirt, nuts or bolts place stress on the battery jar.
- Number the cells and start with number "1" to start at the Positive end of the string.
- Ensure the spacing and alignment of the cells is uniform to avoid applying undue stress to the cell posts when the connectors are installed. Use a string and spacer to help achieve this alignment.

B2.2.6 Inter-cell Connector and Hardware Installation

The following general rules must be applied in conjunction with the manufacturer’s specific instructions. If there are no instructions please contact the TSS Auxiliary Equipment Section.

- Install the connectors to allow access for testing by the Alber CRT-400 battery analyzer.
- Ensure the electrical contact portion of the battery posts are polished clean and free of lead dioxide and acid (use only a brass or plastic bristle brush).
- Ensure the electrical contact part of the inter-cell connectors, inter-step connectors, nuts and bolts are free of lead dioxide and acid.
- Torque the inter-cell hardware to the manufacturer’s recommended value (for torque specifications see manufacturer's instructions and Section C8 of this document).
- Dual inter-cell connectors that are on a single post must be mounted on opposite sides of the posts.
- Avoid stressing any battery post by pre-aligning the cells and pre-bending inter-step and main leads.
- Consult the manufacturer’s instructions before applying any grease (some manufacturers do not require the application of any grease).
- Install the flame arrester battery caps once all work is complete. Handle the ceramic vent caps carefully (for more information see Section C5 of this document.

- The flame arrester cap removal tool (if provided) must be labelled and left in the battery room.
- Save the shipping caps; label and store them in the battery room for eventual removal of the batteries.
- Perform initial set of readings as per Section B2.3

B2.2.7 Supply and Install of Accessory Items

The following accessories should be supplied and installed on each battery bank:

- Hydrometers and thermometers - Each battery must have a dedicated hydrometer and thermometer. They must be properly mounted in a holder and clearly identified as to their associated battery. The hydrometer tube can be trimmed to match the minimum electrolyte level to quickly ascertain low levels in the opaque cells. Do not mix these tools or use them on non designated batteries.
- Tools - they must be labelled and stored in the battery room. Be sure to neutralize prior to storage except for the lifting strap which must be discarded after use. Age and corrosion will make the strap unreliable for future use.
- Neutralizing agent - a quantity of it should be stored in an accessible location in each battery room (see Section C6.1 for specifics). The container should be labelled as to its contents and purpose.
- Signs - Install during a battery installation:
  - A sign near each battery identifying its name and purpose (not supplied)
  - A sign near each hydrometer and thermometer to identify the battery to which they are designated.
  - An identifying sign on the battery room door (MH Central stores Material ID Number 74-01-10).
  - An additional sign on the battery room door stating "Caution-Eye Protection Must be Worn" (MH Central Stores Material ID Number 27-10-24 for decal or 74-01-25 for Lamecoid).
- Battery Data Record - must be mounted near the battery. This is an eForm document # 1750 (if required, contact TSS Auxiliary Equipment Section for assistance).
- Safety Equipment - Aprons, safety shields and protective gloves should be permanently stored in a convenient location for easy access in emergencies.

B2.3 Battery Electrical Testing

Newly installed battery banks must be tested at various stages of the installation to:

- Identify deficiencies
- Determine satisfactory state of charge
- Establish benchmark readings

B2.3.1 Identify Deficiencies (Test 1)

1. With the battery string fully assembled, take the following initial readings.
   - voltage
   - cell resistance
   - inter-cell and inter-step resistance
   - specific gravity
   - temperature
2. Review the readings to identify any obvious anomalies and to determine the as-found condition of the battery installation. Pay close attention to the inter-cell and inter-step connection resistances. If required, take immediate corrective action.

These readings will be kept only until the battery is satisfactorily in service. Contact TSS Auxiliary Equipment Section if you have any questions or concerns.

B2.3.2 Determine Satisfactory State of Charge (Test 2)

1. After the initial readings are deemed acceptable, place the battery on an equalize, or freshening charge. Apply the following guidelines:
   - Refer to the manufacturer's instructions.
   - If the batteries are connected to station load, limit charging to the voltage rating of the station equipment (currently 2.25 volts per cell for AMD stations). This level of freshening is effective but can take much longer.
   - If the battery is not connected to the station load, use the manufacturer's recommended voltage.
   - If charging at the higher voltages recommended by the manufacturer, ensure personnel are on site to monitor the temperature and gassing of the battery. They must be available to terminate the freshening charge if problems arise. Be aware of the time and temperature limits during this charge.

     NOTE: *Batteries from storage are not at full capacity even if the voltages are near the required level. Do not rely on newly installed batteries to provide rated capacity until they have received a freshening charge.*
2. At the predetermined time of the freshening charge, measure the voltage and specific gravity of all cells.
3. Compare the readings from above to the following four criteria:
   - all cell voltages are equal (within ± 0.05 volts of the average)

- total of cell voltages equals the applied freshening voltage
- specific gravity readings are equal (within ± 0.015 of average)
- specific gravity readings are as high as the nominal SG value

If the above four criteria are true, return charger to float. If false, continue the freshening voltage and re-test at a predetermined time. This entire set of readings will be kept only until the battery is satisfactorily in service.

B2.3.3 Establish Reference Readings (Test 3)

Each MH battery installation has a unique reference value for cell resistance. The value cannot be found on any website and must be taken from the battery installation itself. The original installation readings (from test 1) cannot be used because the chemical status of a battery in storage may affect the resistance (i.e. sulphation). The freshening set of readings (from test 2) cannot be used because the excessive gassing can also affect the cell resistance. Proceed as follows to establish battery reference readings.

1. Schedule a time to take a complete set of readings on the new battery that is two weeks or more after it has been on a float charge. This will ensure the chemical properties are stable and the gas bubbles have settled to a nominal level. This complete set of readings includes:
   - voltage
   - cell resistance
   - inter-cell and inter-step resistance
   - specific gravity
   - temperature

   If the above readings are deemed acceptable, they will be used to determine the reference values for the life of the battery.
2. Attach the resulting ".cdf" file to the appropriate battery nameplate in RMS.
3. Use these same results to make the following calculations and record the attained values on the Battery Data Record installed in the battery room:
   - Reference Cell Resistance
     Add up all the cell resistances and divide by the number of cells to obtain the average.
   - Average Inter-cell Resistance
     Add up all the inter-cell resistances (not including the inter-step resistances) and divide the total by the number of readings.
   - Inter-step Resistance
     Each inter-step connector resistance may be different and can be listed individually on the Battery Data Record. If they are similar, calculate the average by adding up all the inter-step connector resistance values and dividing by the number of cells.

   Threshold limits can now be entered into the CRT-400 site templates based on these results.

B3 Battery Capacity Test

A battery capacity test, sometimes called a battery discharge test, is the most reliable method of determining the remaining capacity of a battery bank. The test is not performed regularly since repeated capacity tests can reduce battery bank life. Instead regularly scheduled battery ohmic checks are performed and their results are tracked. These checks are less intrusive, easier, safer and do not impact the life of the battery bank. The capacity test is triggered by a trend of results, from the battery ohmic checks, that indicate reduced battery capacity.

Battery capacity tests are performed on all new battery banks, by the manufacturer/distributor, according to the MH battery purchase specification.

An in-service battery capacity test, if required, will be requested by the TSS Auxiliary Equipment group. It can be requested for any the following reasons:

- Warranty investigation
- As indicated by trending ohmic checks
- End-of-life replacement priority determination
- Other suspected degradation

▲ WARNING ▲

- **Batteries give off explosive gasses. Keep open flames and sparks away from the batteries. Discharge to ground any possible static electricity.**
- **Use tools with insulated handles when working on batteries.**
- **Battery electrolyte is corrosive. Wear protective clothing while working on the batteries (including face shields, protective aprons and acid resistant gloves).**

While performing any battery maintenance, please observe the following:

- Only qualified personnel may work on the batteries.
- Ensure the availability of electrolyte neutralizing solution (Bicarbonate of Soda) prior to beginning work.
- Be aware of the presence and location of the nearest portable fire extinguisher.
- Have a battery room spill kit on site and readily available.
- Perform a Job Plan prior and post near the work area.

B3.1 Battery Capacity Test Task Description

A capacity check is performed following IEEE 450 Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.

B3.1.1 Test Length and Discharge Rate

Test Length - A battery capacity test is ideally performed for the length of time that the battery bank is required to provide its capacity (typically 12 and 16 hours for station class batteries). With 48 volt communications batteries this can be as high as 24 to 36 hours. Since a test time of 12 and 16 hours is impractical and the test need only provide an indication of capacity, it is typically performed during a regular work day.

Capacity test time is therefore normally done over 5 hours or until the specified terminal voltage is reached (unless otherwise notified). Any special test length requirements would be suggested by TSS-Auxiliary Equipment Section.

NOTE: *As an example, if a battery reaches the specified terminal voltage before the 5 hours then it has less than 100% capacity*.

Discharge Rate - For the capacity test, the discharge rate is a constant-current load based on the manufacturer's rating of the battery for the selected test length. After the test a temperature correction is applied to the capacity calculation. The discharge rate is taken from the manufacturer's literature and will be provided by TSS-Auxiliary Equipment Section.

Meaningful capacity test results require that the discharge rate remain constant. Be aware that some of the MH load boxes do not have automatic load adjustment and load through these must be continuously monitored and adjusted to maintain a constant discharge current.

B3.1.2 Initial Preparations

The battery bank must be properly prepared before the test to ensure meaningful results and to prevent any incidental problems. Be aware that some preparations need action weeks before the actual test.

Apply the following guidelines:

- Ventilation must be adequate during the test and subsequent recharge. Consider leaving the exhaust fan on continuously for the duration.
- Place the load box in a position to allow the substantial heat it creates to escape without causing damage.
- It is strongly recommended that an infrared scan be performed during the discharge and/or recharge cycle. It will identify problems not otherwise detectable.
- In anticipation of weak cells, have the appropriate leads and bypass jumpers made and ready along with the necessary insulated tools. Consider the discharge rate when sizing these leads.
- Have a Battery Acid Spill kit on site during the test.

Make the initial test preparations as follows:

1. Equalize the battery sufficiently to return it to a full state of charge.
2. Once a full state of charge is reached, return the battery to float for a minimum of 72 hours prior to the test.
3. Perform an integrity and diagnostic check on the battery and resolve any deficiencies. Unresolved deficiencies must be brought to the attention of the TSS-Auxiliary Equipment Section. They will determine if the test can go on even with the deficiencies (note deficiencies on the capacity test results page).

4. Prepare a test spreadsheet specific to the battery being tested. Readings prior to the test can be entered ahead of time. Readings during the test can be entered on paper or via a laptop. A template spreadsheet is available electronically from TSS-Auxiliary Equipment Section. A sample is shown in this document.

B3.1.3 Test Procedure

▲ WARNING ▲

Keep staff clear of battery/battery room when switching battery load (or turning the charger on or off) Battery failure is most likely to occur during such activities.

1. Isolate the battery being tested and ensure the remaining station DC system is intact.
2. Record the as-found measurements:
   - Cell resistances
   - Inter-cell resistances
   - Cell voltages
   - Battery bank voltages
   - specific gravities
   - temperatures
3. Connect the load bank to the battery.
4. Start the timing, and maintain the selected discharge rate for the duration of the test.

Every 15 minutes record the individual cell voltages and the overall battery terminal voltage. Periodically take a temperature reading of the cells and connections.

▼ Caution ▼

Take the individual cell voltage readings from the positive terminal of one cell to the positive terminal of the next cell to include the voltage drop of each inter-cell connector.

5. Continue the test until the battery bank end voltage is reached. If the specified end voltage is reached without any issues stop the test and calculate the battery capacity (see explanation on the next page).

   NOTE: *The specified end voltage is identified on the battery data record as a per-cell value. A station control battery is typically 1.75 volts per-cell which equates to 1.75 x 60 cells or 105 volts. A communications battery can have a different per-cell end voltage depending on location and criticality.*

6. Halt the test if one of the four following situations occurs.
   - (1) the temperature of a cell or a connection is abnormally high
     An infrared spot meter, thermal imaging camera or a thermometer would reveal the abnormally high cell or connection temperature (see manufacturer's literature for specific temperatures or use 45 °C as a safe limit). The test can be interrupted if a remedy results in down time of less than six minutes, and the problem occurs only once. The test can continue with time re-adjusted to compensate for the length of the outage. Otherwise it must be halted.

   NOTE: *The remedy can include bypassing a hot cell or repairing/replacing a bad connector, among other solutions.*

   - (2) one or more cells degrade to 1.0 volts or lower
     Weak cells must be removed from the test circuit (remove a 3 cell jar at 5 Volts; a 6 cell jar at 10 Volts). Bypass the cells with the pre-made jumpers and continue the test to the newly calculated battery bank end voltage. Cell removal must take no longer than six minutes and can only occur one time during the test. The timing must be re-adjusted to compensate for the lost time.

   NOTE: *If only one or two readings are left before the expected end of test, continue to the battery bank end voltage without bypassing the weak cell(s).*

   - (3) a problem occurs with the load bank test circuit
     The test can be interrupted if a remedy results in down time of less than six minutes, and the problem occurs only once. The test can continue with time re-adjusted to compensate for the length of the outage. Otherwise it must be halted.
   - (4) the five hours is up and operational priorities require that the 5 hour capacity test be halted before the end voltage has been reached.
7. Remove the load bank from the battery
8. Take and record a final terminal recovery voltage reading.
9. Recharge the battery.
10. Once the batteries are fully recharged, return them to service.
11. Calculate battery capacity using the following formula:

$$C = \left[\frac{t_A}{(t_S) \times K_T}\right] \times 100$$

Where:

C	=	percent battery capacity at 25 °C
t_A	=	actual time of test to specified terminal voltage
t_S	=	rated time to specified terminal voltage
K_T	=	correction factor for electrolyte temperature prior to start of test (see tables C3-1 & C3-2)

NOTE: *For specific temperature correction contact battery manufacturer.*

Tables C3-1 and C3-2 show typical temperature correction factors for batteries under different conditions as suggested by Enersys and IEEE 450.

Table C3-1: Batteries with 1.215 Nominal SG and 25 °C Nominal Temp. (IEEE 450)

Temp	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C	40 °C
K_T	N/A	0.684	0.790	0.873	0.942	1.000	1.045	1.090	1.134

Table C3-2: Batteries with 1.240 Nominal SG and 20 °C Nominal Temp. (Enersys)

Temp	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C	35 °C	40 °C
K_T	0.80	0.86	0.91	.096	1.00	1.03	1.05	1.07	1.08

B3.1.4 Analysis of Results

Apply the following to the results of battery capacity test.

- Batteries with 80 % or less capacity (after all factors are taken into consideration) are at or near end of life and should be considered for replacement within the year.
- Cells that reduced to 1.5 volts or less during the test are deemed failed.

Decisions on a course of action must be made in consultation with the Auxiliary Equipment Group of TSS.

C TECHNICAL INFORMATION

C1 Temperature Compensation on Vented Lead Acid Batteries

At the present time the Apparatus Maintenance Division uses vented lead acid (VLA) batteries in the majority of stationary battery installations. They are robust batteries that normally provide a 20 year life in all types of conditions. The battery industry is however promoting the use of valve regulated lead acid (VRLA) batteries which are not as robust and have a shorter life. They are also less tolerant to abuse, and typically experience an undesirable failure mode. The one major advantage VRLA batteries have is that they are a smaller size. Currently these batteries see limited use in the Corporation but there are plans for more (likely on the communications side).

The intent of adding a temperature compensation factor to the float voltage of station class VLA batteries is essentially to prepare for the installation of VRLA batteries. Use of temperature compensation on present installations has a small benefit but its introduction now will shorten the learning curve for the eventual necessity of temperature compensation on future VRLA installations.

The MH formula to calculate a temperature compensation factor for a station class VLA battery is as follows:

$$\Delta V = \Delta T \text{ x } 0.0025 \text{ V/°C x no. of cells}$$

Where:

ΔV	=	the change in voltage related to the battery temperature, the temperature adjusted voltage = Rated float voltage + ΔV
ΔT	=	25 - battery temp (°C), or the change in temperature from the set point of 25 °C
0.0025V/°C	=	the voltage change per degree Celsius change from the set point of 25 °C

NOTE: *The value of 25 °C is a conservative average of all manufacturers' parameters.*

Example: A 60 cell battery installation operating at 40 °C.
The ΔT at this installation will be 25 - 40 or (-15).

Applying the formula: $\Delta V = \Delta T \text{ x } 0.0025 \text{ V/°C x no. of cells}$

ΔV = (-15) x 0.0025 x 60

ΔV = (- 2.25)

The temperature adjusted voltage for this installation will be:
Float voltage (133.2) + ΔV (-2.25) or **130.95 Volts**

Limits are applied to the compensation settings for the following reasons.

- The high temp/low volt limit on 125 and 48 volt systems is set by the battery manufacturer
- The low temp/high volt limit on 48 volt systems is set by TSS at 0 °C)
- The low temp/high volt limit on 125 volt systems is set by the Station Design equipment limit of 135 volts

Compensation setting limits:

48 volt systems:	Max temp	=	40 °C @ 52.40 V
	Min temp	=	0 °C @ 54.80 V
125 volt systems:	Max temp	=	40 °C @ 130.95 V
	Min temp	=	13 °C @ 135.00 V

C2 Accessories and Supplies

Table C2-1 is a table of parts and supplies commonly used when working with batteries and any associated equipment.

Table C2-1: Accessories and Supplies

Item	Material ID Code	Description
Battery - Emergency spare battery		Local distributor or designated spare Contact TSS - AEG
Battery - Radio Standby		Local distributor. Contact TSS-AEG
Battery Flame Arrestor Caps	03-26-65, 03-26-67, 03-26-68 (AMD Shop Stores)	Varta small quantities - AMD Stores Others, and large quantities - Contact TSS-AEG
Battery Inter-cell Connectors		Contact TSS-AEG
Battery Shipping Container (standard)	04-55-38 (Central Stores)	31”H x 48”L x 40”W. I.D. For batteries up to 20" in height. Kit includes all instructions, labels and packing material
Battery Shipping Container (large)	43-11-90 (Central Stores)	36”H x 48”L x 40”W. I.D. For batteries over 20" in height. Kit includes all instructions, labels and packing material
Waste Battery Labels (Alkali)	43-38-04 (Central Stores)	Labels as included with above kit
Waste Battery Labels (Acid)	43-38-03 (Central Stores)	Labels as included with above kit
Battery Shipping Container ‘This side up’ labels	99-39-28 (Central Stores)	Red "UP" arrows
Battery Shipping Container Hazardous Materials Labels (class 8 corrosive)	99-39-30 (Central Stores) 99-51-23 (Central Stores)	Adhesive label Placard for truck
Battery Data Record form		eForm 1750, TSS-AEG will assist with filling in document
Battery Commissioning Report Form		eForm 325a Corresponds to commissioning procedure
Bill of Lading Form		eForm 0467 For transport of waste batteries (see Hazardous Goods manual for details on filling form)
Battery Operating Checklist		eForm 0414 - Obsolete form
Grease - No-oxide	12-46-06 (Central Stores)	For battery connections (conductive) Use manufacturer supplied product preferably. Follow manufacturer application rules.
Grease - Dow #4	20-95-88 (Central Stores)	For battery tops. *Not typically required. On special request only
Hydrometer c/w 3 tips	91-77-25 (Central Stores)	Includes three tips for use in tight locations or on cells with small vent holes
Hydrometer Holder	05-13-56 (Central Stores)	For wall mounting hydrometers
Hydrometer	31-69-96 (Central Stores)	For station class flooded batteries. One required per battery bank
Neutralant - Boric Acid		For neutralization of Ni-cad electrolyte (Potassium Hydroxide 20-30%) Available at most drugstores
Neutralant - Bicarbonate of Soda		For neutralization of Lead-acid electrolyte (dilute sulphuric acid) Available at any grocery store

Table C2-1: Accessories and Supplies (continued)

Item	Material ID Code	Description
Neutralant - Light Soda Ash	55-95-43 (Central Stores)	For neutralization of Lead-acid electrolyte (dilute sulphuric acid) in 50 lbs bags Also available at Stanchem (Wpg)
Paint - Acid Resistant		For battery racks and floors. Cloverdale ‘Clovamastic’ 83110 epoxy mastic paint Available at Local paint suppliers
Paint - Safety Tread	53-31-30 (Central Stores)	
Protective Rubber Gloves	32-20-30 (Central Stores) 32-20-23 (Central Stores) 32-20-25 (Central Stores)	Neoprene gloves Disposable polyethylene gloves Nitrile gloves
Protective Rubber Boots	10-11-50 (Central Stores)	Neoprene boots
Protective Face Shield	73-74-05 (Central Stores) 73-74-10 (Central Stores) 73-74-20 (Central Stores)	Replacement head gear Replacement shield Hard hat shield
Acid Resistant Apron	02-74-05 (Central Stores)	For protection of clothes
Sign - Eye Protection	74-01-25 (Central Stores)	"Caution - Eye protection must be worn"
Sign - Battery Room	74-01-10 (Central Stores)	"Battery Room – No Smoking or Open Flames"
Thermometer	47-51-74 (Central Stores)	Alcohol, Celsius scale -30 to +55 degrees
Distilled Water	86-92-05 (Central Stores)	5 gallon jug
Water Filler Nozzle "Activator Dry Charge Battery Filler"		Filler nozzle to attach to tubing for easier flow when topping up cells Available at Prairie Battery in Winnipeg Model 604
Battery Acid (Electrolyte) Spill Kit		Available at various locations in Manitoba Hydro or contact MEP Environmental, 68 Paramount Rd. at 204-632-4118
Electrolyte Spill Cleanup Pail	06-92-72 (Central Stores)	Plastic pail for waste generated from cleanup as per MH Hazardous Materials Management Handbook
Eyewash - Maintenance Record	27-10-42 (Central Stores)	Generic Eyewash maintenance tag to hang on eyewash
Eyewash - Sterilizing Agent	75-15-60 (Central Stores)	Sodium Metabisulphite for cleaning pure water type eyewash (Encon yellow tub)
Eyewash - I.D. Labels	27-10-40 (Central Stores)	Eyewash Station decal
Eyewash - Fendall Pure Flow 1000		Portable eyewash with saline solution and 15 min flow. Fendall p/n 32-001000-0000 Available from: Levitt Safety, Acklands and other safety supply outlets
Eyewash - Replacement Saline Water Cartridge		Standard cartridge replacement. Fendall p/n 32-001050-0000 NOTE: *Sterile or high humidity cartridges are not necessary and are more expensive.*
Eyewash - Replacement Eyewash Tamper Stickers		Fendall p/n 32-001017-0000 Available from: Safety supply outlet or contact TSS-AEG

C3 Taking Hydrometer Readings with Bulb-type Hydrometer

Each battery bank is equipped with a dedicated bulb-type hydrometer. It is only for use on its designated battery to avoid cross contamination. This hydrometer is meant as a backup to the Anton Paar DMA 35 or DMA 35n portable density meter. It can also be used to check the calibration of the Anton Paar device, and for spot checks when it is not available.

The sampling tube of the bank hydrometers can be cut short to bring the end of the tube to the minimum electrolyte level. This will reduce the tendency of the hydrometer to throw electrolyte when moving from cell to cell or when taken from the holder. It also gives an indication of low electrolyte levels in opaque cells.

▲ WARNING ▲

- **Batteries give off explosive gasses. Keep open flames and sparks away from the batteries. Discharge to ground any possible static electricity.**
- **Use tools with insulated handles when working on batteries.**
- **Battery electrolyte is corrosive. Wear protective clothing while working on the batteries (including face shields, protective aprons and acid resistant gloves).**

While performing any battery maintenance, please observe the following:

- Only qualified personnel may work on the batteries.
- Ensure the availability of electrolyte neutralizing solution (Bicarbonate of Soda) prior to beginning work.
- Be aware of the presence and location of the nearest portable fire extinguisher.
- Have a battery room spill kit on site and readily available.
- The hydrometer must be in serviceable condition. An inspection should include checking the top, bottom, and sides of the hydrometer bulb for damage. The inside of the float should also be checked for signs of moisture (i.e. wet paper scale).

  NOTE: *Moisture inside the float will take the hydrometer out of calibration which will require that the hydrometer be replaced.*
- Take hydrometer readings very carefully and avoid dripping or splashing acid on the exterior of the cell. Wipe up any acid immediately.
- Avoid taking hydrometer readings after equalizing. Large amounts of gas, present during equalize, will affect the accuracy of hydrometer readings.
- Some cells have electrolyte withdrawal tubes extending down into the electrolyte. Use them only when stratification of the electrolyte is likely and only to withdraw electrolyte from the cell. Electrolyte must be returned to the cell through the filler vent (to prevent overflow).
- If stratification of the electrolyte in the cell has occurred, a more accurate specific gravity reading is possible by first filling and then emptying the hydrometer several times to promote mixing.
- Perform a Job Plan prior and post near the work area.

Take hydrometer readings as follows:

1. Hold the hydrometer in a vertical position and draw in enough electrolyte to suspend the float (it should not touch either the top or the bottom of the float barrel).
2. Note whether a large temperature differential exists between the electrolyte and the hydrometer. If it does, fill and empty the hydrometer several times to equalize the temperature.
3. Wait for any bubbles that appear to rise to the surface. If bubbles cling to the float bulb or the sides of the hydrometer, clean the hydrometer with soap and water before taking any readings.
4. With all pressure released from the bulb, hold the hydrometer at eye level (approximately the same as the electrolyte) and note the scale reading at the exact point where the float scale emerges from the electrolyte (see Figure C3-1).
5. Return sample electrolyte taken from a particular cell to the same cell.

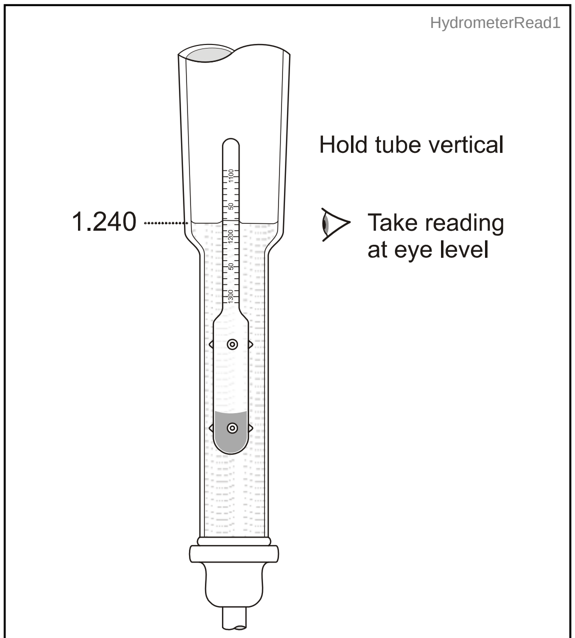


Figure C3-1: Reading a Hydrometer

C4 Thermometers

Mercury filled thermometers are not suitable for use in batteries. Mercury is a conductor and should any escape from the thermometer the mercury could cause shorting of plates. Use only alcohol filled type of thermometers for measuring cell temperatures.

NOTE: *Never use thermometers with a silver coloured tip. This metallic cover will contaminate batteries.*

C5 Battery Vent Caps

Two types of battery caps are presently in use on Manitoba Hydro batteries.

- the flame arrester vent cap (ceramic caps)
- the standard vent cap (shipping plugs)

C5.1 Flame Arrester Vent Cap

Flame arrester vent caps virtually eliminate the possibility of igniting the hydrogen gas within the cell from an external source. All new batteries must have flame arrester caps installed while in service.

C5.1.1 Removal and Installation

Flame arrester vent caps must be removed and installed by holding the lower portion of the cap (see Figure C5-1). The ceramic vent part of the cap (upper part) is quite fragile and must be handled with care.

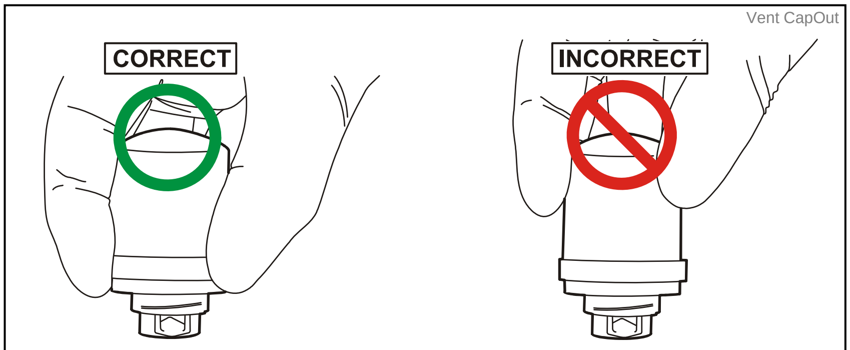


Figure C5-1: How to Remove/Install Flame Arrester Caps

C5.1.2 Repair

The ceramic portion of the vent caps can crack or break. If this happens they become ineffective. A repair is possible however if the break is clean and the crack can be completely sealed. To repair, apply epoxy glue in the crack as needed and allow the glue to cure (12-24 hours). Do not re-install the cap until the glue has cured.

C5.1.3 Replacement

To order replacement flame arrester vents caps, contact the Auxiliary Equipment group of AMD-Technical Support Services.

C5.1.4 Maintenance

Proper flame arrester vent cap maintenance only requires that the ceramic vent part of the cap be washed if it is clogged or appears wet with electrolyte. In no case should the ceramic vent be painted, varnished or greased.

Wash ceramic vents in clean water only (preferably hot). Once clean, shake out as much water as possible and allow time to air dry before re-use. Do not use any cleaning compounds or neutralizing agents.

C5.2 Standard Vent Caps (Shipping Plugs)

Most cells are shipped with standard vent caps, sometimes called shipping plugs. They must not be discarded since the caps will be needed when the battery is removed or when extensive maintenance is required.

▲ WARNING ▲

An explosion hazard exists around battery cells fitted with standard vent caps. An explosive mixture of hydrogen gas is likely to exist beneath the caps, particularly after an equalize charge. Exercise prescribed safety precautions.

Proper maintenance of the standard vent caps requires that their ports be kept free of all obstructions (dirt, grease, etc.). Washing is not normally required; however, should the vents become partially blocked, wash in clean water only (preferably hot). Once clean, shake out as much water as possible and allow time to air dry before re-use. Do not use any cleaning compounds or neutralizing agents.

C6 Battery Electrolyte Spills

When moving batteries or when the potential of an electrolyte spill is increased (i.e. while performing battery capacity test), a spill kit should be on site. Every AMD work centre should have access to at least one battery acid spill response kit. New kits are available from MEP Environmental Supply (see Section C2 of this standard for more information).

In general, the strategy for managing releases of battery electrolyte is to absorb as much of the electrolyte as possible and then to neutralize the residue. A procedural flow chart with complete information on dealing with releases of battery electrolyte is available in:

- each battery acid spill kit
- each battery shipping container
- on mPower's Corporate Safety Website:
  http://fa.hydro.mb.ca/csh/we/Documents/battery%20and%20spill.pdf
- in Part 4 - Section 2 of the MH Corporate Safety and Health Hazardous Materials Management Handbook:
  http://fa.hydro.mb.ca/csh/ppt/Documents/Hazardous%20Materials%20Handbook%20Part_4.pdf

Become familiar with its content and follow the prescribed steps.

C6.1 General Information

Lead acid batteries contain sulphuric acid as the electrolyte. Its specific gravity (1.215 to 1.300) or concentration and its quantity will vary with the type of battery. Precautions must be taken when handling this electrolyte since the sulphuric acid in it is highly corrosive. The electrolyte reacts with many other chemicals and upon exposure can cause severe burns to the skin and damage to the eyes.

The spill kit powder (Kolorsafe NPS 440001), is used in the standard battery acid kit to neutralize the residue of sulphuric acid.

A Nickel-Cadmium battery contains potassium hydroxide as the electrolyte. This is an alkali or caustic base solution and requires Kolorsafe NPS 450001 (contact MEP to order) to neutralize the residue of potassium hydroxide. The battery banks in the emergency mobile trailers are made up of Nickel-Cadmium batteries.

C6.2 Safety Checks

Before cleaning any spilled electrolyte, please observe the following:

- Wear the required safety equipment supplied in the kit.
- Examine the battery area for other hazards.
- Remove any sources of flame of spark.
- Remove any metallic jewellery to prevent accidental short circuits.
- Insulate all tools (any object brought near the battery must not have exposed metallic parts).
- Make sure to discharge static charges by touching a grounded metallic object prior to working on the battery.
- Ensure the lighting and ventilation systems are operational.
- Clean all ventilation filters where applicable.
- Ensure there is access to plenty of clean water.
- Amend the Job Plan and keep the document in a conspicuous location
- Perform an integrity check on the eyewash station if not already done and record its completion on the Job Plan. Complete and hand in the Job Plan to meet the requirement of the Corporate Safety and Health document titled "*Emergency Eyewash Stations and Showers: Installation and Maintenance*".

C7 Handling Waste Batteries

The following information is a brief outline of the procedures and requirements for the handing of waste batteries from service site to Waverley Service Centre Central Stores Investment Recovery. The categories discussed include:

- Disposal of Waste Batteries
- Transportation and Documentation Requirements

For complete and up-to-date information refer to the TDG Regulations, or Part 4 of the MH Hazardous Material Management Handbook, available on mPower:
http://fa.hydro.mb.ca/csh/ppt/Documents/Hazardous%20Materials%20Handbook%20Part_4.pdf

C7.1 Disposal of Waste Batteries

The preferred method used by Manitoba Hydro to dispose of station batteries that are no longer suitable for service is to ship them to Waverley Service Centre Central Stores Investment Recovery Department. At this location the expired batteries are stored and later sold as scrap to local metal recyclers.

C7.2 Transportation and Documentation

When waste station batteries must be shipped, the preferred mode of transportation is with a Corporate vehicle (excluding a Corporate passenger car). Please observe the following when shipping batteries complete with acid or alkali electrolyte.

- Shippers of waste batteries (transporting or documenting) must have a current TDG certification and must also carry proof of certification.
- Shipments of multiple batteries must be in the battery shipping containers available from Central Stores (04-55-38 for batteries up to 20” in height, and 04-55-39 for batteries over 20”).
- Shipments to Central Investment Recovery require a Bill of Lading. Manitoba Hydro has an Equivalency Certificate SU10071 for transporting wet filled acid or alkaline batteries that gives authorization to ship batteries in compliance with the conditions of the certificate instead of the requirements of the TDG Regulations for means of containment. Ensure that the certificate accompanies the Bill of Lading, and that the statement: "*Dangerous Goods Certificate No. SU 10071 - by road or railway vehicle or by ship on a domestic voyage - expiry date: August 31, 20xx*" from the Equivalency Certificate is written on the Bill of Lading. This certificate expires every two years. The newest version is available on the Corporate Safety website.
- Pack the batteries according to the instructions supplied with the battery shipping container.
- Shipments of only one or two cells, can be placed in 6 mil plastic bags and then in a plastic pail (instead of using a battery shipping container). Waste Battery labels and Bill of Lading are still required.
- The waste residue of a battery spill cleanup must be placed in bags provided in the Battery Acid Spill Kits and then in a rigid container (i.e. plastic pail or battery shipping container). If less than 5 kg, Waste Battery labels and Bill of Lading are required. If more than 5 kg, then Waste Battery labels, Bill of Lading and Waste Manifest are required.
- A Waste Manifest is not required when shipping batteries (and no other battery waste material) to Central Investment Recovery because all waste batteries are sent to a recycler for recycling.
- A Waste Manifest is required when shipping residue of a battery spill greater than 5 kg. The statement "In case of a Dangerous Goods Emergency call Canutec (613) 996-6666" must be on the document.
- A Bill of Lading will always be required. Examples of a Bill of Lading and a Waste Manifest are available in Part 4 of the MH Hazardous Materials Management Handbook:

  http://fa.hydro.mb.ca/csh/ppt/Documents/Hazardous%20Materials%20Handbook%20Part_4.pdf

  Once complete the Bill of Lading document(s) can be reviewed, and advice given, by contacting the Corporate Safety and Health Dangerous Goods officers prior to shipping.

C8 Torque Specifications

The following connector torque values have been compiled for your convenience. The manufacturer's instruction manual specific to each installation has the latest updates to torque values.

A torque check is not a regular practice and should only be performed on installation or if measurements indicate the need for remedial action.

C8.1 Inter-cell Connector Torque

The inter-cell, inter-tier and inter-step connection resistances have a measurement limit that must be maintained throughout the life of the installation. These limits are stated on the appropriate battery data record which is mounted near the battery bank. When these connection resistances go out of tolerance, apply the following corrective action:

> *Re-torque the connections to the specified value and re-measure the resistance. If more than ½ turn was required to regain the specified torque value, or if re-torquing did not resolve the resistance problem, then disassembly and cleaning of the connection is required.*

If disassembly for cleaning is required please note the following:

- All tools must be insulated.
- All safety procedures and policies must be followed.
- The electrical contact part of the battery posts must be polished clean (using only a brass or plastic bristle brush) to remove any lead dioxide and acid.
- The electrical contact part of the inter-cell, inter-tier and inter-step connectors, the nuts and bolts must be free of lead dioxide and acid (clean with a brass or plastic bristle brush).
- The manufacturer's instructions must be consulted before applying any grease since some manufacturers do not require the application of grease.
- The no-oxide grease will affect the torque value of the connector bolts if the bolts have grease on the threads. The connector bolts must be free of grease before torquing.
- The cell post must not deform when torquing. Stop the procedure if any such deformation is observed.
- When torquing is complete, an inter-cell resistance check must be performed using the Alber CRT-400 battery analyzer.
- Caution must be used when tightening hardware on cells with flag type terminals. Since the flag terminal is a welded connection, it is best to use two wrenches to minimize the stress on the weld.

C8.2 Table of Torque Values

Cell Make and Model	Bolt Size	Torque		
Enersys / Varta	**mm**	**Nm**	**in lbf**	**ft lbf**
Vb 611 to Vb 428	M 6	7.5	66	5.5
Vb 12101 to Vb 4118	M 8	15.0	132	11
Vb 12142 to Vb 6159	M 8	12.0	106	8.85
Vb 2305 to Vb 2421+	M 10	25.0	222	18.4
4 OPzS 200 to 24 OPzS 3000	M 10	25.0	222	18.4
4 OPzS 200 to 24 OPzS 3000	M 12	18.0	160	13.3
Powersafe SBS 15-60	M 6	3.95	35	2.91
PowerSafe C, D, E 3CC-5M, 7M, 9M	1/4 -20	8.0 - 8.5	70 - 75	5.83 - 6.25
WX-15, 17		13.5	120	10
BAE				
BAE Ogi and OPzS	M10	22	195	16.2
C & D				
KT, KCT, LT, LCT, DU, DCU, DCU-13, 15, 17, KC(R)-5, 7, 9, 11, 13		12.5	110	9
3DCU-5		8	70	6
3XDJ-11		12.5	110	9
TEL 12-105F, TEL 12-150F		12.5	110	9
KCR-21	with copper inserts	18	160	13.3
XTJC-11		18	160	13.3
3DJ- 110, 155, 200		12.5	110	9
Exide				
3CC-5,7,9		8	70	6
GNB				
2-ETC-7		8.5	75	6.25
ETC-13		11.25	100	8.3
FIAMM				
SD-11		11.25	100	8.3
MIDAC				
2 OPzS 100 to 24 OPzS 3000		23 - 25	204 - 222	17 - 18.4
All NI-CAD's (with threaded stud posts)				
Bottom nut	10 mm post	3.5	30	2.5
Top nut (use two wrenches when torquing top nut)	10 mm post	11.25	100	8.3
Bottom nut (cell with metal case)	20 mm post	11	95	8
Top nut (cell with metal case, use two wrenches when torquing top nut)	20 mm post	28	250	21
Bottom nut (cell with plastic case)	20 mm post	4.5	40	3.33
Top nut (cell with plastic case, use two wrenches when torquing top nut)	20 mm post	28	250	21

C9 Definitions

Automotive Radio Standby Battery Any automotive type battery used for emergency supply of V.H.F. radio systems. The radio is usually used as the battery charger. The normal life rating of these automotive batteries when used in constant float applications is four years.

Cranking Battery All automotive or heavy duty batteries used for engine cranking of standby or prime power diesel generators. The normal life ratings of a standard SO' or 70 type battery in diesel applications is approximately four years.

Grids The main structure of a cell plate which acts to hold together the active material of a cell. The following diagram (Figure C9-1) shows the grids of a cell with some active material missing.

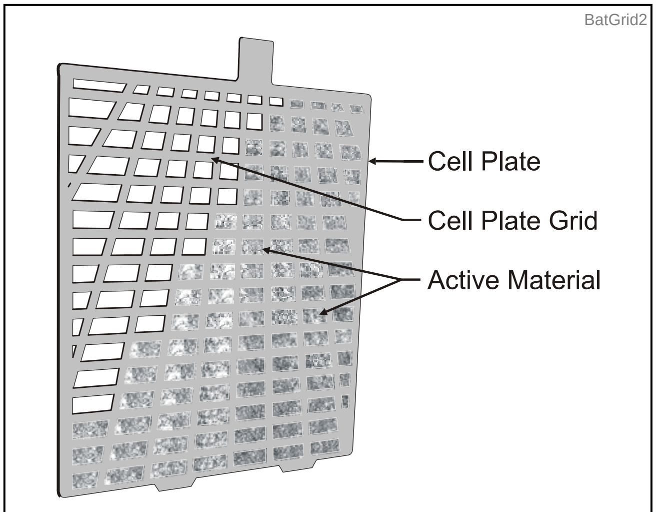


Figure C9-1: Individual Cell Plate Showing Grid

Lead Acid Cell A lead acid cell is any cell which uses sulphuric acid as an electrolyte and lead as an active ingredient. The active materials on the plates are lead dioxide on the positive plates and sponge lead on the negatives. Lead antimony, lead calcium, and lead selenium cells (also called low-antimony) are all lead acid cells. The chemical reaction within the cells is as follows: During charge, lead sulphate is converted to lead on the negative plate and to lead dioxide on the positive plate. The sulphate liberated in this reaction combines with hydrogen from the water to form sulphuric acid at both plates. When lead sulphate is not readily available for this reaction, the current decomposes the water to form hydrogen at the negative plates and oxygen at the positive plates and the cell starts to gas. On discharge the opposite effect takes place and the lead and lead dioxide form lead sulphate. Since during charge the specific gravity (SG) of the electrolyte increases as sulphuric acid from the plates is added to the water in the electrolyte, SG is an indicator of state of charge of lead acid cells. Also, because of the SG change of the electrolyte when discharging, the freezing point will also change. Fully discharged lead acid batteries will freeze at approximately the freezing point of water.

Lead Antimony Cell Any cell which uses more than 3 % antimony content in the grid structures of the cell plates. The antimony is used as an alloy to strengthen the grids. The high antimony content has certain disadvantages such as, higher water usage, increased maintenance, and a shorter life. The main advantage of antimony cells is that they will withstand cycling. Antimony batteries are now used for electric vehicle and floor maintenance equipment applications. Antimony batteries normally have a life span of 15 years.

Lead Calcium Cell Any cell which uses calcium in the cell grid structures to strengthen the cell plates. The advantages of lead calcium over lead antimony are less water usage, less maintenance and longer life (a 20 year rating for station type cells). Lead calcium cells do not tolerate repeated discharges and have a life of only 75 discharge cycles.

Lead Selenium Cell Any cell which uses selenium in the cell grid structures to strengthen the cell plates. These types of cells can have a low percentage of antimony in the grids and are sometimes called low antimony cells. In general these cells should be treated the same as lead calcium cells. The advantages of lead selenium over lead antimony are less water usage, less maintenance, and longer life (station type cells are rated at 20 years). Lead selenium cells also have an advantage over lead calcium in that they can be cycled.

Ni-Cad Cell Any battery which uses nickel and cadmium as active materials, and potassium hydroxide as an electrolyte.

Chemical Reaction - The electrolyte of a Ni-Cad is an aqueous solution of potassium hydroxide (sometimes with the addition of lithium hydroxide) having a specific gravity of 1.190 to 1.200. The positive active material is a nickel oxide (or hydroxide). The negative active material is cadmium. The charge-discharge reaction is a transfer of oxygen (or OH groups) from the positive to the negative plate during discharge and from the negative to the positive plate on charge. The composition of the electrolyte does not vary appreciably throughout the cycle of charge and discharge; therefore its conductivity and specific gravity (SG) remain constant. This is why for Ni-Cad's an SG check is not an indicator of the state of charge. The absence of charge has the advantage of no change in the freezing point of the electrolyte when discharged, thus the Ni-Cad cell can be stored in cooler temperatures when discharged. Although normal electrolyte will still freeze, special low temperature electrolyte is available if freeze protection is desired.

Sealed Lead Acid Cell Any lead acid cell that does not allow normal venting of internal gasses to the atmosphere. Sealed cells normally operate under a slight pressure which promotes the recombination of gasses given off in the charging process. Under normal conditions oxygen and hydrogen gasses given off due to the electrolysis of the water in the electrolyte will recombine internally without the need to vent the gasses to atmosphere. Under abnormal conditions (such as high voltage) the recombination process cannot keep up to the generation of gasses and the pressure relief cap will operate. Sealed cells use an immobilized electrolyte or gelled electrolyte which cannot be accessed for hydrometer readings. The vent cap from a sealed cell must never be removed. Normal sealed battery life ratings are anywhere between 5 and 20 years, depending on the battery type.

MAINTENANCE TASK TEMPLATE

No. BAT002

Batteries - Station Class - Valve Regulated Lead Acid
Station Standby

Tasks	Triggers			
	Not Critical	Low	Medium	High
Integrity Check	3 months	3 months	3 months	3 months
Battery Ohmic Check	3 months	3 months	3 months	3 months

Integrity Check	Visual inspection of cells
	Visual inspection of Battery Room
	Functional check of heaters, thermostat, and fan operation
Battery Ohmic check	Battery Ohmic Test

Track & Trend	Battery Ohmic Test	Micro-ohms

No.	Date	Revision	AMR Specialist	Eq. Specialist	Insul. Eng.	AMR Eng.	
4	2010 04 13	Changed Conductance Check to Battery Ohmic Check	CM	RWE		GV	Original signed by G. A. Verch 2010 04 15
3	2002 08 21	Changed the conductance check trigger from 6 months to 3 months. Changed header.	GW	ARB		DW	
2	2001 08 02	Removed infrared scan. Changed diagnostic check to conductance check	GW	ARB		DW	
1	2000 07 05	Added criticality levels	JC	ARB		DW	

MAINTENANCE JOB DESCRIPTION

Family - BAT002
Equipment - VALVE REGULATED LEAD ACID (VRLA) BATTERIES
Make/Model – All

TASKS

Integrity Check

The integrity check is performed to ensure the integrity of the components and basic functions of the battery bank and its peripherals. This is mainly a visual inspection of the batteries along with some functional checks of associated equipment. The batteries will remain in service during the check.

Before working in the battery room ensure that there is a clear path to the eyewash station and ensure the eyewash station receives an integrity inspection. Identify the presence and location of the dedicated fire extinguisher.

Ensure that a job plan has been completed prior to starting the following checks.

Integrity Check Task Description

Please contact TSS - Auxiliary Equipment Group if any of the following conditions are excessive or questionable.

A. Visual inspection of battery:
- Cracked jars (gelled electrolyte leaks)
- Swollen jars
- Post seal leakage and/or corrosion
- Battery rack corrosion (if severe, remedial action is required)
- General cleanliness of batteries (clean as required with a water soaked rag)

B. Visual inspection of Battery Room:
- Ensure the appropriate Battery Data Record is present and properly filled out. If missing or in error, make arrangements to have it repaired or replaced. No corrective is necessary.
- Ensure the battery room is clean and free of clutter.
- Ensure there is a clear path to the eyewash station.
- Ensure there is a dedicated CO_2 fire extinguisher available for use in the battery room.
- Ensure the battery room is properly identified. (CIIC# 74-01-10)
- Ensure each battery bank has an identifying sign.
- Ensure the battery cells are numbered.

NOTE: *Refer to the Station Design Department Battery Room Design Standard for further battery room information.*

C. Other Inspections:
- Functionality of heaters and thermostats
- Functionality of exhaust fan and timer

INTEGRITY CHECK
BATTERIES
Valve Regulated Lead Acid (VRLA)
All Makes/Models
Template no. BAT002

Station: ___________________ **Battery Designation:** _____________ **Date:** _______________

Other Information: ____________________________

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to starting the check.

		Complete	Corrective Required
A.	**Visual Inspection of Battery**		
	- Cracked jars, leaks	______________	________________
	- Swollen jars	______________	________________
	- Post seal leakage and/or corrosion	______________	________________
	- Battery rack corrosion	______________	________________
	- Cleanliness of batteries	______________	________________
B.	**Visual Inspection of Battery Room**		
	- Battery data record sheet present	______________	________________
	- Battery room clean	______________	________________
	- Path to eye wash station	______________	________________
	- Fire extinguisher	______________	________________
	- Battery room signage	______________	________________
	- Battery bank identifying signs	______________	________________
	- Battery cell number labels	______________	________________
C.	**Other Inspections**		
	- Functionality of heaters and thermostats	______________	________________
	- Functionality of exhaust fans and timers	______________	________________

NOTE: *This form and its information are intended for your immediate reference only. After entering required correctives into RMS, this check list may be discarded.*

Battery Ohmic Check

The battery ohmic check on Valve Regulated Lead Acid batteries (VRLA) is performed at the same time and frequency as the integrity inspection. This test is used to help diagnose the health of the battery.

VRLA batteries are a sealed, recombinant design and specific gravity readings cannot, and should not, be taken.

Before working in the battery room ensure that there is a clear path to the eyewash station and ensure the eyewash station receives an integrity inspection. Identify the presence and location of the dedicated fire extinguisher.

Ensure that a job plan has been completed prior to starting the following checks.

Battery Ohmic Check Task Description

Tools required: Alber CRT-400 Battery Analyser

For the appropriate method of testing, follow the Manitoba Hydro Application Guide for Battery Ohmic Measurements. This document is supplied with the CRT-400 instrument and is also available on the TSS Website.

1. Using the Cellcorder, measure and record the following:
   - Cell/jar internal resistance
   - Intercell/interstep resistance
   - Cell/jar voltage
2. Compare the readings to the pass / fail parameters for this test in the application guide. If any of the test results fall outside the threshold values, make sure the results are valid before taking further action.
3. Attach the readings (in the form of a .cdf file) to the appropriate nameplate in RMS

Any issues can be reported to the TSS - Auxiliary Equipment group and should be recorded in RMS via a failure report.

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
2	2011 04 08	Updated the task template as per revision detail, matched document header to task template added comment to Main Contact Check	All	DJD	GV
1	2008 09 09	Technical and formatting changes, as described in the Maintenance Standard Alert dated 2008 09 09	All	DJD	DW
0	2005 03 02	New Maintenance Standard	---	DJD	DW

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Circuit Breakers - Air Blast (Air Operator) General Electric AT				
	Triggers			
Tasks	Not Critical	Low	Medium	High
Integrity Check	12 months	12 months	12 months	12 months
Functional Check	< 1 operation / 24 months	< 1 operation / 24 months	< 1 operation / 24 months	< 1 operation / 24 months
Air System Check	60 months	60 months	60 months	60 months
Insulation Check	120 months	120 months	120 months	120 months
Mechanism Check	200 operations / 120 months	200 operations / 120 months	150 operations / 84 months	100 operations / 60 months
Main Contact Check	FAO's / ASO's / 15 years	FAO's / ASO's / 15 years	FAO's / ASO's / 15 years	FAO's / ASO's / 15 years

6	2010 12 10	Increased frequency of Integrity Check from 6 to 12 months	CM	DJD		GV	Original signed by G. A. Verch 2011 01 30
5	2004 04 29	Changed valve check trigger from 100 ops to 200 ops / 120 months. Renamed Valve Check to Mechanism Check. Added 15 year criteria to Main Contact check trigger	CM	DJD		DW	
4	2001 11 20	Added the timing / motion tests to the main contact check.	GW	DJD		DW	
3	2001 07 05	Changed Diagnostic to Main Contact Check. Removed infrared scan.	GW	TR		DW	
2	2000 05 23	Add ASO's & Visual Insp	BC				
1	2000 04 11	Add pressure relief valve change		WD		DW	
No.	Date	Revision	AMR Specialist	Tech Supp Services	Insul. Eng.	AMR Eng.	

A2 Integrity Check

The Integrity Check is performed to ensure the integrity of the basic functions of the circuit breaker. It consists primarily of a visual inspection of the equipment and it is done with the circuit breaker in service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A2.1 Integrity Check Task Description

A2.1.1 Circuit Breaker Inspection

1. Foundation

   Inspect the circuit breaker's foundation for signs of deterioration and movement.

2. Grounds

   Inspect the frame grounds to ensure that there are two connections diagonally opposing each other. The control cabinet must also be grounded in one location. All ground connections must be tight and the conductor free from damage.

3. Air Leaks

   Listen for air leaks at each pole base and all associated piping.

4. Paint Condition

   Check the condition of the paint to ensure that the circuit breaker is not rusting.

5. Primary Bus Tension

   Visually inspect the primary bus expansion connections to ensure that the tension is adequate for all weather conditions.

6. Primary Connections

   Visually inspect the primary connections for missing hardware. Check that hardware connections appear tight.

7. Insulator Condition

   Visually inspect all support and air column insulators for damage and/or contamination.

8. Air Lines

   Visually inspect all air lines from the control cabinet to each pole, inter-pole and inter-phase. Ensure that they are adequately supported and are not damaged.

9. Wiring

   Visually inspect all wiring from the control cabinet to each pole and inter-phase. Ensure that they are adequately supported and are not damaged.

A2.1.2 Main Control Cabinet Inspection

1. Cabinet Condition

   Inspect the internal and external condition of the control cabinet. This includes inspecting the condition of the doors, hinges, latches and weather stripping.

2. Cabinet Ground

   Inspect the control cabinet ground for conductor tightness and conductor damage.

3. Cabinet Cleanliness

   Inspect the interior of the control cabinet to ensure that it is clean.

4. Position Indicator

   Inspect the position indicator to ensure that the linkage is intact and indicating correctly.

5. Humidity Indicator

   Inspect the humidity indicator to ensure that it is blue in colour. The moisture sensitive material inside the indicator is normally blue (indicating dry) and will turn pink when the specified relative humidity has been reached. There are three graduated segments to indicate 20, 40 and 60 % relative humidity of the air system.

   Consider any segment turned pink, or with an indistinct border, an air system Functional Failure. The moisture level of the air system should be checked, and the humidity indicator changed.

6. Air Pressure Gauges

   There are three air pressure gauges, one inside and two on the front of the cabinet. These are for indication of the input air system, operating and the insulating air pressures.

   Check the air pressure gauges and ensure that they are indicating as specified

   – Input Air System Pressure Gauge: 890 to 910 psi
   – Operating Air Pressure Gauge: 345 to 355 psi
   – Insulating Air Pressure Gauge: 58 to 62 psi

7. Air Leaks

   The air system uses a 350 psi regulator that constantly purges air from a bleed orifice on top. Listen carefully to ensure that this is the only audible air leak on the air system.

8. Heater Current

   Measure the current of the heaters in the control cabinet. These values must be ±5% of the value indicated on the circuit breaker schematic. Consider the failure of a heater inside the control cabinet as a Functional Failure.

9. Thermostat Operation

   Check that the thermostat in the control cabinet is operating correctly as indicated on the circuit breaker schematic. Consider the failure of the thermostat inside the control cabinet as a Functional Failure.

10. Operation Counter Reading

    Record the value of the operation counter. Enter this value in the computerized maintenance system as an Operation Counter type reading.

11. Fault Operations

    Determine and record the number of fault operations the circuit breaker has performed. Enter this reading in the computerized maintenance system as a Breaker Fault Points type reading.

A2.1.3 Pole Control Cabinets Inspection

1. Cabinet Condition

   Inspect the internal and external condition of the pole control cabinets. This includes inspecting the condition of the cover and the weather stripping. Ensure that the nylon sealing washers on the cover bolts are present and in good condition.

2. Heater Current

   Measure the current of each pole heater. These values are to be ± 5 % of the value indicated on the circuit breaker schematic. Consider the failure of a pole heater as a Functional Failure.

3. Air Leaks

   Listen for any audible air leaks in each pole control cabinet.

A2.2 Integrity Check List

Station: ________________ Breaker Designation: ____________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

A2.1.1 Circuit Breaker Inspection	Complete	Failed
1. Foundation	☐	☐
2. Grounds	☐	☐
3. Air Leaks	☐	☐
4. Paint Condition	☐	☐
5. Primary Bus Tension	☐	☐
6. Primary Connections	☐	☐
7. Insulator Condition	☐	☐
8. Air Lines	☐	☐
9. Wiring	☐	☐
A2.1.2 Main Control Cabinet Inspection		
1. Cabinet Condition	☐	☐
2. Cabinet Ground	☐	☐
3. Cabinet Cleanliness	☐	☐
4. Position Indicator	☐	☐
5. Humidity Indicator	☐	☐
6. Air Pressure Gauges	☐	☐
7. Air Leaks	☐	☐
8. Heater Current	☐	☐
9. Thermostat Operation	☐	☐
10. Operation Counter Reading	*Record in RMS*	
11. Fault Operations	*Record in RMS*	
A2.1.3 Pole Control Cabinets Inspection		
1. Cabinet Condition	☐	☐
2. Heater Current	☐	☐
3. Air Leaks	☐	☐

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A3 Functional Check

The Functional Check is performed on circuit breakers that have remained in either an open or closed state for a defined period of time. It is used to exercise the circuit breaker and to check operation. Obtain the applicable permission to operate the circuit breaker and ensure that it will not cause a customer outage or create undue stress on the system.

Ensure that a Job Plan has been completed prior to starting the following checks.

A3.1 Functional Check Task Description

1. As Found Operation Counter Reading

   Record the as found circuit breaker operation counter reading.

2. Visual Inspection

   Visually inspect the circuit breaker prior to it being operated to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

3. Operate the Circuit Breaker

   Change the circuit breaker status by either:
   - Close operation: remotely by SCC or by station local control
   - Open operation: by protection relay (if possible) or remotely by SCC

   When applicable, during circuit breaker operations, listen for and note any abnormalities, from a safe location.

4. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready for immediate operation. Investigate any abnormalities found and complete the appropriate corrective.

5. Operate the Circuit Breaker

   Change the circuit breaker status by either:
   - Close operation: remotely by SCC or by station local control
   - Open operation: by protection relay (if possible) or remotely by SCC

   During circuit breaker operation and from a safe location, listen for and note any abnormalities.

6. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

7. As Left Operation Counter Reading

   Record the as left value on the circuit breaker's operation counter and ensure that it has incremented from the as found reading. Enter the as left reading into the computerized maintenance system as an Operation Counter type reading.

   Classify an operation counter failure as a Potential Failure due to the potential delay of maintenance triggers. Delays in maintenance affect the circuit breaker’s functional operation and could lead to a Functional Failure.

A3.2 Functional Check List

Station: ________________ Breaker Designation: ____________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	Visual Inspection	☐	☐
2.	Operate the Circuit Breaker	☐	☐
3.	Visual Inspection	☐	☐
4.	Operate the Circuit Breaker	☐	☐
5.	Visual Inspection	☐	☐
6.	As Left Operation Counter Reading	☐	☐

NOTE: *This form and its information are intended for your immediate reference only. After entering required correctives into RMS, discard this check list.*

A4 Air System Check

The Air System Check is performed to ensure that the pressure relief valves comply with Manitoba Department of Labour Regulations. This is achieved by the replacement of the pressure relief valves with new certified valves at every Air System Check. All air system indicating devices will also be checked. The circuit breaker must be cleared during the check since the operator is disabled.

Ensure that a Job Plan has been completed prior to starting the following checks.

A4.1 Air System Check Task Description

1. Obtain Listed Specialty Tools and Parts
   - Ultrasonic leak detector
   - Calibrated air pressure gauge
   - Pressure relief valves (2)
     - set pressure 400 psig (CIIC 48-23-32)
     - set pressure 80 psig (CIIC 02-78-07)

2. Air Pressure Gauge Calibration Check

   There are three air pressure gauges inside the operating cabinet, with the following nominal pressures: supply air @ 900 psi, operating air @ 350 psi and insulating air @ 60 psi. Check the operating and insulating air pressure gauges to ensure they are indicating within the range specified, the supply air pressure gauge will not be checked.

   - Operating Air Pressure Range: 348 to 352 psi
   - Insulating Air Pressure Range: 59 to 61 psi

   Check the pressure gauges as follows:

   a) Connect the calibrated air pressure gauge to the test port valve of the gauge to be checked.
   b) Open the test port valve.
   c) Verify that the two air pressure readings are ± 2 psi of each other and that both are within the range specified.
   d) Close the test port valve and remove the calibrated air pressure gauge.

3. Operating-Air Pressure-Switch Calibration Check

   There are four air pressure switches for the 350 psi operating air. All air pressure switches are calibrated for operation on falling pressure and should be checked for correct actuation as specified in Table A4-1.

   a) Close the circuit breaker.
   b) Shut off the air supply valve for the circuit breaker.
   c) Open the DC knife switch.

d) Remove the cover from each pressure switch and visually inspect the contact condition and wiring.

e) Slowly open the operating air drain valve.

f) Close the operating air drain valve when each pressure switch operates and record the operating air pressure gauge reading.
The pressure switches should operate at ± 2% of the value specified in Table A4-1. Any pressure switch operating outside of the range specified is considered a Functional Failure.

g) Slowly open the operating air drain valve until the operating air pressure is reduced to zero.

h) Ensure that the insulating air pressure does not change to verify correct operation of the check valve between the two systems.

4. Insulating-Air Pressure-Switch Calibration Check

There is one pressure switch for the 60 psi insulating air. The pressure switch is calibrated for operation on falling pressure and should be checked for correct actuation as specified in Table A4-1.

a) Slowly open the insulating air drain valve.

b) Close the insulating air drain valve when the pressure switch operates and record the insulating air pressure gauge reading.
The pressure switch should operate at ± 5% of the value specified in Table A4-1. If the pressure switch is operating outside of the range specified it is considered a Functional Failure.

c) Slowly open the insulating air drain valve until the air pressure is reduced to zero.

Table A4-1: Action & Actuating Pressures

Operating Air Pressure Switches	**Action on falling pressure**	**Close p.s.i.**	**Open p.s.i.**
Low Pressure Alarm (63AA)	Close	300	320
Trip-free Cutout (63AC)	Open	315	295
Trip-free Cutout (63AT1, 63AT2)	Open	310	290
Low Pressure Emergency Close (63AE)	Close	200	220
Insulating Air Pressure Switch	---	---	---
Low Pressure Alarm (63AL)	Close	55	57

5. Pressure Relief Valve Replacement

   There are two pressure relief valves, one for the operating air (350 psi) and one for the insulating air (60 psi). Remove and replace each pressure relief valve.

   Replacement pressure relief valves are available from Waverley Shop Stores (see CIIC numbers below). Send the old pressure relief valves to Waverley Shop Stores for refurbishment.

System Pressure	Pressure Relief	CIIC
350 psig	400 psig	48-23-32
60 psig	80 psig	02-78-07

6. Air Filter

   Remove the in-line air filter and ensure that it is clean, and then re-install.

7. Air System Refill

   When restoring the air system pressure, be sure not to admit air too fast. Refer to Table A4-1 and note whether the pressure switches are resetting correctly. Record reset values in step 3 & 4 on the Check Sheet.

   Restore the air system pressure as follows:

   a) Open the high pressure air supply valve slowly and then close when the operating air pressure gauge indicates 100 psi.
   b) Check the entire air system for air leaks with the ultrasonic detector.
   c) Open the high pressure air supply valve slowly and then close when the operating air pressure gauge indicates 200 psi.
   d) Check the entire air system for air leaks with the ultrasonic detector.
   e) Open the high pressure air supply valve slowly and restore full pressure.
   f) Check the entire air system for air leaks with the ultrasonic detector.

8. Air Consumption Check

   a) Ensure that the circuit breaker is closed.
   b) Close the air supply valve.
   c) Wait until the pressure stabilizes (two minutes) before recording the operating and insulating air pressures.
   d) Close the DC knife switch.
   e) Open the circuit breaker.
   f) Wait until the pressure stabilizes (two minutes) before recording the operating and insulating air pressures.
   g) Open the air supply valve.

   There should be no change in the insulating air pressure. If the operating air pressure consumed after the open operation is greater than 30 psi, identify the condition as a Functional Failure.

A4.2 Air System Check List

Station: ________________ Breaker Designation: ____________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

				Complete	Failed

1.	Obtain Listed Specialty Tools and Parts
	- Ultrasonic leak detector
	- Calibrated air pressure gauge
	- Pressure relief valves (2)
	  - set pressure 400 psig (CIIC 48-23-32)
	  - set pressure 80 psig (CIIC 02-78-07)
				☐	

2.	Air Pressure Gauge Calibration Check			☐	☐
3.	Operating-Air Pressure-Switch Calibration Check	Open (psig)	Closed (psig)		
	– Low pressure alarm (63AA)	________	________		☐
	– Trip-free cut-out (63AC)	________	________		☐
	– Trip-free cut-out (63AT1, 63AT2)	________	________		☐
	– Low pressure emergency close (63AE)	________	________		☐
4.	Insulating-Air Pressure-Switch Calibration Check	Open (psig)	Closed (psig)		
	– Low pressure alarm (63AL)	________	________		☐
5.	Pressure Relief Valve Replacement			☐	☐
6.	Air Filter			☐	☐
7.	Air System Refill (reset values in step 3 & 4)			☐	☐
8.	Air Consumption Check	Initial	After 1Trip		
	– Operating Air Pressure	________ psi	________ psi		☐
	– Insulating Air Pressure	________ psi	________ psi		☐

NOTE: *This form and its information are intended for your immediate reference only. After entering required correctives into RMS, discard this check list.*

A5 Insulation Check

The Insulation Check is performed to ensure that the insulating properties of the grading capacitors are within specified values by measuring their capacitance and dissipation factor. The grading capacitors must be capable of performing their function of evenly distributing the voltage across the contacts of a multi-break per phase circuit breaker. The circuit breaker must be cleared to complete this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A5.1 Insulation Check Task Description

The Insulation Engineering and Testing Department website contains all the required information to complete this task. The link to their website is; http://coil.hydro.mb.ca/insulation_eng_testing/index.html. Once in the site, click on "Technical Info", then "Procedures for use of Model 100 Capacitance Bridge".

Refer to:

- Section A "General Information & Instructions - Test Sheet Distribution"
- Section J "Model 100 Capacitance Bridge Testing", "Air Blast, Minimum Oil, or SF_6 Circuit Breakers with Multiple Interrupters" Alternate Method. Refer to Section J, "Analysis of Results" and compare the capacitance and dissipation factor test results with:
    - a) The limits set in Section J7.3 "CGE Type AT 230 kV" (replace any grading capacitor which exceeds these limits).
    - b) Historical test values for the same grading capacitor and/or current test values for similar grading capacitor on the circuit breaker.

Large variations may be an indication of a developing failure. Contact Insulation Engineering and Testing for a recommendation before returning the circuit breaker to service.

A6 Mechanism Check

The Mechanism Check is performed to ensure that the circuit breaker's operating characteristics are within specifications and to check the lubrication of the mechanism. The circuit breaker must be cleared for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A6.1 Mechanism Check Task Description (Interim)

References:

- Form J1587A/f Rev 93 06 Circuit Breaker Maintenance Inspection Record, 230 kV GE Type AT, specific tasks from:
  - Section B "Analysis" items 2-4 inclusive (timing only)
  - Section C "Main Control Cabinet" items 4 (visual), 12 -15, 21, 22
  - Section D "Pole Control Cabinets" items 7, 8, 9, 18 (visual)
  - Section E "Crank Box" item 8
- EAM Manual Memo #4

A7 Main Contact Check

The Main Contact Check is performed to inspect the main contacts and ensure that they are in satisfactory condition. The circuit breaker must be cleared for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A7.1 Main Contact Check Task Description (Interim)

The contact wear will determine if there is a need to adjust the frequency for subsequent Main Contact Checks. Determine the contact wear and consult with the interrupting Equipment specialist to discuss what is appropriate.

References:

– Form J1587A/f Rev 93 06 Circuit Breaker Maintenance Inspection Record, 230 kV GE Type AT, specific tasks from:
  - Section B "Analysis" items 1-5 inclusive
  - Section D "Pole Control Cabinets" items 10, 11
  - Section E "Crank Box" items 1-8 inclusive
  - Section F "Upper Control & Metering Valve" items 1-7 inclusive
  - Section G "Air Column" items 1-8 inclusive
  - Section H "Interrupter Head Overhaul" items 1, 2, 4 (visual), 5-13 & 15
  - Section H (A) "Resistor Switch Measurement" items 1-5, 7-9

– EAM Manual Memo #4

B NON-REPETITIVE MAINTENANCE TASKS

Tasks will be added as required.

C TECHNICAL INFORMATION

Information will be added as required.

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
2	2011 05 04	Updated the task template as per revision detail, matched document header to task template, made technical edits to the Main Contact Check	All	DJD	GV
1	2008 09 09	Technical and formatting changes, as described in the Maintenance Standard Alert dated 2008 09 09	TOC, Sctn A	DJD	WS
0	2004 10 26	New Maintenance Standard	---	DJD	DW

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Circuit Breakers - Bulk Oil (Air Operator)
General Electric KSO, KLO & Westinghouse BR3500, BR5000, BPOB, GM-3

Tasks	Triggers			
	Not Critical	Low	Medium	High
Air System Check	6 months	6 months	6 months	6 months
Integrity Check	12 months	12 months	12 months	12 months
Functional Check	< 1 operation in 24 months	< 1 operation in 24 months	< 1 operation in 24 months	< 1 operation in 24 months
Compressor Check	50 hours	50 hours	50 hours	50 hours
Major Air System Chk	60 months	60 months	60 months	60 months
Insulation Check	120 months	120 months	120 months	120 months
Standard Oil Sample	FAO's / ASO's / 120 months	FAO's / ASO's / 120 months	FAO's / ASO's / 120 months	FAO's / ASO's / 120 months
Main Contact Check	FAO's / ASO's	FAO's / ASO's	FAO's / ASO's	FAO's / ASO's
Mechanism Check	300 operations / 10 years	250 operations / 9 years	200 operations / 8 years	150 operations / 7 years

							Original signed by G. A. Verch 2011 01 30
6	2010 12 14	Increased Air System Check interval from 3 to 6 months. Increased Oil sample frequency from 5 to 10 years. Decreased Mech. Check interval to 10 years	CM	DJD		GV	
5	2004 04 19	Increased air system check and integrity check trigger intervals	CM	DJD		DW	
4	2004 03 10	Added refer to bushing template detail for integrity check description	CM	DJD		DW	
3	2001 06 04	Added time trigger to mechanism check. Removed particulate oil sample. Removed infrared scan. Changed diagnostic check to main contact check	GW	DJD		DW	
2	2000 05 23	Add ASO's & Part oil chg	BC	WD		DW	
No.	Date	Revision	AMR Specialist	Tech Supp Services	Insul. Eng.	AMR Eng.	

A2 Air System Check

The Air System Check is performed to ensure satisfactory operation of the air system and reduce the amount of moisture inside the air receiver. This check is completed without removing the circuit breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A2.1 Air System Check Task Description

1. Compressor Hour Meter Reading

   Record the compressor hour meter and date. Enter this reading into RMS as a Run Hours type reading.

2. Compressor Average Daily Run Time

   The average run time for the compressor is an indication of the circuit breaker's air system integrity. Record on the test sheet: the previous reading, the run time, and the days since the last reading. Use those figures to calculate the average number of hours the compressor ran in each of the days since the last recording. Apply the appropriate instruction that follows:

   - Average daily run time ≤ 2 hrs: examine the trend of past daily averages.
     - No increasing trend: normal, no action required
     - Increasing trend but ≤1.5 hrs: no action required
     - Increasing trend beyond 1.5 hrs: identify as a Potential Failure.
   - Average daily run time > 2 hrs: identify as a Functional Failure (maximum allowable limit is 2 hours).

3. Air Receiver Moisture Removal

   Open the air receiver drain valve and drain air until the compressor governor switch starts the compressor motor. Once the compressor motor starts, close the drain valve. Repeat if signs of moisture are still evident. Listen for excessive noise and check for indications of belt slippage.

A2.2 Air System Test Sheet

Station: ________________ Breaker Designation: ____________ Date: ____________
Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

1. Compressor Hour Meter Reading — *Record in RMS* _________________ Date:_____________
2. Compressor Average Daily Run Time
   - a) Previous Reading ____________hrs Date:_____________
   - b) Run Time ____________hrs
   - c) Days Since Last Reading ___________days
   - d) Average Daily Run Time ____________hrs/day
   - e) Within ≤ 2 hrs/day limit ? ☐ O.K. ☐ Corrective Req’d
3. Air Receiver Moisture Removal ☐ O.K. ☐ Corrective Req’d

NOTE: *Record corrective action details in the space above or on back of the sheet.*

A3 Integrity Check

The Integrity Check is performed to ensure the operation of the circuit breaker's basic functions. It consists primarily of a visual inspection of the equipment and it is done without removing the circuit breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A3.1 Integrity Check Task Description

A3.1.1 Circuit Breaker Inspection

1. Foundation

   Inspect the circuit breaker's foundation for any signs of deterioration and movement.

2. Grounds

   Inspect the frame grounds to ensure that there are two connections diagonally opposing each other. All ground connections must be tight and the conductor free from damage.

3. Insulating Oil Level

   Check that the insulating oil level gauge or sight glass indicates an oil level within acceptable limits for the ambient temperature.

   If the oil level has dropped below the sight glass or below the low limit indicated on the sight glass or gauge, consider the condition a Functional Failure. If the oil level is near the Functional Failure point and indications are that it will drop to that point before the next Integrity Check, classify the failure as a Potential Failure.

4. Insulating Oil Leaks

   Inspect all valves and gaskets for signs of leaking insulating oil.

5. Paint Condition

   Check the paint condition to ensure that the circuit breaker is not rusting.

6. Riser Tension

   Visually inspect the risers to ensure the tension is adequate for all weather conditions.

7. Primary Connections

   Visually inspect the primary connections for missing hardware and tightness.

A3.1.2 Bushings Inspection

Apply any correctives from this inspection to the bushing nameplate in RMS.

1. Oil Leaks

   Check for signs that oil is leaking or has leaked from the bushing.

2. Sight Glass Condition

   Visually check the condition of the bushing sight glass.

3. Oil Colour

   Visually check that the oil in the sight glass is not discoloured as compared to other bushings.

4. Insulation Condition

   Visually check the condition of the bushing insulation for cracks or deterioration.

5. Capacitance / Test Tap

   Visually check if the capacitance or test tap cap is present and if it appears tightly fastened.

6. Bushing Tag

   Ensure the Manitoba Hydro bushing tag is visible and in good condition. If it is not, refer to the applicable bushing maintenance standard.

A3.1.3 Operating Mechanism Cabinet Inspection

1. Cabinet Condition

   Inspect the internal and external condition of the operating mechanism cabinet. This includes inspecting the condition of the doors, hinges, latches and weather stripping.

2. Cabinet Ground

   Inspect the operating mechanism cabinet ground for conductor tightness and conductor damage.

3. Cabinet Cleanliness

   Inspect the interior of the operating mechanism cabinet to ensure that it is clean. If Perrelli control cable is used, ensure that the seepage is contained (typically green in colour).

▲ WARNING ▲

Avoid contacting the substance seeping from the control cables, as some Perrelli control cables may contain PCB's.

4. Operating Mechanism Components

   Visually inspect the operating mechanism components to ensure that there are no signs of damaged or missing parts. Visually inspect the lubrication on rollers and latches to ensure that a light film is present and that it is not dirty.

5. Position Indicator

   Inspect the position indicator and ensure that it is in the correct position.

6. Air Compressor

   Turn off the AC supply to the compressor motor and then check the oil level in the air compressor. Ensure that there is no evidence of oil leaks from the air compressor or signs of belt deterioration and then turn on the AC supply.

7. Air Pressure Gauge

   Check the air pressure gauge to ensure that it is indicating ±2 % of the system operating range specified on the circuit breaker schematic.

8. Air Leaks

   Ensure that there are no audible air leaks on the air system.

9. Closing Dashpot (if applicable)

   Visually check the closing dashpot and ensure that there is no evidence of leaking oil. If evidence exists, consider the condition a Potential Failure.

10. Cabinet Heater Current

    Measure the current of the heaters in the operating mechanism cabinet. Measured values must be ±5 % of the value indicated on the circuit breaker schematic. If the heater failure is 50 % or more of the total heat inside the operating mechanism cabinet, consider the condition a Functional Failure.

11. Cabinet Thermostat Operation and Setting

    Check the thermostat in the operating mechanism cabinet for correct operation and setting as indicated on the circuit breaker schematic. The failure of a thermostat inside the operating mechanism cabinet must be considered a Functional Failure.

12. Control Valve Heater Current (GE only)

    Measure the current of the control valve heater in the main, and if applicable, auxiliary control valve. Measured values must be within ±5 % of the value indicated on the circuit breaker schematic. If the control valve heater has failed or the measured value is outside of the specified limit, consider the condition as a Functional Failure.

13. Tank Heater Current

    Measure the current of the heaters that are in the tank. Measured values must be within ±5 % of the value indicated on the circuit breaker schematic. If the heater failure is 50 % or more of the total heat inside the tank, consider the condition as a Functional Failure.

14. Tank Thermostat Operation and Setting

    Check the tank heater thermostat in the operating mechanism cabinet for correct operation and setting as indicated on the circuit breaker schematic. If the tank heater thermostat has failed, consider the condition as a Functional Failure.

15. Operation Counter Reading

    Record the value of the operation counter. Enter this value into RMS as an Operation Counter type reading.

16. Fault Operations

    Determine and record the number of fault operations the circuit breaker has performed. Enter this reading into RMS a Breaker Fault Points type reading.

A3.2 Integrity Check List

Station: _______________ Breaker Designation: ___________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

A3.1.1 Circuit Breaker Inspection

	Item	Complete	Failed
1.	Foundation	☐	☐
2.	Grounds	☐	☐
3.	Insulating Oil Level	☐	☐
4.	Insulating Oil Leaks	☐	☐
5.	Paint Condition	☐	☐
6.	Riser Tension	☐	☐
7.	Primary Connections	☐	☐

A3.1.2 Bushings Inspection

Apply any correctives from this inspection to the bushing nameplate in RMS.

	Item	Complete	Failed
1.	Oil Leaks	☐	☐
2.	Sight Glass Condition	☐	☐
3.	Oil Colour	☐	☐
4.	Insulation Condition	☐	☐
5.	Capacitance / Test Tap	☐	☐
6.	Bushing Tag	☐	☐

A3.1.3 Operating Mechanism Cabinet Inspection

		Complete	Failed
1.	Cabinet Condition	☐	☐
2.	Cabinet Ground	☐	☐
3.	Cabinet Cleanliness	☐	☐
4.	Operating Mechanism Components	☐	☐
5.	Position Indicator	☐	☐
6.	Air Compressor	☐	☐
7.	Air Pressure Gauge	☐	☐
8.	Air Leaks	☐	☐
9.	Closing Dashpot (if applicable)	☐	☐
10.	Cabinet Heater Current	☐	☐
11.	Cabinet Thermostat Operation and Setting	☐	☐
12.	Control Valve Heater Current (GE only)	☐	☐
13.	Tank Heater Current	☐	☐
14.	Tank Thermostat Operation and Setting	☐	☐
15.	Operation Counter Reading	*Record in RMS*	
16.	Fault Operations	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A4 Functional Check

The Functional Check is performed on circuit breakers that have remained in either an open or closed state for a defined period of time. It is used to exercise the circuit breaker and to check operation. Obtain the applicable permission to operate the circuit breaker and ensure that it will not cause a customer outage or create undue stress on the system.

Ensure that a Job Plan has been completed prior to starting the following checks.

A4.1 Functional Check Task Description

1. As Found Operation Counter Reading

   Record the as found circuit breaker operation counter reading.

2. Visual Inspection

   Visually inspect the circuit breaker prior to it being operated to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

3. Operate the Circuit Breaker

   Change the operational status by either:

   – Close operation: remotely by SCC or by station local control
   – Open operation: by protection relay (if possible) or remotely by SCC

   When applicable, during circuit breaker operations, listen for and note any abnormalities, from a safe location.

4. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready for immediate operation. Any abnormalities found are to be investigated and the appropriate corrective completed.

5. Operate the Circuit Breaker

   Change the operational status by either:

   – Close operation: remotely by SCC or by station local control
   – Open operation: by protection relay (if possible) or remotely by SCC

   When applicable, during circuit breaker operations, listen for and note any abnormalities, from a safe location.

6. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

7. As Left Operation Counter Reading

   Record the As Left value on the circuit breaker's operation counter and ensure that it has incremented from the As Found reading. Enter the as left reading into RMS as an Operation Counter type reading.

   Classify an operation counter failure as a Potential Failure due to the potential delay of maintenance triggers. Delays in maintenance affect the circuit breaker's functional operation and could lead to a Functional Failure.

A4.2 Functional Check List

Station: _______________ Breaker Designation: ___________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	As Found Operation Counter Reading	*Record in RMS*	
2.	Visual Inspection	☐	☐
3.	Operate the Circuit Breaker	☐	☐
4.	Visual Inspection	☐	☐
5.	Operate the Circuit Breaker	☐	☐
6.	Visual Inspection	☐	☐
7.	As Left Operation Counter Reading	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A5 Compressor Check

The Compressor Check is performed to ensure that the air system will provide adequate operating air for the circuit breaker. The check requires removing the circuit breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A5.1 Compressor Check Task Description

1. As Found Compressor Hour Meter Reading

   Record the As Found compressor hour meter reading.

2. Air Pressure Gauge

   Check the air pressure gauge and ensure that it is indicating ±2 % of the system operating range specified on the circuit breaker schematic.

3. Check Valve

   Loosen the output fitting on the compressor. Ensure that the system air pressure does not change, and that there is no audible air leak.

4. Air Pressure Switches

   There are three air pressure switches and they are identified as governor, alarm and cut-off. Check the air pressure switches for correct operation with either falling or rising pressure, depending on the application. Air pressure switches should operate within ±2 % of the value specified on the circuit breaker schematic. If any pressure switch is not operating within the specified values, consider the failure a Functional Failure.

5. Transfer Pressure Switch (GE only)

   The transfer pressure switch is only on GE pneumatic operators with an auxiliary control valve. The contacts are normally open and will close when there is air in the operating cylinder. The function is to ensure the control is set up for a trip-free operation.

   Close the circuit breaker and visually check that the transfer pressure switch contacts close during the close motion, and then re-open. If the transfer pressure switch is not operating as described, consider the failure a Functional Failure.

6. Air Pressure Loss

   With the air system at normal operating pressure, turn off the AC supply to the air compressor motor. After one hour, the air pressure should not drop more than 5 psi.

7. Air Receiver Drain

   Slowly open the air receiver drain valve and reduce system air pressure to zero. Ensure that the air drains freely.

8. Compressor
   - Inspect the compressor condition; ensure that it is mounted securely and that there are no signs of leaking oil.
   - If applicable, check that the cooling fins are clean and not damaged.
   - Remove the inlet filter element and ensure that it is clean.

9. Compressor Oil

   Change the oil in the air compressor with the appropriate replacement oil as specified by the manufacturer.

10. Compressor Motor
    - Inspect the compressor motor condition
    - Check the compressor to motor pulley alignment
    - Check the drive belt tension

    Lubricate the motor bearings in the manner appropriate for the type of bearings used in the motor. Sleeve bearings will have a hinged lid for adding several drops of light machine oil. Motors with ball bearings will have grease fittings.

11. Air System Piping

    Inspect all associated air system piping for signs of corrosion, restriction or wear.

12. Compressor Rate

    Restore AC supply to the air compressor motor. Measure and record the time required for the compressor to restore system pressure from 0 psi. Apply the applicable instruction that follows:
    - Elapsed time ≤50 minutes: normal, no action required
    - Elapsed time >50 minutes but ≤60 minutes: identify as a Potential Failure
    - Elapsed time >60 minutes: identify as a Functional Failure

    If either failure is identified, the compressor should be replaced, contact Shop Stores at the Waverley Service Centre.

13. As Left Compressor Hour Meter Reading

    Ensure that the hour meter is operating correctly. Record the As Left compressor hour meter reading. Enter this reading into RMS as a Run Hours type reading.

A5.2 Compressor Check List

Station: ______________ Breaker Designation: __________ Date: __________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Open (psi)	Closed (psi)	Complete	Failed
1.	As Found Compressor Hour Meter Reading			Record in RMS	
2.	Air Pressure Gauge			☐	☐
3.	Check Valve			☐	☐
4.	Air Pressure Switches				
	– Governor	________	________		☐
	– Alarm	________	________		☐
	– Cut-off	________	________		☐
5.	Transfer Pressure Switch (*GE only*)			☐	☐
6.	Air Pressure Loss (*< 5 psi in 1 hour*)			☐	☐
7.	Air Receiver Drain			☐	☐
8.	Compressor				
	– Mounting			☐	☐
	– Cooling Fins			☐	☐
	– Inlet Filter			☐	☐
	– Oil Leaks			☐	☐
9.	Compressor Oil			☐	☐
10.	Compressor Motor				
	– Motor Condition			☐	☐
	– Pulley Alignment			☐	☐
	– Drive Belt Tension			☐	☐
	– Lubrication			☐	☐
11.	Air System Piping			☐	☐
12.	Compressor Rate (*≤ 60 minutes*)			☐	☐
13.	As Left Compressor Hour Meter Reading			Record in RMS	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A6 Major Air System Check

The Major Air System Check is performed to ensure that the pressure relief valve complies with Manitoba Department of Labour Regulations. The pressure relief valve will be replaced with a new certified valve. The circuit breaker will be taken out of service since the operator is disabled during the check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A6.1 Major Air System Check Task Description

1. As Found Compressor Hour Meter Reading

   Record the As Found compressor hour meter reading.

2. Air Receiver Drain

   Turn off the AC supply for the air compressor, slowly open the air receiver drain valve and reduce system pressure to zero. Ensure that the air drains freely.

3. Pressure Relief Valve Replacement

   Remove the existing pressure relief valve and replace with a new certified valve from the Waverley Shop Stores. Use the valve specified in the following tables.

System Pressure (psi)	Pressure Relief (psi)	Material Number	Size (in.)
145	175	13 08 37	½
170	200	83 20 44	½
175	190	83 72 46	¼
190	220	38 40 37	½
225	250	49 12 07	½
250	275	77 44 77	½

4. Compressor Rate

   Restore AC supply to the air compressor motor. Measure and record the time required for the compressor to restore system pressure from 0 psi. Apply the applicable instruction that follows:

   – Elapsed time ≤50 minutes: normal, no action required
   – Elapsed time >50 minutes but ≤60 minutes: identify as a Potential Failure
   – Elapsed time >60 minutes: identify as a Functional Failure

   If either failure is identified, the compressor should be replaced, contact Shop Stores at the Waverley Service Centre.

5. Air Pressure Loss

   With the air system at normal operating pressure, turn off the AC supply to the air compressor motor. After one hour, the air pressure should not drop more than 5 psi.

6. As Left Compressor Hour Meter Reading

   Record the As Left compressor hour meter reading. Enter this reading into RMS as a Run Hours type reading.

A6.2 Major Air System Check List

Station: _______________ Breaker Designation: ___________ Date: ___________
Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	As Found Compressor Hour Meter Reading	*Record in RMS*	
2.	Air Receiver Drain	☐	☐
3.	Pressure Relief Valve Replacement	☐	☐
4.	Compressor Rate (≤*60 minutes*)	☐	☐
5.	Air Pressure Loss (≤*5 psi in one hour*)	☐	☐
6.	As Left Compressor Hour Meter Reading	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A7 Insulation Check

The Insulation Check is performed to ensure that the insulating properties of the bushings, interrupters and lift rods are acceptable. Circuit breakers that have capacitive tap type bushings will require additional tests. Insulation Engineering and Testing Department will review the results and make recommendations. The circuit breaker will need to be removed from service for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A7.1 Insulation Check Task Description

The Insulation Engineering and Testing Department website contains all the required information to complete this task. The link to their website is; http://coil.hydro.mb.ca/insulation_eng_testing/index.html. Once in the site, click on "Technical Information", then "Procedures We Maintain" then "Procedures for Use of Model 100 Capacitance Bridge".

Refer to:

- Section A "General Information & Instructions - Test Sheet Distribution"
- Section D "Model 100 Capacitance Bridge Testing, Bulk Oil Circuit Breakers"
- Section E "Model 100 Capacitance Bridge Testing, Bushings with Capacitance or Power-Factor Test Taps" (*if applicable*)

NOTE: *Both the open breaker and the closed breaker tests are done to evaluate the condition of the interrupters, lift rods, tank liners and bushings. If the bushings have capacitance taps or power factor test taps, a separate test must also be performed on the bushings using the capacitance tap test method. This test <u>does not</u> replace the open breaker test but it is <u>in addition</u> to the open breaker test.*

Before sending the test results to Installation Engineering and Testing, review the dissipation factor values to determine whether bushing(s) require immediate replacement. Compare the values with:

1. The limits identified in Section D (*replace bushings exceeding these limits*).
2. Historical test values for the same bushing and/or present test values for similar bushings on the breaker. Large variations may be an indication of a developing failure. Contact Insulation Engineering and Testing for a recommendation before returning the breaker to service.

A8 Standard Oil Sample

The Standard Oil Sample is performed to determine if the circuit breaker’s insulating oil quality is sufficient to perform the necessary insulating and arc extinction functions.

The Standard Oil Sample will be taken from the bottom of the main tank, with the circuit breaker in service. The test results must be compared to the values specified, and if they are not acceptable, a second sample is required. The second sample is taken from the top of the main tank, with the circuit breaker removed from service, and the test results compared to the values specified. The oil must be changed if the top of main tank sample results are not acceptable. Indicate on the Oil Sample Data Sheet which sample was taken.

The circuit breaker must remain in service to sample oil from the bottom of the main tank, and then removed from service to sample oil from the top of the main tank.

Ensure that a Job Plan has been completed prior to starting the following checks.

A8.1 Standard Oil Sample Task Description

A8.1.1 Bottom of Main Tank Sample

The Insulation Engineering and Testing Department website contains all the required information to complete this task. The link to their website is; http://coil.hydro.mb.ca/ insulation_eng_testing/index.html. Once in the site, click on "Technical Information", then "Procedures We Maintain", then “Insulating Oil Properties". The specific method is titled “Sampling in Metal Cans through Drain Valve”.

A8.1.2 Top of Main Tank Sample

The Insulation Engineering and Testing Department website contains all the required information to complete this task. The link to their website is; http://coil.hydro.mb.ca /insulation_eng_testing/index.html. Once in the site, click on "Technical Information", then "Procedures We Maintain", then "Insulating Oil Properties". The specific method is titled "Sampling in Glass Bottles through Top Manhole".

Apply the specified instructions but be aware that the sampling location stipulated does not apply. Instead the sample will be drawn though the analyzer hole in the top of the circuit breaker tank.

The Work Area is responsible for evaluating oil sample results and deciding if further action is required by using the Standard Oil Sample Flowchart (see Figure A8-1). The flowchart is an interpretation of the "Insulating Oil Properties" table that details oil specifications. A failure of the Dielectric Strength, Dissolved Water Content or Dissipation Factor of the insulating oil is considered a Functional Failure.

A8.1.3 Standard Oil Sample Flowchart

Derived from Insulating Oil Properties - Section A6.5, p.27, Test Results

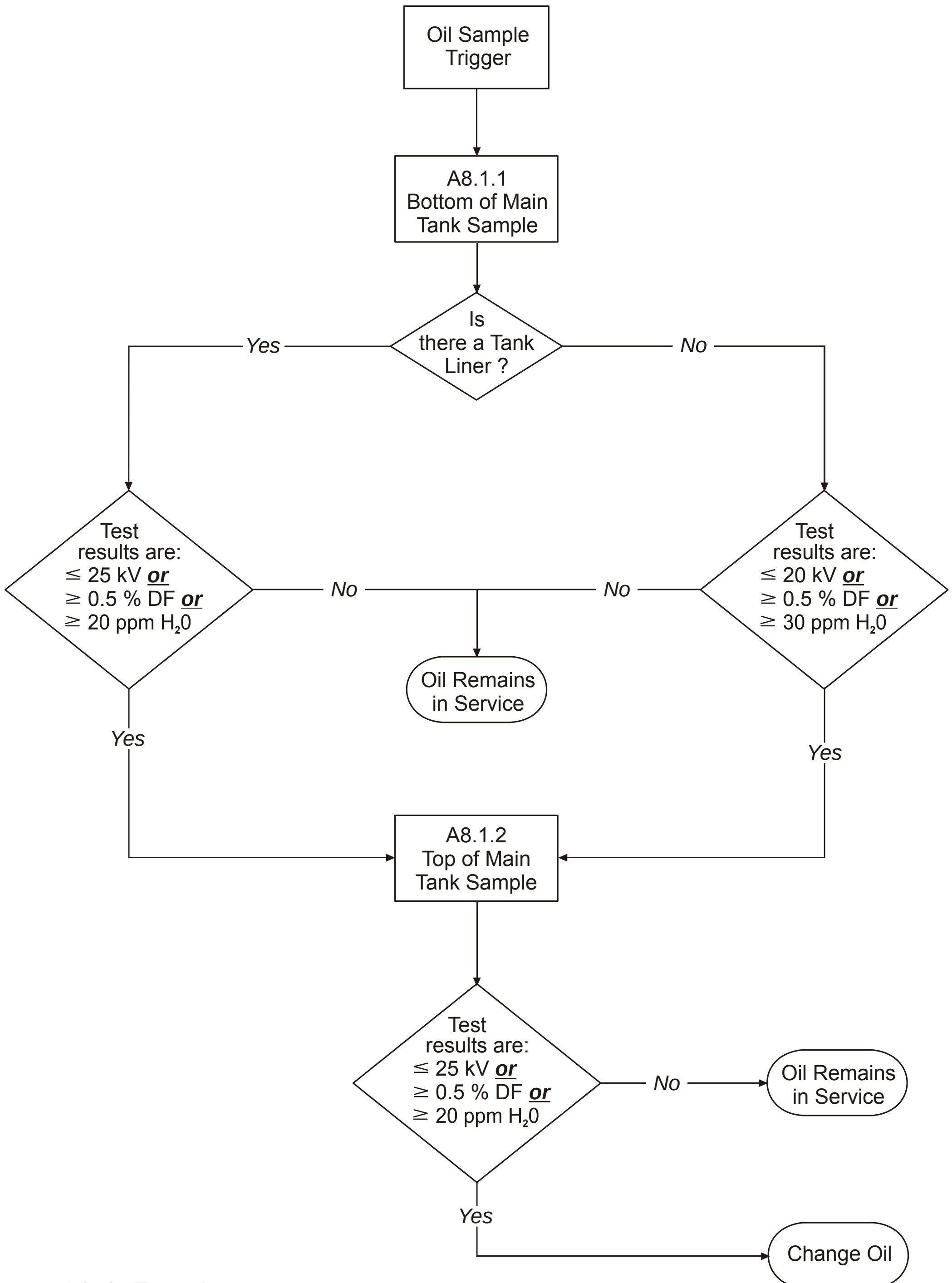


Figure A8-1: Flowchart

A9 Main Contact Check

The Main Contact Check is performed to inspect the main contacts and ensure that they are in satisfactory condition. The circuit breaker will be removed from service for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A9.1 Main Contact Check Task Description

1. Circuit Breaker Identification

   Identify the positioning of: the circuit breaker control cabinet, the bushings/interrupters and the phases.

2. Static Contact Resistance

   Measure and record the static contact resistance of each phase. The measured value must be less than 200 % of the contact resistance for new circuit breakers (see Table A9-1). If any static contact resistance value is higher than 200 % consider the condition a Functional Failure.

   Do not return a circuit breaker to service until the resistance value is below 150 % of the new circuit breaker value.

Table A9-1: Maximum Contact Resistance for New Breakers

General Electric	Resistance (μΩ)
KSO (66 kV 3500 MVA)	300
KSO (115 kV 2500 MVA)	600
KSO (115 kV 3500 MVA)	600
KSO (115 kV 5000 MVA)	400
KSO (115 kV 7500 MVA)	400
KSO (115 kV 10 000 MVA)	350
KSO (138 kV 3500 MVA)	600
KLO (230 kV 7500 MVA)	350
Westinghouse	**Resistance (μΩ)**
BPOB (66 kV)	320
BQOB (115 kV)	500
GM3H (115 kV)	290
BR3500 (115 kV 3500 MVA)	500
BR5000 (115 kV 5000 MVA)	500

3. Main Contact Shunt Resistor Check

   Measure and record the main contact shunt resistor for each interrupter position. The measured value must be within ±10 % of the value specified below.

   - General Electric, Type 201 Interrupter 1620 ohms
   - General Electric, Type 401 Interrupter 1350 ohms
   - Westinghouse, Multi-Flow Grid 250 000 ohms

4. Main Contact Wipe / Compression

   Depending on the main contact style, measure and record the main contact wipe or compression for each interrupter. Compare these values to the original inspection sheet to determine whether they are within specification. If adjustments are required, consider the condition a Functional Failure.

5. Main Contact Inspection

   a) Moving Contact Measurement
      Inspect and measure each moving contact to determine the amount of erosion.

   b) Fixed Contact Measurement
      Inspect and measure each fixed contact to determine the amount of erosion

   Contact erosion is measured from the original length of the contact and is represented as a percentage of the allowable erosion.

   For example, if the allowable erosion is 1/8" and the measured erosion is 3/64" the percentage of allowable erosion is 37.5 %. Record these readings on the following test sheet.

   Formula for Percent Erosion:

$$\frac{\text{Measured Contact Erosion}}{\text{Allowable Contact Erosion}} \times 100 = \%\ \text{Erosion}$$

   Allowable Contact Erosion: 0.125"

   If the original length cannot be determined, contact the Interrupting Equipment Group of Technical Support Services, for assistance.

   The contact wear will determine if there is a need to adjust the frequency for subsequent Main Contact Checks. Determine the contact wear and consult with the Interrupting Equipment specialist to discuss what is appropriate

6. As Left Timing/Motion Analysis

   Perform an As Left Timing/Motion Analysis according to the reference information in Section A10 "Mechanism Check."

A9.2 Main Contact Test Sheet

Station: _______________ Breaker Designation: ___________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

1. Circuit Breaker Identification (Fig. A9-1)

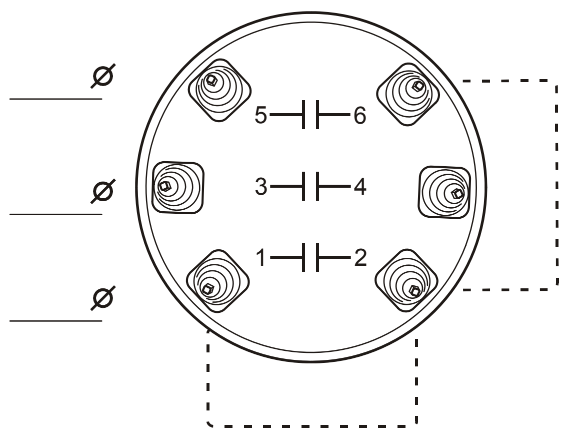


Figure A9-1

2. Static Contact Resistance

A Ø ________________µΩ	B Ø ________________µΩ	C Ø ________________µΩ

3. Main Contact Shunt Resistor Check

Interrupter Position	1	2	3	4	5	6
Resistance (Ω)						

4. Main Contact Wipe / Compression

Interrupter Position	1	2	3	4	5	6
Wipe/ Compression						

5. Main Contact Inspection

a) Moving Contact Measurements

Interrupter Positions

Moving Contact 1	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Moving Contact 2	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Moving Contact 3	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Moving Contact 4	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

b) Fixed Contact Measurements

Interrupter Positions

Fixed Contact 1	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Fixed Contact 2	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Fixed Contact 3	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

Fixed Contact 4	1	2	3	4	5	6
Measured Contact Erosion:						
Percent Erosion:						

6. As Left Timing/Motion Analysis *C* ☐ *F* ☐

A10 Mechanism Check

The Mechanism Check is performed to ensure that the circuit breaker's operating characteristics are within specifications and to check the lubrication of the mechanism.

Ensure that a Job Plan has been completed prior to starting the following checks.

A10.1 Mechanism Check Task Description (Interim)

References:

- Form E1587N Circuit Breaker Maintenance Inspection Record, General Electric Type KSO 115/138 KV MAP 15 / MAP 15A Operator, specific tasks from:
  - Section B "Analysis" items 3-5 inclusive
  - Section D "Operating Mechanism" items 10, 13-15 inclusive
- EAM Manual Memo #4

B NON-REPETITIVE MAINTENANCE TASKS

Tasks will be added as required.

C TECHNICAL INFORMATION

Information will be added as required.

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
6	2011 11 09	Updated the task template as per revision detail, matched document header to task template, made technical edits to the Main Contact Check	All	DJD	GV
5	2004 04 19	Updated the TOC	TOC	DJD	DW
4	2002 08 21	Updated the Table of Contents, added text on the Hydraulic System Check and the Standard Oil Sample	All	DJD	DW
3	2002 08 14	Added text on the Integrity Check	All	DJD	DW
2	2002 06 07	Added the Functional Check Sheet	A4.2	DJD	DW
1	2002 06 05	Added text on the Insulation Check, the Main Contact Check, and the Mechanism Check	All	DJD	DW
0	2002 06 07	New Maintenance Standard	All	DJD	DW

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Circuit Breakers - Minimum Oil (Hydraulic Operator)
Brown Boveri Oerlikon FS5 & FS9

Tasks	Triggers			
	Not Critical	Low	Medium	High
Pump Check	6 months	6 months	6 months	6 months
Integrity Check	6 months	6 months	6 months	6 months
Functional Check	< 1 op. in 24 months	< 1 op. in 24 months	< 1 op. in 24 months	< 1 op. in 24 months
Insulation Check	120 months	120 months	120 months	120 months
Hydraulic System Check	8000 pump starts	7000 pump starts	6000 pump starts	5000 pump starts
Standard Oil Sample	FAO's / ASO's 60 months	FAO's / ASO's 60 months	FAO's / ASO's 60 months	FAO's / ASO's 60 months
Main Contact Check	FAO's / ASO's	FAO's / ASO's	FAO's / ASO's	FAO's / ASO's
Mechanism Check	400 operations / 10 years	400 operations / 9 years	400 operations / 8 years	400 operations / 7 years

							Original signed by G. A. Verch 2011 01 30
6	2010 12 14	Increased the pump check trigger interval from 3 to 6 months. Decreased Mech. Check interval to 10 years.	CM	DJD		GV	
5	2004 04 19	Increased the pump check trigger interval	CM	BO		DW	
4	2002 07 04	Changed the hydraulic sample oil test criteria from particulate to dielectric strength, H_2O, D.F.	GW	BO		DW	
3	2001 11 14	Changed the header to FS5 & FS9 from FS5 &FS9. Moved recording the counter operations from the integrity check to the pump check.	GW	BO		DW	
2	2001 06 04	Added time trigger to mechanism check. Added main contact check. Removed interrupter particulate oil sample. Removed on-line monitor from mechanism check. Removed infared scan.	GW	TR		DW	
No.	Date	Revision	AMR Specialist	Tech Supp Services	Insul. Eng.	AMR Eng.	

A2 Pump Check

The Pump Check is designed to ensure the integrity of the basic functions of the circuit breaker’s hydraulic system. It includes recording of the number of pump and breaker operations, and involves the evaluation of the number of pump operations performed since the last pump check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A2.1 Pump Check Task Description

1. Hydraulic Pump Starts Counter Reading

   Record the value on the circuit breaker’s pump starts counter. Enter this reading into RMS as an "Equipment Start" type reading.

2. Hydraulic Pump Starts Per Day Calculation

   The average number of hydraulic pump starts per day is a leading indicator of the circuit breaker’s hydraulic system integrity. Use the current and previous pump start readings and the number of days between pump checks to calculate a daily hydraulic pump starts average for the circuit breaker. The maximum allowable limit is 10 operations per day. If the average pump starts per day approaches the allowable limit, identify the failure as a "Potential Failure".

3. Operation Counter Reading

   Record the value on the circuit breaker’s operation counter. Enter this reading into RMS as an "Operation Counter" type reading.

4. Fault Operations

   Determine and record the number of fault operations the circuit breaker performed. Enter this reading into RMS as a "Breaker Fault Points" type reading.

A2.2 Pump Check List

Station: ________________ Designation: __________________ Date: ____________
Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

	Complete	Failed
1. Hydraulic Pump Starts Counter Reading	*Record in RMS*	
2. Hydraulic Pump Starts per Day Calculation		
a) Previous reading	________________	
b) Number of starts (*line 1 – line 2a*)	________________	
c) Days since last reading	________________	
d) Average starts/day (*line 2b / line 2c*)	________________	
e) Within limit (*< 10 operations/day*)	☐	☐
3. As Found Operation Counter Reading	*Record in RMS*	
4. Fault Operations	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A3 Integrity Check

The Integrity Check is designed to ensure the integrity of the basic functions of the circuit breaker. It consists primarily of a visual inspection of the equipment that is done without removing the circuit breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A3.1 Integrity Check Task Description

A3.1.1 Circuit Breaker Inspection

1. Foundation

   Inspect the circuit breaker's foundation for any signs of deterioration and movement.

2. Support Structure Grounds

   Inspect the support structure grounds for connector tightness and conductor damage. Each support structure must have two ground locations on opposite corners of the structure.

3. Frame and Support Structure

   Inspect the circuit breaker's frame and support structure for signs of deterioration and loose fasteners.

4. Porcelain Condition

   Visually inspect all porcelain for damage and contamination.

5. Riser Tension

   Visually inspect the risers to ensure the tension is adequate for all weather conditions.

6. Primary Connections

   Visually inspect the primary connections for missing hardware and tightness.

7. Hydraulic Oil Levels

   Check that the hydraulic oil level of each circuit breaker head is within acceptable limits. Take the ambient temperature into consideration when assessing if the oil level is acceptable. An oil level that has dropped below the sight glass or a limit that is indicated on the sight glass is considered a "Functional Failure". If the oil level has dropped to the point where it is judged it will fall to the point of Functional Failure before the next Integrity Check, then the failure is classified as a "Potential Failure".

8. Insulating Oil Levels

   Check that the insulating oil level of each interrupter is within acceptable limits. Take the ambient temperature into consideration when assessing if the oil level is acceptable. An oil level that has dropped below the sight glass or a limit that is indicated on the sight glass is considered a "Functional Failure". If the oil level has dropped to the point where it is judged it will fall to the point of Functional Failure before the next Integrity Check, then the failure is classified as a "Potential Failure".

9. Oil Level Sight Glass Condition

   Inspect the condition of the sight glasses on each phase and note whether any require cleaning or replacement.

10. Hydraulic Oil Leaks

    Visually inspect all pipe fittings for signs of leaking hydraulic oil. Slight sweating of hydraulic oil at the fittings sometimes occurs and is not considered a failure but all other oil leaks are considered "Functional Failures" because of the small volume of hydraulic oil contained within these circuit breakers.

11. Insulating Oil Leaks

    Visually inspect all valves, gaskets and seals for signs of leaking insulating oil. All insulating oil leaks are considered "Functional Failures" because of the small volume of insulating oil contained within these circuit breakers.

A3.1.2 Control Cabinet and Pole Base Inspections

1. Cabinet Condition

   Inspect the internal and external condition of the control cabinet. This includes inspecting the condition of the doors, hinges, latches and weather stripping.

2. Cabinet Ground

   Inspect the control cabinet ground for connector tightness and conductor damage. The control cabinet must have at least one ground location.

3. Cabinet Cleanliness

   Inspect the interior of the operating mechanism cabinet for cleanliness.

4. Hydraulic System Pressure Reading

   Check whether the hydraulic system pressure is within the range specified for the appropriate circuit breaker.

   – FS5: *310 - 325 kg/cm*^{2} *(4410 - 4620 psi)*
   – FS9: *310 - 340 kg/cm*^{2} *(4410 - 4840 psi)*

5. Hydraulic Oil Leaks

   Inspect all pipe fittings, valves and gaskets located in the control cabinet for signs of leaking hydraulic oil. Slight sweating of hydraulic oil at the fittings sometimes occurs and is not considered a failure but all other oil leaks are considered "Functional Failures" because of the small volume of hydraulic oil contained within these circuit breakers.

   NOTE: *Some of the pressure gauges installed in the control cabinets contain a glycerin/glycol mixture (clear liquid) which has been known to leak from the gauge. If this is found, do not generate a corrective because the functionality of the gauge is not affected by the absence of this liquid.*

6. Heater Currents

   Measure the current drawn by the thermostat-controlled anti-condensation heaters in the control cabinet and pole base control cabinets. Compare these values to the expected values, which can be calculated from information on the schematic for the circuit breaker.

   The thermostat controlled cabinet and pole base heaters are critical to the circuit breakers functional operation and it is for this reason that a failure of either of these heaters is considered a "Functional Failure". A failure of an anti-condensation heater is considered a "Potential Failure".

7. Thermostat Operation and Settings

   Check the thermostats for correct operation and setting. The cabinet and pole base thermostats are critical to the circuit breakers functional operation and it is for this reason that a thermostat failure is considered a “Functional Failure”.

A3.2 Integrity Check List

Station: ________________ Designation: __________________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

A3.1.1 Circuit Breaker Inspection

		Complete	Failed
1.	Foundation	☐	☐
2.	Structure Support Grounds	☐	☐
3.	Frame and Support Structure	☐	☐
4.	Porcelain Condition	☐	☐
5.	Riser Tension	☐	☐
6.	Primary Connections	☐	☐
7.	Hydraulic Oil Levels	☐	☐
8.	Insulating Oil Levels	☐	☐
9.	Oil Level Sight Glass Condition	☐	☐
10.	Hydraulic Oil Leaks	☐	☐
11.	Insulating Oil Leaks	☐	☐

A3.1.2 Control Cabinet and Pole Base Inspections

		Complete	Failed
1.	Cabinet Condition	☐	☐
2.	Cabinet Ground	☐	☐
3.	Cabinet Cleanliness	☐	☐
4.	Hydraulic System Pressure Reading	☐	☐
5.	Hydraulic Oil Leaks	☐	☐
6.	Heater Currents	☐	☐
7.	Thermostat Operation and Settings	☐	☐

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A4 Functional Check

The Functional Check is performed on circuit breakers that have remained in either an open or closed state for a defined period of time, and is used to exercise the circuit breaker and to check its operation. Obtain the applicable permission to operate the circuit breaker and ensure that it will not cause a customer outage or create undue stress on the system.

Ensure that a Job Plan has been completed prior to starting the following checks.

A4.1 Functional Check Task Description

1. As Found Operation Counter Reading

   Record the As Found circuit breaker operation counter reading.

2. Visual Inspection

   Visually inspect the circuit breaker prior to it being operated to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

3. Operate the Circuit Breaker

   Change the circuit breaker status by either a:
   - Close operation: remotely by SCC or by station local control
   - Open operation: by protection relay (if possible) or remotely by SCC

   During circuit breaker operation, listen for and note any abnormalities.

4. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

5. Operate the Circuit Breaker

   Change the circuit breaker status by either a:
   - Close operation: remotely by SCC or by station local control
   - Open operation: by protection relay (if possible) or remotely by SCC

   During circuit breaker operation, listen for and note any abnormalities.

6. Visual Inspection

   Visually inspect the circuit breaker to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

7. As Left Operation Counter Reading

   Record the As Left value on the circuit breaker's operation counter and check that it is one more than the As Found operation counter reading. Enter the As Left value into RMS as an Operation Counter type reading.

   Classify an operation counter failure as a Potential Failure due to the potential delay of maintenance triggers. Delays in maintenance affect the circuit breaker's functional operation and could lead to a functional failure.

A4.2 Functional Check List

Station: ________________ Designation: __________________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	As Found Operation Counter Reading	*Record in RMS*	
2.	Visual Inspection	☐	☐
3.	Operate the Circuit Breaker	☐	☐
4.	Visual Inspection	☐	☐
5.	Operate the Circuit Breaker	☐	☐
6.	Visual Inspection	☐	☐
7.	As Left Operation Counter Reading	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list*

A5 Insulation Check

The Insulation Check is designed to determine the condition of the circuit breaker's grading capacitors, and ensure that they are capable of performing their function of evenly distributing the voltage across the contacts of multi break per phase circuit breakers.

Ensure that a Job Plan has been completed prior to starting the following checks.

A5.1 Insulation Check Task Description

Model 100 Capacitance Bridge tests on circuit breakers with grading capacitors. Reference EAM Manual Memorandum 18 Section J Test Sheet I-94E

A6 Hydraulic System Check

The Hydraulic System Check is an out of service check designed to ensure the integrity of the basic functions of the hydraulic system. It consists of:

- a high-pressure accumulator integrity check,
- a check of the hydraulic system's pump controls
- a circuit breaker lockouts & alarm check
- a sample of the hydraulic oil

The circuit breaker must be removed from service for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A6.1 Hydraulic System Check Task Description

A6.1.1 High Pressure Accumulator Pre-Charging Pressure Test

1. As Found Hydraulic Pump Starts Counter Reading

   Record the value on the circuit breaker's pump starts counter. Enter this reading into RMS as an "As Found Equipment Start" type reading.

2. As Found Operation Counter Reading

   Record the value on the circuit breaker's operation counter. Enter this reading into RMS as an "As Found Operation Counter" type reading.

3. Full Pressure Reading (5 minutes after close)

   Close the circuit breaker and allow the hydraulic system to re-charge to full pressure. Record the hydraulic system's full pressure reading after the hydraulic system pressure has been allowed to settle for at least five minutes.

4. Pressure Reading After 1 Trip Operation (5 minutes after trip)

   Open the stopping switch for hydraulic pump's motor and then trip the circuit breaker. Record the hydraulic system pressure reading after the hydraulic system pressure has been allowed to settle for at least five minutes.

5. Pressure Difference

   Calculate the pressure difference between the full pressure reading and the pressure reading after one trip operation. This value must not exceed 30 kg/cm^2 (450 lbs/in^2) at 20 °C. If the pressure difference is greater than the above limit, consider the condition a "Functional Failure".

A6.1.2 Hydraulic Pump Control, Lockout and Alarm Checks

Perform steps 1 and 2 at the same time.

1. Trip Re-charging Time

   After the above readings have been taken after the trip operation, close the stopping switch for hydraulic pump's motor and measure the amount of time it takes for the hydraulic system to reach the hydraulic pump stop pressure. The measured time should be less than 20 seconds. If longer, consider the condition a "Functional Failure".

2. Hydraulic Pump Stop Pressure

   Record the hydraulic system pressure reading when the pump stops. Acceptable readings are as follows.

   – FS5: *315 - 335 kg/cm^2 (4450 - 4750 psi)*
   – FS9: *330 - 350 kg/cm^2 (4700 - 5000 psi)*

   If the pressure reading is outside of these limits, consider the condition a "Functional Failure".

Perform steps 3 and 4 at the same time.

3. Hydraulic Pump Start Pressure

   Open the stopping switch for the hydraulic pump's motor and depressurize the hydraulic system's high-pressure side slowly by opening the pressure release valve slightly. When the coil of the sequencing relay (48) energizes, close the pressure release valve finger tight and record the hydraulic system pressure reading. Do not over tighten the pressure release valve because this will damage the valve seat. The relay should energize when the hydraulic system's pressure is 310 ±10 kg/cm^2 (4400 ±150 lbs/in^2), for a FS5 or FS9 circuit breaker. A pressure reading outside of this limit is considered a "Functional Failure".

4. Excessive Pump Running Time Alarm Setting

   When the coil on the sequencing relay (48) energizes, measure the time required to energize the coil of the excessive pump run time alarm relay (74). The coil should energize in 240 ±10 seconds. A time outside of this range is considered a "Potential Failure".

5. Closing Lockout Pressure

   Continue to depressurize the hydraulic system's high-pressure side slowly by opening the pressure release valve slightly. When the coil of the closing lockout relay (86-1) energizes, close the pressure release valve finger tight and record the hydraulic system pressure reading. Do not over tighten the pressure release valve because this will damage the valve seat. The closing lockout relay should energize when the hydraulic system's pressure is 260 ±10 kg/cm^2 (3700 ±150 lbs/in^2), for a FS5 or FS9 circuit breaker. A pressure reading outside of this limit is considered a "Functional Failure".

6. Opening Lockout Pressure

   Continue to depressurize the hydraulic system's high-pressure side slowly by opening the pressure release valve slightly. When the coil of the opening lockout relay (86-2) energizes, close the pressure release valve finger tight and record the hydraulic system pressure reading. Do not over tighten the pressure release valve because this will damage the valve seat. The opening lockout relay should energize when the hydraulic system's pressure is 235 ±10 kg/cm^2 (3350 ±150 lbs/in^2), for a FS5 or a FS9 circuit breaker. A pressure reading outside of this limit is considered a "Functional Failure".

A6.1.3 Hydraulic Oil Sample

1. Temperature and Humidity Measurements

   Measure and record the ambient temperature and relative humidity on the "Oil Sampling and Test Record" test sheets.

   NOTE: *Before sampling the oil ensure ambient temperature is above 0 °C and the relative humidity is below 75% (not raining or snowing). If possible, the sample container should be warmer than the ambient temperature to reduce the possibility of condensation within the sample container.*

2. Depressurize Hydraulic System

   Completely depressurize the hydraulic system's high-pressure side by opening the pressure release valve.

3. Obtain Can Sample

   a) Record the sample can number.
   b) Remove the dust cap from the drain/filling valve and wipe it with a clean lint-free cloth to remove any particle matter.
   c) Attach the sample fitting and plastic tubing assembly to the drain valve.
   d) Drain a small quantity of hydraulic oil into a pail to flush the valve, the fitting and the plastic tubing.
   e) Place the free end of the plastic tubing down into the bottom of the vertically held sample can.
   f) Draw oil to approximately a quarter of the sample can.
   g) Remove the plastic tubing from the can and support it to prevent contaminating the portion that was in the can.
   h) Measure the temperature of the hydraulic oil in the can and record on the "Oil Sampling and Test Record" sheet as the flushing oil temperature.
   i) Cap the sample can and rotate it to rinse all surfaces within the sample can with the hydraulic oil.
   j) Remove the screw cap and discard the oil.
   k) Place the free end of the plastic tubing down into the bottom of the vertically held sample can.

l) Draw oil to completely fill the sample can (to overflow).
m) Slowly remove the plastic tubing.
n) Gently squeeze the sample can to bring the oil level to the lip of the can then tightly install the screw cap.
o) Fill in the remaining required fields on the "Oil Sampling and Test Record" sheet and forward the sample and documentation to the Waverley Oil Lab for testing.

4. Pressurize Hydraulic System

   Start the hydraulic pump motor by closing the pressure release valve (finger tight only) and closing the stopping switch for the hydraulic pump's motor. The high-pressure side of the hydraulic system will begin pressurizing. Do to not over tighten the pressure release valve because this will damage the valve seat. After approximately four minutes the excessive pump running time alarm relay will shut off the pump. Restart it by resetting the relay (to completely pressurize so hydraulic system). Reset the relay by opening and closing the stopping switch for the hydraulic pump motor.

5. As Left Hydraulic Pump Starts Counter Reading

   Record the value on the circuit breaker's pump starts counter. Enter this reading into RMS as an "Equipment Start" type reading.

6. As Left Operation Counter Reading

   Record the value on the circuit breaker's operation counter. Enter this reading into RMS as an "Operation Counter" type reading.

7. Oil Sample Result Analysis

   The dielectric strength of the sampled hydraulic oil must be greater than 30 kV and have a dissipation factor at 100 °C of less than 5 %. If it does not meet these criteria, replace with reconditioned hydraulic oil (available from the Waverley Service Centre). A failure of the dielectric strength or the dissipation factor of the hydraulic oil is considered a "Functional Failure".

A6.2 Hydraulic System Check List

Station: ________________ Designation: __________________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

Complete Failed

A6.1.1 High Pressure Accumulator Pre-charging Pressure Test

1. As Found Hydraulic Pump Starts Counter Reading — *Record in RMS* ______
2. As Found Operation Counter Reading — *Record in RMS* ______
3. Full Pressure Reading (5 minutes after close) ______
4. Pressure Reading After 1 Trip Op. (5 min. after close) ______
5. Pressure Difference ☐ ☐

   (Maximum: 30 kg/cm^2 (450 lb/in^2))

A6.1.2 Hydraulic Pump Control, Lockout and Alarm Checks

1. Trip Re-charging Time ☐ ☐

   (Maximum: 20 seconds)
2. Hydraulic Pump Stop Pressure ☐ ☐

   FS5: 325 ± 10 kg/cm^2 (4600 ± 150lb/in^2)
   FS9: 340 ± 10 kg/cm^2 (4850 ± 150lb/in^2)
3. Hydraulic Pump Start Pressure ☐ ☐

   FS5 or FS9: 310 ± 10 kg/cm^2 (4400 ± 150lb/in^2)
4. Excessive Pump Running Time Alarm Setting ☐ ☐

   (240 ± 10 seconds)
5. Closing Lockout Pressure ☐ ☐

   FS5 or FS9: 260 ± 10 kg/cm^2 (3700 ± 150lb/in^2)
6. Opening Lockout Pressure ☐ ☐

   FS5 or FS9: 235 ± 10 kg/cm^2 (3350 ± 150lb/in^2)

A6.1.3 Hydraulic Oil Sample

1. Temperature and Humidity Measurements ______
2. Depressurize Hydraulic System ☐ ☐
3. Obtain Can Sample ☐
4. Pressurize Hydraulic System ☐ ☐
5. As Left Hydraulic Pump Starts Counter Reading — *Record in RMS* ______
6. As Left Operation Counter Reading — *Record in RMS* ______
7. Oil Sample Result Analysis ☐ ☐

   Minimum Dielectric Strength: 30 kV, Maximum Dissipation Factor: 5 %

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A7 Standard Oil Sample

The Standard Oil Sample is designed to determine if the circuit breaker interrupters' oil quality is sufficient to perform the necessary insulating and arc extinction functions.

Ensure that a Job Plan has been completed prior to starting the following checks.

A7.1 Standard Oil Sample Task Description

1. Temperature and Humidity Measurements

   Measure and record the ambient temperature and relative humidity on the "Oil Sampling and Test Record" test sheets.

   NOTE: *Before sampling the oil ensure ambient temperature is above 0 °C and the relative humidity is below 75% (not raining or snowing). If possible, the sample container should be warmer than the ambient temperature to reduce the possibility of condensation within the sample container.*

2. Clear and Ground

   Clear and ground each terminal of the circuit breaker according to the applicable operating order or procedure.

3. As Found Hydraulic Pump Starts Counter Reading

   Record the value on the circuit breaker's pump starts counter into RMS as an "As Found Equipment Start" type reading.

4. As Found Operation Counter Reading

   Record the value on the circuit breaker's operation counter into RMS as an "As Found Operation Counter" type reading.

5. Depressurize Hydraulic System

   Completely depressurize the hydraulic system by opening stopping switch of the hydraulic pump's motor and by slowly opening the pressure release valve.

6. Obtain Can Samples

   Apply the following to take can samples from the interrupter closest to the control cabinet on each phase.

   a) Record the sample can number in the appropriate phase location on the Standard Oil Sample Check Sheet.
   b) Remove the dust cap from the interrupter drain/filling valve and wipe it with a clean lint-free cloth to remove any particle matter.
   c) Attach the sample fitting and plastic tubing assembly to the drain valve.
   d) Drain a small quantity of insulating oil into a pail to flush the valve, the fitting and the plastic tubing.
   e) Place the free end of the plastic tubing down into the bottom of the vertically held sample can.
   f) Draw oil to approximately a quarter of the sample can.
   g) Remove the plastic tubing from the can and support it to prevent contaminating the portion that was in the can.

h) Measure the temperature of the insulating oil in the can and record on the "Oil Sampling and Test Record" sheet as the flushing oil temperature.
i) Cap the sample can and rotate it to rinse all surfaces within the sample can with the hydraulic oil.
j) Remove the screw cap and discard the oil.
k) Place the free end of the plastic tubing down into the bottom of the vertically held sample can.
l) Draw oil to completely fill the sample can (to overflow).
m) Slowly remove the plastic tubing.
n) Gently squeeze the sample can to bring the oil level to the lip of the can then tightly install the screw cap.
o) Fill in the remaining required fields on the "Oil Sampling and Test Record" sheet and forward the sample and documentation to the Waverley Oil Lab for testing.
p) Check that the insulating oil level of the interrupter is within acceptable limits (taking into account ambient temperature). Add if required.
q) Repeat steps "b" through "p" for all remaining phases.

7. Pressurize Hydraulic System

   Start the hydraulic pump motor by closing the pressure release valve (finger tight only) and closing the stopping switch for the hydraulic pump’s motor. The high-pressure side of the hydraulic system will begin pressurizing. Do to not over tighten the pressure release valve because this will damage the valve seat. After approximately four minutes the excessive pump running time alarm relay will shut off the pump. Restart it by resetting the relay (to completely pressurize so hydraulic system). Reset the relay by opening and closing the stopping switch for the hydraulic pump motor.

8. As Left Hydraulic Pump Starts Counter Reading

   Record the value on the circuit breaker’s pump starts counter. Enter this reading into RMS as an "Equipment Start" type reading.

9. As Left Operation Counter Reading

   Record the value on the circuit breaker’s operation counter. Enter this reading into RMS as an "Operation Counter" type reading.

10. Oil Sample Results Analysis

   The sampled insulating oil must meet the following criteria:
   - dielectric strength - greater than 15 kV
   - dissolved water content - less than 20 ppm
   - dissipation factor (@ 100 °C) - less than 5 %

   If any criteria are not met, replace with reconditioned insulating oil (available from the Waverley Service Centre). Consider the need to replace the oil as a "Functional Failure".

A7.2 Standard Oil Sample Check List

Station: ________________ Designation: __________________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	Temperature and Humidity Measurements	____________	
2.	Clear and Ground	☐	
3.	As Found Hydraulic Pump Starts Counter Reading	*Record in RMS*	
4.	As Found Operation Counter Reading	*Record in RMS*	
5.	Depressurize Hydraulic System	☐	☐
6.	Obtain Can Sample	☐	
7.	Pressurize Hydraulic System	☐	☐
8.	As Left Hydraulic Pump Starts Counter Reading	*Record in RMS*	
9.	As Left Operation Counter Reading	*Record in RMS*	
10.	Oil Sample Result Analysis	☐	☐

- Minimum Dielectric Strength*: greater than 15 kV,*
- Dissolved Water Content*: less than 20 ppm*
- Maximum Dissipation Factor @ 100 ºC*: less than 5 %*

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A8 Main Contact Check

The Main Contact check is done to inspect the main and arcing contacts of the circuit breaker and ensure that they are in satisfactory condition. The check is performed through visual inspections and contact measurements. The circuit breaker must be removed from service for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A8.1 Main Contact Check Task Description (Interim)

1. Visual Inspection

   Perform a visual inspection of one contact per phase. The contact wear will determine if there is a need to adjust the frequency for subsequent Main Contact Checks. Determine the contact wear and consult with the Interrupting Equipment specialist to discuss what is appropriate

2. As Left Timing Analysis

   Perform an As Left Timing Analysis according to the reference information in Section A9 "Mechanism Check."

A9 Mechanism Check

The Mechanism Check is designed to evaluate the performance of the operating mechanism that drives the circuit breaker's main contacts. The evaluation includes using timing analysis and operational checks. The circuit breaker must be removed from service for this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A9.1 Mechanism Check Task Description (Interim)

Reference OIL CIRCUIT BREAKER TEST-MINIMUM Form H55/F Rev 99 03 and EAM Manual Memo #4-2 Section D Complete Inspection.

- III Operational Checks Item 5
- V Analyzer Test 3-a-f inclusive

B NON-REPETITIVE MAINTENANCE TASKS

Tasks will be added as required.

C TECHNICAL INFORMATION

Information will be added as required.

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
6	2011 08 30	Updated the task template as per revision detail, revised document headers, added technical detail and combined the Main Contact Check with the Mechanism Check.	All	DJD	GV
5	2004 05 19	Task Template update (see Rev 4 in revision block)	A1	TR	DW
4	2002 06 13	Updated information according to details provided in the Maintenance Standard Alert dated: 2002 06 18	A2.1	TR	DW
3	2002 05 08	Added interim information with references to EAM manual and manufacturer's manuals	A4, A5, A6, A7, A8, B, C	TR	DW
2	2002 03 27	Information update	A3.1	TR	DW
1	2002 02 25	Information update	A2, A3	TR	DW
0	2002 02 15	New Maintenance Standard	---	TR	DW
No.	**Date**	**Revision Details**	**Section/Page Affected**	**Tech Supp Services**	**AMR Eng.**

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Circuit Breakers - SF6 Live Tank (Hydraulic Operator)
ABB ELF

Tasks	Triggers			
	Not Critical	Low	Medium	High
Pump Check	12 months	12 months	12 months	12 months
Integrity Check	12 months	12 months	12 months	12 months
Functional Check	< 1 operation / 24 months	< 1 operation / 24 months	< 1 operation / 24 months	< 1 operation / 24 months
Density Monitor Check	60 months	60 months	60 months	60 months
Insulation Check	120 months	120 months	120 months	120 months
Mechanism and Main Contact Check	5000 operations / 15 years/ FAO's	4250 operations / 14 years/ FAO's	3750 operations / 13 years/ FAO's	3000 operations / 12 years/ FAO's

5	2010 12 14	Increased pump check interval from 6 to 12 months. Combined Mech and Main contact check into one task.	CM	DJD		GV	Original signed by G.A. Verch 2011 04 26
4	2004 05 19	Integrity Check task was changed from 6 month to 12 month interval.	CM	TR		DW	
3	2001 12 15	Removed the SF6 Gas Quality Check from the Main Contact Check. Removed the Vibration Measurement test from the Mechanism Check. Changed header.	GW	TR		DW	
2	2001 06 04	Added time trigger to mechanism check. Removed infrared scan. Changed diagnostic check to Main Contact Check.	GW	TR		DW	
1	2000 05 23	Added ASO's	BC	WD		DW	
No.	Date	Revision	AMR Specialist	Tech Supp Services	Insul. Eng.	AMR Eng.	

A2 Pump Check

The Pump Check is performed to ensure the integrity of the basic functions of the circuit breaker’s hydraulic system. The check involves recording and evaluating the number of pump starts and circuit breaker operations. This check is completed without removing the circuit breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A2.1 Pump Check Task Description

1. Pump Start Counters

   Record the number of pump starts for each of the hydraulic pumps located in each pole mechanism; as indicated on the applicable counters in the main control cabinet.

   a) Ensure the counters are referenced correctly with respect to pole designation rather than phase designation.
   b) Enter these values into RMS as an Equipment Start type reading within each mechanism nameplate.

2. Operation Counter

   Record the value of the main operation counter. Enter this value into RMS as an Operation Counter.

3. Number of Pump Starts per Day

   Calculate the average number of hydraulic pump starts per day, for each operating mechanism to ensure it is not exceeding the allowable value of 10 starts per day. Be sure not to include hydraulic pump starts attributed to circuit breaker operations.

   a) Pump starts that exceed 10 per day are considered a Functional Failure and must be investigated.
   b) A pump motor that is locked out due to excessive run time is considered a Functional Failure.
   c) A sudden increase in pump operations, even if within the allowable 10 starts per day, should be investigated.

A2.2 Pump Check List

Station: ________________ Designation: _________________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	Pump Start Counters		
	- Pole A	*Record in RMS*	
	- Pole B	*Record in RMS*	
	- Pole C	*Record in RMS*	
2.	Operation Counter	*Record in RMS*	
3.	Number of Pump Starts per Day	☐	☐

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A3 Integrity Check

The Integrity Check is performed to ensure the integrity of the basic functions and components of the circuit breaker. This is primarily a visual inspection of the equipment, which is done without removing the breaker from service.

Ensure that a Job Plan has been completed prior to starting the following checks.

A3.1 Integrity Check Task Description

A3.1.1 External Components

1. Foundation

   Inspect the circuit breaker's foundations for any visible signs of deterioration or movement.

2. Frame/Support Structure

   Inspect the steel support columns and frame to ensure they are plumb both vertically and horizontally. Inspect for rust or other forms of deterioration. All structure fasteners must be tight.

3. Frame Grounds

   Inspect the steel support structures to ensure they are grounded in two locations, on diagonally opposite corners. The control cabinet must be grounded in one location. The ground clamps must be tight and the ground conductor undamaged.

4. Control Cables and Supports

   Inspect the inter-pole control cables and the cable raceways to ensure that they are not damaged and are secure.

5. Position Indicator

   Visually inspect the position indicator to ensure it is in the correct position. Improper indication may be caused by operating mechanism related problems.

6. Operating Mechanism

   a) Check each operating mechanism to ensure the hydraulic system is properly charged.

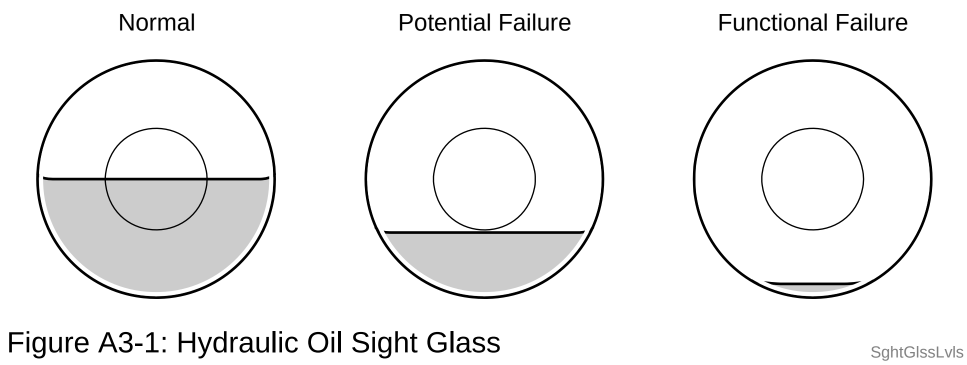


Figure A3-1: Hydraulic Oil Sight Glass

b) Check the hydraulic oil level of each operating mechanism to ensure it is within allowable limits (see Figure A3-1). Top-up if below normal.

c) Inspect the underside of each operating mechanism for the presence of hydraulic oil. Investigate where hydraulic oil is found.

d) Inspect the fibreglass covers of each operating mechanism to ensure they are properly tightened and not deteriorating.

7. Support and Interrupter Porcelain

   Visually inspect the support and interrupter porcelains to ensure they are clean and are free of chips, cracks or other structural damage.

8. Primary Bus

   Visually inspect the primary bus to ensure the tension is correct and all connectors appear tight.

9. Grading Capacitors

   Visually inspect the grading capacitors to ensure they are clean and are free of chips, cracks or other damage.

A3.1.2 Control Cabinet

1. Doors, Hinges and Latches

   Inspect all doors, hinges and latches on the control cabinet to ensure they are functioning properly.

2. Weather Stripping

   Inspect all weather stripping on the control cabinet to ensure it is functioning properly.

3. Cabinet Condition

   Inspect the control cabinet to ensure it is clean and free of debris, structurally sound and free of rust or other deterioration.

4. Cabinet Heater Currents

   Measure the current of all control and operating mechanism heaters, both switched and anti-condensation. Measured values must be within ± 5 % of the value indicated in the manufacturer's instruction manual.

   a) Failure of a control cabinet heater or an anti-condensation heater, regardless of location, is considered a Potential Failure.
   b) Failure of an operating mechanism heater is considered a Functional Failure.

5. Thermostat

   Inspect and when possible operate the thermostat used to control the switched heaters, to ensure it is functioning properly.

   a) Failure of a thermostat is considered a Potential Failure, unless it is controlling an operating mechanism heater.
   b) Failure of a thermostat controlling an operating mechanism heater is considered a Functional Failure.

6. Operation Counter

   Record the value of the circuit breaker's main operation counter. Enter this value into RMS as an Operation Counter type value.

7. Fault Operations

   Determine and record the number of fault operations the circuit breaker has performed. Enter this value in the computerized maintenance system as a Breaker Fault Points type reading.

A3.2 Integrity Check List

Station: ________________ Designation: _________________ Date: ____________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

	Complete	Failed
A3.1.1 External Components		
1. Foundation	☐	☐
2. Frame/Support Structure	☐	☐
3. Frame Grounds	☐	☐
4. Control Cables and Supports	☐	☐
5. Position Indicator	☐	☐
6. Operating Mechanism		
a) Hydraulic system properly charged	☐	☐
b) Hydraulic oil within allowable limits	☐	☐
c) No indication of hydraulic oil leaks	☐	☐
d) Fibreglass covers intact and properly fastened	☐	☐
7. Support and Interrupter Porcelain	☐	☐
8. Primary Bus	☐	☐
9. Grading Capacitors	☐	☐
A3.1.2 Control Cabinet		
1. Doors, Hinges and Latches	☐	☐
2. Weather Stripping	☐	☐
3. Cabinet Condition	☐	☐
4. Cabinet Heater Currents	☐	☐
5. Thermostat	☐	☐
6. Operation Counter	*Record in RMS*	
7. Fault Operations	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A4 Functional Check

The Functional Check is performed on circuit breakers that have remained in either an open or closed state for a defined period of time. It is used to exercise the circuit breaker and to check its operation. Obtain the applicable permission to operate the circuit breaker and ensure that it will not cause a customer outage or create undue stress on the system.

Ensure that a Job Plan has been completed prior to starting the following checks.

A4.1 Functional Check Task Description

1. As Found Main Operation Counter Reading

   Record the circuit breaker's main operation counter.

2. Visual Inspection

   Visually inspect the circuit breaker prior to it being operated to ensure that it is in satisfactory condition and ready to operate. Investigate any abnormalities found and complete the appropriate corrective.

3. Operate the Circuit Breaker

   Change the operational status by either:
   - Close operation: remotely by SCC or by station local control
   - Open operation: by protection relay (if possible) or remotely by SCC

   When applicable, during circuit breaker operations, listen for and note any abnormalities, from a safe location.

4. Visual Inspection

   Visually inspect the circuit breaker to ensure that it has operated correctly, is in satisfactory condition and ready for immediate operation. Investigate any abnormalities and complete the appropriate corrective as required. The visual inspection should confirm the:

   a) correct operation of the circuit breaker
   b) operation of the main operation counter
   c) status of the porcelain components (not damaged when operated)

d) the motor driven hydraulic pump has successfully charged the system
e) hydraulic oil level is correct (see Figure A4-1).

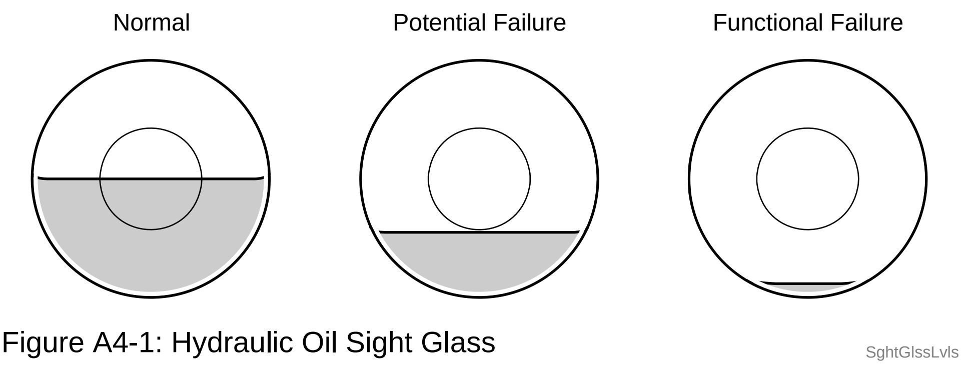


Figure A4-1: Hydraulic Oil Sight Glass

5. Operate the Circuit Breaker

   Change the operational status by either:
   – Close operation: remotely by SCC or by station local control
   – Open operation: by protection relay (if possible) or remotely by SCC

   When applicable, during circuit breaker operations, listen for and note any abnormalities, from a safe location.

6. Visual Inspection

   Visually inspect the circuit breaker to ensure that it has operated correctly, is in satisfactory condition and ready for immediate operation. Investigate any abnormalities and complete the appropriate corrective as required. The visual inspection should confirm the:

   a) correct operation of the circuit breaker
   b) operation of the main operation counter
   c) status of the porcelain components (not damaged when operated)
   d) the motor driven hydraulic pump has successfully charged the system
   e) hydraulic oil level is correct (see Figure A4-1).

7. As Left Operation Counter Reading

   Record the As Left value on the circuit breaker’s main operation counter and ensure that it has incremented from the As Found reading. Enter the reading into RMS as an Operation Counter type reading.

   Classify an operation counter failure as a Potential Failure due to the potential delay of maintenance triggers. Delays in maintenance affect the circuit breaker’s functional operation and could lead to a Functional Failure.

A4.2 Functional Check List

Station: _______________ Designation: _______________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

		Complete	Failed
1.	As Found Operation Counter Reading	*Record in RMS*	
2.	Visual Inspection	☐	☐
3.	Operate the Circuit Breaker	☐	☐
4.	Visual Inspection		
	a) Correct operation of the circuit breaker	☐	☐
	b) Correct operation of the main operation counter	☐	☐
	c) No physical damage (porcelain)	☐	☐
	d) Hydraulic pump charges hydraulic system	☐	☐
	e) Insulating gas pressure	☐	☐
5.	Operate the Circuit Breaker	☐	☐
6.	Visual Inspection		
	a) Correct operation of the circuit breaker	☐	☐
	b) Correct operation of the main operation counter	☐	☐
	c) No physical damage (porcelain)	☐	☐
	d) Hydraulic pump charges hydraulic system	☐	☐
	e) Insulating gas pressure	☐	☐
7.	As Left Main Operation Counter Reading	*Record in RMS*	

NOTE: *This form and its information are intended for your immediate reference only. After entering readings and required correctives into RMS, discard this check list.*

A5 Density Monitor Check

The Density Monitor Check is performed to ensure the correct operation of each density monitor. Each phase has a density monitor to indicate low gas pressure in the circuit breaker and to block operation if the gas pressure drops below a specified level. This is an out of service test.

Ensure that a Job Plan has been completed prior to starting the following checks.

A5.1 Density Monitor Check Task Description (Interim)

1. Obtain Specialty Tools
   - density monitor test set,
   - gas pressure gauge,
   - gas testing instruments and appropriate adapters
2. Determine Expected Values

   Refer to the manufacture instruction manual and nameplate to determine the expected values.
3. Test Insulating Gas

   Test the insulating gas for purity (%) and moisture to ensure that it is in within the specified values.
4. Test Density Monitors

   Remove and test each density monitor taking into consideration the pressure gauge used.

Contact Technical Support Services (TSS) Interrupting Equipment Section if there are any questions.

A6 Insulation Check

The Insulation Check is performed to ensure that the insulating properties of the grading capacitors are within specified values by measuring their capacitance and dissipation factor. The grading capacitors must be capable of performing their function of evenly distributing voltage across contacts of the multi-break per phase circuit breakers. The circuit breaker must be cleared to complete this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A6.1 Insulation Check Task Description

The circuit breaker is pressurized with SF6 gas, use extreme caution when moving around with an aerial device.

The Insulation Engineering and Testing Department website contains all required information to complete this task. The link to their website is; http://coil.hydro.mb.ca/insulation_eng_testing/index.html. Once in the site, click on Technical Info, then Procedures for use of Model 100 Capacitance Bridge.

- Section A "General Information & Instructions - Test Sheet Distribution"
- Section J "Model 100 Capacitance Bridge Testing", "Air Blast, Minimum Oil, or SF6 Circuit Breakers with Multiple Interrupters" Complete using the "Alternate Method"
- Test Sheet H94E, "Minimum Oil or Air Blast Circuit Breaker"

A7 Mechanism and Main Contact Check

The Mechanism and Main Contact Check is performed to evaluate the performance of the operating mechanism and the condition of the main contacts. The mechanism's evaluation includes timing/motion analysis, operational checks and a visual inspection. The main contact check will determine the percentage of erosion of the arcing contact and determine the condition of the main contacts. The circuit breaker must be cleared to complete this check.

Ensure that a Job Plan has been completed prior to starting the following checks.

A7.1 Mechanism and Main Contact Check Task Description (Interim)

- Timing / Motion Analysis
- Dynamic Resistance Measurement (DRM)
- Static Contact Resistance
- Inspection of the operating mechanisms
- Operational tests

Contact Technical Support Services (TSS) Interrupting Equipment Section if there are any questions.

B NON-REPETITIVE MAINTENANCE TASKS

Tasks will be added as required.

C TECHNICAL INFORMATION

Information will be added as required.

EAM MANUAL - MEMO 5

BULLETIN #20

MAINTENANCE MANUAL BULLETIN

SCHEDULED AND UNSCHEDULED INSPECTIONS

Please insert *Bulletin #20* at the front of *Memo 5, Transformers*. The objective of Bulletin #20 is to specify inspection frequencies and requirements in a concise manner and to reference pertinent test and/or inspection procedures for the convenience of the EAM Technician.

Bulletin #20 is essentially a summary of existing maintenance practices pertaining to power class reactive apparatus in Memos 2, 5, 7, and 18 and should not conflict with those practices with the exception of the inspection frequencies identified in Memo 5, Section A6.4.5. The Semi-Annual, 1 Year, 2 Year, 3 Year and 5 Year Maintenance Inspections will be superseded by the scheduled inspections specified in Bulletin #20. The maintenance inspection frequency for all power class reactive apparatus will now be 5 years. Additionally, major and special application apparatus will be inspected annually, in an economical and expedient manner (i.e. generally not requiring removal from service) to ensure operating integrity.

Bulletin #20 has been developed as a "Stop-Gap" measure until Memo 5 can be rewritten, at which time it will be incorporated into the rewrite. In the meantime, it is hoped that Bulletin #20 will organize the existing material into a logical format therefore making it easier to use.

Prepared By: B. Hembroff
Approved By: W.G. Stephens
Date: 1993 09 17

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A. SCHEDULED INSPECTIONS

A1. GENERAL

OBJECTIVE

To identify scheduled inspection frequencies and requirements in a concise manner, and to reference pertinent test and/or inspection procedures.

DEFINITIONS

i) Scheduled Inspection - an inspection which is planned. Time (i.e. time in service) is the only factor which initiates a scheduled inspection.

ii) Unscheduled Inspection - an inspection which is not planned. An event or deficiency would initiate an unscheduled inspection.

iii) Insulation Test Procedure (IT Procedure) - any procedure developed by the Insulation Engineering/Testing group is referred to as an IT Procedure. When an IT procedure is specified as a required inspection the appropriate procedure(s) will be referenced.

iv) Visual and Audible Inspections - denotes that the required inspection is an observation.

v) Functional Inspection - denotes that the required inspection is to prove that the designated component is operational (i.e. capable of performing its designed purpose).

vi) Calibration - denotes that the designated component is to be tested, inspected and adjusted ensuring that it is functional within very specific parameters.

vii) Mechanical Procedure - a procedure which requires detailed mechanical (as opposed to electrical) measurements and/or observations. Usually associated with load tapchangers.

A2. WARRANTY INSPECTION

SCOPE

Applicable to all new and factory repaired oil immersed power class reactive apparatus (transformers, reactors and regulators). Not applicable to older apparatus which is being relocated.

FREQUENCY

The following tests and inspections are to be performed after the first year of service.

PURPOSE

The purpose of the warranty inspection is to identify any manufacturing defects or deficiencies. Note: Apparatus is generally warranted (complete) for one year. Hence, the Apparatus Engineering Section, Stations Department, E & C should be notified immediately if a deficiency is found on a new unit so that a claim can be initiated.

Diagnostic Tests:

ITEM	REQUIRED INSPECTION	REMARKS
Insulation System	IT Procedure Model 100 CB (see Note 1)	Refer to Memo 18: B General Instructions for Using the Model 100 CB C Two Winding Transformers V Three Winding Transformers X Two Winding Transformers with Isolated ϕ Bus E Bushings Cap Tap Method F Bushings Draw Lead Method G Bushings Hot Collar Method H Insulating Oil
Core Ground	Core Ground Tests: Model 100 CB Megger LV Ohmmeter	Perform only if core is grounded externally. Refer to Memo 5 Section B2 Core Ground Test Procedure, and Memo 18 Section C Two Winding Power Transformers. Record insulation resistance (min 50 MΩ at 500 V DC). Also OHMIC value and rating (watts) of core ground resistor.

ITEM	REQUIRED INSPECTION	REMARKS
DGA	Sample (See Note 1)	Refer to Memo 2: C1.1 Scope C4 Routine Sampling Points C5 Restriction on Welding C6 30ml Syringe Sampling Method C6.1 Samples from BMT or Forced Oil Circulation Pump C9 Shipment of Samples C10 Location of Sampling Equipment
Standard Oil	Sample (See Note 1)	Refer to Memo 2: A1 Purpose A2 Sample Container A2.1 Availability A2.2 Detailed Sampling Instructions A2.3 Points to be Sampled A4.1 Routine Tests A6 Processing of Test Results
Note 1: This test may be an additional test to the requirements specified in the respective sections of the EAM Manual which are referenced.		

Primary Components:

ITEM	REQUIRED INSPECTION	REMARKS
All		Perform same as specified in Section A4, Maintenance Inspection.

Auxiliary Components:

ITEM	REQUIRED INSPECTION	REMARKS
All		Perform same as specified in Section A4, Maintenance Inspection.

A3. INTEGRITY INSPECTION

SCOPE

Applicable only to oil immersed reactive power class apparatus:

i) Rated 230 kV and greater, and/or

ii) Rated 40 MVA and larger, and

iii) All reactors, and

iv) All three phase regulators (LTC), and

v) All generator step-up transformers, and

vi) All HVDC converter transformers

OBJECTIVE

To verify the operating integrity of major and special application apparatus in an economical and expedient manner. Unless a deficiency is identified the integrity inspection should (generally) not necessitate the removal of the unit from service.

FREQUENCY

The following tests and inspections are to be performed after every year of service unless the maintenance inspection is scheduled in which case the maintenance inspection would supersede the integrity inspection.

Diagnostic Tests:

ITEM	REQUIRED INSPECTION	REMARKS
DGA	Sample (See Notes 1 & 2)	Refer to Memo 2: C1.1 Scope C3 Routine Sampling Frequency C4 Routine Sampling Points C5 Restriction on Welding C6 30 ml Syringe Sampling Methods C6.1 Samples from BMT or Forced Oil Circulation Pump C9 Shipment of Samples C10 Location of Sampling Equipment
Standard Oil	Sample (See Notes 1 & 2)	Refer to Memo 2: A1 Purpose A2 Sample Container A2.1 Availability A2.2 Detailed Sampling Instructions A2.3 Points to be Sampled A3 Frequency of Sampling A4.1 Routine Tests A5 Action on the Basis of Test Results A6 Processing of Test Results

Note 1: Requirements to sample for routine dissolved gas analysis and standard oil tests are identified in other sections of the EAM Manual as referenced. Annual sampling is not required in all cases. Perform only as specified in the relative section which is referenced.

Note 2: In certain geographical areas or work centres it may be more efficient to schedule standard oil test and dissolved gas analysis sampling as an activity separate from the one year integrity inspection.

Primary Components:

ITEM	REQUIRED INSPECTION	REMARKS
All	Visual and Audible	Perform same as specified in Section A4, Maintenance Inspection.

Auxiliary Components:

ITEM	REQUIRED INSPECTION	REMARKS
Fast Gas Relay	Visual	Check for accumulation of gas, mechanical damage to relay and piping, oil leaks, status of valves. Refer to Memo 5, Section C4 Field Test on Gas Detector Relay.
Top Oil Temperature Gauge(s)	Visual	Compare indications on WT gauge to OT gauge. WT should be equal to, or greater than OT. If OT is greater calibrate. Check for mechanical damage and oil leaks. Refer to Memo 5, Section C3 Field Test Method of Calibration for Dial Type Temperature Indicators, Section C1 Mechanical Test and Inspections, and applicable manufacturer's information.
Winding Temperature Gauge(s)	Visual	Same as OT gauge
Oil Level Gauge(s)	Visual	Are oil level indications normal? Refer to Memo 5, Section C1 Mechanical Tests and Inspections and applicable manufacturer's information.
Fans	Visual Functional	Ensure fans are operational; run using manual control. Refer to Memo 5, Section C1 Mechanical Tests and Inspections, and Section B7 Functional Tests of Controls and Wiring Checks.
Pumps (Cooling) Motor Controls Pressure and flow Devices	Functional Load Test	Refer to Memo 5, Section B1.1.1 Load Test, and Section C1 Mechanical Tests and Inspections
Pressure Relief Devices	Visual	Refer to Memo 5, Section C1 Mechanical Tests and Inspections.
Neutral Resistor	Visual	Check bus, insulators and terminals. Refer to Memo 5, Section C1 Mechanical Tests and Inspections.
Neutral Reactor	Visual	Same as neutral resistor.

ITEM	REQUIRED INSPECTION	REMARKS
Breathers (Dryers)	Functional	Refer to Memo 5, Section A5 Maintenance Procedures, Sections C1 & C5 Mechanical Tests and Inspections. Also manufacturer's info.
Control Cabinet Heater Seals weather vermin oil	Visual Functional	Refer to Memo 5, Section B7 Functional Tests of Controls and Wiring Checks.
LTC	Calibration Functional	Calibrate device 90. Refer to Memo 7 and the manufacturer's information for detailed calibration procedures. Ensure heaters and thermostat are functional.

A4. MAINTENANCE INSPECTION

SCOPE

Applicable to all oil immersed power class reactive apparatus (transformers, reactors and regulators).

FREQUENCY

The following tests and inspections are to be performed after every five years of service.

Diagnostic Tests:

ITEM	REQUIRED INSPECTION	REMARKS
Insulation System	IT Procedure Model 100 CB (See Notes 1 and 2)	Refer to Memo 18: A Frequency B General Instruction for Using the Model 100 CB C Two Winding Transformers V Three Winding Transformers X Two Winding Transformers with Isolated Phase Bus E Bushings Cap. Tap Method F Bushings Draw Lead Method G Bushings Hot Collar Method H Insulating Oil
Core Ground	Core Ground Tests: Model 100 CB Megger LV Ohmmeter	Perform only if core is grounded externally. Refer to Memo 5 Section B2, and Memo 18 Section C Two Winding Power Transformers. Record insulation resistance (min 50 MΩ at 500 V DC). Also OHMIC value and rating (watts) of core ground resistor.
DGA	Sample (See Notes 1 & 3)	Refer to Memo 2: C1.1 Scope C3 Routine Sampling Frequency C4 Routine Sampling Points C5 Restriction on Welding C6 30ml Syringe Sampling Method C6.1 Samples from BMT or Forced Oil Circulation Pump C9 Shipment of Samples C10 Location of Sampling Equipment

ITEM	REQUIRED INSPECTION	REMARKS
Standard Oil	Sample (See Notes 1 & 3)	Refer to Memo 2: A1 Purpose A2 Sample Container A2.1 Availability A2.2 Detailed Sampling Instructions A2.3 Points to be Sampled A3 Frequency of Sampling A4.1 Routine Tests A5 Action on the basis of test results A6 Processing of Test Results

Note 1: Requirements to perform routine capacitance bridge tests, and to sample for dissolved gas analysis and standard oil tests are identified in other sections of the EAM manual. Perform only as specified in the relative section which is referenced. Five years does not correspond to the specified routine inspection frequency in all cases. The inspection may not be required in some cases; while in other cases additional, more frequent inspections are required.

Note 2: Routine Model 100 CB tests are required every 4 to 6 years (as per Memo 18) in almost all cases. In the interest of efficient utilization of corporate resources this test should be coordinated with the five year maintenance inspection.

Note 3: In certain geographical areas or work centres, it may be more efficient to schedule standard oil tests and dissolved gas analysis sampling as an activity separate from the five year maintenance inspection.

Primary Components:

ITEM	REQUIRED INSPECTION	REMARKS
General: Mechanical Damage Oil Levels Paint Noise Oil Leaks Rads Conservator Main Tank X-vent Bushings Terminals Risers H_o + X_o Ground Bus Vents (Breathers) Ground Terminals Valves Nameplate Surge Arresters	Visual and Audible	Refer to memo 5, Section C1 Mechanical Tests and Inspections, and Memo 3 Bushings

Auxiliary Components:

ITEM	REQUIRED INSPECTION	REMARKS
Fast Gas Relay	Functional	Refer to Memo 5, Section C4, Field Test on Gas Detector Relay. Trip test if possible.
Top Oil Temperature Gauge(s)	Calibration	Refer to Memo 5, Section C3 Field Test Method of Calibration for Dial Type Temperature Indicators, Section C1 Mechanical Tests and Inspections, and Section B7 Functional Tests of Controls and Wiring Checks. Also refer to specific mfg. info.
Winding Temperature Gauge(s)	Calibration	Same as 'OT' gauge.
Oil Level Gauge(s)	Functional	Refer to Memo 5, Section C1 Mechanical Tests and Inspections. Also refer to specific Mfg. info.

ITEM	REQUIRED INSPECTION	REMARKS
Fans Motors Controls	Functional Megger Test Load Test	Refer to Memo 5, Section B1 Insulation and Continuity Tests (Megger), Section B1.1.1 Load Test, Section B7 Functional Tests of Controls and Wiring Checks, and Section C1 Mechanical Tests and Inspections. Record insulation resistance (Min 1 MΩ at 500 V DC).
Pumps (Cooling) Motors Controls Pressure and Flow Devices	Functional Megger Test Load Test	Same as Fans.
Off-Load (Ratio Adjusting) Switch	Functional Wind. Res. Test Ratio Test	Refer to Memo 5, Section A4.2.6 Off-Circuit Tapchanger Equipment, and Section B3 Transformer Ratio Test. Use Multi-Amp Transformer Ohmmeter to perform winding resistance measurement. Refer to Manitoba Hydro application guide and the Multi-Amp instruction manual.
Pressure Relief Devices	Functional	As per manufacturer's instructions. Check alarms. Refer to Memo 5 Section C1 Mechanical Tests and Inspections.
Neutral Resistor	Visual	Check bus, insulators and terminals. Refer to Memo 5, Section C1 Mechanical Tests and Inspections.
Neutral Reactor	Visual	Same as neutral resistor.
Breathers (Dryers)	Functional	Refer to Memo 5, Section A5 Maintenance Procedures, Sections C1 and C5 Mechanical Tests and Inspections. Also manufacturer's information.
CTs and PTs	Megger	Refer to Memo 5, Section B1 Insulation and Continuity Tests (Megger)

ITEM	REQUIRED INSPECTION	REMARKS
Control Cabinet Terminals Wiring, Cable Heater Seals Weather Vermin Oil	Visual Megger	Refer to Memo 5, Section B1 Insulation and Continuity Tests (Megger), Section B7 Functional Tests of Control and Wiring Checks, and Section C1 Mechanical Tests and Inspections.
LTC	Mech. Procedure Wind. Res. Test Ratio Test Calibration (See Note 4)	Refer to Memo 5, Section A4 Load Tap Change Equipment, Section B8 Load Tapchanger Tests, Section C2 Mechanical Tests and Inspections, and Section B3 Transformer Ratio Test. Use the Multi-Amp Transformer Ohmmeter to perform the winding resistance test. Refer to the Manitoba Hydro application guide and the Multi-Amp instruction manual. Calibrate device 90. Refer to Memo 7 and the manufacturer's information for detailed inspection procedures.
Note 4:	In certain geographical areas and work centres it may be more efficient to schedule the calibration of the device 90 and/or the maintenance inspection of the LTC as an activity(s) separate from the five year transformer inspection.	

B. UNSCHEDULED INSPECTIONS

B1. GENERAL

OBJECTIVE

To identify unscheduled inspection requirements in a concise manner, and to reference pertinent test and/or inspection procedures.

DEFINITIONS

See Section A1 of Bulletin #20, Scheduled Inspections - General, for definitions of terms used.

SCOPE

Applicable to all oil immersed power class reactive apparatus (transformers, reactors and regulators).

B2. INSPECTION AFTER FAULT (FORCED OUTAGE)

Refer to:

i) EAM Manual Memo 18 Section A5 - Trouble Shooting Power Transformers (Reactors) and Accessories.

ii) Corporate Directives Manual PD301 - Restoring Service or Planning Interruptions, Part I Service Interruption, and Part III Station Transformer Failure.

Follow the appropriate decision tree in Memo 18 Section A5. The inspections and tests required to trouble shoot reactive apparatus are identified in a concise and logical format. For additional assistance contact:

i) Insulation Engineering/Testing Department - Waverley Service Centre

ii) Electrical Apparatus Maintenance Section - Regional Services

PD301 defines the responsibility of the District Operator and identifies the inspection procedures he is to follow.

B3. OFF LOAD TAP CHANGE

The following tests and inspections are to be performed whenever the ratio adjusting switch is operated:

REQUIRED INSPECTION	REMARKS
Functional Winding Resistance Test Ratio Test	Refer to Memo 5, Section A4.2.6 Off-Circuit Tapchanger Equipment, and Section B3 Transformer Ratio Test. Use Multi-Amp Transformer Ohmmeter to perform winding resistance measurements. Refer to the Manitoba Hydro application guide and the Multi-Amp instruction manual.

Table of Contents

Revision History

No.	Date	Revision Details	Section/Page Affected	Tech Supp Services	AMR Eng.
2	2011 09 12	Revised document headers, added formal details to DGA and Standard oil sampling sections, updated the Task Template to match its 8th revision.	All	GCD	GV
1	2008 09 09	Document revision information additions and formatting changes as described in Maintenance Standard Alert dated 2008 09 09	TOC, A2	GCD	WS
0	2004 12 24	New Maintenance Standard	---	JK	DW

A REPETITIVE MAINTENANCE TASKS

A1 Maintenance Task Template

Transformer - Power
Rated ≥ 230 kV or ≥ 50 MVA (max rating)

Tasks	Triggers			
	Not Critical	Low	Medium	High
Integrity Check	12 months	12 months	12 months	12 months
DGA Oil Sample	12 months	12 months	12 months	12 months
Standard Oil Sample	12 months	12 months	12 months	12 months
Maintenance Inspection	120 months	120 months	120 months	120 months

No.	Date	Revision	AMR Specialist	Eq. Specialist	Insul. Eng.	AMR Eng.	
8	2011 07 05	Removed tapchangers & reactors from eq. family. Changed classification rating from 80 MVA to 50 MVA	CM	GCD		GV	Original signed by G. A. Verch 2011 07 13
7	2005 03 22	Insulation check task merged into Maintenance Inspection.	CM	JK		DW	
6	2004 10 12	Bushing tasks returned to template.	CM	JK		DW	
5	2004 03 10	Added refer to bushing template detail for integrity check description.	CM	JK		DW	
4	2002 06 13	Integrated the tapchanger tasks into the transformer tasks.	GW	JK		DW	

A2 Integrity Check

The Integrity Check is performed to ensure the operational integrity of power class transformers including associated equipment such as the tapchanger. The integrity check should not necessitate the removal of the unit from service unless a deficiency is found.

Ensure that a Job Plan has been completed prior to starting the following checks

A2.1 Integrity Check Task Description

A2.1.1 Visual Checks

1. Nameplate

   Ensure the nameplate is attached and readable, request a replacement from Technical Support Services if required.

2. Transformer Pad

   Ensure the concrete pad is level and not deteriorating. An unlevel pad will affect the gas bubble flow to the gas relay and oil levels. A transformer slope is greater than 4 degrees needs to be corrected.

3. Physical Condition

   Inspect the tank, radiators, cabinet(s), and tapchanger for corrosion, deteriorated paint, or damage. Ensure all radiator valves are open and all radiators feel the same temperature.

4. Noise Level

   Listen for any abnormal noise both internally and externally (i.e. noisy fans or pump motor bearings).

5. Oil Leaks

   Check for oil leaking from the transformer.

6. Bushing Condition

   Check the condition of the bushings according to the following criteria. Apply any bushing correctives to the applicable bushing and not on the transformer.

   a) Oil leaks
      Check for signs that oil is leaking or has leaked from the bushing.

   b) Oil level
      Check to ensure oil levels are normal. Normal is generally considered as the halfway point of a sight glass, or the appropriate ambient temperature mark in the case of a sight gauge. Consider the ambient temperature when assessing oil level.

   c) Oil colour
      Check that the oil in the sight glass is not discoloured compared to the other bushings.

d) Sight glass condition
Check the condition of the bushing sight glass. Ensure it is not cracked, damaged, or stained.

e) Sight gauge condition
Check that the glass is not cracked, damaged, or stained. Check that the needle is clearly visible, and is not bent or damaged. Check that there are no signs of oil leaks near the gauge.

f) Insulation condition
Check the bushing insulation for cracks and deterioration. Also check for excessive dust or debris.

g) Capacitance / test tap
Check if the capacitance or test tap cap is: in place, appears tightly fastened, and in good condition.

h) Bushing tag
Ensure the Manitoba Hydro bushing tag is visible and in good condition. If it is not, create an incidental failure report and apply Section B of the applicable bushing maintenance standard (all bushing maintenance standards contain "tag" information in Section B).

i) Bushing riser connections
Visually check the risers to ensure tension is neither too taut nor too slack. Also check for signs of damage such as corrosion or overheating due to loose or cracked connectors.

Direct any bushing concerns to the Technical Support Services, Auxiliary Equipment Group.

7. HO and XO Ground Bus

Ensure that the neutral connections and crimps are tight and show no signs of heating. Check bus support insulators. Measure the current on the neutral wire with a clip on ammeter to ensure the ground path is okay. Investigate possible open neutral if no current is measured.

8. Frame Grounds

Ensure the frame grounds are undamaged and their connectors appear tightly fastened.

9. Gas Detector Relay

Check for mechanical damage to the relay and piping, and the status of the valves. Look at the gauge for gas accumulation and take immediate action if there is gas present. Inspect wiring condition.

10. Oil and Winding Temperature Gauges

    Check the oil and winding temperature gauges (OT and WT) and capillary tubes for mechanical damage. Compare the WT and OT readings. The WT should be equal to or greater than OT. If this is false, contact TSS for further information

11. Oil Level Gauges

    Ensure oil levels are normal as per the oil temperature. Check the gauges for mechanical damage.

12. Pressure Relief Device or Explosion Vent

    Check the status of the pressure relief devices PRD(s) by looking at the indicating pin on top. Check to ensure the explosion vent diaphragm is intact. Inspect wiring condition and arrange replacement of deteriorated components.

13. Conservator Breathers/Dryer System

    Ensure the conservator(s) breather system is not plugged and that the valves to compartments are open. Check the breather/dryer status. For inspection details, refer to applicable manufacturer's information. If the unit is fitted with a silica gel breather, check the colour of silica and change if required. Inspect wiring condition and arrange replacement of deteriorated components.

14. Control Cabinet(s) Condition

    Check the general condition of the following cabinet items: terminals, wiring, cables, heaters, weather stripping, door hinges, and door latches. Ensure the cabinet does not have excessive dirt, oil and moisture that will affect the operation of components. Check operation of the cabinet light.

A2.1.2 Operational Checks

1. Heater Currents

   Measure the thermostat controlled cubicle heater currents and compare these values to the expected values, which can be calculated from the information in the schematics for the transformer and tapchanger. Inspect wiring condition and arrange replacement of deteriorated components. Because of the importance of the cubicle heaters, consider a heater failure as a Functional Failure.

2. Thermostat Operation and Setting (if accessible)

   Check the heater thermostat for correct operation and setting of no less than 13 ºC. Because of the importance of the thermostat, consider its failure as a Functional Failure.

3. Cooling System

   a) Cooling fans

      Operate the fans and check for correct rotation. Measure the running and start current for each cooling stage of the fans and compare with the rated nameplate value.

Make note of any fans that do not operate and arrange that they be repaired or replaced.

Visually check the following:

- Fan guards are in place
- Fan blades are undamaged
- Components are correctly mounted
- Drain plugs are pointing downward
- Contactors, wiring and fuses are the proper rating and in good condition

b) Cooling pumps

▼ Caution ▼

Do not turn off pumps that are intended to run continuously.

Operate the pumps manually and perform the following:

- Measure running current and compare to nameplate
- Check for correct rotation by sight glass or by pressure differential switch
- Contactors, wiring and fuses are the proper rating and in good condition
- Note any unusual noise or vibration

4. LTC Filtration System

Visually check the filtration system for leaks. Record the pressure and running hours. If applicable, check condition of filter cartridges. Refer to manufacturer's information for cartridges change requirements.

5. Voltage-Regulating Relay

▼ Cautions ▼

1. **Where possible, check with SCC before performing this check due to the possible impact on customer and system voltage.**
2. **Do not exceed the maximum or minimum voltages supplied to the customer (110 - 125 volts at the customer service entrance).**

Check the calibration of the voltage-regulating relay. Refer to manufacturer's information for details. While operating the tap-changer in the following tasks ("a" to "e"), note any unusual sounds from either the motor drive or the tap-changer compartment.

a) Tap position and drag hand indicators
Record the raise and lower drag hand position and the present tap-changer position.

b) As Found voltage
Measure voltage from control output and compare to the current setting information.

c) On load operation checks (compensation off)

This will check the applied voltage level and bandwidth settings by adjusting the voltage.

i Place the voltage regulating relay in manual operating.

ii Manually operate out of bandwidth (without exceeding the upper and lower limits of 125 and 110 volts when load is connected). Measure the voltage with a meter and check for equal and constant increases and decreases in voltage per tap position.

iii Place the function switch back to automatic and check for correct time delay before the tap-changer operates.

iv Allow automatic return to bandwidth and monitor the voltage to ensure the tap-changer stops inside the bandwidth.

v Repeat test in the other direction.

vi While operating the device note any unusual sounds from the tap-changer.

d) On load operation checks (compensation on)

Individually increase either the reactance or resistance from 0 to maximum. The tap-changer should call for a raise at a uniform rate over the entire range when the power factor lags. If the power factor leads, the reactance adjustment will have the opposite effect and the tap-changer should call for a lower. Apply the required compensation settings and test the voltage regulating relay again using the same procedure as in step "c".

e) As left status

Verify the voltage regulating relay setting. Ensure it is returned to auto, and reset the drag hands.

6. Record Tap-Changer Operations

Record the value on the tapchanger operation counter. Enter the reading into RMS as an Operation Counter type reading.

A2.2 Integrity Check List

Station: ________________ Transformer Designation: ________ Date: ___________

Other information: ____

Know the details of the task description to ensure the completion of a comprehensive Job Plan prior to the start of the check. Enter failed checks into RMS as a corrective.

A2.1.1 Visual Checks

	Complete	Failed
1. Nameplate	☐	☐
2. Transformer Pad	☐	☐
3. Physical Condition	☐	☐
4. Noise Level	☐	☐
5. Oil Leaks	☐	☐
6. Bushing Condition	☐	☐
a) Oil leaks	☐	☐
b) Oil level	☐	☐
c) Oil colour	☐	☐
d) Sight glass condition	☐	☐
e) Sight gauge condition	☐	☐
f) Insulation condition	☐	☐
g) Capacitance / test tap	☐	☐
h) Bushing tag	☐	☐
i) Bushing riser connections	☐	☐
7. HO and XO Connections	☐	☐
8. Frame Grounds	☐	☐
9. Gas Detector Relay	☐	☐
10. Oil and Winding Temperature Gauges	☐	☐
11. Oil Level Gauges	☐	☐
12. Pressure Relief Device (PRD) or Explosion Vent	☐	☐
13. Conservator Breathers/Dryer System	☐	☐
14. Control Cabinet(s) Condition	☐	☐

A2.1.2 Operational Checks		Complete	Failed
1.	Heater Currents	☐	☐
2.	Thermostat Operation and Setting (if accessible)	☐	☐
3.	Cooling System	☐	☐
	a) Cooling fans	☐	☐
	b) Cooling pumps	☐	☐
4.	LTC Filtration System	☐	☐
5.	Voltage-Regulating Relay		
	a) Tap position and drag hand indicators	☐	☐
	b) As Found voltage	☐	☐
	c) On load operation checks (compensation off)	☐	☐
	d) On load operation checks (compensation on)	☐	☐
	e) As left status	☐	☐
6.	Record Tap-Changer Operations	*Record in RMS*	

A3 DGA Oil Sample

Sampling of oil for dissolved gas-in-oil analysis or DGA is performed to detect internal defects before they reach serious proportions. The sampling intervals will be according to the task template unless test results warrant more frequent sampling.

A3.1 DGA Oil Sample Task Description

The transformer has only one compartment for its components submersed in the same oil. Therefore, the DGA sample will be taken from the bottom main tank sampling valve.

1. Fill Sample Syringe

   Fill a 30 mL glass syringe from the transformer valve according to the procedure Section C7.1 of "Sampling for and Analysis of Free and Dissolved Gasses in Insulating Oil" (located on the Insulation Engineering and Testing website "http://coil.hydro.mb.ca/insulation_eng_testing/" under "Technical Information" and "Procedures We Maintain").

2. Complete the DGA Request Form

   a) Print the required form as found on the Insulation Engineering and Testing website "http://coil.hydro.mb.ca/insulation_eng_testing" under "Technical Information" and "Procedures We Maintain". The form is also available through eForms (2430a).
   b) Complete the form with all required information including the transformer serial number.
   c) Identify the sample point as the Bottom Main Tank "BMT".

3. Ship Sample for Analysis

   Ship sample to the Oil Laboratory according to Section C10 of "Sampling for and Analysis of Free and Dissolved Gasses in Insulating Oil".

▲ WARNING ▲

Do not draw oil samples from transformers that are under vacuum. Such action may result in equipment damage and/or injury. Transformers under vacuum are typically sealed with no conservator or are instrument transformers. If a vacuum check proves positive, contact TSS for further instructions.

A4 Standard Oil Sample

Sampling of the insulating oil is performed to detect poor oil qualities before they reach serious proportions.

The sampling intervals will be according to the task template unless test results warrant more frequent sampling. Oil samples must be taken after a transformer is filled with oil, for example, after processing.

A4.1 Standard Oil Sample Task Description

The transformer has only one compartment and its components submersed in the same oil. Therefore, the oil sample will be taken from the bottom main tank sampling valve and the transformer conservator.

1. Fill Sample Container

   Fill a can or jar from the sample points of the transformer and its conservator according to the procedure in Section A4 of "Insulating Oil Properties" (located on the Insulation Engineering and Testing website "http://coil.hydro.mb.ca /insulation_eng_testing" under "Technical Information" and "Procedures We Maintain").

2. Complete the "Oil Test Request Form"

   a) Print the required form as found on the Insulation Engineering and Testing website "http://coil.hydro.mb.ca/insulation_eng_testing" under "Technical Information / Procedures We Maintain". The form is also available through eForms (form number 0070a).
   b) Complete the form with all required information including the transformer serial number.
   c) Identify the sample as the Bottom Main Tank "BMT". Also identify the transformer conservator sample point as "CMT".

▲ WARNING ▲

Do not draw oil samples from transformers that are under vacuum. Such action may result in equipment damage and/or injury. Transformers under vacuum are typically sealed with no conservator or are instrument transformers. If a vacuum check proves positive, contact TSS for further instructions.

A4.2 Oil Sample Reviewing

1. Review test results

   Use the two criteria below to review the oil sample.

   a) Apply the oil test results against the appropriate tables found in the insulation testing website. The applicable table row to use is "Bottom of Main Tank" and "Bottom of Main Conservator".
   b) Failed test results must be compared to previous samples that provide a trend to ensure the sample is legitimate. A worsening trend of results may indicate that the failed test result is legitimate. Similarly, if previous results showed no problems, the failed test may be due to a contaminated oil sample.

   Apply the following to the outcome of the result review.

   - analysis indicates no change to frequency - no action required
   - analysis indicates a frequency change is needed - contact TSS
   - analysis indicates a recondition or reclaim - make corrective and take appropriate action
   - analysis indicates a sample that does not match trend - proceed to step 2

2. Perform re-sample

   a) Create a Corrective Work Order on the apparatus to initiate a re-sample task and classify the task as a Potential Failure (classed as such to make available any Mode/Component/Subcomponent selections).
   b) Enter the failed test results into the memo field within RMS. Enter the words "Oil Sample Failed" into the summary field.
   c) Follow the oil sampling procedure carefully to ensure a quality sample is taken.

3. Review re-sample test results

   Use the two methods below to review the oil sample and continue with the steps if the sample does not match trend.

   a) Compare the test results to previous samples that will provide a trend to ensure the sample is legitimate.

b) Apply the oil test results against the appropriate tables found in the insulation testing website and enter the re-sampled test results into the memo field within RMS. Apply the appropriate instruction below to the corrective and take the appropriate course of action.
   - analysis indicates no change to frequency - change the failure mode to Incidental and close the corrective
   - analysis indicates a frequency change is need - contact TSS, change the failure mode to Incidental and close the corrective
   - analysis indicates a recondition or reclaim is required - arrange for the work to be completed, change the failure mode to Functional and charge required work to the corrective

If there are any questions in regard to the above contact RMS Support or the Reactive Equipment group.

A5 Maintenance Inspection (Interim)

Perform Maintenance Inspection as per EAM Manual Bulleting #20, Section A4. This would include internal inspection of tap-changer (LTC).

- Reference to frequencies are superseded.
- Although DGA and Standard Oil Samples are separate tasks identified on the task template, both samples are required if oil is removed from a compartment on the transformer. For example, if one or more tap-changers require an internal inspection, a sample of tap changer oil must be taken prior to removing the oil and another sample taken after putting in the new oil. These samples should be taken as per documents specified in section A3 and A4.

Perform the Insulation Test as per Insulation Engineering & Testing document "Model 100 Manual". This document is located on the Insulation Engineering & Testing website under Technical Information /Procedures We Maintain.

B NON-REPETITIVE MAINTENANCE TASKS

Tasks will be added as required.

C TECHNICAL INFORMATION

Information will be added as required.

Appendix IV – Protection Maintenance Testing Standards

Transmission System Operations

RCM Ground Rules for Protection Schemes

RCM Ground Rules for Protection Schemes

RCM Ground Rules for Protection Schemes

1. Protection Systems with main relays identified.

Generator Protection
1. Differential
2. Impedance
3. Overcurrent
4. Etc.

Line Protection
1. Phase comparison
2. Impedance
3. Overcurrent

Transformer / Reactor / Ground bank / Station service protection
1. Differential
2. Overcurrent
3. Gas relay

Bus protection
1. Differential
2. Overcurrent

Capacitor bank protection
1. Differential
2. Overcurrent

Remedial Action Systems (RAS)
- Under frequency
- Breaker fail
- HVDC Reduction
- Cross trip

Control Systems
- Synchronizers

2. Definition of a Failure

A relay failure is defined as: The “as found” test is outside the specified error band in the test plan for any test. This includes all quantifiable electrical and mechanical checks. Note: all electrical checks to be performed must be accomplished before removal from the case for mechanical inspection if possible.

Protection scheme type

TYPE	CHARACTERISTICS
A/B	A fully redundant protection system that provides identical levels of protection, no compromises in speed, selectivity. (eg. DLP/SHPM).
Main/Backup	Failure of main package is backed up by protection within the same zone (some compromise of speed or selectivity).
Main	Failure of main package would require operation of protection outside of zone.
RAS	Remedial Action System: functions to remedy a failure in conventional protection or alleviate a system condition.

3. Maintenance Factor Calculation

Several various factors are combined to calculate the Maintenance Factor. This maintenance factor will be used to calculate maintenance frequencies.

3.1. Failure Consequence Factors (FC)

Integers are arbitrarily applied to define/scale the failure of consequence for the *Major Relay* within the protection scheme design. These factors are designated below and applied into a table defining FC for each TYPE based on the technology employed. The technologies of interest are electro-mechanical, solid state, digital non-monitored, and digital monitored. The Failure Consequence is ranked as follows:

Non-critical (N/C) =	0
Low =	1
Medium =	2
High =	3

Applying these to the Scheme type and technology yields the matrix

Failure Consequence Matrix [S,T]

	TECHNOLOGY [T]			
Scheme Type [S]	1. Electro-Mechanical	2. Solid State	3. Digital – Not Monitored	4. Digital – Monitored
1. A/B	1	1	1	0
2. Main/Backup	2	2	2	1
3. Main	3	3	3	2

For RAS systems the following Failure consequences will be applied.

-	Under frequency	0 (non impact for single failure mode)
-	Breaker Failure	individual determination based on location and function
-	HVDC Reduction	0 (Digital - monitored)
-	Cross-trips	2 (medium due to system stability concerns)

Control systems

-	Synchronisers	0

3.2. Failure Probability Factors (FP_T)

For each technology a relative Failure Probability is defined. These factors can be later refined and normalised to yield better results. For now we will assign either low (1) or high (2). See section 6 for more details.

1.	Electro-Mechanical =	2
2.	Solid State =	1
3.	Digital, Not Monitored =	1
4.	Digital, Monitored =	1

3.3. Environmental Factors (E_i)

Additionally, the environment at that relay location will also have an influence on the wear of a relay. A good environment would be a clean, vibration free similar to a terminal station. A poor environment would be determined by analysis on a per case basis. All environments are initially set as good.

1. Good = 1
2. Poor = 2

3.4. Maintenance Factor (MF)

The maintenance factor (MF) for any given Scheme Type and Technology can be calculated as

$$MF = FC_{S,T} \times FP_T \times E_i$$

Higher values indicate greater maintenance requirements.

For example: The MF for an A/B system digital relay (not monitored) in a good environment would be

FC[3,1] = 1
FP[3] = 1
E[1] = 1

$$MF = FC_{3,1} \times FP_3 \times E_1 = 1 \times 1 \times 1 = 1$$

Calculating the MF matrix based on the above formula for a good environment would produce:

Maintenance Factor Matrix – good environment

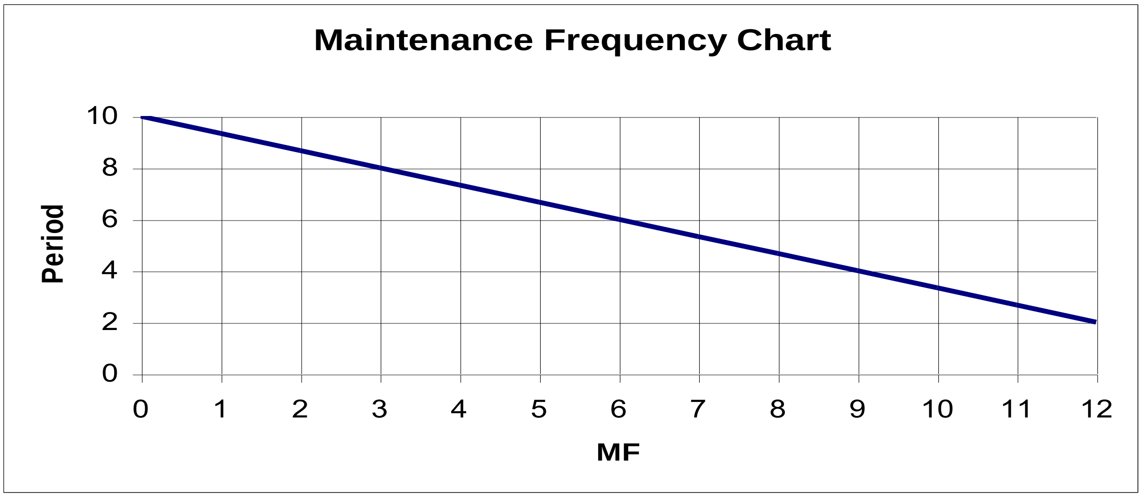
	TECHNOLOGY [T]			
Scheme Type [S]	1. Electro-Mechanical	2. Solid State	3. Digital – Not Monitored	4. Digital – Monitored
1. A/B	2	1	1	0
2. Main/Backup	4	2	2	1
3. Main	6	3	3	2

Maintenance Factor Matrix – poor environment

	TECHNOLOGY [T]			
Scheme Type [S]	1. Electro-Mechanical	2. Solid State	3. Digital – Not Monitored	4. Digital – Monitored
1. A/B	4	2	2	0
2. Main/Backup	8	4	4	2
3. Main	12	6	6	4

5. Maintenance Frequency

Maintenance frequency can be calculated simply via linear interpolation. Systems with the highest MF have the highest frequency of maintenance. The chart below was calculated using a maximum maintenance period of 10 years and a minimum period of 2 years.



Before adoption of the above maintenance frequency chart, typical protection systems will be tested against the formula to ensure a good fit.

6. PROBABILITY OF FAILURE

This factor is the value that is adjusted based on the living maintenance program.

Appendix V – Tools and Test Equipment for Electrical Maintenance Shops

Appendix V

Tools and Equipment

The following is a list of suggested tools and equipment each work center should have available to perform work on station apparatus: (Note: This is not intended to be a complete list)

Personal Hand Tools: (Basic technician tools) *$2500+ each*

- Wrench sets(1/8" - 1 ¼", plus metric equivalent,)
- Adjustable spanners (6'', 10", 12")
- Pipe wrenches
- Vice grips
- Socket sets(¼", 3/8", and ½" drive, metric and imperial)
- Screw driver sets (Phillips, Robertson, torques, standard)
- Allen wrench set
- File set
- Utility knife
- Multi-meter
- Pliers (needle nose, pump, bull nose)
- Side cutters
- Crimping and wire stripping tool
- Metal chisels, drift punches and center punches
- Hammers and mallet
- Pry/pinch bar
- Insulated (wood)Ruler, and a tape measure
- Nut drivers (metric and imperial)
- Spirit level
- Eye protection (safety glasses/goggles/shield)
- Hearing protection
- Fall arrest equipment

Additional Basic Work Center Tools: (tools to be shared)

- ¾" drive socket set *$400 each*
- Impact tools (electric, air) *$200 - $600 each*
- Impact socket set - $200 each
- Hand drills *$230 each*
- Drill press *$600* +
- Drill bits (imperial and metric) *$225 per set*
- Grinders (bench & portable) *$100 - $300 each*
- Hydraulic press (20 – 50 Ton) *$500 - $1.5k*
- Welding equipment (gas) *$600* +
- Welding equipment (electric) *$800* +
- Test bench with ac and dc supplies and loading transformer *$3k* +
- Work bench(s) mechanical *$500 - $1k each*
- Ladders (fiberglass) *$100 - $300 each*
- Come-a-longs (chain hoists) *$100 - $300* each
- Portable hydraulic jacks (5 – 50 Tons) *$50 - $150 each*
- Large pinch/pry bars *$30 - $150 each*
- Oil pumps, hoses and accessories *$2k* +
- Air compressor and accessories *$1k - $3k*
- SF6 gas cart with accessories (if WC has SF6 equipment) *up to$50k*
- Lifting accessories (slings, spreaders, rope, shackles, etc.) *$500* +
- Hydrometers and thermometers (batteries) *$100*
- Torque wrenches *$50 - $200 each*
- Special manufactures' tools (as recommended by Mfg.)

Work Center Test Equipment:

- Capacitance bridge *Model 100 Cap bridge about $10k plus $2k if range extender required (for CVTs), Doble 10 kV Bridge about $65-$70k*
- Transformer dc resistance *$20k for a 10 Amps unit, for 50 Amps about $40k*
- OT & WT test and calibration *$7k*
- Hi-pot dc 5KV *$15k*
- Insulation resistance test meter 1000volts *$200*
- Circuit breaker test & analyzing equipment (dependent on breaker type/mfg.) $50K
- Relay test/analyzers (dependent on relays, Mfg recommendations) $50 K
- Ultrasonic leak detector (only if WC has compressed air systems) *$500*
- Standard/calibrated pressure gauges (only if WC has compressed air systems) *$1.5k*
- Oil tester *$7k*
- Oscilloscope *$500 - $5k*
- Battery ohmic/conductance tester *$1.5k*
- Infrared scope, thermal imaging *$200 - $9k*
- Micro-ohmmeter *$3k*

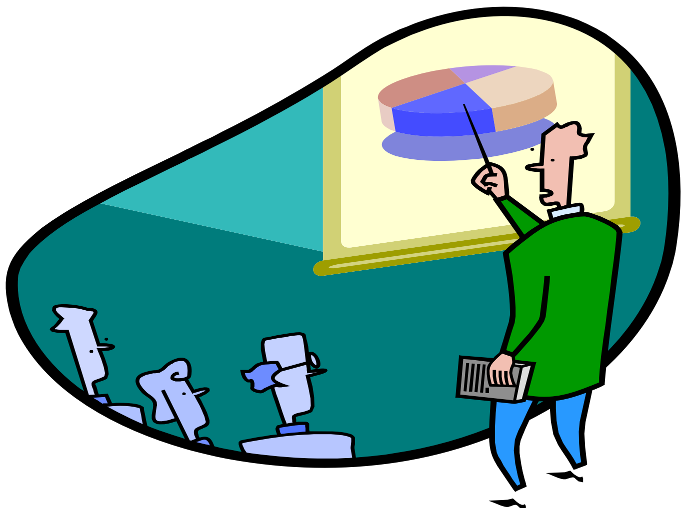
Work Center Vehicles and mobile equipment: (~ $1M)

- Man lift (2 Man Platform Scissor Lift)
- Boom truck (lifting equipment)
- Trucks: Hilux or larger (transportation of staff, tools and materials)
- Trailer (hauling oil drums, pump and hoses)
- Small tanker trailer
- Trailer (hauling larger materials and equipment)

Note: There are many choices and variables which dictate price. Prices shown are +/- 30%, and are intended as guidelines for initial budgeting.

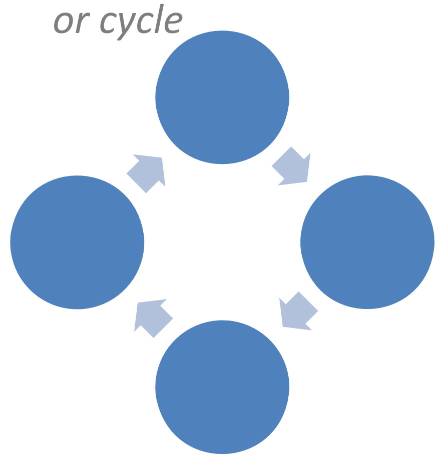
Appendix VI – Work Management System

Work Management Cycle



Work Management Cycle

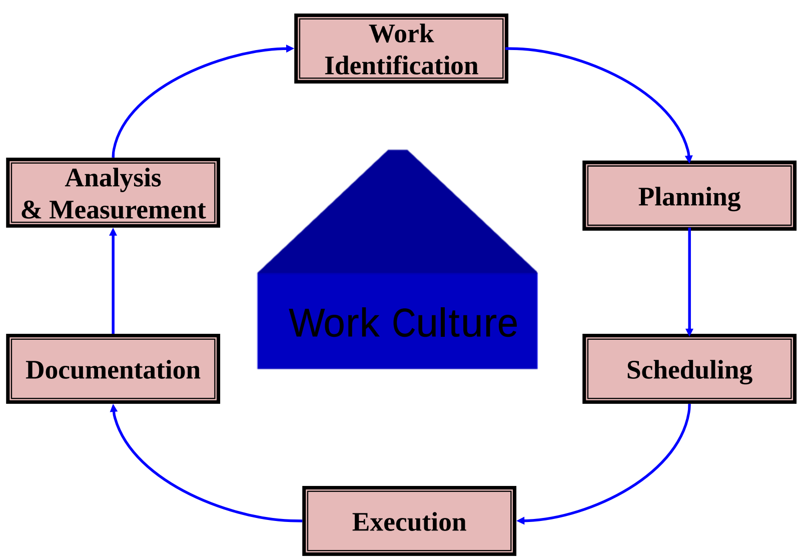
a series of interconnected work management processes that form a loop or cycle

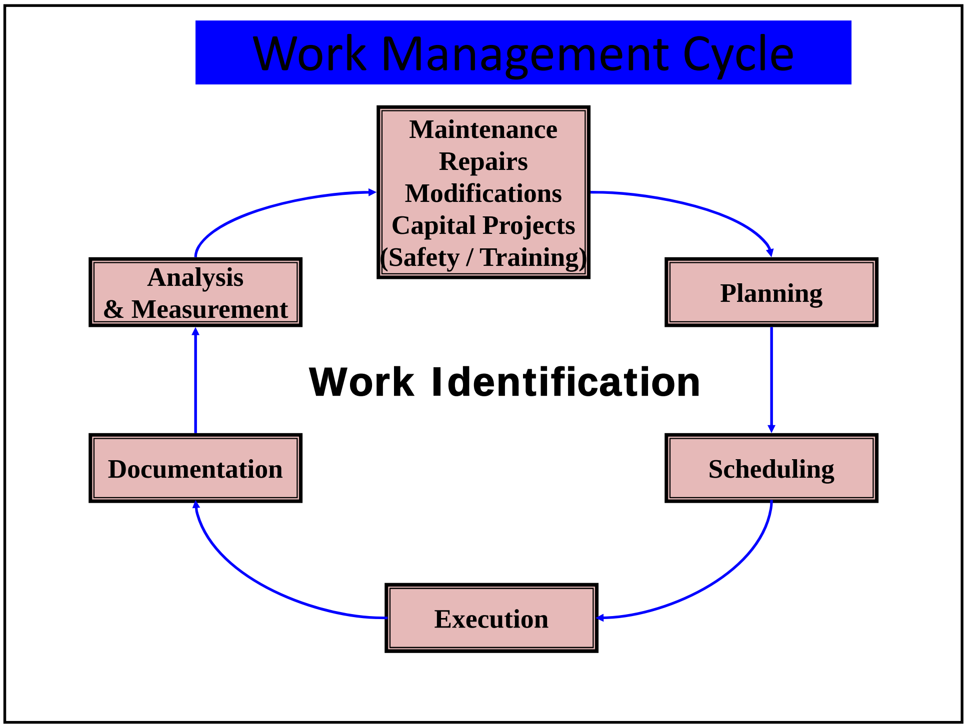


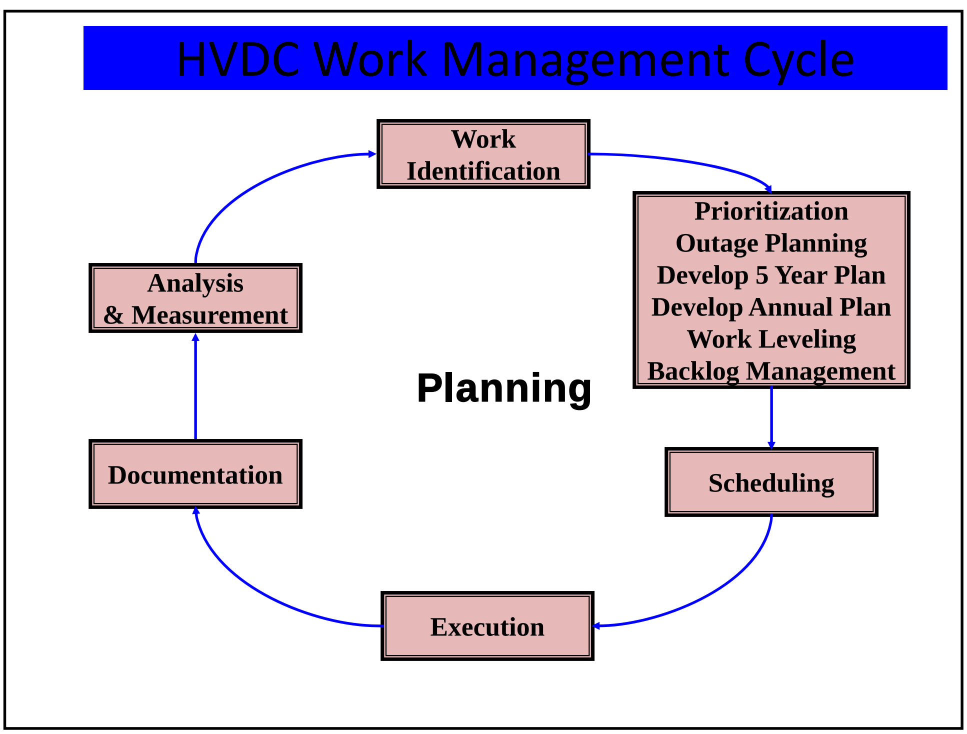
Background

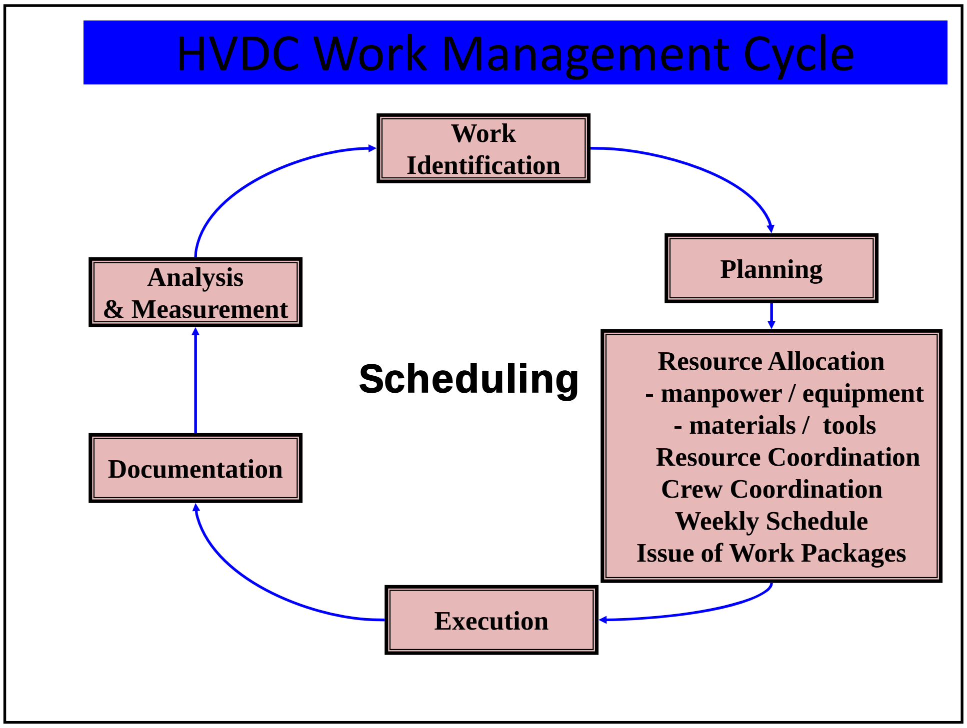
- Spin-off as a result of the RCM process
- Helped the HVDC Division recognize the 6 processes that form Work Management
- Enabled us to identify gaps in the processes, and take corrective action

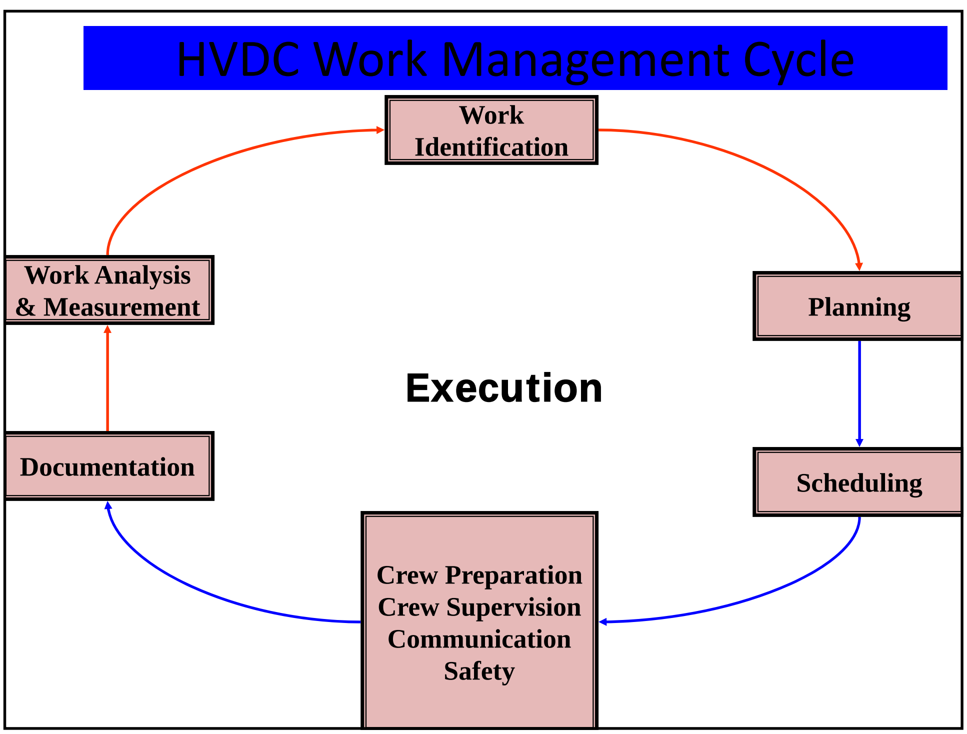
Work Management Cycle (or System)

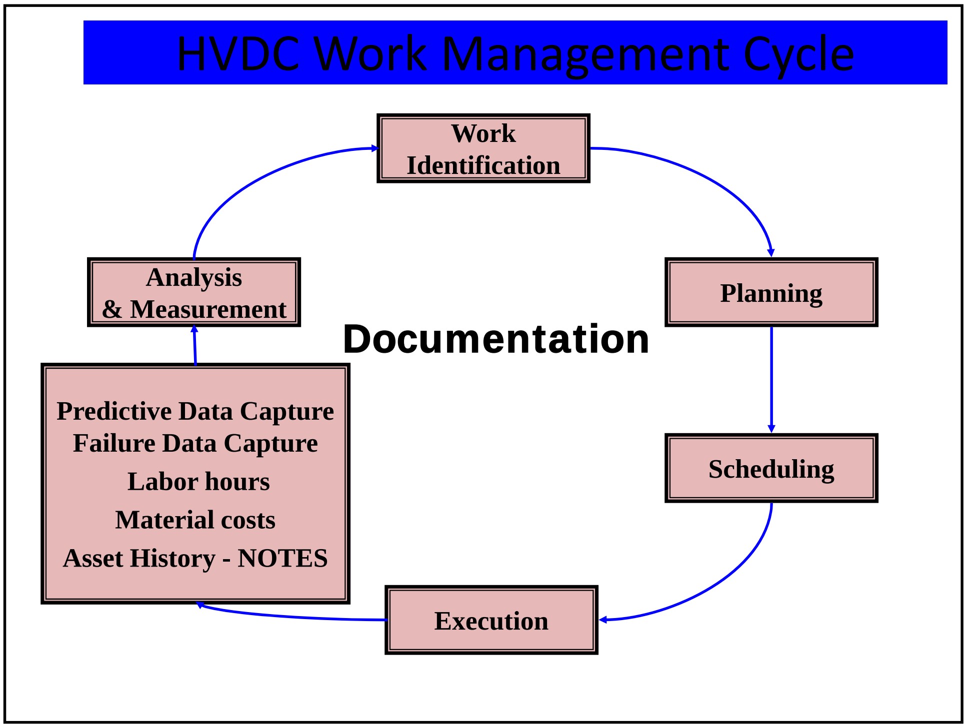


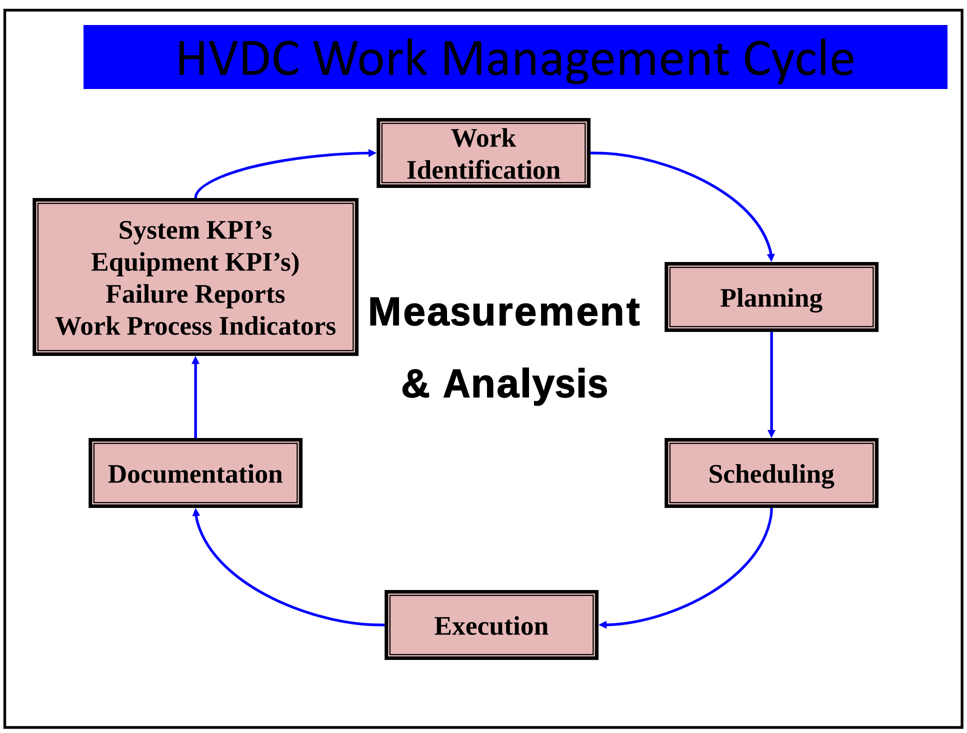

Work Management Cycle
Maintenance
Repairs
Modifications
Capital Projects
(Safety / Training)
Analysis
& Measurement
Planning
Work Identification
Documentation
Scheduling
Execution

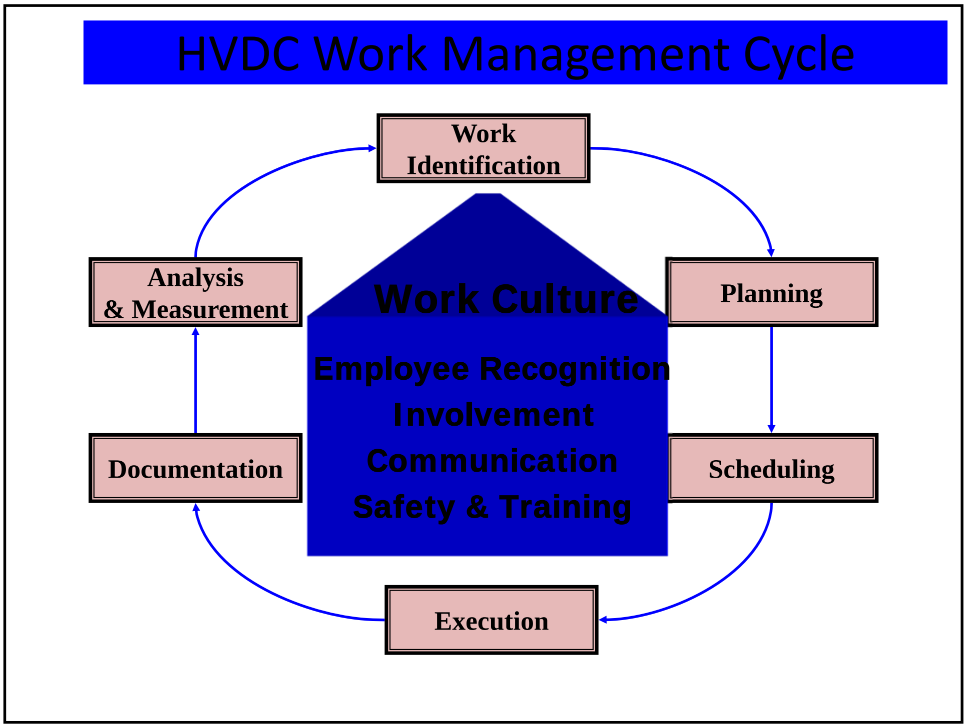

HVDC Work Management Cycle
Work
Identification
Prioritization
Outage Planning
Develop 5 Year Plan
Develop Annual Plan
Work Leveling
Backlog Management
Analysis
& Measurement
Planning
Documentation
Scheduling
Execution

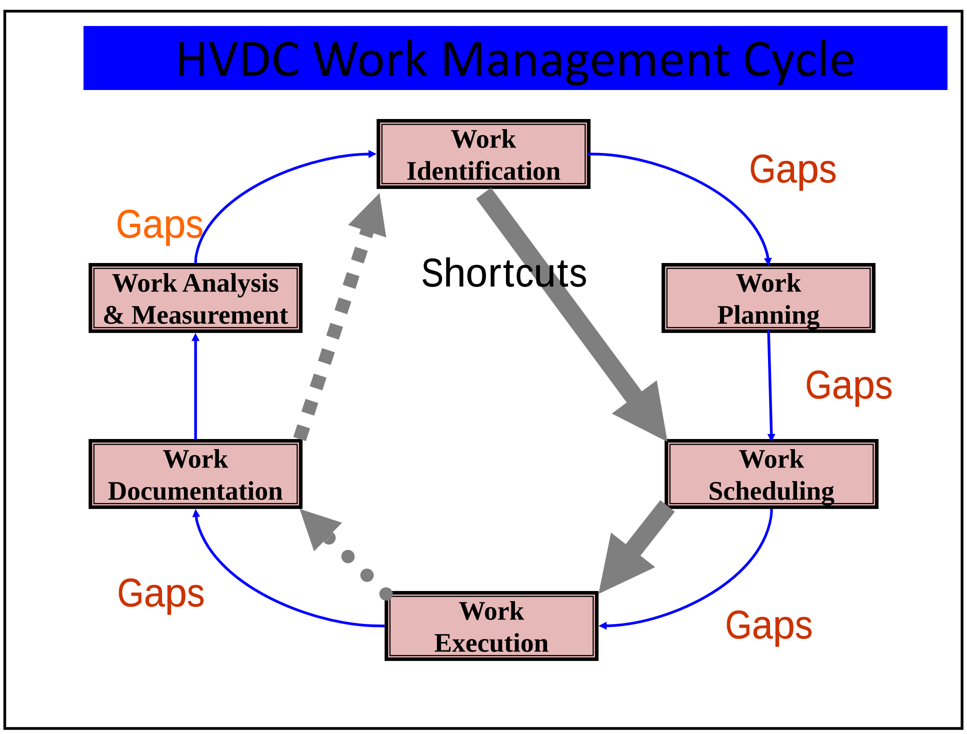

HVDC Work Management Cycle
Work Identification
Planning
Resource Allocation
- manpower / equipment
- materials / tools
Resource Coordination
Crew Coordination
Weekly Schedule
Issue of Work Packages
Execution
Documentation
Analysis & Measurement
Scheduling


HVDC Work Management Cycle
Work Identification
Planning
Scheduling
Crew Preparation
Crew Supervision
Communication
Safety
Documentation
Work Analysis & Measurement
Execution


HVDC Work Management Cycle
Work Identification
Planning
Scheduling
Execution
Predictive Data Capture
Failure Data Capture
Labor hours
Material costs
Asset History - NOTES
Analysis & Measurement
Documentation


HVDC Work Management Cycle
Work Identification
Planning
Scheduling
Execution
Documentation
System KPI’s
Equipment KPI’s)
Failure Reports
Work Process Indicators
Measurement
& Analysis


HVDC Work Management Cycle
Work Identification
Planning
Scheduling
Execution
Documentation
Analysis & Measurement
Work Culture
Employee Recognition
Involvement
Communication
Safety & Training


HVDC Work Management Cycle
Work Identification
Gaps
Work Planning
Gaps
Work Scheduling
Gaps
Work Execution
Gaps
Work Documentation
Work Analysis & Measurement
Gaps
Shortcuts

Thank - You

Identifying Work

Principles

- To ensure all work is identified in a timely and consistent manner
- Anyone can identify work

Scope

- Maintenance Program
  - Routine Pre-Scheduled Maintenance
  - Condition / Performance Monitoring of Equipment
  - Predictive Maintenance
  - Inspections
  - Minor Overhauls
- Capital Projects & Special Maintenance Requirements
- Repair Work (Emergency & Non-Emergency)
- Regulatory Requirements (Legislated, Environmental)
- Periodic Training

Work ID - Other Considerations

- Development of “Authorization Standard / Process” to ensure that work is authorized before the Planning Process starts
  - Does the work need to be done?
- Ensuring that relative information is provided when possible
  - Due date
  - Estimated time
  - Outage requirements
  - Manpower requirements
  - Parts
  - Tools
  - Training requirements before the job starts
- Prioritization Process

Planning Work

Principles

- To ensure the optimum utilization of resources
- To minimize equipment downtime (maximize availability)

Scope

- Planning the work includes determining what is involved in doing the work and considering various factors that impact on the work itself as well as when and how it may best be done.
- This becomes the planner's responsibility
- Outputs:
  - Five Year Outage Plan (Planned) – Generation / Transmission
  - One Year Outage Plan (Committed) – Generation / Transmission

Planning Work – Other Considerations

- What equipment outages are required to do the work ?
- What resources are required to do the work?
  - Manuals, Tools, Parts, Staff, and External Resources
- Training Requirements / Opportunities:
  - What Training (if any) is required to perform the work?
  - Is specialized training required for either Technicians or Apprentices?
  - Is there an opportunity for other staff to be trained?
  - Has it been allocated?
- Is there related work that can be done at the same time?
- Is there similar work to be done on other pieces of equipment?
- What are the logistics of doing the work?
- What is the best time period to consider doing the work?
- Are the work procedures appropriate for the work?
- Is a Critical Path Method layout of the work required?
- Have safety and environmental issues been considered?
- HOW TO HANDLE CHANGES that effect the Outage Plan

Scheduling Work

Principles

- That all planned work is scheduled after all resources are in place.

Scope

- Scheduling will commit the identified resources to the planned work.

- This is an iterative process between planning and scheduling, it is internal to planners & external to the plants.

- It will:
  - Commit the resources to the plan
  - Commit the outages with S.C.C. to the plan as required

- Results In:
  - Detailed weekly work schedule
  - Detailed Work Package will be issued to work crew supervisor

Executing Work

Principles

- To have all trades coordinate their efforts, resources and perform the assigned tasks in a professional safe and environmentally conscious manner.

Scope

- Supervisors to lead, coach, teach, motivate & remove barriers.
- Supervisors are responsible for ensuring scheduled work is completed with consideration to:
  - Safety
  - Job Planning
  - The environment
  - Quality Work
  - Schedule (On time)
  - Coordination with other crews
  - Appropriateness of Work Procedures.

Documentation Process

Principles

- To ensure that all required data from the assigned task is documented for future reference in a consistent manner.
- Can also include gathering and documentation of information required for measuring the Performance of Equipment (KPIs)

Scope

- Documenting the work means capturing pertinent information of the job that has been done. This will include:
  - Work order notes
    - What was done?
    - As found /As left readings
    - Any other corrective actions not identified on the work order
    - Any enhancements that may improve the job the next time
  - Detailed Written Reports

- Documenting equipment performance information required to determine
  - Availability
  - Unavailability
    - Scheduled outage
    - Emergency outage
    - Deferred outage
  - Utilization

Analysis Process

Principles

- To have all documented information evaluated to identify any necessary corrective actions or improvements required
- This includes work related information or equipment performance information

Scope

- Analyzing the work includes reviewing what was done, why it was done, how it was done, appropriate quality, and is “follow-up” action required
- Analyzing equipment KPI’s to see if performance meets targets
- Analyzing major breakdowns (or reoccurring breakdowns) to determine the cause (or root cause) such as:
  - Incorrectly operated equipment
  - Poor / incorrect maintenance
  - Defective component due to ageing, design, etc
  - Equipment is generally too old and cannot operate as intended anymore

Analysis Process – Other Considerations

Reporting

- Performance Reports
- Forced Outage Reports
- Root Cause Failure Analysis Reports

When a solution to prevent future breakdowns is identified, does this feedback into the Work ID Process? This can include:

- Revisions to how we operate the equipment
- Revisions to the maintenance standard or procedure
- Change-out of similar components on similar equipment (major overhaul)
- Replacement of the equipment entirely (capital replacement program)

Do you keep track of recommended “solutions” and ensure that they aren’t lost until the problem suddenly re-appears again (are they included in the plan / schedule)

Would a “Performance Review Team” be helpful

Manitoba
HYDRO INTERNATIONAL

Questions to Consider When Developing the WMC

Work ID

Who identifies the following “work” ?

- Inspections
- Routine Maintenance
- Emergency Repairs
- Non-Emergency Repairs
- Major Overhauls
- Major Capital Projects
- Special Tests
- Repetitive Support Work
  - Training
  - Safety Related Work (Fire Extinguisher Inspections)
  - Periodic Meetings (Safety, General Meetings)

How is this information gathered in a timely fashion ?

Do you use a form for gathering this information ?

Planning

How is this work prioritized and planned ?
Are outages requirements identified at the same time ?

- (can also be part of Work ID)

Are resource requirements identified at the same time ?
People, equipment, parts
Is the “duration” estimated (Level of Effort)
Do you have a 5 year “Equipment Scheduled Outage Plan” ?
Do you have a 1 year “Equipment Scheduled Outage Plan”?

Who is responsible for the development of the plan ?
Is coordination between work crews considered?
If a 1 year plan is developed, how do you address changes after the plan is developed?

Scheduling

Do you take the 1 year plan and develop a monthly / weekly schedule from it
Do you use a Work Order System
Is work (Work Orders) assigned to the crew supervisor and he/she then assigns to individuals (daily ?)
Is the expected LOE (Level of Effort) noted and is the information passed on to the techs ?
Do you have a daily crew supervisors meeting during "maintenance outages"
Do you use PERT / GANTT Charts for major outages
If coordination between staff / crews is required, what happens when a delay occurs that affects others

Execution

Problems ??

- Quality of Work
- On-Time
- Equipment / Tools available as needed

Do Techs Come For Help If Needed

Do Techs report back if they are running into scheduling difficulties

Do Techs report in if work is finished in advance of schedule ?

Documentation

Is "Equipment Performance" measured

- Availability
- Unavailability

    - Emergency
    - Forced Maintenance
    - Routine Planned Maintenance
- Utilization

When defective equipment is repaired, is the following information recorded:

- Problem found
- Repair work completed
- Parts used
- Time taken

Do you have standard naming conventions ?

- Inspection
- Emergency Repair
- Routine Scheduled Maintenance
- Deferred Maintenance (usually a result of an inspection or "condition monitoring")
- Defective Equipment
- Are work orders reconciled when completed (estimates versus actual)

<u>Analysis</u>

Is "Equipment Performance" analyzed and compared to target performance

- Availability
- Unavailability
    - Emergency
    - Forced Maintenance
    - Routine Planned Maintenance
- Utilization

Are "defectives" analyzed to see if there are repeat problems

Are costly breakdowns analyzed to determine the cause and / or root cause:

- Incorrectly operated equipment
- Poor / incorrect maintenance
- Defective component due to ageing, design, etc
- Equipment is generally old in its entirety

When a solution to the future prevention of the breakdown occurs, does this feedback into the Work ID Process:

- Revise how we operate the equipment
- Revise the maintenance standard and / or procedure
- Change-out the components on similar equipment
- Replace the equipment entirely

Do you keep track of recommended “solutions” and ensure that they aren’t lost until the problem re-appears.

Would a Performance Review Team be helpful ?

Appendix VII – Recommended Equipment List For Vehicle Repair Facility

Recommended List of Equipment Per Vehicle Repair Facility

The following is a list of shop equipment recommended for one (1) repair facility. This is a typical list that would be required in any repair facility. A complete shop and tool list should be compiled to compare with other repair facilities within TCN and to develop a consistent system of need and/or organization.

a. Two (2) additional hand ***tool sets and tool boxes*** to ensure each mechanic has their own. Each individual could then be responsible for their tools/tool box. Small and cheaper set with small box $500.00 - $1,000.00. Larger set with a large box $10,000.00 - $50,000.00.

b. One (1) ***oxygen and acetylene torch***, used for heating and cutting. Tanks are usually rented. $500.00

c. One (1) ***digital auto scanner*** to diagnosis areas in need of repair on computer-based cars and trucks from 1981 to current year. $2,000.00

d. A variety of handheld ***electric disc grinders***, varying in sizes and angles. $300.00

e. An assortment of three-eighths inch (3/8") and one-half inch (1/2") ***electric handheld drills***. $300.00

f. One (1) ***battery charging machine*** $600.00 and one (1) **amperage v*oltage resistance (AVR)* machine $1,500** for testing batteries and charging systems. A separate battery room with exhaust fan is needed to clear out fumes when servicing batteries.

g. One (1) ***computer with internet access*** to conduct research, keep updated on repairs, and to be used for an up-to-date computer-based maintenance system. $10,000.00

j. One large industrial compressor with air hose and air tools. $10,000.00

k. One welder. $12,000.00 - $15,000.00

Sub-Total (Tools and Equipment): (~$55,000)

Additional Vehicle Requirements

One (1) ***workshop tow vehicle*** that could also serve as a service repair truck. $100,000.00

One (1) additional ***HIAB lorry*** for transporting material, craning and towing. $180,000 - $200,000

One Telehandler machine with some attachments. $150,000.00

Sub-Total (Vehicles): (~$450,000)