CONGRESO DE MANTENIMIENTO & CONFIABILIDAD MÉXICO

ORGANIZADO POR:

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RCM-R® Case Studies

James Reyes-Picknell

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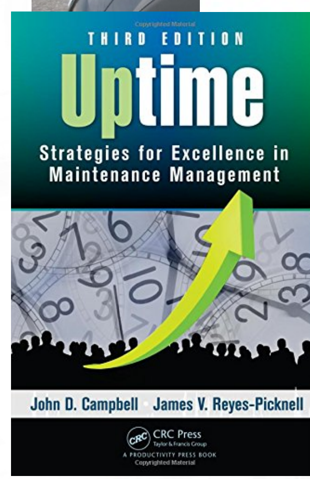
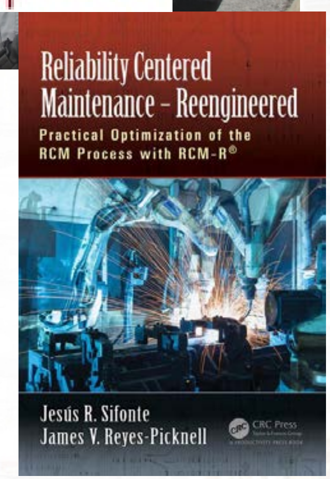
- •Principal Consultant, Conscious Asset and Conscious Reliability
- •Mechanical Engineer, University of Toronto, 1977
- •40 year career in Maintenance and Asset Management.
- •Wide variety of industries hands-on in technical and in managerial roles.
- •Consulting since 1995; Director (Associate Partner) in PwC Consulting / IBM
- •Conscious Asset founded 2004
  - –Specialist consulting firm ensuring the delivery of value from physical assets.
- •Thought-leader in Reliability, Maintenance and Asset Management.
  - –Columnist and regular contributor to several publications. Frequent public speaker.
  - –Blogger: www.consciousasset.com/blog
  - –Author:
    - •"Uptime - Strategies for Excellence in Maintenance Management", 3rd edition
    - •“Reliability Centered Maintenance – Re-Engineered: Practical Optimization of the RCM Process with RCM-R®” 2017
    - •“No Surprises” 2016, “ISO 55000, What’s Not to Like” 2016, “Uptime Made Easy” 2009, “Reliability Centred Maintenance: A Key to Maintenance Excellence” 2000
- •2016 – awarded PEMAC’s prestigious Sergio Guy Award for significant contributions to the profession
- •2017 – co-founder of Conscious Reliability





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What is RCM?

A method to determine the most appropriate failure management strategies for any physical asset in its present operating context.

Outputs include:

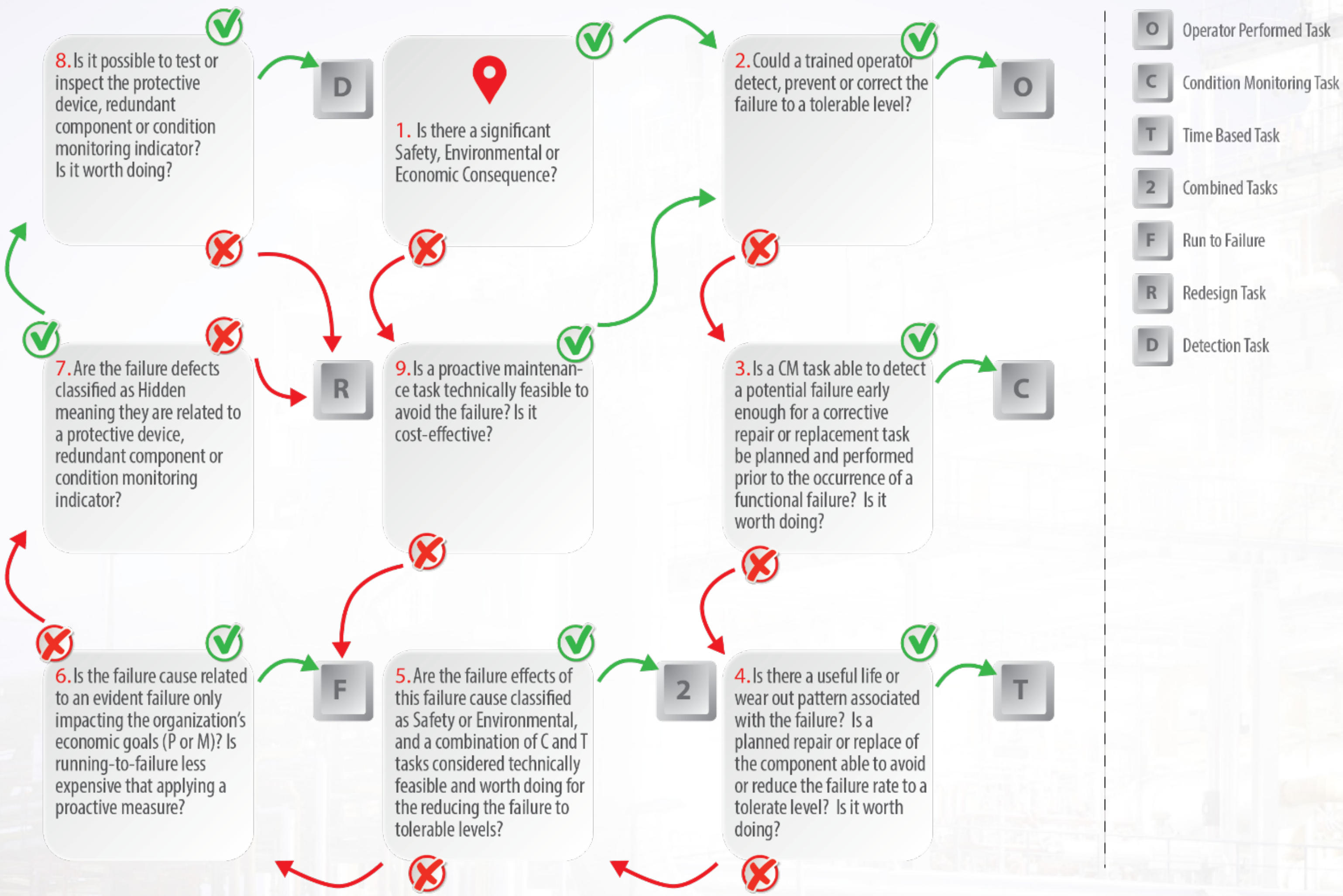
- Predictive maintenance tasks
- Preventive maintenance tasks
- Detection (failure finding) tasks
- One time changes
  - Training
  - Procedures / practices
  - Design
- Run-to-failure

Per SAE JA-1011:

For the operating context:

1. Functions and performance standards
2. Functional failures (failed states)
3. Failure modes & their causes
4. Effects
5. Consequence designation
6. Proactive tasks (PdM, PvM)
7. Defaults (depend on consequences)

RCM-R® Decision Diagram



Electric Distribution Utility

toronto hydro
electric system

SF6 Gas Insulated Transformer

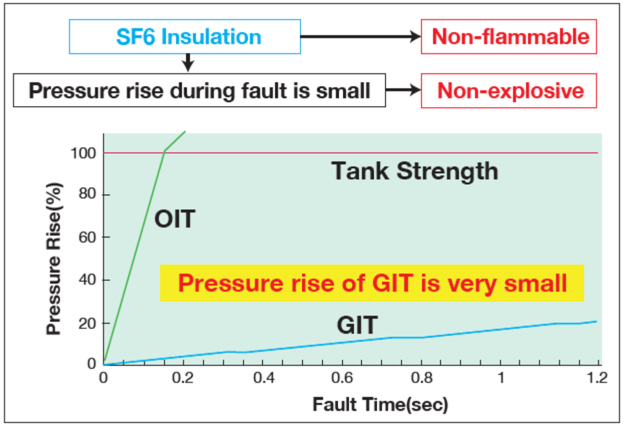
High Voltage

130 MVA

Why GIT?

Features	Advantages with GIT
Non-flammability	GITs employ SF6 gas as the insulation & cooling medium, which avoids the need for fire fighting equipment, oil collection tanks and pits outside the transformer room.
Non-explosive feature	Since the rise in tank pressure for an internal fault is very small compared with the GIT tank withstand strength, the GIT tank will not explode on internal fault ensuring the safety of equipment within the substation.
Compactness	Since neither a conservator nor pressure relief arrangement is required, the height of the transformer room can be reduced. For the case of a 275kV 300MVA class application, approximately 2 to 2.5 meter reduction in height can be achieved.
Excellent interface with Gas Insulated Switchgear (GIS)	The application of GIT together with GIS offers a very compact substation design as the equipment is installed in the same room. A significant cost reduction for civil construction can thus be achieved.

Pressure rise on internal fault



Comparison GIT / OIT

Features of GIT

Oil Immersed Transformer (OIT)	Gas Insulated Transformer (GIT)
① Insulation / Cooling	
Insulating Oil	SF_6 Pressure 0.14 or 0.43MPa-g(20℃)
② Solid Insulation Material	
Oil Impregnated Paper, Pressboard	PET Film,PPS Film, Aramide Paper, Pressboard
③ Conservator	
Necessary	Unnecessary
④ On-Load Tap Changer	
Diverter Switch	
Arcing Switching in Oil	Vacuum Interrupter
Tap Selector	
Slide Contact	Roller Contact

The construction of a GIT is basically the same as an OIT, with the exception of insulating material and cooling medium. Therefore, broad experience of OIT technology can be applied to GIT design, manufacturing and maintenance.

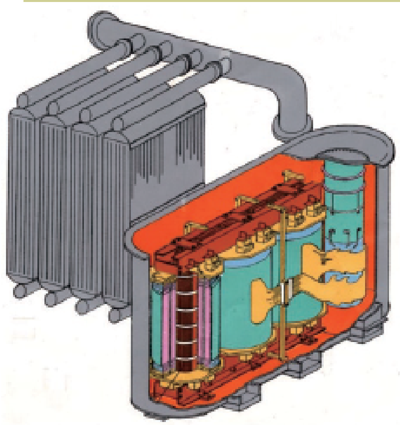


Fig.6

GIT appears more complex Includes gas piping, heat exchangers, blowers for SF6 internally, cooling fans for air flow over exchangers.

Use SF6 gas – a known green-house gas and toxic.

On surface expected maintenance requirements to be greater than OIT's currently in use.

RCM Analysis

- 45 Functions were identified
- We found 155 plausible failure modes
  - Typical oil filled transformer has about 100
  - 10 were hidden (all 4 with safety implications were hidden)
    - Simple tests and visual inspections were sufficient to deal with these
- Failure modes were generally less “critical” in terms of effects when compared with AIT designs
  - Analysis confirmed the design was largely “fail-safe”
  - Safety consequences due to structural failures (floor settling, external damage to piping and resultant leaks) and failure of micro-switches in sudden pressure relays (which prevent normal operation under fault) had to be dealt with

Maintenance Program

- Several predictive and preventive maintenance tasks
  - For gas leakage, floor settling, external corrosion on grounding, SF6 gas sample testing (for contamination), small component replacements (contacts, gauges, switches), fan and blower bearing lubrication, heat exchanger cleaning
  - Task frequencies in “years” (varies by task)
- Overall maintenance requirements were less than those for AIT despite the appearance of increased complexity

Significant findings

- Even though design is proven with hundreds of installations world-wide
  - Testing of sudden gas pressure relay required potentially harmful release of SF6 gas to simulate fault conditions (testability needed in design)
    - This was new to Toshiba (manufacturer) and they are improving their design as a result
  - Transformer vault needs improved ventilation due to potential for SF6 leaks that could harm personnel
    - Vault designers had “bought into” manufacturer claims about benefits and not provided enough ventilation

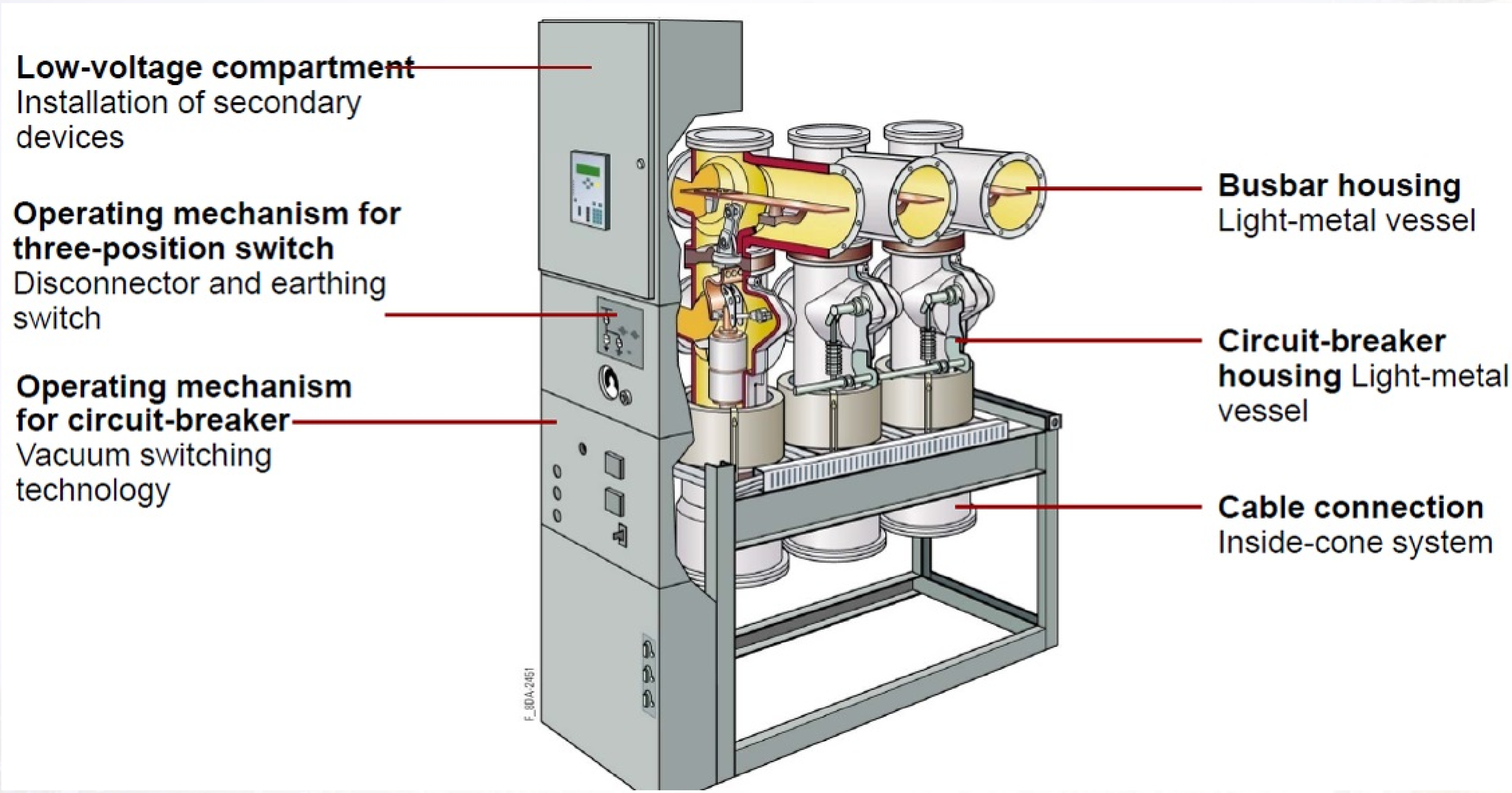
Electric Distribution Utility

toronto hydro
electric system

SF6 Gas Insulated Breaker

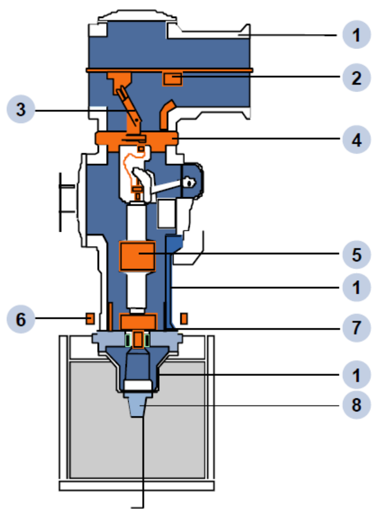
Medium Voltage

Major components



Benefits of SF6 Breakers

- Low pressure SF_6 used as an insulating medium for all primary components
- Primary components do not require maintenance due to controlled gas environment
- Fix mounted vacuum circuit breaker with three-position switch (closed – open –ready to ground)



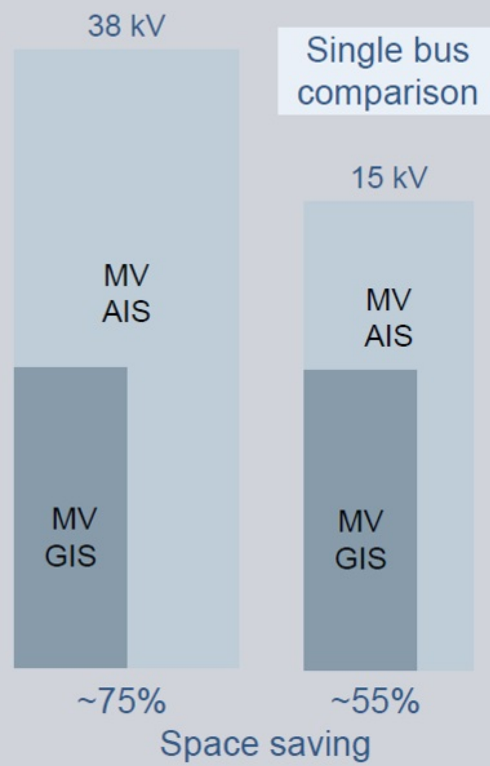
1. Cast aluminum housing
2. Bus bar with sliding supports
3. Three-position switch
4. Gas tight bushing
5. Vacuum interrupter
6. Torodial current transformer
7. Capacitive voltage sensor
8. Shock-proof cable termination

- Sealed pressure system protects against environmental influences
- Single-pole enclosure eliminates possibility of phase-to-phase faults inside switchgear
- Division of components into compartments enables fast fault localization
- Mean Time Between major Failure:
  - MV GIS — 2,750 years (estimate)
  - MV AIS — 856 years (estimate)

Sources: IEEE 493 Gold Book (for MV AIS), Siemens internal data (for MV GIS)

Space savings due to compact design

Footprint comparison (MV AIS & MV GIS - only equipment size considered)



Inherently safer

Grounding Using 3-Position Switch
Arc Resistant during Grounding

Traditional Way of Grounding
NOT Arc Resistant during Grounding

RCM Findings

- Switch provides 15 functions
- We found 45 plausible failure modes
  - 7 were safety related (winding faults, CTs replaced with incorrect size, SF6 contamination, grounding, maintenance leaves covers off)
    - All dealt with using specialist and refresher training of personnel
  - 4 hidden failures (grounding lost - inspect, SF6 contamination - sampling, gauge calibration – regular checks, anti-pumping relay – functional test)
- Overall the new design is safer and less maintenance intensive than existing air insulated breakers
- No “surprise” problem areas were identified except need for additional training and acquisition of minor test equipment
  - Had the analysis not been performed the utility would have been far more dependent on manufacturer for a more extensive / expensive maintenance program

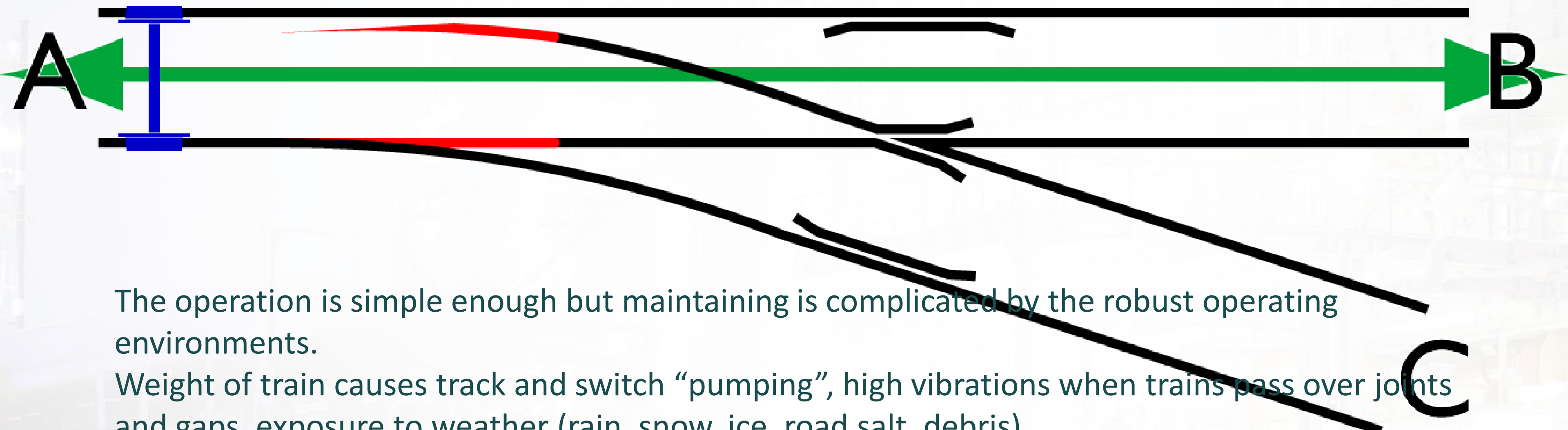
Public Transportation

SUBWAY

Subway (Metro) Infrastructure

Track Switches

Railway switch function
“To redirect a train”



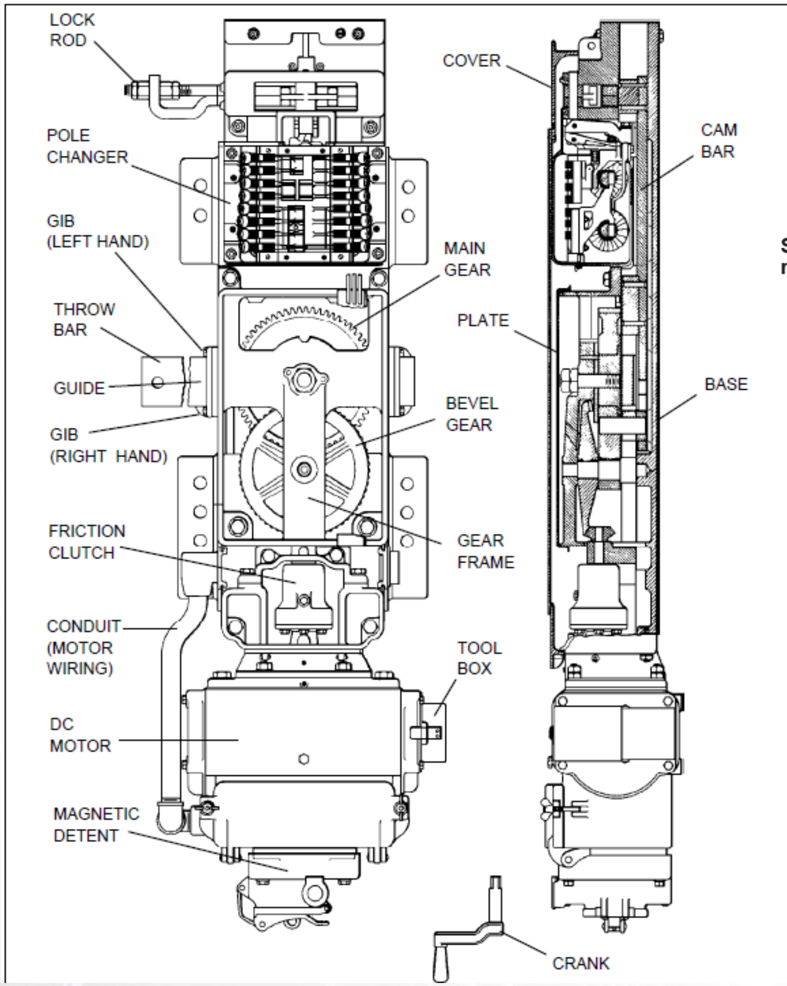
The operation is simple enough but maintaining is complicated by the robust operating environments.

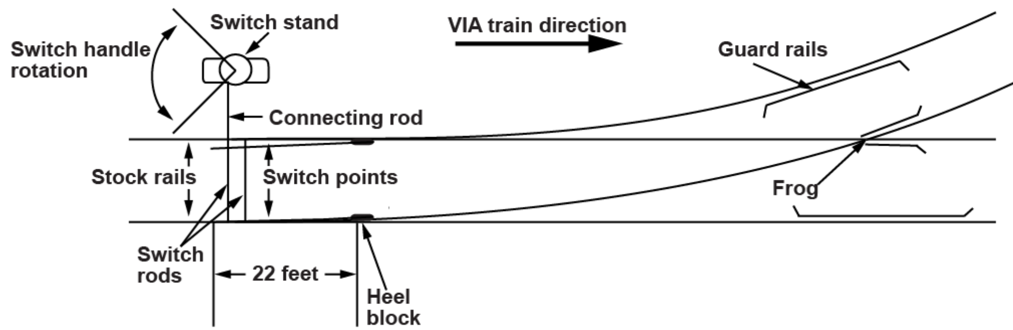
Weight of train causes track and switch “pumping”, high vibrations when trains pass over joints and gaps, exposure to weather (rain, snow, ice, road salt, debris).

Despite their simplicity and robust construction, the set-up of these switches is a precision maintenance activity.

Failures in switches cause significant numbers of long delays in service.

Switch moves track “points” to re-direct train





Model 5 Switch

- On command from signals (control), DC motor turns gear-set
- Gear-set moves “comm bar” to unlock the switch allowing it to move
- When unlocked, a yoke creates left / right push / pull on a “throw bar” to move the track points to redirect train
  - Movement must be enough to fully open and close the rail points or derailment is possible
- When points move a “detection bar” moves electrical contacts and re-locks the switch
  - Detection bar must move the contacts and locking bar enough to send the correct electrical signals and engage the lock (so the switch can’t move)
- When movement completes its cycle the DC motor has a dynamic snubbing feature to prevent over-running

Known problems with switches

- Mis-alignments
  - Horizontally due to loosening of setting bolts and locking nuts
  - Vertically due to distortion of track layout / rail bed ballast and tie deterioration
- Movement blocked by ballast rocks or debris
- Freezing (snow, ice build up, failure of heaters)
- Parts coming apart (disconnected) or broken internally
- Excessive friction (lubricant washed away)
- Loose wiring

- Current maintenance
  - All units receive 6 monthly "maintenance" (greasing, cleaning, testing, adjustments)
  - Re-furbish at 10 or 15 years depending on light / heavy usage
  - 25 / 15 years replacement cycle (lower/ heavy usage locations)

RCM findings

- Defined 6 functions (divert train, lock in position, detect position of switch, keep dirt and debris out, allow manual operation, prevent operation if switch not in correct position)
- 72 failure modes identified, 13 were hidden, 10 with potential safety implications
- 30 failure modes could be allowed to Run to failure (low consequence)
- A number of failure modes were due to human error (dealt with using training refreshers and enforcement of existing procedures)
- Newer technology (vibration and shock recording, track geometry readings) enables RR to identify troublesome locations before they fail
- Maintenance routines could be fine tuned eliminating excessive work on switches that see little use. Efforts become more targeted.
  - Overall reduction in maintenance requirements with expectation of fewer in-service failures

One significant change to maintenance to avoid service delays

- If alignments are “off” (vibration, pumping, loose components), then switch may not be able to lock even though all movements are completed
  - This failure, is hidden
  - There are two redundant detection systems operating independently but failure of either stops trains
- If switch is unlocked it’s position is “unclear” and all train movement stopped until it is confirmed
  - Correcting alignment is a matter of simple adjustment
- There is a simple ¼ inch test of alignments that can detect this failure before it occurs (saving a lot of service disruption)
  - Test used to be done every 6 months
  - Calculations showed it was needed every 3 days for heavily used switches, every 2 weeks for low use switches

Public Transportation

SUBWAY

Subway (Metro) Infrastructure

Train Stop

Train stop function

- To trip the automated braking system on a train if the train passes through a restrictive signal (stop light)
  - The trip arm is raised by a spring.
  - In event of loss of power, the trip arm raises (fail safe position)
  - Trip Arm is driven down against the spring and held in place electrically
    - At running capacitor creates phase shift to drive the motor, connected to a sector gear. At the bottom of stroke, a drive contact opens, a holding capacitor and resistor are inserted into the circuit creating a stall torque to hold the arm against the return spring force (in the "clear" position)
  - A control circuit detects trip arm position via direct mechanical linkage, making and breaking contacts

Known problems

- Broken sector gear teeth and ratchet gear teeth
- Burned out drive motor
- Keeper loop (to hold trip arm down for maintenance) is left in wrong position after work completed and vibration causes it to shift and hold the trip arm in the "clear" position (unsafe)
- Jamming of mechanism due to movement caused by ballast tamping

RCM Findings

- 9 functions:
  - to enforce signals (stop trains),
  - to allow them when permitted,
  - to return to trip position on power failure,
  - to operate in a specified cycle time,
  - to return to “danger” after each clear cycle,
  - to permit manual operation,
  - to keep debris and dirt out,
  - to be visible to train operators,
  - to provide trip arm status to signals

RCM Findings

- 78 failure modes identified
  - Only 2 were hidden, both with safety implications (potential train collisions)
  - Total of 18 failure modes with safety implications
- Some seasonal maintenance required before winter and after heavy snowfalls
- 17 failures could be dealt with by targeted inspections (condition monitoring)
  - Some required identification of high vibration locations using new track monitoring equipment
- 7 preventive restorations (cleaning, tightening, gear unit replacement and re-painting of trip arm to make it visible)
- 5 preventive replacement (relays, fatigued spring in control unit, sector gear)
- 1 failure finding task for a hidden failure (jamming of the unit) that tends to appear after tamping activities

- Significant change was in “who” could do most of the work. Track patrol crews could be assigned work formerly assigned to signals technicians

Conclusions

- RCM works well for both old assets and new ones
- Can produce design and maintenance program changes
- Can produce “surprises” even for assets that have been in service for many years
- Optimizes maintenance programs
  - Reduces excessive task assignment
  - Targets failure modes
  - Assigns the best resource to execute the tasks, redistributing workload (often to lower skilled employees)
- Excellent learning opportunity for employees
- Excellent collaboration opportunity among departments

CONGRESO DE
MANTENIMIENTO
& CONFIABILIDAD
MÉXICO

¡GRACIAS!

ORGANIZADO POR:

AMGA

Nombre del conferencista

Insertar puesto actual

SI TIENES PREGUNTAS O COMENTARIOS…

¡No dudes en acercarte!