Nov 30, 2010

Braking Systems Compliance and Testing

Workplace Safety North “Driving Towards Zero” 2010

Richard Riach, Vale

Items to be covered

Regulatory Requirements

- Brake system functions
- Initial model verification
- Pre-use testing

Design Validation Testing

- Underground Rubber Tired Vehicles
- Surface Rubber Tired Vehicles
- Crawler Tracked Vehicles – Surface and Underground

Pre-use Testing Options

- Static and Dynamic Testing Options
- Establishing Proper Pre-tests

VALE

Regulatory Requirements

Regulatory Overview

Ontario Regulation 854 (s119)

- *(2) The brake system on a motor vehicle that is operated on a grade, slope or ramp shall be able to perform the individual system function requirements of,*
  - *(a) a service brake system;*
  - *(b) an emergency brake system; and*
  - *(c) a parking brake system.*

- *4) Any combination of the system function requirements described in clauses (2)(a), (b) and (c) may be performed by a single brake system.*

- *(5) Each brake system shall be capable of being,*
  - *(a) tested independently; and*
  - *(b) readily applied by a worker seated in the driver's seat.*

VALE

Regulatory Overview

Ontario Regulation 854 (s119)

- *(6) A service brake system may consist of a hydraulic pump motor drive system.*

- *(7) The service brake system and the emergency brake system shall be capable of safely stopping the motor vehicle while it is being operated,*
  - *(a) on the maximum grade, slope or ramp in its area of operation;*
  - *(b) at its maximum authorized speed; and*
  - *(c) with its maximum authorized load.*

- *(8) The parking brake system shall be capable of holding the motor vehicle stationary, with its maximum authorized load, on the maximum grade, slope or ramp in its area of operation.*

- *(9) The emergency brake system shall be set up so that, whether the brake is applied automatically or manually, a deliberate act is required to release it.*

VALE

Regulatory Overview

Ontario Regulation 854 (s119.1)

Initial Model Verification

- Commonly known as Ramp Testing
- Now conducted in accordance with 3 different standards depending upon machine configuration and intended area of application
  - Underground rubber tired machines tested according to CSA M424.3-M90
  - Surface rubber tired machines tested according to CSA-M3450-03
  - U/G & Surface crawler tracked machines tested according to ISO 10265: 1998

Ontario Regulation 854 (s105)

Pre-use Testing

- *7) A procedure for the testing, maintenance and inspection of each motor vehicle shall be adopted and the procedure shall,*
  - *(a) schedule the testing of brakes, steering, lighting and other safety components prior to initial use of the motor vehicle for the shift;*

VALE

Design Validation Testing

Requirements for testing or re-testing

Does a valid test report exist?

- The equipment OEM will often be able to provide a record of testing
- Other sources such as Vale conduct independent testing
- Assumptions are often made that since a machine was in use elsewhere that a valid test must exist
  - This may not be the case!

Is the test report still valid?

- Where problems can arise are:
  - The test report is for a machine built or modified by a different company
  - Modifications are made by other companies and not tested
  - Regulations have changed and the machine is now “first used” on site
  - The model designation has changed or the machine has been upgraded
  - The machine is brought in from another jurisdiction not requiring testing

VALE

Requirements for testing or re-testing

Triggers that indicate a new brake performance test may be required:

- Change in model designation
  - New design features can affect components and control systems used
- Change in horsepower
  - Faster machines require longer stopping distances
- Change in transmission
  - May affect vehicle speeds
- Change in axles, brake make or model
  - Can affect brake performance thus stopping distance
- Brake actuation control
  - Plumbing changes can increase or decrease brake response time
- Machine mass has increased
  - Heavier machines may require longer to stop if brakes have not changed
- Machine mass has been re-distributed
  - Balance, stability, and traction may be affected

VALE

Vehicle Testing Summary

Underground Rubber Tired Vehicle Testing

- Testing done according to CSA M424.3-M90
- Vehicles built or adapted for underground will require testing at the time of construction or conversion

Crawler Track Vehicle Testing

- Testing done in accordance with ISO 10265: 1998
- Vehicle OEM's will quite often have already conducted this testing for machines used in surface applications
- Review of the machine for compliance with other underground braking requirements is still necessary

Surface Rubber Tired Vehicle Testing

- Testing done in accordance with CSA-M3450-03
- Vehicle OEM's will quite often have already conducted this testing for machines used in surface applications
- Review of the machine for compliance with other surface braking requirements is still necessary

VALE

Underground Rubber Tired Vehicle Testing

Ramp Testing Background and Process

- Vale has conducted ramp testing for over 25 years
- 700+ tests recorded.
- Conducted at the Copper Cliff Mines (North) 20% grade test ramp
- Testing carried out in accordance with CSA M424.3-M90 standard
- Vehicles are typically tested at maximum rated Gross Vehicle Weight
  - Testing of empty vehicles or above rated payload may occur depending upon intended application or OEM requirements
- Vehicles are tested in the direction of worst case stability during tramming where feasible
- Vehicles are tested to maximum speed using all available gears
  - If preliminary checks indicate speed is excessive in higher gears then testing will be limited to lower gears

VALE

Underground Rubber Tired Vehicle Testing

Copper Cliff Mine (North) 20% Grade Test Ramp

Underground Rubber Tired Vehicle Testing

Test Process is comprised of several phases

- Pre-test evaluation of machine to determine if any specialized test preparation is necessary
- Initial documentation of test vehicle
- Static testing of brake systems including actuation devices
- Speed checks
- Brake system stopping distance tests
- Additional vehicle checks

VALE

Underground Rubber Tired Vehicle Testing

Pre-test evaluation of machine

- Testing needs to be conducted so that brake system functions are tested independent of each other

- Brake systems that have components in common between Service and Emergency require the failure of common components to be considered
  - Example: Axles where the external actuator pull rod is used for both systems
  - Example: Emergency brake systems supplemented by application of service brakes

- Some drive train or brake configurations may require special preparation
  - Example: Some hydrostatic drive vehicles may need isolation systems

VALE

Underground Rubber Tired Vehicle Testing

Pre-test evaluation of a hydrostatic drive machine

- Hydrostatic drives can present different challenges as they are commonly the service brake system as well as the means of propulsion
- When testing the emergency brakes a means of discounting the effects of the hydrostatic drive is necessary
- Options can include:
  - Shifting the geared transmission (where available) to neutral prior to braking
  - Installing a temporary drive loop neutralizer circuit that is opened during stops
  - Maintaining full drive power during application of the emergency brakes
  - Demonstrating that the effect of the hydrostatic drive is negligible
    - Typically applicable to systems where the Service brake system has supplemental mechanical brakes

VALE

Underground Rubber Tired Vehicle Testing

Initial documentation of test vehicle

- Verification of machine data
- Pictures of machine from several angles documenting load

Static testing of brake systems

- Static brake tests of brake systems where feasible
- Test of brake actuation systems to verify operator force requirements

Speed checks

- Vehicle speeds are checked using a radar gun
  - Vehicle speed on flat
  - Vehicle speed down ramp
  - Vehicle speed down ramp – engine retardation
  - Vehicle speed up ramp

VALE

Underground Rubber Tired Vehicle Testing

Brake system stopping distance tests

- Service
  - 5 stops conducted in each gear
- Emergency
  - 3 stops conducted in each gear
- Park
  - When combined with emergency – no additional tests required
  - When separate from emergency – tested to verify hold on maximum grade (20%)

VALE

Underground Rubber Tired Vehicle Testing

VALE

Underground Rubber Tired Vehicle Testing

VALE

Underground Rubber Tired Vehicle Testing

Additional vehicle checks

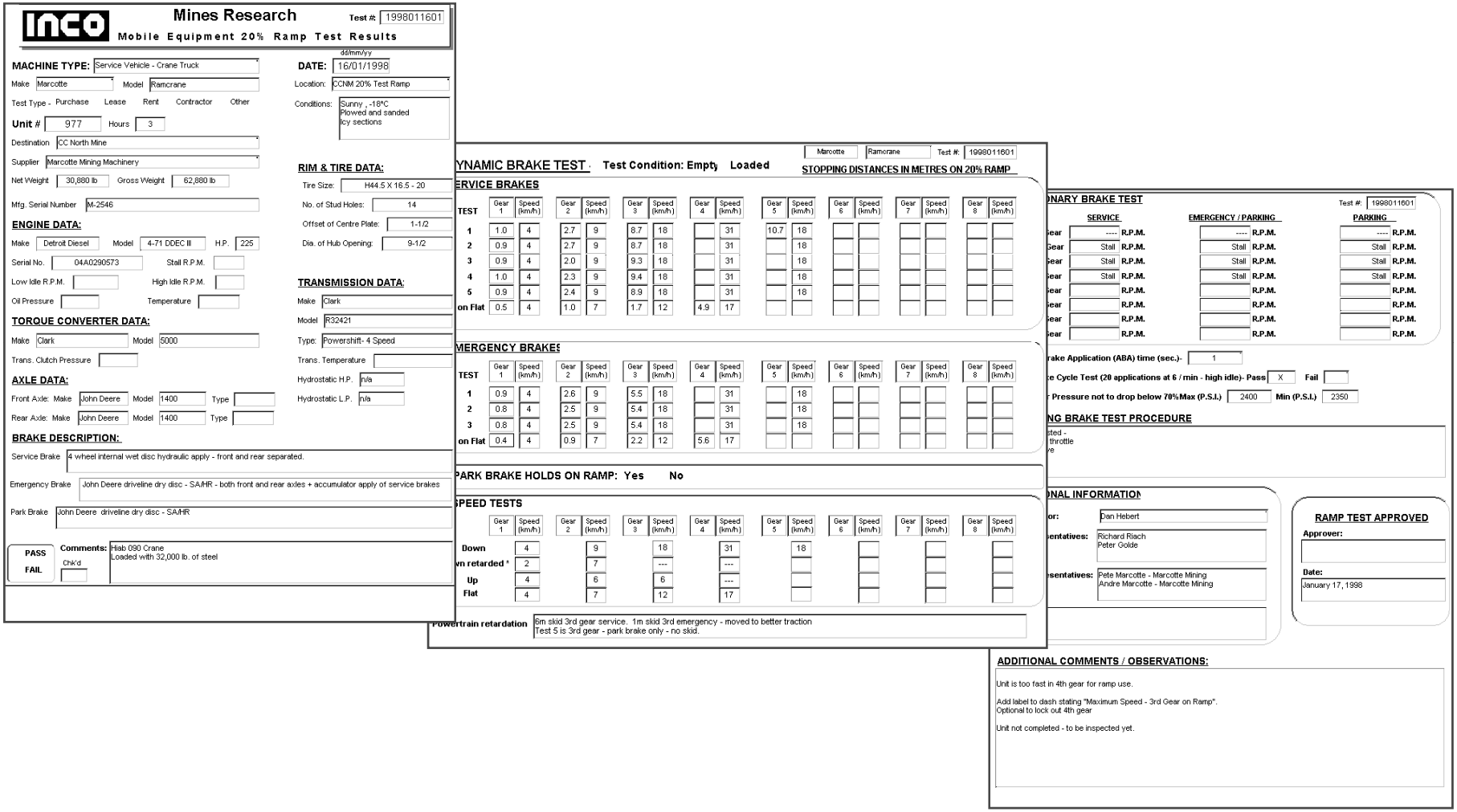
- Vehicle general stability
- Wheel chock size and performance

VALE

Underground Rubber Tired Vehicle Testing

VALE

Underground Rubber Tired Vehicle Testing



Mines Research — Mobile Equipment 20% Ramp Test Results — Test #: 1998011601

MACHINE TYPE: Service Vehicle - Crane Truck — DATE: 16/01/1998 (dd/mm/yy)
Make: Marcotte — Model: Ramcrane — Location: CCNM 20% Test Ramp
Test Type - Purchase / Lease / Rent / Contractor / Other — Conditions: Sunny , -18*C; Plowed and sanded icy sections
Unit #: 977 — Hours: 3
Destination: CC North Mine
Supplier: Marcotte Mining Machinery
Net Weight: 30,880 lb — Gross Weight: 62,880 lb
Mfg. Serial Number: M-2546

ENGINE DATA:
Make: Detroit Diesel — Model: 4-71 DDEC III — H.P.: 225
Serial No.: 04A0290573 — Stall R.P.M.:
Low Idle R.P.M.: — High Idle R.P.M.:
Oil Pressure: — Temperature:

TORQUE CONVERTER DATA:
Make: Clark — Model: 5000
Trans. Clutch Pressure:

AXLE DATA:
Front Axle: Make: John Deere — Model: 1400 — Type:
Rear Axle: Make: John Deere — Model: 1400 — Type:

BRAKE DESCRIPTION:
Service Brake: 4 wheel internal wet disc hydraulic apply - front and rear separated.
Emergency Brake: John Deere driveline dry disc - SA/HR - both front and rear axles + accumulator apply of service brakes
Park Brake: John Deere driveline dry disc - SA/HR

RIM & TIRE DATA:
Tire Size: H44.5 X 16.5 - 20
No. of Stud Holes: 14
Offset of Centre Plate: 1-1/2
Dia. of Hub Opening: 9-1/2

TRANSMISSION DATA:
Make: Clark
Model: R32421
Type: Powershift- 4 Speed
Trans. Temperature:
Hydrostatic H.P.: n/a
Hydrostatic L.P.: n/a

PASS / FAIL — Chk'd — Comments: Hiab 090 Crane, Loaded with 32,000 lb. of steel

YNAMIC BRAKE TEST — Test Condition: Empty / Loaded — Marcotte / Ramcrane — Test #: 1998011601
STOPPING DISTANCES IN METRES ON 20% RAMP

ERVICE BRAKES

TEST	Gear 1	Speed (km/h)	Gear 2	Speed (km/h)	Gear 3	Speed (km/h)	Gear 4	Speed (km/h)	Gear 5	Speed (km/h)	Gear 6	Speed (km/h)	Gear 7	Speed (km/h)	Gear 8	Speed (km/h)
1	1.0	4	2.7	9	8.7	18		31	10.7	18						
2	0.9	4	2.7	9	8.7	18		31		18						
3	0.9	4	2.0	9	9.3	18		31		18						
4	1.0	4	2.3	9	9.4	18		31		18						
5	0.9	4	2.4	9	8.9	18		31		18						
on Flat	0.5	4	1.0	7	1.7	12	4.9	17								

MERGENCY BRAKES

TEST	Gear 1	Speed (km/h)	Gear 2	Speed (km/h)	Gear 3	Speed (km/h)	Gear 4	Speed (km/h)	Gear 5	Speed (km/h)	Gear 6	Speed (km/h)	Gear 7	Speed (km/h)	Gear 8	Speed (km/h)
1	0.9	4	2.6	9	5.5	18		31		18						
2	0.8	4	2.5	9	5.4	18		31		18						
3	0.8	4	2.5	9	5.4	18		31		18						
on Flat	0.4	4	0.9	7	2.2	12	5.6	17								

PARK BRAKE HOLDS ON RAMP: Yes / No

PEED TESTS

	Gear 1	Speed (km/h)	Gear 2	Speed (km/h)	Gear 3	Speed (km/h)	Gear 4	Speed (km/h)	Gear 5	Speed (km/h)	Gear 6	Speed (km/h)	Gear 7	Speed (km/h)	Gear 8	Speed (km/h)
Down		4		9		18		31		18						
n retarded *		2		7		---		---								
Up		4		6		6		---								
Flat		4		7		12		17								

Powertrain retardation: 6m skid 3rd gear service. 1m skid 3rd emergency - moved to better traction. Test 5 is 3rd gear - park brake only - no skid.

ONARY BRAKE TEST — Test #: 1998011601

	SERVICE	EMERGENCY / PARKING	PARKING
Gear	---- R.P.M.	---- R.P.M.	---- R.P.M.
Gear	Stall R.P.M.	Stall R.P.M.	Stall R.P.M.
Gear	Stall R.P.M.	Stall R.P.M.	Stall R.P.M.
Gear	Stall R.P.M.	Stall R.P.M.	Stall R.P.M.
Gear	R.P.M.	R.P.M.	R.P.M.
Gear	R.P.M.	R.P.M.	R.P.M.
Gear	R.P.M.	R.P.M.	R.P.M.
Gear	R.P.M.	R.P.M.	R.P.M.

rake Application (ABA) time (sec.): 1
e Cycle Test (20 applications at 6 / min - high idle)- Pass: X — Fail:
Pressure not to drop below 70% Max (P.S.I.): 2400 — Min (P.S.I.): 2350

NG BRAKE TEST PROCEDURE
cted - throttle ve

ONAL INFORMATION
or: Dan Hebert
entatives: Richard Riach, Peter Golde
sentatives: Pete Marcotte - Marcotte Mining, Andre Marcotte - Marcotte Mining

RAMP TEST APPROVED
Approver:
Date: January 17, 1998

ADDITIONAL COMMENTS / OBSERVATIONS:
Unit is too fast in 4th gear for ramp use.
Add label to dash stating "Maximum Speed - 3rd Gear on Ramp". Optional to lock out 4th gear
Unit not completed - to be inspected yet.

Sample Ramp Test Report

VALE

Crawler Tracked Vehicle Testing

Test Process follows many of the same phases as U/G Vehicle Ramp Testing

- Pre-test evaluation of machine
- Initial documentation of test vehicle
- Static testing of brake systems including actuation devices
- Speed checks are not conducted as testing is done statically
- Brake system capacity is evaluated against tractive force

Brake Test Procedure

- Vehicle is pulled in neutral at very low speed with Service brakes applied
- Forced being applied to pull vehicle is measured
- Force is increased until brakes permit tracks to rotate or they lose traction
- Force is recorded and used with vehicle weight to calculate maximum allowed operating grade
- Testing is repeated for Emergency and Park brakes

VALE

Crawler Tracked Vehicle Testing

Static Pull Testing

VALE

Crawler Tracked Vehicle Testing

Vale Inco **Tracked Vehicle Brake Performance Test** **Test #** 2008020801
(per ISO 10265)

MACHINE DATA:

Type: ITH Drill
Make: MTI **Model:** SR 360T
Unit #: 3554 **Hours:** New
Destination: CCSM
Supplier: MTI
Net Weight: **Gross Weight (M):** 16,335 kg
Drill – 13,150 kg incl. rods Compressor- 3,185 kg

TEST DATE: Feb 8,2008

TEST SITE:
Location: MTI - Sudbury
Conditions: Gravel / Concrete floor

TRANSMISSION DATA:
Make: Parker
Model:
Type: Hydraulic – 2 speed
Hydrostatic HP: n/a
Hydrostatic LP: n/a

ENGINE DATA:
Make: Deutz **Model:** BF2011M **H.P.:** 73
Serial #:
Low Idle: 920 **High Idle:** 2800

BRAKE DESCRIPTION:

Service: Hydraulic open loop drive with integral motor mounted counterbalance valves. Left and right drive circuits are independent.

Emergency: SA/HR application of wet disc brakes on each drive motor.

Park: Same as emergency

TEST CONFIGURATION: (Brake tests conducted according to ISO 10265 (1998-05-01) section 6.1.2)

Tow Vehicle: 2 Cat forklifts **Tow surface:** Gravel / Concrete floor
Tow Speed: n/a
Tow Force measurement:
- Hydraulic cylinder with pressure gauge measuring rod end pressure.
- Effective area –

2008020801 MTI ITH - CCSM.doc page 1 of 2

Vale Inco **Tracked Vehicle Brake Performance Test** **Test #** 2008020801
(per ISO 10265)

TEST RESULTS:

Gravel

Service Brake Retarding Force: 2100 psi X 8.39 in^2 = **17,619 lb.f = 78,373 N**
Emergency Brake Retarding Force: 2100 psi X 8.39 in^2 = **17,619 lb.f = 78,373 N**
Park Brake Retarding Force: 2100 psi X 8.39 in^2 = **17,619 lb.f = 78,373 N**
Comments: Skidded on gravel surface – tracks did not turn. Service brakes apply with Emergency / Park.

Concrete

Service Brake Retarding Force: 1500 psi X 8.39 in^2 = **12,585 lb.f = 55,980 N**
Emergency Brake Retarding Force: 1500 psi X 8.39 in^2 = **12,585 lb.f = 55,980 N**
Park Brake Retarding Force: 1500 psi X 8.39 in^2 = **12,585 lb.f = 55,980 N**
Comments: Skidded on concrete surface – tracks did not turn. Service brakes apply with Emergency / Park.

Control Application Forces: Service – Drive control levers spring return to apply.
Emergency / Park – push button to apply (approx 10 lb f)

GRADE CAPABILITY: (Drill and compressor weight combined)

Gravel – F = 78,373N M = 16,335 kg

Service Brakes: Force (N) = 9.8 X M X Sin slope angle **Slope Capability = 29 degree = 55%**
Emerg. / Park Brakes: Force (N) = 9.8 X M X Sin slope angle **Slope Capability = 29 degree = 55%**

Concrete – F = 55,980N M = 16,335 kg

Service Brakes: Force (N) = 9.8 X M X Sin slope angle **Slope Capability = 20 degree = 36%**
Emerg. / Park Brakes: Force (N) = 9.8 X M X Sin slope angle **Slope Capability = 20 degree = 36%**

DAILY BRAKE TEST:
All brake tests to be done at full engine throttle (2800 RPM)

For Manual Tram Control At Rear of Machine –
1) Push and hold service brake test button – advance control valve levers for 5 seconds – machine should not move – repeat in reverse.
2) Apply park brake on remote tram console - advance control valve levers for 5 seconds – machine should not move – repeat in reverse.

For Electric Remote Tram Control With Harness –
1) Push and hold service brake test button - advance control valve levers for 5 seconds – machine should not move – repeat in reverse.
2) Apply park brake - advance control valve levers for 5 seconds – Tram function should not activate
3) Push and hold park brake test button - advance control valve levers for 5 seconds – machine should not move – repeat in reverse.

TEST OPERATOR:
Wes Fowler (MTI)

APPROVED BY: Richard Riach (Vale Inco) **Date:** Feb 11, 2008

2008020801 MTI ITH - CCSM.doc page 2 of 2

Sample Test Report

Surface Rubber Tired Vehicle Testing

Testing follows a similar process as U/G Vehicle Ramp Testing with different test parameters

- Differences include:
  - Vehicle testing is on the flat with the exception of “dumpers” that are tested at a 9% ramp grade
  - Vehicles may be tested with or without payload
    - Specific conditions and stopping distances apply to different classes of machines
  - Holding performance test for service and park brakes
    - 25% grade for the service brakes on most machines
    - 20% grade for park brakes on specified empty machines
    - 15% grade for park brakes on specified loaded machines

VALE

Pre-Use Testing Options

Pre-Use Testing

Pre-Use Testing Per Regulation 854 and Guidelines

- Brake performance must be verified prior to use *(s105 -7).*
  - The regulations also require testing prior to entering a main ramp area.

- Service and Emergency verification can be performed as either a static test against the machines drive train, or as a dynamic stopping test.
  - Testing is conducted on the flat prior to entering the ramp area

- Park brakes can be tested as either a static test against the drive train, as a dynamic test, or as a static test on maximum grade against vehicle load
  - Load test on grade is only acceptable once Service and Emergency tests have been successfully passed

VALE

Pre-Use Testing

Testing Option Challenges

- Static testing against drive train load is preferred as it provides the least exposure to risk to the operator
  - Not all vehicles are configured to permit driving against the brakes
    - Modifications may be possible to temporarily override transmission neutralizing circuits or to hold brakes applied
  - Tests may be dependent upon specific gear selection and engine rpms
    - Tachometer failure can put a machine out of service due to inability to test
- Dynamic testing may be required where drive train and brake configuration do not permit static testing
  - Dynamic testing is most common in hydrostatic / hydraulic drive vehicles where the drive is also designated as the service brake
  - Vehicle with standard transmissions are also commonly tested dynamically
  - Best practice is to arrange tests such that static tests of emergency brakes are conducted prior to putting the vehicle in motion

VALE

Pre-Use Testing

Test Procedures Determination

- Testing Procedures need to be rigorous enough to ensure brake condition is properly represented
- Procedures should not be so rigorous as to cause unnecessary damage
- Static tests against drive train can be determined one of two ways
  - Theoretical calculation of drive train torque output vs. brake torque required
  - Ramp test determination of appropriate gear and rpm based on static holding capacity vs. on ramp performance
- Dynamic brake stopping tests are typically based on actual stopping distances of a machine with the brakes in good condition and with proper adjustment

VALE

Summary

- Work with the Suppliers / OEM's / local MOL inspector to help ensure new machines (including used but new to you) meet current regulations
- Check that machines have been tested according to appropriate standard and procedures
- Know what the pre-use tests are, and how they are to be performed for the machine model / configuration that you are using

VALE

Questions?

Thank you!

Richard Riach
Production Support, Specialty Engineering

Phone: 705 682-6450

Email: Richard.Riach@vale.com


VALE