STERLING MATERIALS

100 Serra Drive

Verona, KY. 41092

Phone (859)567-7300

Fax (859)567-7313

www.SterlingMaterials.com

MINE ID #15-18068

Visit us at www.jimcoproductsinc.com

JIMCO PRODUCTS, INC.

101 Jimco Drive

Hollister, MO 65672

(417)-335-8803

Fax: (417) 335-8804

Mississippi Lime Co.

525 Hanse Rd.

Verona ,Ky. 41092

8/17,2015.

Mr. Trevor Tallent,

On August 13,2015. Mike Musko(Orica) myself,Dan West(Jimco Products) with assistance of Troy Porter and Zack Barrett performed a pull test on your facility.

Pull test was done on bolt #1 at NW-7

Bolts used/ Orica #6 x 72" grade 60 headed rebar.

Plates used / Orica 8"x 8" x 1"" grade 3.

Resin used / Orica 2834 VLIF35. 2 sticks per hole.

Pull test was done on bolts #2 & #3 at NW-8.

Bolts used/ Minova #6 x 72" grade 60 headed rebar.

Plates used / Minova 8"x8" x 1" grade 3.

Resin used / Minova 2824 LIF50 . 2 sticks per hole

Bolt #1 Pulled to 32,000# anchorage held firm.

Bolt #2 Pulled to 32,000# anchorage held firm.

Bolt #3 Pulled to 32,000# anchorage held firm.

The Pull test was satisfactory. There does not appear to be any issues at this time with either the bolts or resin. Installation was according to Orica recommendations.

We do want to thank all of the employees at this facility for their assistance during this test.

Daniel V.West

Vice President Jimco Products Inc.
Jimco Products Inc.
101 Jimco Drive
Hollister,Mo.65672
417-335-8803 office
417-337-1636 cell
Visit us at http://www.jimcoproductsinc.com

Orica Ground Support
150 Summer Court
Georgetown, KY 40324
Tel: 502-863-6800
Fax: 502-863-1374

ORICA

Pull Test Results

Date: 8-13-15

Mining Company: MISSISSIPPI LIMESTONE Mine Name: STERLING MATERIALS

Test Location: SEE BACK Mine Temperature: 60°

Tested By: DAN WEST Witness: MIKE MISKO Witness: TROY PORTER
ZACK BARRETT

Roof Description: LIMESTONE

Test Number	1	2	3	4
Resin Manufacturer	ORICA			
Resin Specification	(2) 2834 VLIF 35			
Resin Temperature	60°			
Bolter RPM	375 RPM			
Spin Time	5-8 sec			
Hold Time	10-14 sec			
Bolt Manufacturer	ORICA			
Bolt Type	REBAR HEADED			
Diameter	#6 3/4"			
Length	72"			
Steel Grade	GR 60			
Length Grouted	72" FULL GROUT			
Plate Type	FLAT			
Plate Size	8"x8"x3/8"			
Hole Dia. And Length	1 1/4" x 73"			
Expansion Shell	NA			
Anti-Friction Washer	NA			
Installed Torque	NA			
Bolt Tension	NA			
Time Installed	8-10-15	8-10-15	8-10-15	8-10-15
Time Pulled	8-13-15	8-13-15	8-13-15	8-13-15

	NW-6	NW-7	NW-8	NW 8
Test Number	1	2	3	4
	Displacement (Thousandths of Inch)			
1 Ton		OK	OK	OK
2 Ton	W/Org	OK	OK	OK
3 Ton	Pull Collar	OK	OK	OK
4 Ton	Installed	OK	OK	OK
5 Ton		OK	OK	OK
6 Ton		OK	OK	OK
7 Ton		OK	OK	OK
8 Ton		OK	OK	OK
9 Ton		OK	OK	OK
10 Ton		OK	OK	OK
11 Ton		OK	OK	OK
12 Ton		OK	OK	OK
13 Ton		OK	OK	OK
14 Ton		OK	OK	OK
15 Ton		OK	OK	OK
16 Ton		OK	OK	OK
17 Ton				
18 Ton				
19 Ton				
20 Ton				
21 Ton				
22 Ton				
23 Ton				
24 Ton				
25 Ton				

Bolt Bar Capacity

In Diameter	Grade, KSI	Yield load, tons
5/8 No. 5	55	8
5/8 No. 5	60	9
5/8 No. 5	75	12
3/4 No. 6	40	9
3/4 No. 6	55	12
3/4 No. 6	60	13
3/4 No. 6	75	17
7/8 No. 7	55	17
7/8 No. 7	60	18
7/8 No. 7	75	23
1 No. 8	55	22
1 No. 8	60	24

Comments:

Sterling Materials

Ground Control Plan

Mine ID #15-18068

100 Sierra Drive

Verona, Ky. 41092

Table of Contents:

Introduction:

This Ground Control Plan outlines the system used to manage ground control at Sterling Materials Mine. All aspects of ground control are included in the Plan from Geological Information through the design phase to the requirements of the Standard Working Procedures. All supporting documentation is readily available and reviewed regularly.

This document shall form part of the Mine Management Plan and will be used in conjunction with this plan. It is also the primary document which addresses the requirements of the Underground Ground Control Standard at the mine.

Objective and Scope:

The objective of the Ground Control Plan is to ensure the systematic planning and effective implementation of the ground control systems in order to safely and efficiently operate Sterling Materials Mine. This Ground Control Plan applies to all personnel at Sterling Materials Mine.

Accountabilities/ Responsibilities:

The accountabilities and responsibilities shall be included in the appropriate job descriptions. Where there are alternative positions held the responsibilities and accountabilities shall be assigned to those positions.

Sterling Materials Compliance Agreements:

Sterling Materials shall correct any Ground Conditions that create a hazard to persons before other work or travel is permitted in the affected area. Until such work is completed the hazardous area shall be bermed or posted to impede unauthorized entry. Also notification will be given to any persons whom could potentially enter the area. Sterling Materials shall follow all regulations regarding 30 CFR §57.3200.

Sterling Materials shall perform scaling from a safe location which will not expose persons to injury from falling material. Scaling shall be performed from either a machine designed for scaling, or by barring back or ribs from a safe location. Sterling Materials shall follow all regulations regarding 30 CFR §57.3201.

Sterling Materials shall perform manual and mechanical scaling with the appropriate tools necessary to perform the job safely. When manually scaling, the bar provided shall be of a length and design that will allow the removal of loose material without exposing the person performing the work to injury. Sterling Materials shall follow all regulations regarding 30 CFR §57.3202.

Sterling Materials shall obtain a manufacturer's certification that the material was manufactured and tested in accordance with the specifications of ASTM F432-95 and make the certification available to an authorized representative of miners (Attached). Fixtures and accessories used will be of appropriate specifications for the mine strata. At the start of each working shift the rock bolt driller shall conduct torque tests on all rock bolts to withstand 150 foot-pounds of torque and shall not use any damaged or deteriorated resin cartridges. Sterling Materials shall follow all regulations regarding 30 CFR §57.3203.

Sterling Materials shall use ground support where ground conditions or mining experience in similar ground conditions in the mine indicate that is necessary. Rock bolts shall be installed throughout the entirety of the third level of the mine and subsequent parts of the mine where management deems necessary. The rock bolt spacing shall be placed on a 5 foot by 5 foot pattern with rib bolts being no more than 2.5 feet from the rib or face (Attached Pattern). All rock bolts shall be maintained, repaired, or replaced in any area where rock bolts have been damaged which creates a hazard to persons prior to any work or travel in the affected area. Sterling Materials shall follow all regulations regarding 30 CFR §57.3360.

Sterling Materials shall have persons designated by the mine operator that is experienced in examining and testing for loose ground. Appropriate supervisors or other designated persons shall examine and, where applicable, test ground conditions in areas where work commencing, after blasting, and as ground conditions warrant during the work shift. Underground haulageways and travelways and surface area highwalls and banks adjoining travelways shall be examined weekly or more often if changing ground conditions warrant. Sterling Materials shall follow all regulations regarding 30 CFR §57.3401.

Sterling Materials shall not permit persons to work or travel between machinery or equipment and the highwall or bank where the machinery or equipment may hinder escape from falls of slides of the highwall or bank. Travel shall only be permitted when necessary for persons to dismount. Sterling Materials shall follow all regulations regarding 30 CFR §57.3430.

Sterling Materials shall not permit maintenance work between machinery or equipment and ribs unless the area has been tested and, when necessary, secured. Sterling Materials shall follow all regulations regarding 30 CFR §57.3460.

Sterling Materials shall follow all regulations regarding 30 CFR §57.3400 and 30 CFR §57.3461.

To: Mi

Date: Ja

Re: AS

This letter is to
manufactured b
letter covers an

Listed below ar

Manufacturin

"B1"	"B
"B2"	"B
"B3"	"B
"B4"	"B
"B5"	"B
"B6"	"B
"B8"	"B

BE – Eclipse Bo

Please contact

Regards,

David Buick

MINOVA

To: Minova USA Roof Support Customers

Date: January 2, 2014

Re: ASTM F432-13 Certification

This letter is to certify that all roof bolts, plates, accessories and resin capsules manufactured by Minova USA meet or exceed ASTM F432-13 specifications. This letter covers any products shipped during 2014.

Listed below are the manufacturing symbols used by each Minova USA steel plant:

Manufacturing Symbol		Location
"B1"	"BE1"	Bowerston, OH
"B2"	"BE2"	Clearfield, UT
"B3"	"BE3"	Marion, IL
"B4"	"BE4"	South Point, OH
"B5"	"BE5"	Grundy, VA
"B6"	"BE6"	Cadiz, OH
"B8"	"BE8"	Stoney Creek, ON

BE – Eclipse Bolt

Please contact your local Minova representative if you have any questions.

Regards,

David Buick

Minova USA Inc.
150 Carley Court
Georgetown, KY 40324
Tel: 502-863-6800
Fax: 502-868-6238

To: Minova USA Roof Support Customers

Date: January 5, 2012

Re: ASTM F432-10 Certification

This letter is to certify that all roof bolts, plates, accessories and resin capsules manufactured by Minova USA meet or exceed ASTM F432-10 specifications. This letter covers any products shipped during 2012.

Listed below are the manufacturing symbols used by each Minova USA steel plant:

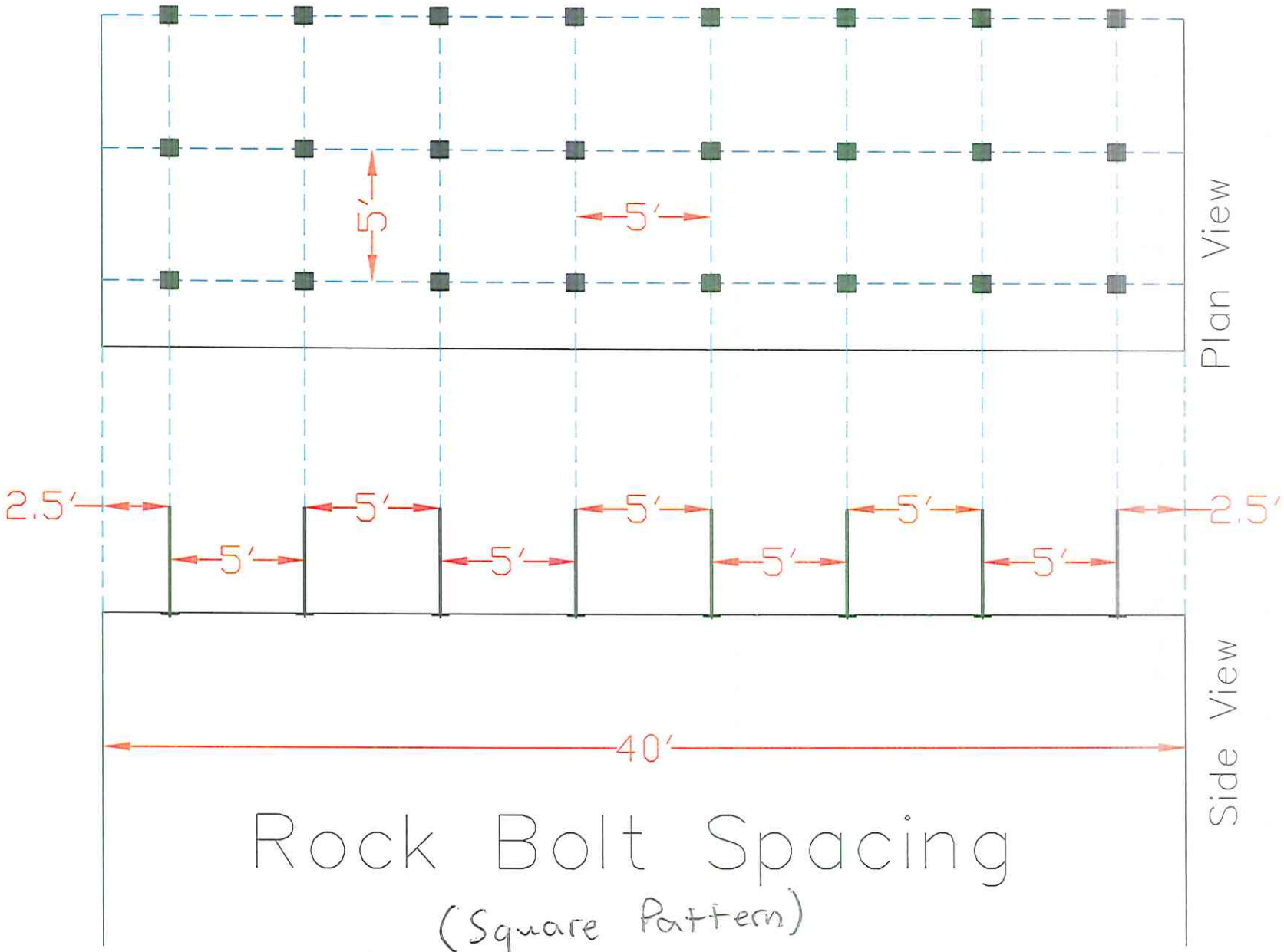
Manufacturing Symbol		Location
"B1"	"BE1"	Bowerston, OH
"B2"	"BE2"	Clearfield, UT
"B3"	"BE3"	Marion, IL
"B4"	"BE4"	Proctorville, OH
"B5"	"BE5"	Grundy, VA
"B6"	"BE6"	Cadiz, OH
"B8"	"BE8"	Stoney Creek, ON

BE – Eclipse Bolt

Please contact your local Minova representative if you have any questions.

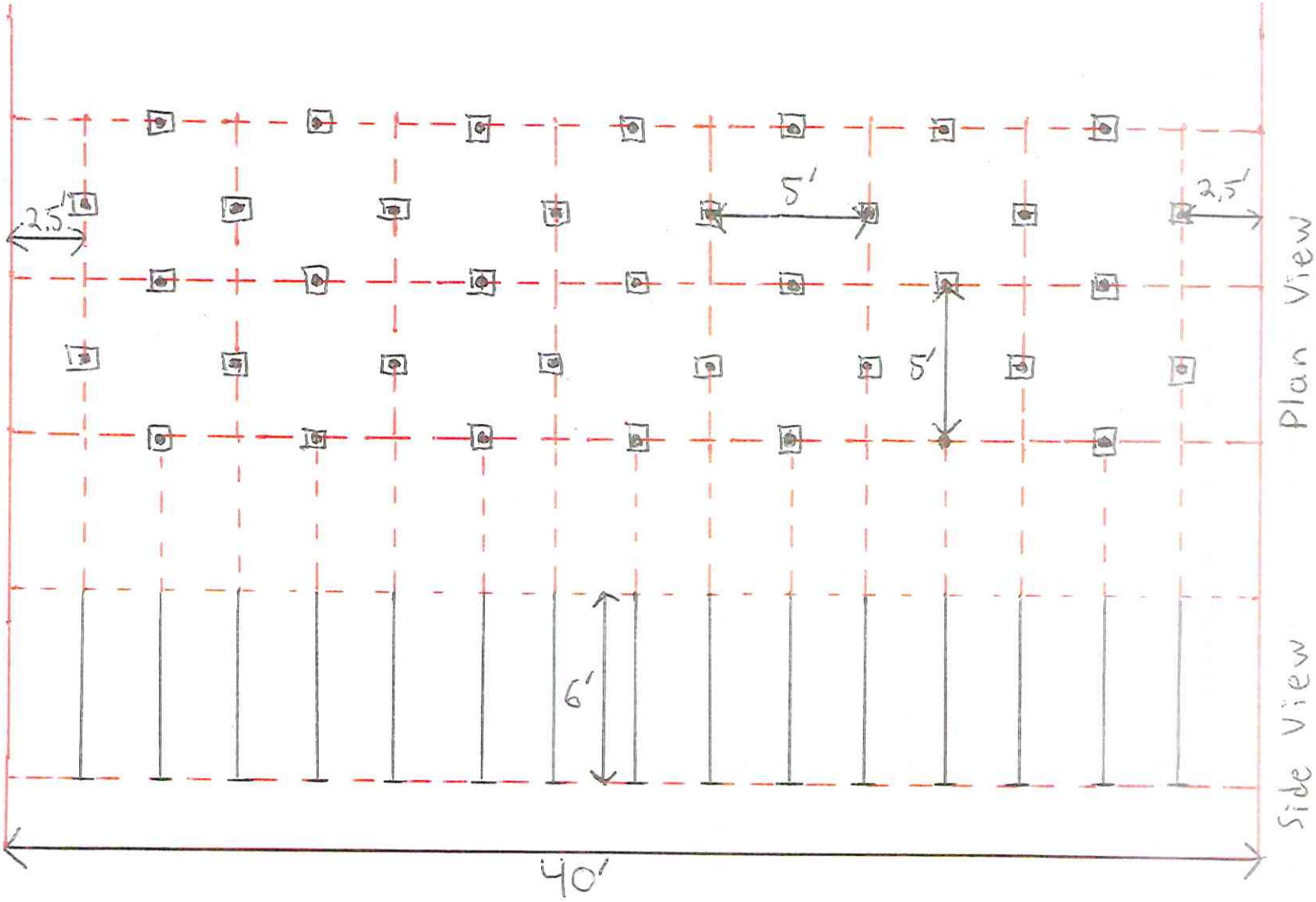
Regards,

Jim Earl
President & CEO



Rock Bolt Spacing

(Square Pattern)



Diamond Pattern Spacing

Scale: 1" = 5'

5'

Ground Control Equipment/Supplies:

The following Equipment/Supplies shall be used to ensure the Ground Control Safety of persons Underground at Sterling Materials:

Antraquip AQ-3 (Rotary Head Scaler) attached to a 320 Caterpillar Excavator.

Antraquip AQ-4 (Rotary Head Scaler) attached to a 330 Caterpillar Excavator.

VP-285 (Vibratory Pick Scaler) attached to a 330 Caterpillar Excavator.

Orange Safety Cones or Berms.

JLG 800S Manlift/ Genie S60 Manlift

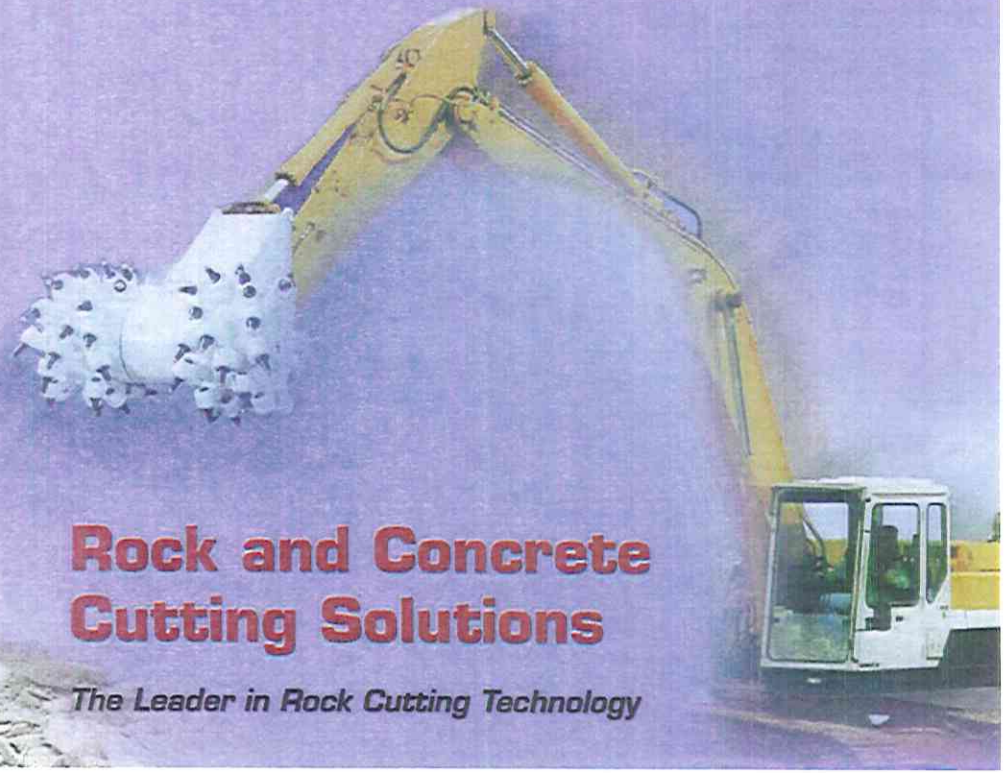
- Midwest Mach Jackleg
- Scaling Bar
- Torque Wrench (150 lbs Torque)

Oldenburg Cannon Roof-Bolting Machine Model: DPI-HD-MB O/U

- Minova #6 Gr60 Rebar Bolt
- Minova 8"X 8" Donut Bearing Plate
- Minova Lokset Resin CArtridges A Series
- Scaling Bar
- Torque Wrench (150 lbs Torque)

ANTRAQUIP

Antraquip Hydraulic Cutter Boom Attachments



Rock and Concrete Cutting Solutions

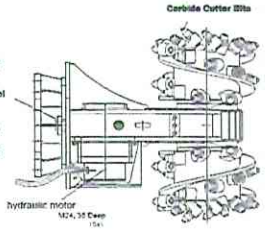
The Leader in Rock Cutting Technology

For More Information Contact:
Antraquip Corporation PO Box 28 Hagerstown, MD 21741 USA
Tel: +1 301-665-1165 Fax: +1 301-665-9079
Email: info@antraquip.net Web: www.antraquip.net

Antraquip rock and concrete cutting attachments for excavators are the new innovation that has taken the construction industry by storm. AQ rotary cutters are powerful attachments that can excavate rock and concrete efficiently while limiting noise and vibrations. The models ranging from the AQ-1 to the AQ-6 can be mounted on and operated by the hydraulics of excavators ranging in size from 1.5 tons to 120tons.

The controlled excavation of rock and concrete with AQ cutters is unparalleled whether you need to excavate a trench to the desired dimension or whether you require the excavation of a tunnel to profile. So for your next project consider AQ cutter boom attachments as the potential solution for numerous applications including trenching, controlled demolition, scaling, profiling, slurry wall construction, tunneling, and remediation.

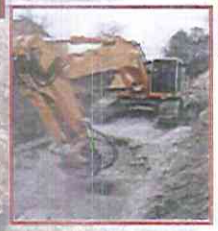
Antraquip is now offering a variety of cutting drums designed for specific applications. These include specialized drums for tunneling, profiling, remediation, and stump grinding. In addition, there are various types of carbide cutter bits (picks) available for each machine that are designed for different applications



Some of the advantages that Antraquip cutter boom attachments offer include:

- Rugged gears and housing
- The use of a powerful high torque hydraulic motor
- Robust cutting drums to ensure maximum production and a long life span
- A swivel mechanism that allows the cutter to be turned at 22.5 degree increments without having to remove the cutterhead from the excavator.
- Experienced field technicians and office personnel available for technical support at all times

AQ-5 Demolition Project AQ cutting attachments can cut up to one inch rebar



AQ-4 mounted on Liebherr 944 excavator working in medium hard limestone

AQ-4 removing layer of concrete from bridge, mounted on a Hitachi 30 ton excavator

AQ-4 mounted on Komatsu PC400 mining Talc producing 100+ tons per hour

Dimensions and Specifications

Transverse Cutters

The AQ transverse cutting attachments are designed for hard rock excavation and demolition for excavators in weight classes from 3 to 150 tons.

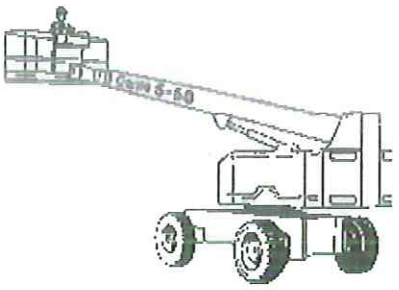
	Unit	AQ-1	AQ-2	AQ-3	AQ-4	AQ-5	AQ-6XL
Cutting head diameter	in	12	16	23	26	32	37
Cutting head width	in	21	24	31	39 (5) , 47 (II)	52	63
Speed 0		X	X	X	75 at Q = 47 gpm	X	X
Speed 1	RPM	90 at Q=9 gpm	X	80 at Q = 32 gpm	75 at Q = 63 gpm	62 at Q= 92 gpm	52 at Q=185 gpm
Speed 2	RPM	90 at Q=11 gpm	90 at Q=15 gpm	80 at Q = 40 gpm	75 at Q = 69 gpm	57 at Q=106 gpm	48 at Q=211 gpm
Speed 3	RPM	90 at Q=12 gpm	90 at Q=18 gpm	X	72 at Q = 79 gpm	53 at Q=119 gpm	48 at Q=250 gpm
Speed 4	RPM	90 at Q=13 gpm	75 at Q=21 gpm	X	X	X	X
Oil Flow	gpm	9 - max. 21	11 - max. 26	32 - max. 45	47 - max. 84	92 bis max. 158	180 - max. 260
Oil pressure max.	PSI	5075	5075	5075	5075	5075	5075
Max Torque output	ft lb	1,374	3,824	7,647	17,206	34,400	80,500
Max Cutting force	lbs	2,736	5,834	8,112	15,697	26,073	53,380
Approx. weight	lbs	484	990	1,980	3,850 (4,070)	7,260	13,200
Maximum input power	HP	42	60	87	160	270	470
Recommended carrier weight	tons	3 - 7	6 - 17	10 - 22	25 - 40	50 - 80	80 - 150
Recommended engine power of carrier	HP	17 - 60	27 - 90	80 - 120	150 - 240	250 - 400	300 - 470

Lengthways Cutters

The AQ lengthways or inline cutting attachment is designed for the excavation of narrow trenches, tunneling, scaling and various other types of specialized applications. They match excavators from 3 to 50 tons.

	unit	AQ-1L	AQ-2L	AQ-3L	AQ-4L
Cutting Head Diameter	in	16	16	18	27
Cutting Head Width	in	16	16	18	27
Speed 0	RPM	X	X	X	75 at Q = 47 gpm
Speed 1	RPM	X	80 at Q = 32 gpm	80 at Q = 32 gpm	75 at Q = 63 gpm
Speed 2	RPM	90 at Q=15 gpm	80 at Q = 40 gpm	80 at Q = 40 gpm	75 at Q = 69 gpm
Speed 3	RPM	90 at Q=18 gpm	X	X	72 at Q = 79 gpm
Speed 4	RPM	75 at Q=21 gpm	X	X	X
Oil Flow	gpm	40 - max. 100	32 - max. 45	32 - max. 45	47 - max. 84
Oil Pressure Max.	PSI	5075	5075	5075	5075
Max Torque output 4 (at 5,075 PSI)	ft lb	3,824	7,647	7,647	17,206
Max Cutting Force 4 (at 5075 PSI)	lbs	5,834	11,663	10,382	15,466
Approx. Weight	lbs	770	820	900	2,860
Maximum Input Power	HP	60	87	87	160
Recommended Carrier Weight	tons	3 - 15	10 - 20	10 - 20	25 - 50
Recommended Engine Power of Carrier	HP	27 - 90	80 - 120	80 - 120	120 - 240

Genie S-60/S-65 Specifications
Self-Propelled Telescopic Boom



Standard Features

- Oscillating axle system on 4x4 models
- Dual extended cylinders
- Fully proportional controls
- Self-leveling platform
- Drive enable system
- 360° continuous turntable rotation
- 160° hydraulic platform rotation
- Positive traction drive
- AC wiring to platform
- Auxiliary power unit
- Locking turntable covers
- Anti-restart engine protection
- Maintenance-free pivot-point bearings
- Engine monitoring gauges
- Horn
- Tilt alarm
- Hour meter
- Fuel select switch on platform and ground control panels (Gas/LPG models)
- Dual fuel (Gas/LPG) or diesel engine options

Specifications

Model	**S-60**		**S-65**	
	US	*Metric*	*US*	*Metric*
Working height max	66 ft	20.3 m	71 ft	21.8 m
Platform height max	60 ft	18.3 m	65 ft	19.8 m
Height - stowed	9 ft	2.74 m	9 ft	2.74 m
Length - stowed	27 ft 2 in	8.3 m	30 ft 10 in	9.4 m
Width	8 ft	2.44 m	8 ft	2.44 m
Wheelbase	9 ft	2.74 m	9 ft	2.74 m
Ground clearance	12 in	30 cm	12 in	30 cm
Platform length: 6 ft	30 in	76 cm	30 in	76 cm
8 ft	36 in	91 cm	36 in	91 cm
Platform width: 6 ft	72 in	1.83 m	72 in	1.83 m
8 ft	96 in	2.44 m	96 in	2.44 m
Horizontal reach max	51 ft 3 in	15.6 m	56 ft 4 in	17.2 m
Maximum lift capacity 6 ft platform	600 lb	272 kg	500 lb	227 kg
Maximum lift capacity 8 ft platform	500 lb	227 kg	500 lb	227 kg
Turning radius - outside	22 ft 2 in	6.76 m	22 ft 2 in	6.76 m
Turning radius - inside	12 ft 1 in	3.68 m	12 ft 1 in	3.68 m
Turntable rotation	360° continuous		360° continuous	
Turntable tailswing	3 ft 3 1/2 in	1 m	3 ft 3 1/2 in	1 m
Power source	Ford LRG 425 EFI Gas/LPG 82 hp (61 kw) Deutz Diesel F4L 1011 56 hp (42 kw) Perkins Diesel 704-30 60 hp (45 kw)			
Controls	12V DC proportional		12V DC proportional	
Platform rotation	160°		160°	
Tires	15 - 19.5 NHS		15 - 19.5 NHS	
Hydraulic tank capacity	45 gal	170 litre	45 gal	170 litre
Fuel tank capacity	33 gal	125 litre	33 gal	125 litre
Weight	26,060 lb	11,821 kg	28,400 lb	12,882 kg

S-60/S-65	**4x2**		**4x4**	
	US	*Metric*	*US*	*Metric*
Drive speed - stowed	4.4 mph	7.1 km/h	3 mph	4.8 km/h
Gas/LPG models	40 ft/6.2 sec	12.2 m/6.2 sec	40 ft/9.1 sec	12.2 m/9.1 sec
Drive speed - stowed	4 mph	6.4 km/h	2.8 mph	4.5 km/h
Diesel models	40 ft/6.8 sec	12.2 m/6.8 sec	40 ft/9.7 sec	12.2 m/9.7 sec
Drive speed,	0.6 mph	1 km/h	0.6 mph	1 km/h
raised or extended	40 ft/40 sec	12.2 m/40 sec	40 ft/40 sec	12.2 m/40 sec
(all models)				
Gradeability - stowed	30%		40%	

Genie Industries

USA 18340 NE 76th Street
P.O. Box 97030
Redmond, Washington 98073-9730
Telephone **(425) 881-1800**
Toll Free USA/Canada **800-536-1800**
Fax (425) 883-3475
http://www.genielift.com

UK The Maltings, Wharf Road
Grantham
Lincolnshire NG31 6BH
Telephone **(44) 01476-584333**
Fax (44) 01476-584334
http://www.genielift.com

800S

Telescopic Boom Lift

Key Specs

- **Horizontal Outreach**: 71 ft / 21.64 m
- **Platform Capacity - Restricted**: 1000 lb / 453.59 kg
- **Platform Capacity - Unrestricted**: 500 lb / 226.80 kg
- **Platform Height**: 80 ft / 24.38 m

Power Source

Auxiliary Power	12 Volts DC
Capacity - Fuel Tank	31 gal. / 117.35 L
Engine Type - Diesel	DEUTZ TD 2.9L Tier 4 Final 67 hp
Engine Type - Dual Fuel	GM Vortec 3000 MPFI 82 hp (61 kW)

Performance

Axle Oscillation	8 in. / 0.2 m
Drive Speed - 2WD	4 mph / 5.63 km/h
Drive Speed - 4WD	4 mph / 5.63 km/h
Gradeability - 2WD	30 %
Gradeability - 4WD	45 %
Platform Capacity - Restricted	1000 lb / 453.59 kg
Platform Capacity - Unrestricted	500 lb / 226.80 kg
Swing	360 Degrees
Swing Type	Continuous
Turning Radius - Outside	22 ft 6 in. / 6.86 m

Dimensional Data

Ground Clearance	1 ft / 0.3 m
Machine Height	9 ft 11 in. / 3.02 m
Machine Length	37 ft 3 in. / 11.35 m
Machine Width	8 ft 2 in. / 2.49 m
Platform Dimension A	3 ft / 0.91 m
Platform Dimension B	8 ft / 2.44 m
Platform Height	80 ft / 24.38 m
Tailswing	4 ft 8 in. / 1.42 m
Tire Size	15-625 Pnuematic

Reach Specifications

Horizontal Jib Rotation	0 Degrees
Horizontal Outreach	71 ft / 21.64 m
Platform Height	80 ft / 24.38 m
Vertical Jib Rotation	0 Degrees

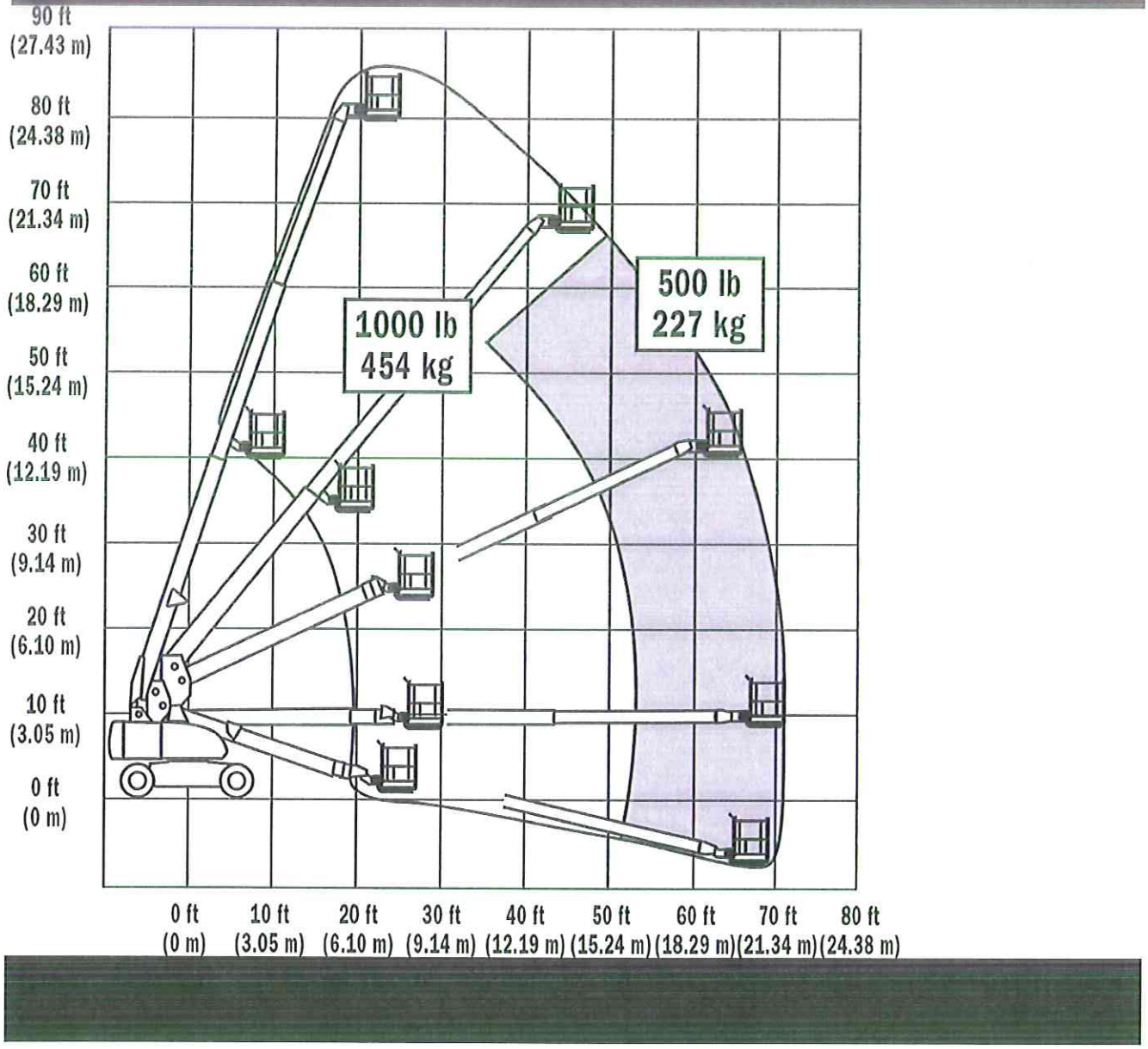
General

Capacity - Hydraulic Reservoir	48 gal. / 181.70 L
Ground Bearing Pressure	72 psi / 5.04 Kg/cm2
Machine Weight	33200 lb / 15059.27 kg

Key Features

- Reach full elevation in less than 70 seconds
- Advanced Design Electronics System reduces your costs by increasing fuel efficiency and reducing emissions
- Equipped with a fuel-efficient Tier 4 engine

Reach



Close

Options

800S

Telescopic Boom Lift

Key Specs

- **Horizontal Outreach**: 71 ft / 21.64 m
- **Platform Capacity - Restricted**: 1000 lb / 453.59 kg
- **Platform Capacity - Unrestricted**: 500 lb / 226.80 kg
- **Platform Height**: 80 ft / 24.38 m

Power Source

Auxiliary Power	12 Volts DC
Capacity - Fuel Tank	31 gal. / 117.35 L
Engine Type - Diesel	DEUTZ TD 2.9L Tier 4 Final 67 hp
Engine Type - Dual Fuel	GM Vortec 3000 MPFI 82 hp (61 kW)

Performance

Axle Oscillation	8 in. / 0.2 m
Drive Speed - 2WD	4 mph / 5.63 km/h
Drive Speed - 4WD	4 mph / 5.63 km/h
Gradeability - 2WD	30 %
Gradeability - 4WD	45 %
Platform Capacity - Restricted	1000 lb / 453.59 kg
Platform Capacity - Unrestricted	500 lb / 226.80 kg
Swing	360 Degrees
Swing Type	Continuous
Turning Radius - Outside	22 ft 6 in. / 6.86 m

Dimensional Data

Ground Clearance	1 ft / 0.3 m
Machine Height	9 ft 11 in. / 3.02 m
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Tailswing	4 ft 8 in. / 1.42 m
Tire Size	15-625 Pnuematic

Reach Specifications

Horizontal Jib Rotation	0 Degrees
Horizontal Outreach	71 ft / 21.64 m
Platform Height	80 ft / 24.38 m
Vertical Jib Rotation	0 Degrees

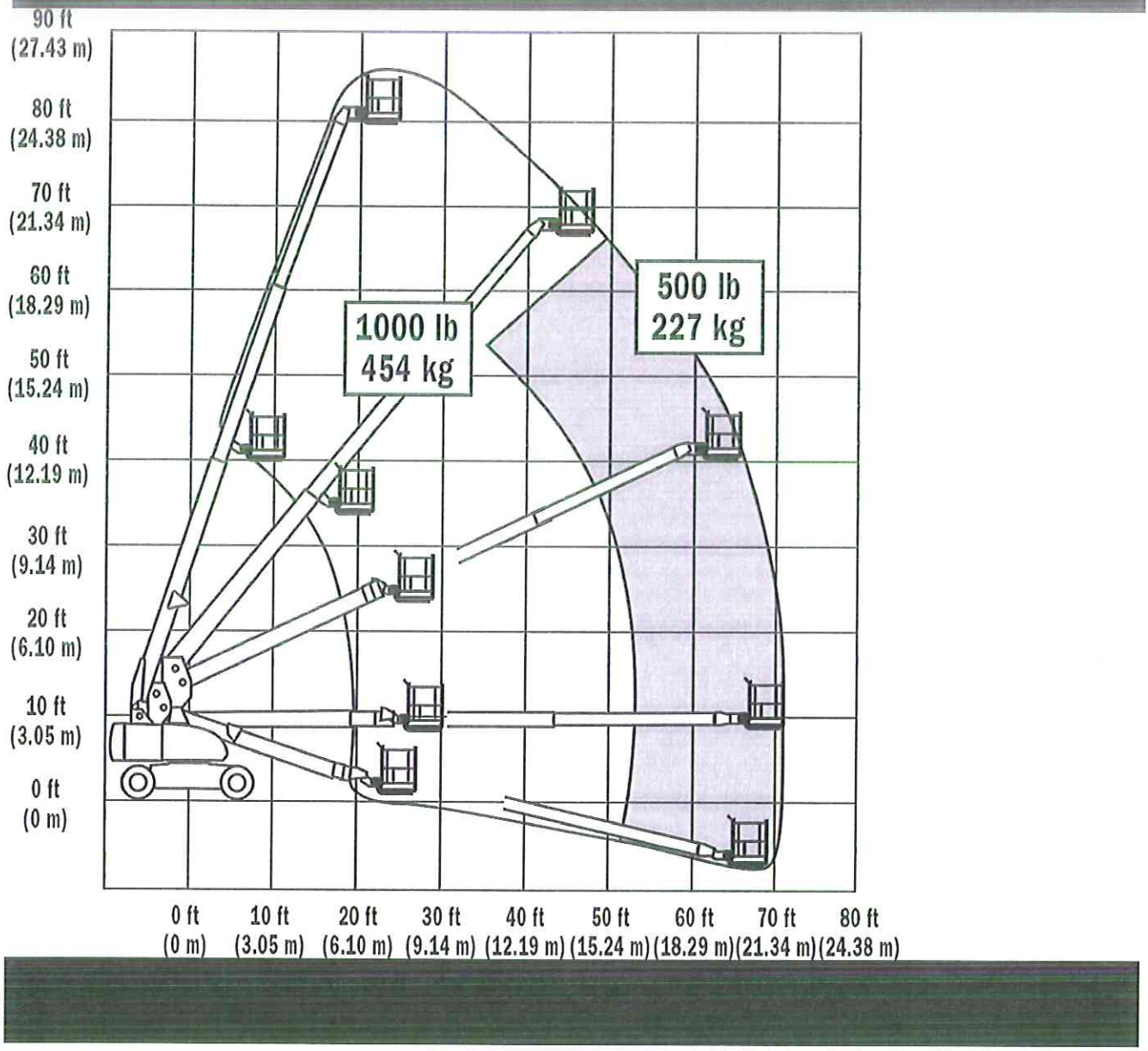
General

Capacity - Hydraulic Reservoir	48 gal. / 181.70 L
Ground Bearing Pressure	72 psi / 5.04 Kg/cm2
Machine Weight	33200 lb / 15059.27 kg

Key Features

- Reach full elevation in less than 70 seconds
- Advanced Design Electronics System reduces your costs by increasing fuel efficiency and reducing emissions
- Equipped with a fuel-efficient Tier 4 engine

Reach



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Options

SkyWelder®
»
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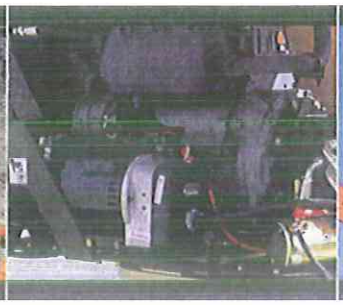

SkyPower®
»
(/en/equipment/options/boom-lift-options/skypower)

SkyGlazier®
»
(/en/equipment/options/boom-lift-options/skyglazier)

SkyCutter®
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(/en/equipment/options/boom-lift-options/skycutter)

SkyAir®
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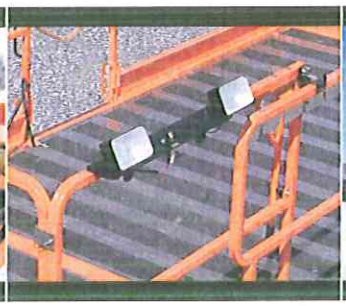
(/en/equipment/options/boom-lift-options/skyair)



Nite Bright®
»
(/en/equipment/options/boom-lift-options/nite-bright)

Cold Weather Packages
»
(/en/equipment/options/boom-lift-options/cold-weather-packages)

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Literature

800 Series Telescopic Boom Lift Spec Sheet (/-/media/jlg/current-materials-no-password/products/americas%20-%20ansi/engine-powered-boom-lifts/telescopic-booms/telescopic-booms-family-materials/docs/800-series-telescopic-boom-lift-spec-sheet.pdf?mw=1382)

Engine Powered AWP Brochure (/-/media/jlg/current-materials-no-password/products/americas%20-%20ansi/awp-family-materials/docs/engine-powered-awp-brochure.pdf?mw=1382)

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JLG Industries, Inc. is the world's leading designer, manufacturer and marketer of access equipment. The Company's diverse product portfolio includes leading brands such as JLG® aerial work platforms; JLG, SkyTrak® and Lull® telehandlers; and an array of complementary accessories that increase the versatility and efficiency of these products. JLG is an Oshkosh Corporation Company [NYSE: OSK].

OSHKOSH

An Oshkosh Corporation Company

Mid-Western, LLC

MWS83 Jack Leg Drill

Proven Design

- The most popular Jack Leg drill on the market
- The OEM of the popular MWS83 Jack Leg Drill and TUL2B & FL7 Feed Legs
- Precision manufactured parts that run better and wear down slower
- Backed by over 65 years of American-made experience

Versatility

- Available in telescopic and power retractable models
- Available in either a 7/8'' on 1'' chuck size
- Sold as either wet or dry (with or without water)
- Can easily be converted to a powerful Sinker drill

Affordability

- Mid-Western drills are high quality and competitively priced
- In-house manufactured parts last longer and perform better

MWS83F Jack Leg Drill Specifications

	US	Metric
Piston Diameter	3"	76 mm
Length of Stroke	2.5"	64 mm
Overall Length	27 1/4"	688 mm
Total Weight	72 lbs.	32.4 kg
Air Hose Size	1"	25 mm
Water Hose Size	1/2"	13 mm
Chuck Size	7/8" or 1" x 4 1/4"	22 mm or 25 mm x 108 mm

Pressure (PSI)	Percussion Speed (Impacts per Minute)
80	2208
90	2292
100	2376

Phone: 417.624. 2400 Fax: 417.624.2430 www.mwdrill.com info@mwdrill.com

FULLY GROUTED SYSTEMS

MINOVA

Rebar Bolt

Minova's Reinforcing Steel Bar (Rebar) is manufactured to critical tolerances and standards to meet the day-to-day needs of our mining customers. Our comprehensive quality control program ensures that each Rebar Bolt order arrives at your site just as you have specified. And, because Minova is a world leader in manufacturing, you can be assured that we will be able to fill your orders quickly and efficiently, regardless of the size of the delivery requirement.

Rebar Bolts are available in all standard diameters and grades as well as in special rolled dimensions (SRD) for your specific applications. Matched Bearing Plate systems and Minova resin capsules are available for all Minova Rebar Bolts.

Minova's Rebar Bolts made from grades 40 and 75 steel can be manufactured as bendable products for low seam applications.

Installation Procedures:

1. Drill hole at proper diameter and depth.
2. Make depth 1" longer than the bolt.
3. Insert appropriate Minova resin cartridge.
4. Insert Rebar Bolt and Bearing Plate to within 1/16" to 1/8" of roofline.

Continued >

Specifications:

Bar Diameter & Grade	Min Yield	Min Tensile	Borehole
#5 (16 mm) Gr60	18,600 lbs	27,900 lbs	1"
#6 (19 mm) Gr40	17,600 lbs	30,800 lbs	1"
#6 (19 mm) Gr60	26,400 lbs	39,600 lbs	1"
3/4" SRD Gr75	27,200 lbs	36,300 lbs	1"
#7 (22 mm) Gr40	24,000 lbs	42,000 lbs	1-1/8", 1-1/4", 1-3/8"
#7 (22 mm) Gr60	36,000 lbs	54,000 lbs	1-1/8", 1-1/4", 1-3/8"
7/8" SRD Gr75	37,400 lbs	49,800 lbs	1", 1-1/4", 1-3/8"
#8 (25 mm) Gr60	47,400 lbs	71,100 lbs	1-1/4", 1-3/8"

Solutions from Materials Technology

Rebar Bolt

5. Rotate to ensure complete mixing of resin.
6. Stop rotation. While maintaining boom pressure, hold in place.
7. Relieve boom pressure.

Consult your Minova Technical Sales Representative for specific mixing and hold requirements.

Minova USA Inc. Products

Bolts and Plates

Anchoring Products

Pumpable Cementitious Grouts

Airtite® Sealants and Coatings

Chemical Grouts

Manufactured and sold under license from Minova International Limited.

Minova USA Inc.
150 Carley Court
Georgetown, KY 40324 USA
Phone 502 863 6800
Fax 502 863 1374
Email sales.info@minovaint.com
Website www.minovausa.com

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Important Note: Warranty

SURFACE SUPPORT

MINOVA

Bearing Plate

Designed for Strength

Minova's Bearing Plates are manufactured from high-strength steel. They are designed to help prevent loose material from falling between the roof bolt patterns and provide strength to your immediate roof.

The "donut-shaped" embossment around the center hole increases deflective strength. The donut distributes the load to the roof bolt and also serves to center the bolt and provide protection to the bolt head.

Bearing Plates are also manufactured with a "dome" embossment. The dome is used in applications where the seam height is greater.

Bearing Plates are available in a variety of sizes and grades to fit your roof plan requirements.

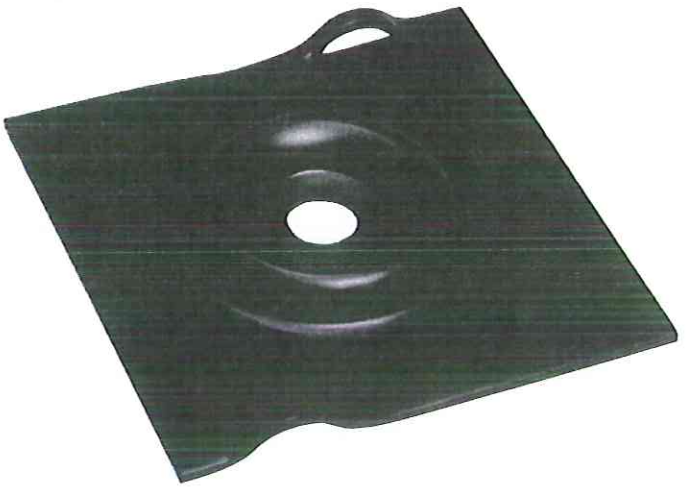
If additional strength is required in the center for stronger bolting systems, the donut embossed Bearing Plates have been designed to accommodate a Donut Plate Insert (DPI) washer.

The DPI can be used between the roof bolt and Bearing Plate. The DPI strengthens the hole location where high loading and deformation occurs. This unique combination provides the required strength in critical areas, the center and the edges. The system effectively reduces bolt pull-through and plate bending in heavy ground conditions.

Specifications:

Size	Grade	Embossment
6"X 6"	2, 3, 4, 5, 6	Dome, Donut, Flat
8"X 8"	2, 3, 4, 5, 6	Dome, Donut, Flat
9"X 9"	2, 3	Donut
6"X 16"	2, 3	Dome, Low Profile

Standard hole sizes are: 13/16", 1", 1-1/8" and 1-3/8"



Solutions from Materials Technology

Minova USA Inc. Products

Bolts and Plates

Anchoring Products

Pumpable Cementitious Grouts

Airtite® Sealants and Coatings

Chemical Grouts

Manufactured and sold under license from Minova International Limited.

Minova USA Inc.
150 Carley Court
Georgetown, KY 40324 USA
Phone 502 863 6800
Fax 502 863 1374
Email sales.info@minovaint.com
Website www.minovausa.com

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Important Note: Warranty

Minova USA Inc. warrants that its products, at the time of shipment, conform to the applicable descriptions set forth in the invoice and are free from defects in material and workmanship. NO OTHER WARRANTY, WHETHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE, SHALL EXIST IN CONNECTION WITH THE SALE OR USE OF ANY MINOVA USA INC. PRODUCT, AND ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY DISCLAIMED AND EXCLUDED.

All claims under this warranty must be made in writing to Minova USA Inc. within 15 days after discovery of the defect, and within 90 days of the date of shipment by Minova USA Inc. of the product claimed defective. Upon timely receipt of a claim, Minova USA Inc. shall have the option either to inspect the product while in Buyer's possession or to request Buyer to return the product to Minova USA Inc. for inspection. Claims not made as provided above and within the applicable time period will be barred. All warranties shall be null and void if the products have not been stored and used in accordance with procedures recommended by Minova USA Inc.

Minova USA Inc. shall, at its option, either replace the nonconforming or defective product or refund to Buyer its purchase price. The foregoing constitutes Buyer's sole and exclusive remedy for any breach or warranty.

ANCHORING PRODUCTS

MINOVA

Lokset® Resin Cartridges A Series

Reinforced Polyester Resin Anchor

Uses

The A Series Lokset® Resin Cartridge is specifically designed to be used in conjunction with a #6 (3/4") steel roof bolt in a 1" borehole. The principal applications for the A Series Lokset® Resin Cartridge include fully grouted rebar, tension rebar, doweling and resin-enhanced mechanical anchors.

Advantages

- **Proven** - Since our introduction of resin anchors to the United States in 1971, Lokset® Resin Cartridges have a proven record of success.
- **Strong** - When used properly, Lokset® Resin Cartridges consistently surpass the strength of the bolt or the surrounding strata, whichever is weaker.
- **Rigid** - Through innovative product engineering and manufacturing, the A Series Lokset® Resin Cartridge is stiff and easy to handle during installation.
- **Variety** - The A Series Lokset® Resin Cartridge is available in a wide variety of lengths and speeds which will satisfy most applications.
- **Viscosity** – The A Series Lokset® Resin Cartridge is available in High, Medium and Low Insertion Force (LIF) viscosities. The LIF formulation is unique in the industry and provides optimum performance with cable and mechanical assisted resin point anchor rock bolts.

Description

In most applications, Lokset® Resin Cartridges can enhance the performance of your current roof control system. The Lokset® cartridge consists of two compartments separated by a physical barrier. One compartment contains a polyester resin mastic and the other an organic peroxide catalyst. The rotation of the bolt during installation ruptures the cartridge, shreds the film and mixes the two components, thus causing a chemical reaction which transforms the resin mastic to a rock solid anchor.

The A Series Lokset® Resin Cartridge is intended for use in a 1" borehole with a #6 (3/4") bolt. The A Series Cartridge is 23mm or 0.9" in diameter. This combination provides the ideal annulus for proper mixing and maximum performance.

The A Series Cartridge is available in lengths ranging from one to eight grouted feet. The cartridge is also available in a variety of speeds including: Super Slow (1530), X-Slow (0510), Slow (-90), Medium (-45), Fast (-35), X-Fast (-20) and Super Fast (-10). A slow cartridge gels in one minute at 90oF, medium gels in one minute at 45oF, etc. For more information, please refer to the Lokset® Resin Cartridge product line brochure.

Continued >

Lokset®
Resin Cartridges
A Series

General Installation Instructions for Fully Grouted Systems

Contact your local representative if the A Series Cartridge is to be used in other applications.

1. Before use, read the installation and safety information provided with each box. Read the material safety datasheet.
2. To obtain a consistent set time, make sure the A Series Lokset® Resin Cartridge and bolt are at mine temperature before use.
3. Drill the borehole to the correct diameter (1") at a depth 1" longer than the bolt.
4. Insert the required number of A Series Lokset® Resin Cartridges.
5. Push the bolt into the hole. Slow rotation of the bolt as it passes through the cartridge is suggested but not required.
6. Just below the roof, stop and spin the bolt to mix the cartridge approximately 3 to 8 seconds.
7. Stop rotation and push the bolt upward with full thrust until the resin sets.
8. Do not overspin the bolt. If bolt rotation continues through the gel time, damage to the anchor may occur.
9. Never re-spin the bolt. Bolt rotation after the final spin may damage the partially set resin.

Packaging

Product packaging is dependent upon cartridge length.

Please refer to the Lokset® Resin Cartridge product line brochure for packaging information.

Shelf Life

One year when stored in a cool, dry place. For maximum performance, stock rotation is strongly recommended.

Minova Americas Products

Bolts and Plates
Anchoring Products
Pumpable Cementitious Grouts
Airtite® Sealants and Coatings
Chemical Grouts

Minova Americas
150 Carley Court
Georgetown, KY 40324 USA
Phone 800 520 6621
Fax 502 863 1374
Email sales.info@minovaint.com
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Important Note: Warranty

Lokset® Resin Cartridges

MINOVA

Minova USA Inc.

Customer Service

Minova USA Inc. has been serving the mining industry for over 30 years with products designed to handle a wide range of applications, from basic roof support to strata control problems requiring the implementation of an innovative solution. Minova's mining experience spans five continents, serving customers ranging from global conglomerates to small, family-owned-and-operated businesses.

Our mission is to respond to the ground control and ventilation needs of our customers for products or assistance regardless of geographic location. Quality customer service is achieved through our network of manufacturing facilities, warehouses, distributors, and field support staff, all strategically located to provide immediate response.

Minova's dedication to customer service is the driving force behind our **Total Quality** effort. We consistently strive to provide products of superior quality to our customers that enhance the efficiency and safety of their operations. Through innovation in product development, manufacturing and application, we aim to provide effective materials technology solutions for the most challenging problems.

This degree of industry cooperation and commitment to innovation has established Minova USA Inc. as your ideal partner in the pursuit of an improved working environment and, ultimately, improved productivity.

Product Innovation

Minova was instrumental in the introduction of resin cartridges. From our founding in 1971, we introduced resin cartridges to the U.S. mining industry and are now the largest manufacturer of resin cartridges in the world. Minova USA Inc. has expanded its product offerings to provide a wide range of options to help solve numerous ground control and ventilation problems.

This long list includes a wide range of bolts and plates, anchoring products, pumpable cribs and pumpable high yield cementitious grouts for underground construction projects, and an extensive line of sealants, liners and coatings for almost any application.

Our experienced staff includes Ph.D.s recognized as leaders in ground control, mining engineers and experienced miners. Our materials specialists in polymer and cement technology have over 20 years experience. There are few problems in ground control or ventilation for which Minova's experienced staff cannot offer a solution.

Please contact your Minova USA Inc. representative for more information on the latest in problem solving through materials technology innovation.

Advantages of Fully Grouted Resin Bolts

1. Eliminates possibility of anchorage failure due to high stress concentration by distributing the load throughout grouted areas.
2. Resists both horizontal and vertical movement in the bedding process.
3. Resists corrosion caused by acidic mine water.
4. Resists blast vibrations.
5. Eliminates need for tensioning or torquing.
6. Minimizes tension loss.

Bar Size	Bolt Diameter	Cartridge Diameter (mm)				
		23mm	28mm	32mm	32mm	32mm
#5	5/8"	X				
#6	3/4"	X	X			
#7	7/8"		X	X		
#8	1"		X	X	X	
#9	1 1/8"				X	X
#10	1 1/4"					X
"X" denotes proper combinations		1"	1 1/4"	1 3/8"	1 1/2"	1 5/8"
		Bore Hole Diameter				

The above table shows the recommended relationship between cartridge, bolt, and hole diameters for fully grouted resin bolts. Call Minova for non-standard bolt or hole sizes.

MINOVA

Why Use Resin Grouted Roof Bolts?

Roof bolts for strata control were first introduced to the United States coal mining industry in the 1950's, and after the 1969 Health and Safety Act was signed into law, roof bolting became the primary means of roof support. In the early 1970's Minova was the first company to introduce resin grouted roof bolts to the U.S. mining industry, and over the past two decades this means of roof support has steadily grown in popularity.

Mechanical expansion shells induce high levels of stress in the anchorage zone and may exceed the compressive strength of the rock surrounding the anchor. This phenomenon, as well as exposure to vibrations from blasting, can initiate tension loss and destroy the integrity of the anchorage. Therefore, periodic inspection for tension loss is necessary to detect a failed anchor.

When using resin grouted bolts and resin-enhanced mechanical anchors, **the anchorage load is distributed over the entire grouted area**, thereby decreasing concentrated levels of stress. Resin grouted bolts also hold up well under blast vibrations and the anchorage of resin bolts, unlike that of mechanical bolts, is improved by undulations in the borehole caused by drill steel movement. Therefore, the use of resin grouted roof bolts can result in better roof control, lower maintenance costs and **safer working conditions**.

The Lokset® Resin Cartridge

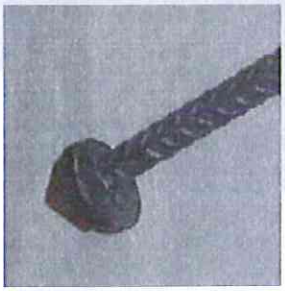
The Lokset® Resin Cartridge is designed with the needs of the roof bolter in mind. Through innovative product engineering and manufacturing, the Lokset® Resin Cartridge provides users with a cleaner, stiffer and faster setting product. By decreasing hold time and making the cartridge easier to handle, worker productivity is enhanced.

The Lokset® Resin Cartridge consists of two compartments separated by a physical barrier. One compartment contains a polyester resin mastic and the other a chemical catalyst. The rotation of the bolt during installation ruptures the cartridge, shreds the package, and mixes the two components, thus causing a chemical reaction which transforms the resin mastic to a rock solid anchor.

In order to achieve maximum performance, the proper cartridge, bolt and hole dimensions are crucial. Minova's professional field support staff is available to provide assistance in selecting the proper cartridge to meet your requirements. Our experienced professionals are available to provide installation training in the field or classroom.

Eclipse bolt showing uniformly mixed resin column.

Standard bolt showing poor mixing and glove fingering.



The Eclipse System has proven itself to be a superior solution when installing B-Series roof bolts in mines. B-Series bolts are defined in the U.S. as 5/8" fully grouted rebar in a one-inch borehole with polyester resin. Note that the 3/8" annulus is larger than the generally considered optimum of 1/4". In many conditions, the lower cost B-Series bolts are an effective roof support when used properly. Because the majority of roof bolts installed in the United States are B-Series bolts, Minova USA Inc. set out to maximize the performance of this system.

Given the critical role played by the resin, a challenge arose to ensure good mixing and minimize glove fingering. The less-than-optimum large annulus has the propensity to cause both these problems. Should these occur, it interferes with the mechanical interlock of the resin and the rock mass, lowering bolt performance.

The Minova solution for this turned out to be Eclipse B-Series Resin, combined with a 1/8" offset between the bolt head and the shaft axis. The Eclipse System's enlarged path of rotation increases turbulence in the hole sufficiently to allow 3/8" B-Series annulus to perform comparably with 1/4" optimal annulus systems. Testing in the field and testing by government agencies have demonstrated this is achieved with no reduction in bolt performance.

Millions of Eclipse Systems are in place today, giving the system a proven track record. The Eclipse System offers you the economic benefits of the B-Series while reducing concerns about poor mixing and glove fingering.

MINOVA

Fully Grouted Rebar Systems

The cartridge volume is controlled by length after diameter has been specified. Minova USA assisted in the development of cartridge volume standards incorporated into the MSHA roof bolting guidelines (ASTM F432-95). The standards assume the hole is one inch too long and the diameter is over drilled by 0.043 inches. Run out of resin is not required and does not always indicate a fully grouted bolt.

The effectiveness of resin anchored roof bolting is dependent upon a complex interaction of many variables. A quality polyester resin can provide approximately 2.5 tons per grouted inch of resistance to pull. However, the cartridge cannot be viewed in isolation. The most effective evaluation methodology is in situ performance of the bolt and cartridge as installed in a specific size hole in a specific rock type. To this end the most valid test of field performance is pull strength and speed of set. To further complicate the issue, the pull testing of full column resin bolts is not a valid indication of resin strength, as the resin anchorage is stronger than the tensile strength of the bolt. A laboratory approximation of resin pull strength for a specific bolt, hole and cartridge combination may be obtained through short encapsulation pull testing. While this methodology does not measure bolt strength or take geologic variation into account, it has been proven to be an effective indicator of resin strength.

The vast majority of Minova USA's cartridges fall into three series specifications:

A Series

- #6 bar (3/4 inch)
- 2.5 tons per grouted inch
- 23mm (.905 inch) cartridge
- 1 inch hole
- 1/4 inch annulus

B Series

- #5 bar (5/8 inch)
- 1.5 tons per grouted inch
- 23mm (.905 inch) cartridge
- 1 inch hole
- 3/8 inch annulus

E Series

- #7 bar (7/8 inch)
- 1.7 tons per grouted inch
- 32mm (1.25 inch) cartridge
- 1-3/8 inch hole
- 1/2 inch annulus

Standard Applications	Ultra Fast (-5)	Super Fast (-10)	X-Fast (-20)	Fast (-35, -37, -40)	Medium (-45, -50)	Slow (-70, -90, -0204)	X-Slow (-0510)	Super Slow (-1530)	Retainer Clip
Fully Grouted Rebar		X	X	X	X	X	X	X	
Tension Rebar-Dome Nut/Shear	X	X	X	X					
Tension Rebar-Two-Speed Resin Combination	X	X	X	X	X	X	X	X	
Resin-Enhanced Mechanical Anchor			X	X	X	X	X	X	
Combination - Resin Rebar/Mechanical		X	X	X					
Special Applications									
Dowelling					X	X	X	X	
Stoper Installation					X	X	X	X	
Robotic Cartridge Insertion									X

Spin Time

Complete mixing of the cartridge contents is vital to obtain the maximum anchorage strength. Spin Time is the amount of time needed to properly mix the cartridge components by bolt rotation. Complete mixing of the components normally requires 30-35 revolutions of the bolt.

Hold Time

After the cartridge is thoroughly mixed, the bolt must be held in place until the resin sets. The amount of time necessary after mixing stops until the bolt is firmly anchored is referred to as Hold Time.

Gel Time

The amount of time necessary until the resin begins to harden is referred to as Gel Time. Practically speaking, Gel Time is the sum of Spin and Hold Times, and is inversely related to temperature.

Typical Spin And Hold Times For Lokset® Cartridges

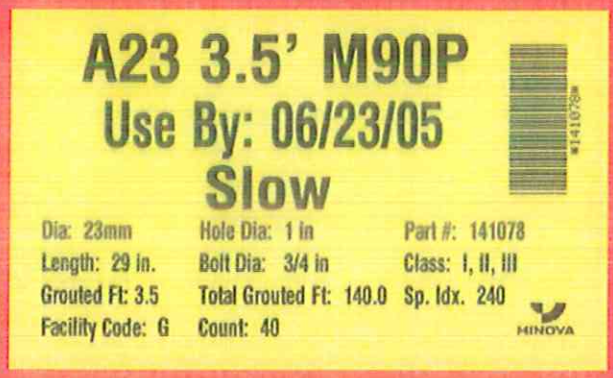
Temperature Reference 60°-65° F

Cartridge Speed	Spin Time (Seconds)	Hold Time
90	5 - 8	105 - 135
50	5 - 8	20 - 24
45	5 - 8	16 - 18
35	5 - 8	10 - 12
20	3 - 6	4 - 6
10	3	3 - 5
5	3	2 - 3

Note: Spin and Hold Times are dependent upon bolt rotation speed and cartridge, bolt and rock temperatures. Field trials are recommended.

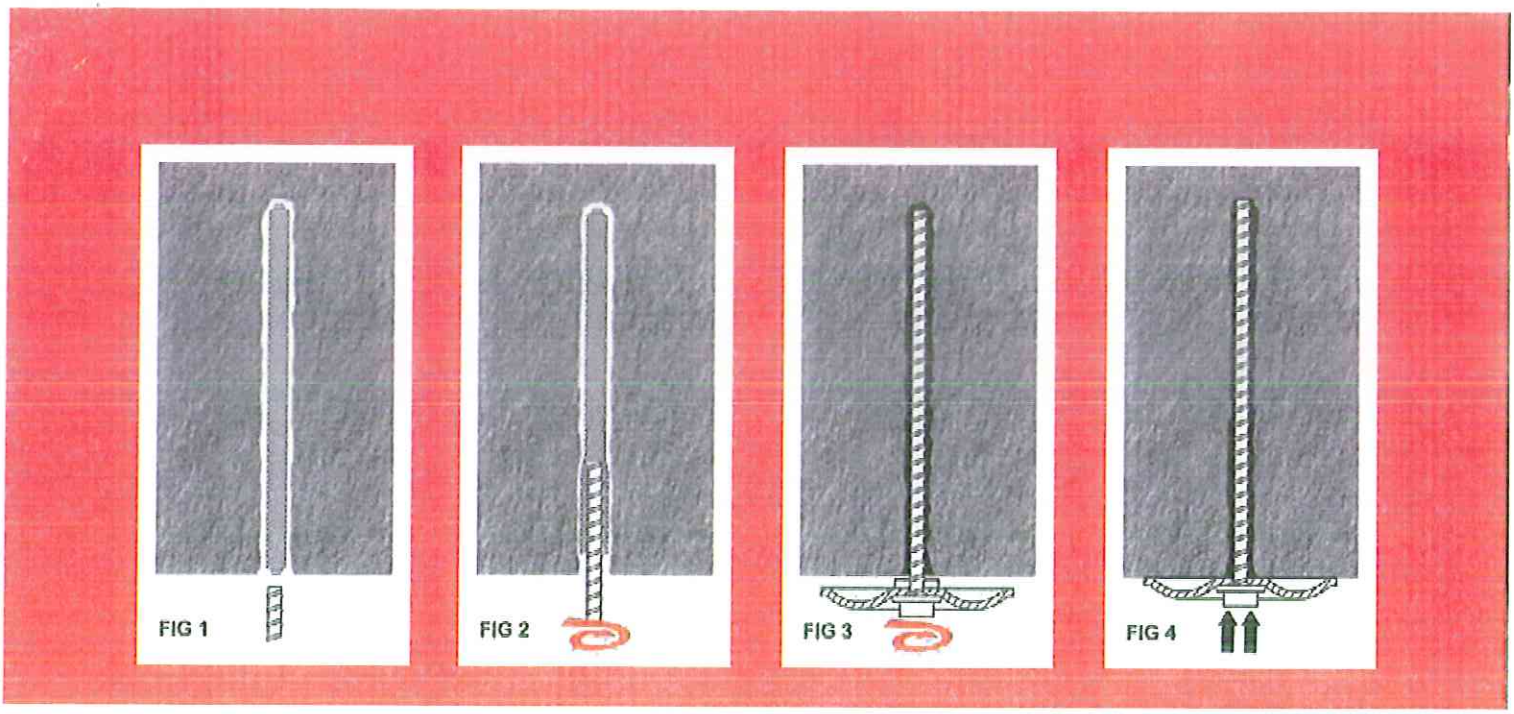
Resin Classification Chart

Cartridge Formulation	Speed Index	Strength Index	Speed Designation	Label Color
5	15	10	Ultra Fast	Purple
10	15	10	Super Fast	Red
20	15	10	X-Fast	Orange
35	30	10	Fast	Blue
37	30	10	Fast	Blue
40	30	10	Fast	Blue
45	60	10	Medium	Green
50	60	10	Medium	Green
70	240	10	Slow	Yellow
90	240	10	Slow	Yellow
0204	240	10	Slow	Yellow
0510	600	10	X-Slow	White
1530	1000	10	Super Slow	White



MINOVA

Label	Description
A	Large letters denote system: A series 3/4" bolt dia., 1" hole dia. B series 5/8" bolt dia., 1" hole dia. C series 3/4" bolt dia., 1-1/4" hole dia. E series 7/8" bolt dia., 1-3/8" hole dia.
23	Denotes cartridge diameter in millimeters
3.5'	Denotes the grouted feet
M	Letter H or M denotes viscosity H - high M - medium The letters LIF denote low insertion force LIF
90	Number denotes cartridge formulation (speed) - see chart
P	B - basket retainer clip P - parachute retainer clip
Use By	Expiration date. Usually one year from date of manufacture.
Slow	Denotes speed relative to cartridge formulation - see chart
Dia.	Diameter of cartridge in millimeters
Length	Length of cartridge in inches
Grouted Ft	How many feet of bolt the cartridge will grout
Facility Code	Denotes in which plant it was manufactured, B-Bluefield, G-Georgetown, J-Grand Junction
Hole Dia.	Applicable borehole size in inches
Bolt Dia.	Applicable bolt diameter in inches
Total Grouted Ft.	Total amount of grouted feet in the box
Count	Number of cartridges in the box
Part#	Minova ordering part number
Class	All Minova cartridges are rated for all I,II,III classes.
Speed Index	See chart



Contact your local representative for specific application instructions.

- Before use, read the installation and safety information and MSDS provided.
- To obtain a consistent set time, make sure the Lokset® Resin Cartridge and bolt are at mine temperature before use.
- Drill the borehole to the correct diameter at a depth equal to the length of the bolt. Mark the drill steel to use as a guide.
- Insert the required number of Lokset® Resin Cartridges. **See Figure 1.**
- Push the bolt into hole. Slow rotation of bolt as it passes through cartridge is suggested but not required. **See Figure 2.** For tension rebar applications, rotation is **not** suggested during bolt insertion.
- Just below the roof, stop and spin the bolt a minimum of 35 revolutions to mix the cartridge. This should take 3-6 seconds depending on the actual RPMs of your equipment. **See Figure 3.**
- Stop rotation. Push bolt upward with full thrust until the resin sets. **See Figure 4.**
- For tension rebar applications, hold time needed depends on gel time. Spin nut until the desired torque is achieved.
- **Do not over spin the bolt.** If bolt rotation continues through the gel time, damage to the anchor may occur.
- **Never re-rotate the bolt.** Bolt rotation after final spin may damage the partially set resin.

Special Cartridges

Lokset® System	Pieces Per Box	Boxes Per Pallet	Pieces Per Pallet	Pallet Size	Approximate Gross Weight Per Pallet
2312	50	75	3750	48 x 44	2293 lbs.
2512	35	75	2625	48 x 44	1894 lbs.
2812	30	75	2250	48 x 44	2057 lbs.
3212	25	75	1875	48 x 44	2230 lbs.
3512	20	75	1500	48 x 44	2136 lbs.
4012	16	75	1200	45 x 42	2228 lbs.
4512	12	75	900	45 x 42	2124 lbs.

Examples:

A	-	4.0
Denotes System		Denotes Grouted Feet For System

or

23	12
Denotes Diameter in MM	Denotes Length in Inches

MINOVA

Standard Box Packaging

Lokset® System	Diameter Bolt	Diameter Hole	Grouted Foot Equivalent	Pieces Per Box	Grouted Feet Per Box	Boxes Per Pallet	Grouted Feet Per Pallet	Pallet Size	Approx. Gross Weight Pallet
A-2.0	3/4"	1"	2.0	50	100	50	5000	48 x 44	2221 lbs.
A-2.5	3/4"	1"	2.5	50	125	48	6000	42 x 44	2618 lbs.
A-3.0	3/4"	1"	3.0	50	150	36	5400	42 x 44	2311 lbs.
A-3.5	3/4'	1"	3.5	40	140	36	5040	42 x 44	2145 lbs.
A-4.0	3/4"	1"	4.0	40	160	36	5760	48 x 44	2432 lbs.
A-5.0	3/4"	1"	5.0	25	125	42	5250	48 x 44	2216 lbs.
A-6.0	3/4"	1"	6.0	25	150	36	5400	56 x 44	2257 lbs.
B-2.0	5/8"	1"	2.0	50	100	36	3600	42 x 44	2074 lbs.
B-2.5	5/8"	1"	2.5	50	125	36	4500	42 x 44	2527 lbs.
B-3.0	5/8"	1"	3.0	40	120	36	4320	48 x 44	2423 lbs.
B-3.5	5/8"	1"	3.5	40	140	36	5040	48 x 44	2777 lbs.
B-4.0	5/8"	1"	4.0	25	100	42	4200	48 x 44	2335 lbs.
B-5.0	5/8"	1	5.0	25	125	36	4500	56 x 42	2473 lbs.
C-305	3/4"	1 1/4"	*NS	30	*NS	75	*NS	48 x 44	2057 lbs.
C-610	3/4"	1 1/4"	*NS	30	*NS	36	*NS	44 x 44	1988 lbs.
C-915	3/4"	1 1/4"	*NS	20	*NS	36	*NS	48 x 44	1999 lbs.
E-2.0	7/8"	1 3/8"	2.0	25	50	50	2500	48 x 44	2553 lbs.
E-2.5	7/8"	1 3/8"	2.5	25	62	36	2232	44 x 44	2269 lbs.
E-3.0	7/8"	1 3/8"	3.0	25	75	36	2700	44 x 44	2666 lbs.
E-3.5	7/8"	1 3/8"	3.5	20	70	36	2520	48 x 44	2499 lbs.

***NS - not specified.**
Contact your local representative for other sizes.

Less Waste - Waste from one pallet of material is approximately the size of a basketball. Current customers cite fewer trash runs and no box gathering and quote trash handling savings up to $30,000 annually.

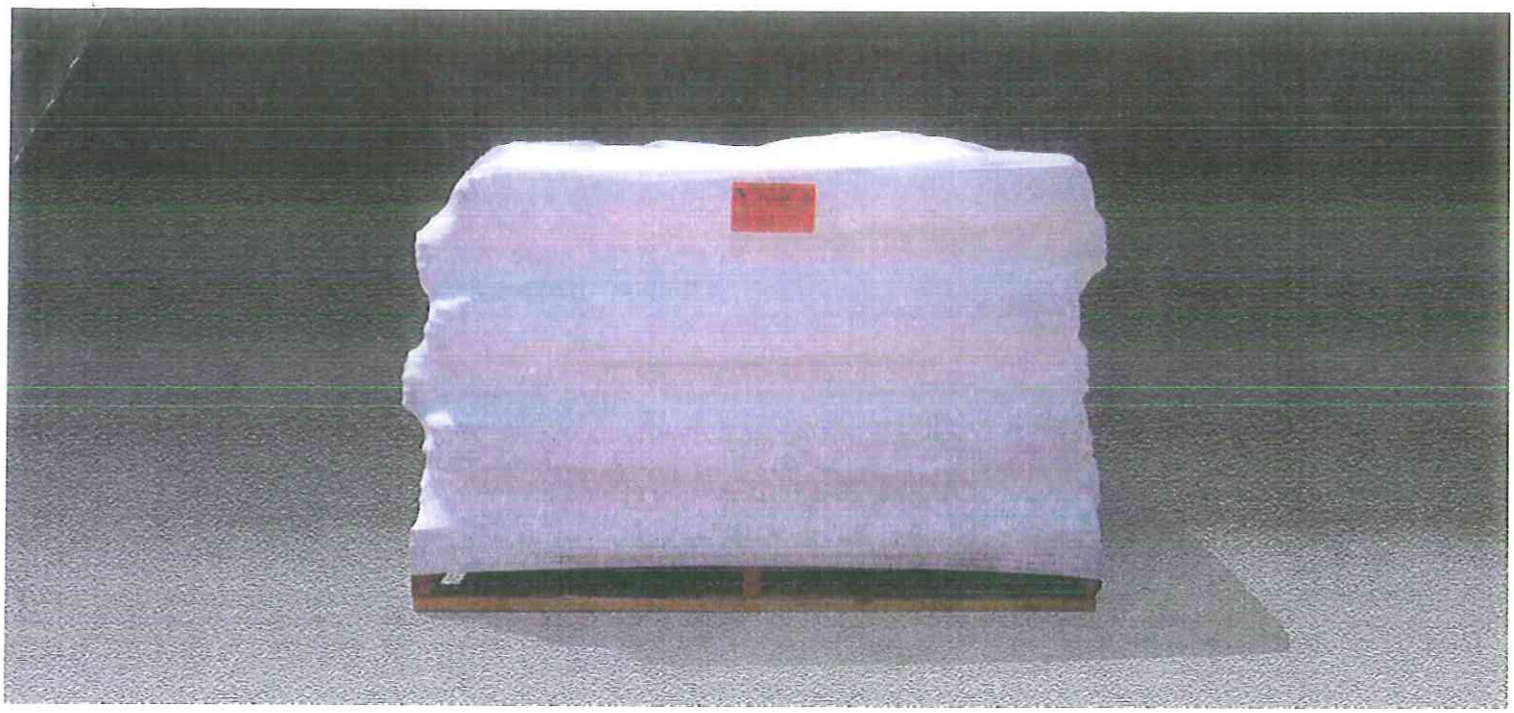
Durable Packaging - This innovation is both water and weather resistant.

Same Efficient Lead Times - Our automated packaging system allows us to provide a more advanced package without adding days to lead times.

Easy to Handle - Bundle packaging makes handling less cumbersome.

Stretchwrap Packaging

Lokset® System	Diameter Bolt	Diameter Hole	Grouted Foot Equivalent	Pieces Per Bundle	Grouted Feet Per Bundle	Bundles Per Pallet	Grouted Feet Per Pallet	Pallet Size	Approx. Gross Weight of Pallet
A-2.0	3/4"	1"	2.0	25	50	90	4500	42 x 44	1977 lbs.
A-2.5	3/4"	1"	2.5	30	75	52	3900	48 x 44	1648 lbs.
A-3.0	3/4"	1"	3.0	30	90	72	6480	56 x 42	2662 lbs
A-3.5	3/4'	1"	3.5	30	105	52	5460	62 x 42	2227 lbs.
A-4.0	3/4"	1"	4.0	25	100	45	4500	42 x 44	1838 lbs.
A-5.0	3/4"	1"	5.0	20	100	45	4500	42 x 44	1822 lbs.
A-6.0	3/4"	1"	6.0	20	120	45	5400	56 x 42	2161 lbs.
B-2.0	5/8"	1"	2.0	30	60	52	3120	48 x 44	1732 lbs.
B-2.5	5/8"	1"	2.5	30	75	52	3900	64 x 42	2124 lbs.
B-3.0	5/8"	1"	3.0	25	75	45	3375	42 x 44	1831 lbs.
B-3.5	5/8"	1"	3.5	25	87.5	40	3500	56 x 42	1987 lbs.
B-4.0	5/8"	1"	4.0	20	80	45	3600	42 x 44	1924 lbs.
B-5.0	5/8"	1	5.0	20	100	45	4500	56 x 42	2377 lbs.
E-2.0	7/8"	1 3/8"	2.0	15	30	80	2400	42 x 44	2365 lbs.
E-2.5	7/8"	1 3/8"	2.5	15	37.5	72	2700	56 x 42	2611 lbs.
E-3.0	7/8"	1 3/8"	3.0	12	36	45	1620	42 x 44	1572 lbs.
E-3.5	7/8"	1 3/8"	3.5	12	42	45	1890	42 x 44	1817 lbs.



MINOVA

Storage Procedures

Lokset® Resin Cartridges are best stored in a dry, well-ventilated area at normal mine temperature (60° - 65° F) out of direct sunlight. Extreme temperatures will affect the shelf life of this product. The product should never be stored for prolonged periods above 90° F.

Pallets should not be stacked. For maximum performance, stock rotation is strongly recommended.

Safety Procedures

Read the material safety datasheet before use.

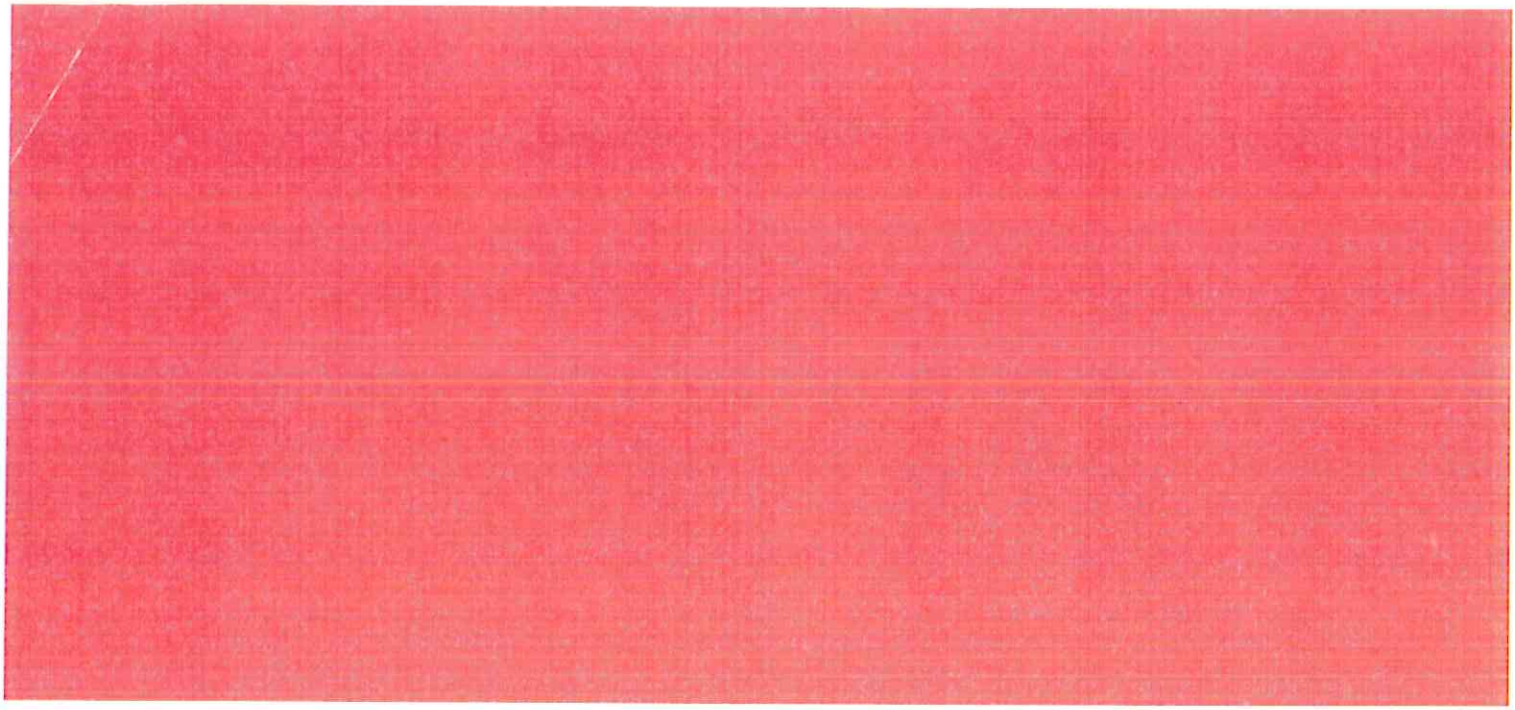
Do not open or puncture cartridges prior to insertion. Contents of cartridges may cause irritation and contact should be avoided. Use in an adequately ventilated area. Avoid prolonged inhalation of high concentrations of vapor. Eye protection should always be used. If resin contacts the eyes, flush immediately with water for at least 15 minutes. Seek medical attention. For skin contact, wash thoroughly with soap and water. If taken internally, seek medical attention.

Shelf Life

One year under proper storage conditions.

Quality

Minova USA Inc. strives to ensure the designs, products and services supplied to our customers will meet or exceed customer expectations. In order to maintain our superior standards, we employ Total Quality Management. TQM enables us to meet and maintain our ISO 9001:2000 certification. This management system also allows Minova to rely on the "team" concept to identify continuous improvement opportunities and if necessary create solutions to problems. By employing the TQM philosophy, we create an environment where everyone is responsible for quality!



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Important Note: Warranty

Minova USA Inc. warrants that its products, at the time of shipment, conform to the applicable descriptions set forth in the invoice and are free from defects in material and workmanship. NO OTHER WARRANTY, WHETHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE, SHALL EXIST IN CONNECTION WITH THE SALE OR USE OF ANY MINOVA USA INC. PRODUCT, AND ALL SUCH WARRANTIES ARE HEREBY EXPRESSLY DISCLAIMED AND EXCLUDED.

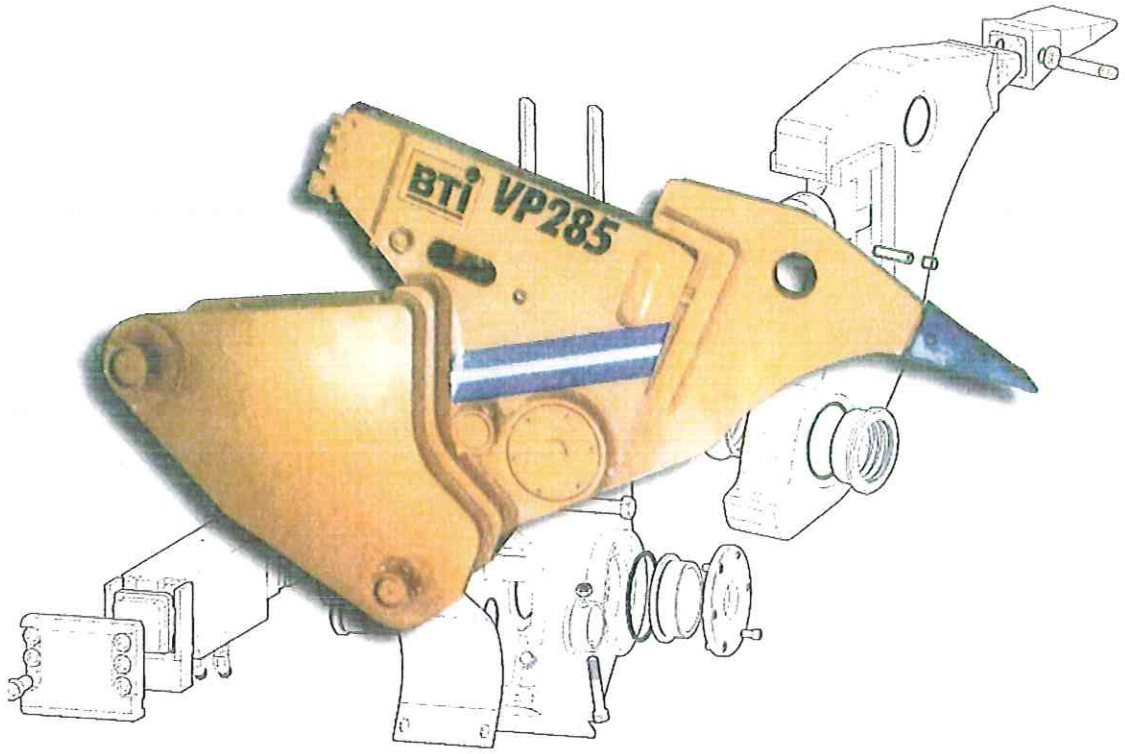
All claims under this warranty must be made in writing to Minova USA Inc. within 15 days after discovery of the defect, and within 90 days of the date of shipment by Minova USA Inc. of the product claimed defective. Upon timely receipt of a claim, Minova USA Inc. shall have the option either to inspect the product while in Buyer's possession or to request Buyer to return the product to Minova USA Inc. for inspection. Claims not made as provided above and within the applicable time period will be barred. All warranties shall be null and void if the products have not been stored and used in accordance with procedures recommended by Minova USA Inc.

Minova USA Inc. shall, at its option, either replace the nonconforming or defective product or refund to Buyer its purchase price. The foregoing constitutes Buyer's sole and exclusive remedy for any breach or warranty.

Revision : 03/2005
Manual # : 150-2081

OWNER'S MANUAL

VP SERIES VIBRATORY PICK



- Installation
- Operation
- Maintenance
- Service

For Models :
VP245 & VP285

BREAKER TECHNOLOGY

BTI BREAKER TECHNOLOGY, INC.
an Astec company

ISO 9001

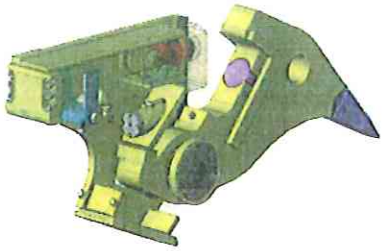
CONTENTS

Introduction:

This patent pending technology has integrated a innovative hydraulic breaker within a scaling pick. The new concept in scaling is the result of combining the best features and benefits of both a conventional pick and a hydraulic breaker.

VP Series streamlined profile provides excellent visibility to the tool in all scaling modes. The robust design enables the transfer of full boom pry forces of the carrier to the scaling surface and gives complete protection to the breaker. The VP Series of scaling pick doesn't mine the rock, but breaks the loose material free, avoiding damage to the carrier thereby extending the life of the equipment.

Single Tooth Design



Breach Release System

Vibratory Pick Features & Benefits:

- The V-285 Vibrating Pick does the work: Reduces the force required by the carrier and increases carrier availability while reducing owning and operating costs.

- Increased production rates: 4 to 5 times faster than a conventional pick, in all phases of the scaling operation (back, face & ribs).

- Total production rates are double that of a conventional pick (average faces per day are doubled over conventional mechanical picks, breakers and rippers - results may vary depending on operator and rock type/formations.)

- Robust design enables the full transfer of the prying power developed by the carrier.

- Pick can also work in static (non- fire) mode for final clean up and grooming operations.

- Adjusting both the flow and nitrogen pressure allows the breaker energy to be tuned to meet the rock requirements of each individual mine and seam conditions. 21% to 121% nominal horsepower delivered to rock.

- Pick impact force can be adjusted from 30% to 110% of nominal breaker force by a simple and accessible adjustment of the nitrogen pressure.

- Impact frequency can be varied by 70% to 110% of the nominal impact frequency by adjusting the flow (GPM).

- Two sizes available, the VP245 and the VP285.

- Exclusive Breach Release System (BRS) allows the operator to simply change the tappets (tool) and the impact button. Replacement of these wear parts does not require V-pick disassembly.

- Button nose pistons combined with flat top tappets (tool) allow for maximum energy transfer to the rock.

- Multiple V-Pick engaging tool types are available.

- Pointed V-Pick tool for primary removal of material (first pass or pre-splitting)

- 4" or 5" wide V-Pick tool for removal of thick layered surfaces, both primary and secondary removal of material

- 8", 10" and 12" wide V-Pick tools for final clean up of the heading.

Danger, Warning, and Caution are hazard alerts used in this manual to identify hazards on or near the carrier and Vibratory Pick.

⚠DANGER

Danger - Immediate hazards, which WILL result in severe personal injury or death if the proper precautions are not taken.

⚠WARNING

Warning - Hazards or unsafe practices, which COULD result in personal injury or death if the proper precautions are not taken.

⚠CAUTION

Caution - Hazards or unsafe practices, which COULD result in product or property damage if the proper precautions are not taken.

BTI cannot anticipate every possible circumstance that might involve a hazard. The hazard alerts in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by BTI is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the Vibratory Pick and carrier will not be damaged or made unsafe by the operation, maintenance or repair procedures you choose.

Head Protection

Foot Protection

Eye Protection

Hearing Protection

⚠WARNING

Only trained mechanics should handle the disassembly of this unit. Learn the location and purpose of all controls, instruments, indicators, and labels. Be sure you understand a service procedure before beginning any work on the machine. If you are uncertain, contact your Breaker Technology representative.

⚠WARNING

Know your site's location of the first aid kit and fire extinguisher, and how to use them. Know where to get help.

⚠WARNING

Always wear safety glasses and safety shoes when working around machines. Wear safety glasses when hitting on any part of the machine with a hammer or sledge. Use welders gloves, hood/goggles, apron and other protective clothing appropriate to the welding being performed.

⚠WARNING

Do not wear loose-fitting or torn clothing. Remove all rings from fingers when working on machinery.

⚠WARNING

Always use the proper tools on the job. Repair or replace any broken or damaged tools, or lifting equipment.

⚠WARNING

Improperly performing lubrication procedures is dangerous and may result in injury or death. Unauthorized modifications to the machine may impair its function, longevity, and safety.

⚠WARNING

Do not work on a machine that is supported only by lift jacks or a hoist. Always use blocks or jack stands to support raised equipment before performing service.

⚠WARNING

Relieve all trapped pressure before performing any service to the hydraulic system. Pressure can be maintained in the hydraulic circuits long after the power source and pump have been shut down.

⚠WARNING

Do not change the pressure setting of any valves unless authorized instruction has been obtained.

⚠WARNING

Use caution when draining hot fluids from the machine. Splashing hot fluids can burn the skin and cause serious injury.

⚠WARNING

When mounting or dismounting a machine, always face the machine and use steps and grab handles. Keep all equipment free of dirt and oil. Clean off oil, grease, mud, snow, or ice etc. from operators station, steps, and handrails. When it is not possible to use the designed access system, provide ladders, scaffolding or work platforms with handrails and kickplates to perform safe repair operations.

⚠WARNING

Avoid back injury, use a hoist when lifting components. Make sure all chains, hooks, slings etc. are in good condition and the correct capacity. Be sure hooks are positioned correctly. Lifting eyes are not to be side loaded during a lifting operation

⚠WARNING

Be careful when removing filler caps, breathers, filters and plugs on the machine. Hold a rag over the cap or plug to prevent being sprayed by liquids under pressure. This danger is greatest if the machine has just been stopped, because fluids can be very hot.

⚠WARNING

Keep your head, hands, feet and clothing away from power driven parts.

Be sure all protective devices including guards and shields are functioning correctly before starting a repair. If a guard or shield must be removed to perform the repair work, use extra caution.

⚠WARNING

If welding the pick housing, it must be removed from the breaker assembly. This will prevent internal damage to the breaker. Internal arcing may cause serious damage to the extremely close tolerances between the cylinder and piston.

⚠WARNING

Do not damage wiring during removal operations. Re-install the wiring so it is not damaged nor will it be damaged during operation by contacting sharp edges, or by rubbing against some object or hot surface.

⚠WARNING

Loose or damaged lubricant and hydraulic lines, tubes and hoses can cause fires. Do not bend or strike high pressure lines or install ones which have been bent or damaged. Inspect lines, tubes and hoses carefully. Do not check for leaks with your hands. Pressurized hydraulic fluid can penetrate the skin and cause serious injury. Use cardboard or paper to locate pin holes.

⚠WARNING

Before disassembling the hydraulic breaker, release all nitrogen gas from the cushion chamber. Refer to the breaker service manual.

⚠WARNING

When charging the breaker cushion chamber, stay clear of the tool. It may jump against the retainer pins as the gas pressure forces the piston down.

⚠WARNING

Stand clear of boom travel and vibratory pick to allow clearance, and to avoid flying debris. No one should be allowed on or near the equipment when it is running unless so equipped for an operator.

⚠CAUTION

Understand correct machine operation and service. Only qualified people should operate and service the vibratory pick. Learn the location and purpose of all controls, instruments, indicators, and labels. Be sure you understand a service procedure before you work on the machine.

⚠CAUTION

Welding repairs must be performed only with appropriate reference information and by someone adequately trained in welding procedures. Determine type of material being welded and select correct welding procedure and electrodes, rods or wire to provide a weld metal strength equivalent to that of the parent material.

⚠CAUTION

The pick and it's components are heavy. Be sure how you will handle them when removing or installing. Support raised equipment.

⚠CAUTION

Do not operate a machine if any rotating part is damaged or contacts any other part during operation. Any high speed rotating component that had been damaged or altered should be checked for balance before using.

⚠DANGER

Avoid all overhead cables and electrical wiring when operating the vibratory pick due to the risk of electrical shock.

⚠WARNING

Lower the boom into the storage position when not in use or at shutdown.

⚠DANGER

Due to the possibility of hose failure, BTI recommends that the operator be protected either with a shield or inside an operator's compartment. Contact the Product Development Group at BTI for more details.

⚠WARNING

Vibration generated by the hydraulic breaker may be transmitted back through the handles of the hydraulic control valve, the vibratory pick should not be operated manually from this position for extended periods of time.

⚠WARNING

Shut off the boom function controls before leaving or after stopping the machine.

⚠WARNING

BTI recommends that an emergency stop switch should be fitted at the boom control valve and that it should be connected to the pump / motor control. Call BTI Product development for more information if required.

⚠DANGER

Always work for safe ground to avoid falling debris and other hazards.

⚠DANGER

Due to the possibility of hose failure, BTI recommends that the operator be protected either with a shield or inside an operator's compartment. An operator's compartment would also protect the operator from bad weather, flying debris and noise generated by the vibratory pick. Contact the Product Development Group at BTI for more details.

⚠WARNING

Ensure that there is adequate lighting in the work area, either in underground applications or on above ground equipment working at night.

⚠WARNING

Hydraulic breakers in operation are loud! Refer to page 13 for noise levels. Ensure the proper hearing protection is worn at all times.

⚠WARNING

The customer is responsible for ensuring local regulations are met with respect to RCCD (Ground Fault) Protection. An isolator switch may be required in order to meet these regulations.

Carrier Sizing:

VP245:

The VP245 is designed to be mounted on BTI QS35 Quarry Scaler, and the DS series Underground Scalers.

It can also be installed on excavators within the 15 - 27 tonne range.

VP285:

The VP285 is designed to be mounted on BTI QS45 Quarry Scaler, and the DS series Underground Scalers.

It can also be installed on excavators within the 22 - 40 tonne range.

Consult Breaker Technology for mounting the Vibratory Picks to purpose built scalling machines, due to the varied configurations and boom sizes. Attachment matching can not be done by GVW alone.

Pressure & Flow Requirements:

VP245:

The operating pressure for the VP245 is between 1400 - 2150 PSI.
Maximum oil flow of 13 GPM is recommended for maximum vibration (frequency) rate.

Nitrogen pressure can be adjusted for local ground conditions. Harder rock such as granite and limestone should have a nitrogen pressure between 6 to 8 bar. Softer material such as gypsum and salt should have a nitrogen pressure of 4 to 6 bar.

VP285:

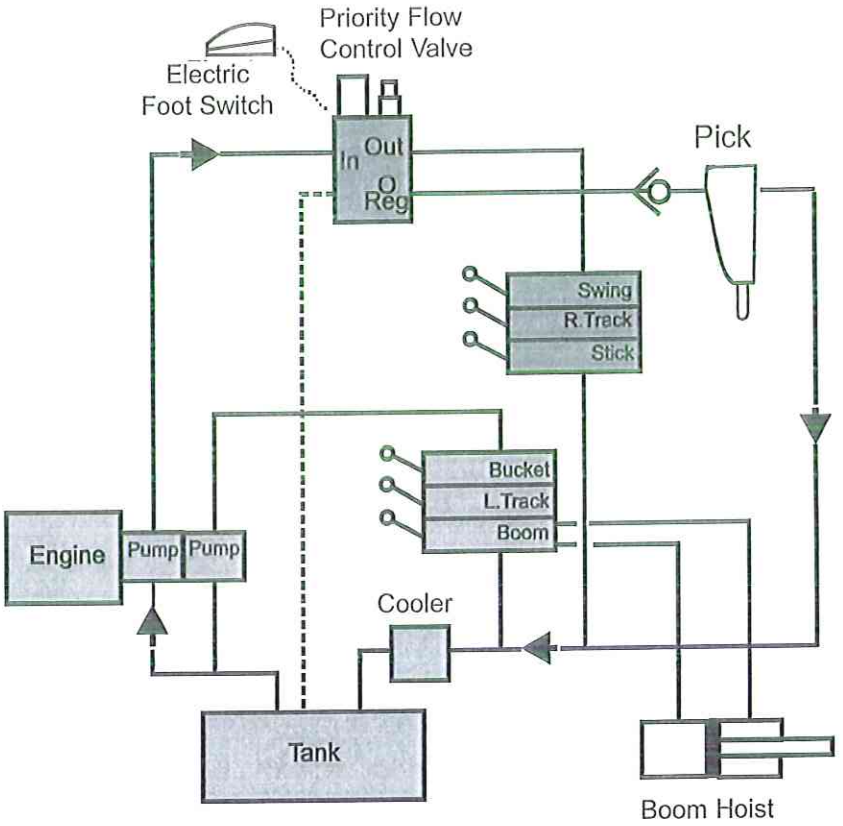
The operating pressure for the VP285 is between at 1400 - 2275 PSI.
Maximum oil flow of 15 GPM is recommended for maximum vibration (frequency) rate.

Nitrogen pressure can be adjusted for local ground conditions. Harder rock such as granite and limestone should have a nitrogen pressure between 6 to 8 bar. Softer material such as gypsum and salt should have a nitrogen pressure of 4 to 6 bar.

Typical Hydraulic Circuit:

If the carrier is not equipped with an auxiliary control valve, you will need to install a priority flow control valve to direct the correct flow away from the normal circuit and operate the attachment (see Fig.3).

The priority flow control is usually equipped with a flow adjustment and pressure relief. These valves often need a check valve on the regulated port to completely close the flow. If dividing too much flow, this circuit will generate heat and will need cooling capacity.



Transporting or Tramming:

When transporting or tramming the carrier from heading to heading with the pick installed, carry the pick as low to the ground as possible.

Machine Heading Setup:

To improve production place the machine in the heading to attain the maximum coverage possible of the heading that is to be scaled.

Modes of Operation:

The Vibratory Pick is designed with two operating modes to give the operator a selection to achieve maximum production.

Static mode is the traditional method of pick scalling. The unit is operated with the hammer off.

Vibratory mode means that the hammer is engaged and the pick vibrates.

Vibratory Mode:

The vibratory mode of the pick is by operator choice, and is activated using the fire button on the joystick. Utilization of the vibratory function of the pick reduces excessive wear to he carrier.

The hammer on the Vibratory Pick is equipped with an Anti-Blank Firing system. To fire the breaker the pick must be "cocked" or engaged against the rock.

⚠WARNING

DO NOT swing the pick from side to side. The pick is meant to be pulled down or pushed into the rock.

The pick can pry while the hammer is firing.

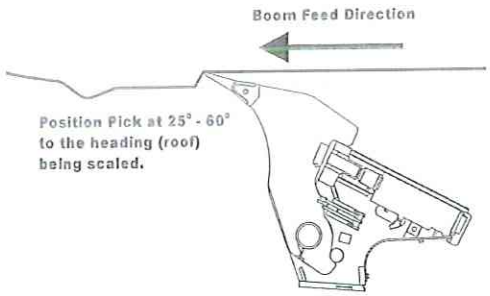
Static Mode:

Using the tilt function the full force of the carrier can be used to pry and shape the material in a simular fashion as a conventional pick.

Working the Back:

The unit is not ment to "mine" or make pockets in the surface. High frequency vibration and limited penetration are used to remove loose material and seamed material form the mine surface.

Position centerline of engaging tool 25 degrees to 60 degrees from the surface, feed the pick across the "back" or roof engaging the hammer fire when required to remove material.

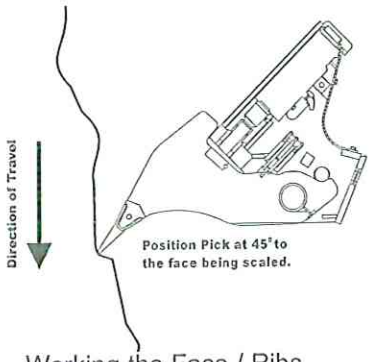


Working the Back

Working the Face:

The unit is not ment to "mine" or make pockets in the surface. High frequency vibration and limited penetration are used to remove loose material and seamed material form the mine surface.

Position centerline of engaging tool 45 degrees to 60 degrees from the surface, feed the pick across the surface engaging the hammer fire when required to remove material.



Working the Face / Ribs

Working the Ribs:

If carrier is equipped with a boom rotate function, this function can be used to angle the pick into the side ribs or corners to gain better tool alignment with the surface.

Using the feed and pry functions, combined with the pick fire to groom the ribs to suite. Work the ribs in the same fashion as the face.

⚠DANGER

Stand clear of carrier travel and pick to allow clearance, and to avoid flying debris. No one should be allowed on or near the machine when it is running.

⚠WARNING

On carriers equipped with 360 degree boom rotate "wrist" functions it is possible to back scale with the pick inverted over the top of the boom. For safety reasons and possible damage to the carrier BTI does not recommend this mode of operation. due to the fact that falling material can damage the boom and harm the operator.

General Operation Tips:

It is not recommended to wedge the pick in a crack while using the vibratory function. Should the material be of a solid mass, it could cause the pick to get jammed tight. The operator would then only have the prying force of the tilt knuckle to try and pull it out. In doing so, it could cause damage to the tip of the unit and possibly break of the shank adapter which secures the tooth to the unit. As well, it could cause damage to the boom.

In general, it is recommended that the angle of approach and contact for the pick when scaling should be at about 45 degrees as much as possible unless your prying of a loose and or working upwards with the unit.

It is recommended and important not to keep the vibratory action engaged at all time. It should be utilized as needed for example when working in fractured, loose and suspended material and when you are scaling the back (roof).

The unit should be visually inspected by the operator at least twice a day and greased at least four time a day if the unit is not equipped with a auto lube system. It is very important that the unit is not operated without a tooth on the end of the shank. This will cause premature wear of the shank which in turn make it almost impossible to keep the teeth secure to it.

Tooth wear is dependent on the abrasiveness of the rock. It is recommended for the best performance that the tooth be in good condition with a sharp edge and corners. Performance and production rates will suffer with a dull tooth. Ground engaging tools can be resharpened to bring back to original specifications.

⚠CAUTION

Do not use cracked or structurally damaged tools or adapters.

VP Tooth Selection:

- Pointed V-Pick tool for primary removal of material. First pass or presplitting

- 4" or 5" wide V-Pick tool for removal of thick layered surfaces, both primary and secondary removal of material.

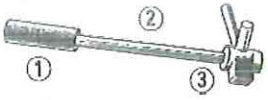
- 8", 10" and 12" wide V-Pick tools for final clean up of the heading.

All tools are available exclusively through your BTI Dealer.

VP Tooth Replacement:

A hammer and extractor are needed for the removal and mounting of the VP Teeth. It is recommended that you wear protective clothing and use a 1Kg hammer.

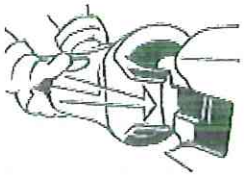
A special extractor has been designed to facilitate the removal of the VP Teeth. The extractor consists of a handle (1), a tube (2), and the head (3). In the head there are two appendages of different lengths and a solid cubic body.



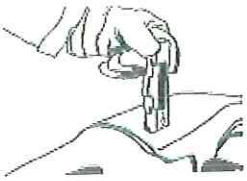
VP Tooth Installation:

Give the guide of the adapter nose and the pin hole a thorough cleaning to allow for adjustment of the tooth.

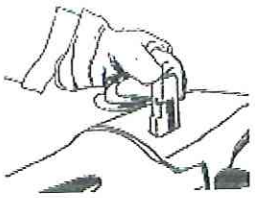
Mount the tooth on the adapter nose by fitting the groove of the ear of the tooth in the lateral guide of the adapter nose.



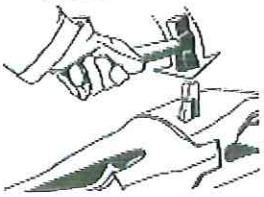
Place the pin in the hole of the adaptor shoulder in the direction marked by the arrow on the pin, with the retainer facing the point of the VP Tooth.



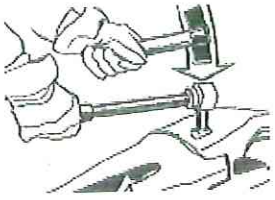
Manually check to ensure the correct position and placement of the retainer pin.



Using the hammer hit the free end of the pin, driving it into the adapter as far as possible.

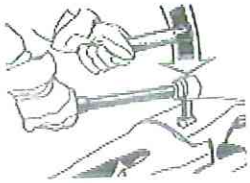


Place the short appendage of the extractor in the end of the pin (flush with the body of the adapter) and hit it with the hammer until the pin is perfectly secured in its casing.

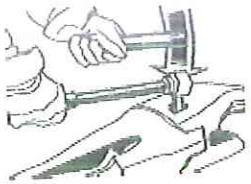


VP Tooth Removal:

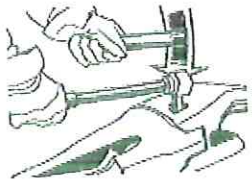
Hit with the hammer until the pin retainer is freed from its casing in the adapter body.

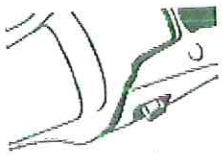


Place the short appendage of the extractor in the end of the pin , from the upper side of the adapter body.

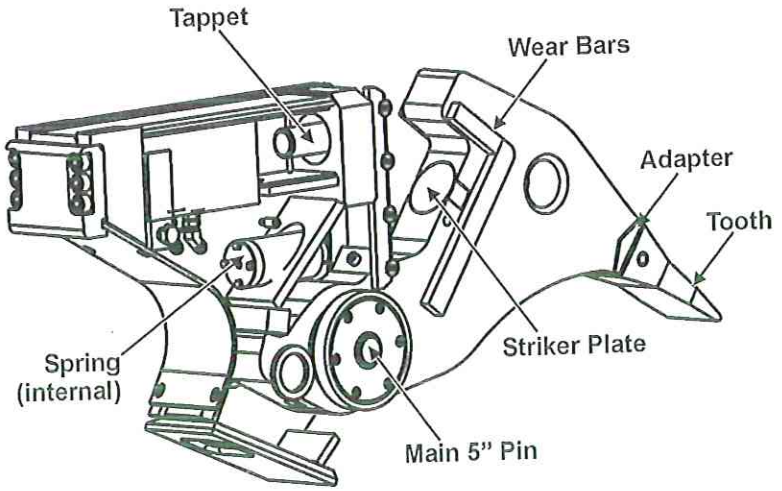


Using the long appendage of the extractor hit the pin until it comes through the bottom end of the adapter.





PROCEDURE	40 HRS	200	400	600	1000	2000
1) Check ground engaging tool, replace when worn	CHECK DAILY OR AFTER EVERY SHIFT.					
2) Inspect all hoses, and grease main pin.	CHECK DAILY OR AFTER EVERY SHIFT.					
3) Inspect tappet, striker plate and return spring. (Breach must be opened).	✔					
4) Inspect wear bars.		✔				
5) Inspect rear isolator and interface plate.		✔				
6) Check main pin for wear movement.		✔				
7) Check cushion chamber nitrogen pressure.		✔				
8) Replace tappet. (as required)			✔			
9) Replace striker plate. (as required)				✔		
10) Replace rear isolator. (as required)					✔	
11) Replace isolator interface plate.						✔

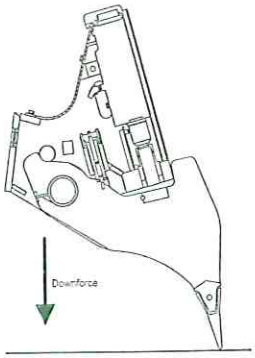


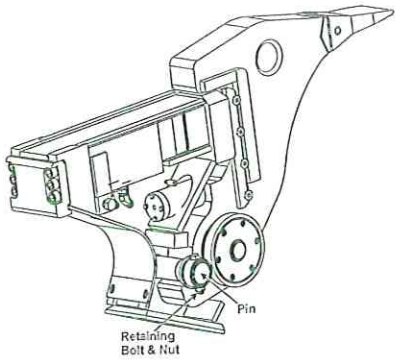
Opening the Breach:

The pick breach should be opened every 40 hours to check for internal wear and damage to the tappet and striker plate.

Lower pick to the ground (or against a face) and apply downforce to load the breaker and to remove the spring tension.

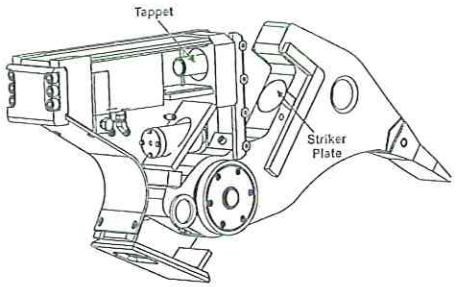
Remove the retaining bolt and locknut.





Inspecting Tappet & Striker Plate:

Remove the breach pin and relieve downforce to open the Pick Breach.



Inspect the tappet and striker plate for damage and mushrooming.

Tappet and striker must be replaced if the mushrooming is too great.

Excessive mushrooming will prevent the breaker from firing.

The tappet is a wear item and designed to last between 400 to 1000 hours depending on nitrogen pressure. Ensure the tappet is well greased to prevent wear of the bushing and tappet, this also helps reduce the ingression of foreign material into the impact chamber of the breaker and possible contamination of the hydraulic circuit.

Closing the Breach:

Re-apply downforce to the unit to close the breach.

Replace the breach pin. Reinstall the retaining bolt and locknut.

Torque the retaining bolt to 120 ft.-lbs in dry condition.

Generic Breaker Information:

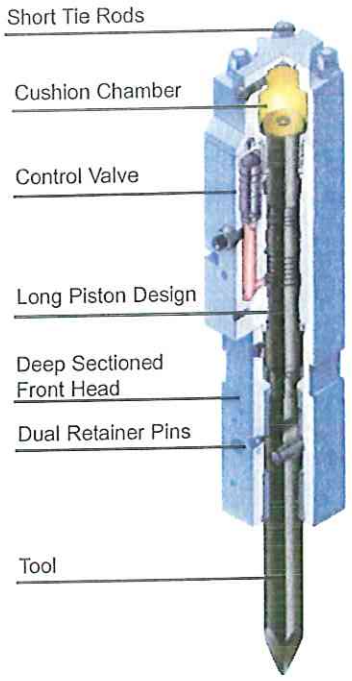
A BTI hydraulic breaker represents the state of the art in rock and aggregate breaking. Our hydraulic breaker is a self-actuated hammer that delivers rock-breaking power with the minimum of parts. The main sections of a BTI breaker are the front head, cylinder, rear head, and control valve.

The FRONT HEAD contains the breaker tool, bushings, and retainer pins. By removing the retainer pins, the tool can be quickly changed.

The CYLINDER contains the moving piston, which strikes the tool. The seals for both ends of the piston are also located in the cylinder.

The REAR HEAD houses the cushion chamber, which is charged with nitrogen gas. The gas in the cushion chamber absorbs the piston's upward recoil and stores this energy for the next blow.

The CONTROL VALVE is mounted on the cylinder and directs the flow of hydraulic oil and therefore the movement of the piston. Located directly above the control valve are the hydraulic oil inlet and outlet ports.



Principle of Operation:

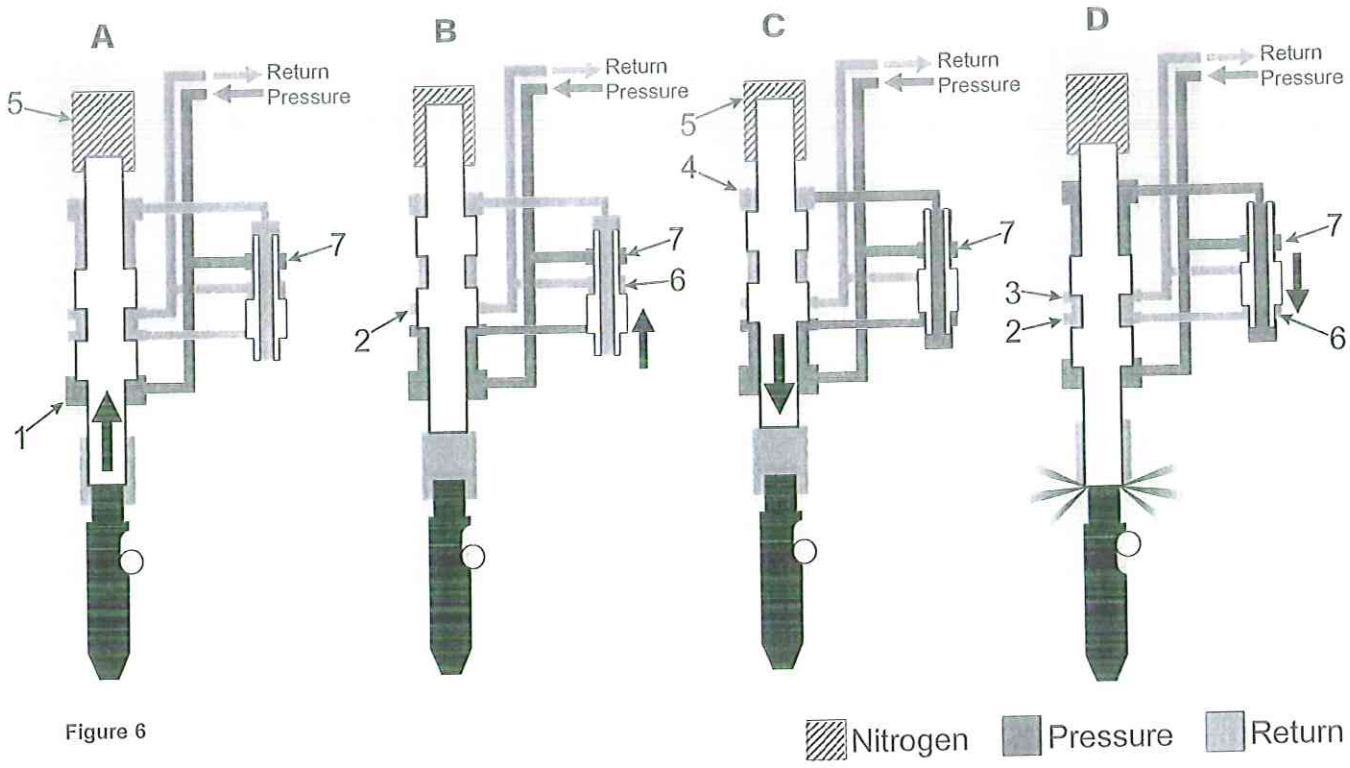
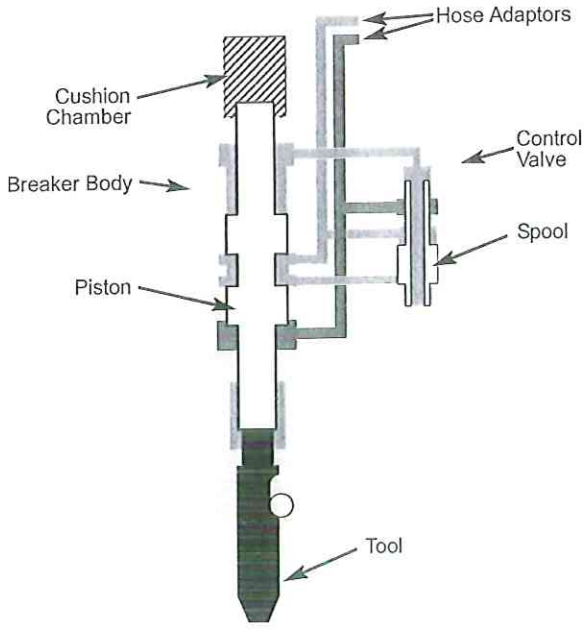


Figure 6

Breaker Parts



(A) UPWARD MOVEMENT
Oil flows into cylinder chamber (1) and control valve chamber (7). The piston is pushed up towards the cushion chamber (5), and the control valve spool is forced down.

(B) REVERSING DIRECTION
When the lower flange fills with oil, it will reach cylinder chamber (2). At this time both control valve chambers (6) and (7) have the same pressure, but the spool moves up due to the flange surface area differences.

(C) DOWNWARD MOVEMENT
When the control valve spool rises and reaches chamber (7), the flow moves through the control valve to chamber (4). Due to the area difference between the piston flange and the extra force from the cushion chamber pressure (5), the piston accelerates down.

(D) IMPACT
The piston hits the tool. The mid section of the piston will hit chamber (2). As a result, chamber (6) will remove pressures through chambers (2) and (3). Since chamber (6) is exhausted, chamber (7) is constantly pressurized and the control valve will moves down.

To keep your vibratory pick working in top operating condition, the following maintenance must be performed. Keep in mind that lubrication is the single most important procedure for sustaining the life of the pick. To make this chore easier, we offer an auto lubrication unit, call BTI for details

Daily Maintenance:

Lubricate the tool with BTI chisel paste or a moly-based grease every two hours of continuous operation and any time you have serviced the tool. Failure to lubricate regularly reduces the life of the tool, tool bushings and front head. Never use ordinary grease, because it melts and runs down the tool providing very poor lubrication.

For proper tool lubrication the pick must be vertical with enough down-force applied to push the tool into the breaker. This will prevent grease from entering the area above the tool.

Open the breach amd check that the tool moves freely in the bushings.

After Every 100 hours:

Every 100 hours the carrier's hydraulic filter must be checked. Inspect your filter or filter indicator and change as necessary. Clean oil is crucial for proper breaker performance and life.

Check all nuts and bolts for the correct torque. Improperly torqued bolts can damage the breaker.

Remove and inspect the tool.

After Every 1000 Hours:

Every 1,000 hours, check the breaker's hydraulic circuit pressure relief and flow settings and adjust to the recommended levels.

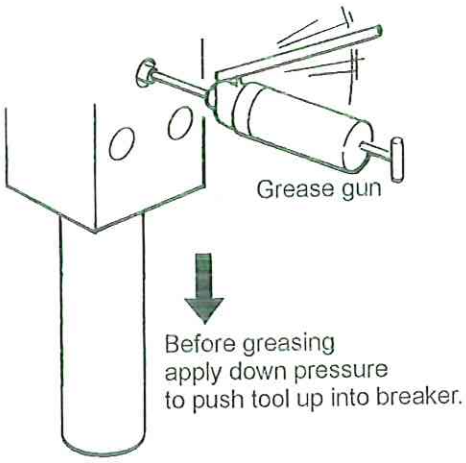
Change the carrier hydraulic oil and the oil filter.

Replace all breaker seals and inspect all wear parts.

Greasing the Bare Breaker:

Failure to lubricate regularly will reduce the life of the tool, tool bushings, and the front head. To properly lubricate the tool, the breaker must be in a vertical position, with enough down pressure applied to force the tool up into the breaker housing. This will prevent excessive grease entering the impact chamber which could cause the breaker to lose power due to cushioning, or to stop operating altogether due to a hydraulic lock in the impact chamber.

The pick should be greased every 30 minutes of use or when the tool appears shiny where it rides inside the front head.



Before greasing, down pressure must be applied to push the tool up into the vibratory pick.

Grease until the grease oozes out around the tool.

Grease the pick every two hours.

Use only BTI Chisel Paste or a molybdenum disulphide based grease.

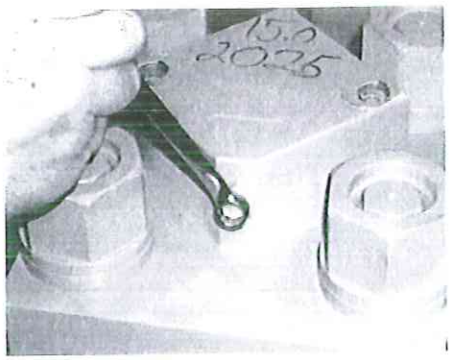
BTI highly recommends the use of an Autolubrication system. Contact BTI for an Autolube system suited to your application and equipment.

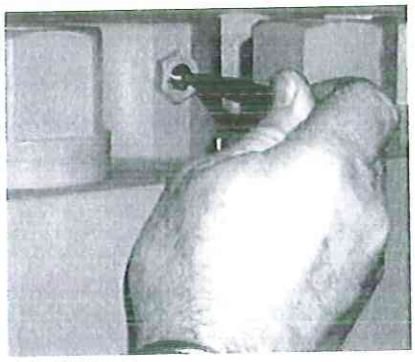
Bleeding the Nitrogen Gas:

⚠WARNING

The cushion chamber in the rear head contains nitrogen gas under pressure. Do not remove the tie rod nuts or gas valve until this pressure is relieved.

To relieve this pressure, remove the gas valve plug and press firmly on the disc in the gas valve with a blunt object. Be sure to protect yourself adequately from the escaping jet of gas.





Removing the Control Valve Spool:

Insert lifting eyes into the rear head and stand the breaker onto the safety stand.
Back off the tie rod nuts a couple of turns, this can be done using a torque multiplier if the breaker is standing up. If the breaker is lying down, use the sledge-wrench method. Then using the hoist, jerk the assembly upwards, which should loosen the rear head from the cylinder.

If the rear head is stuck, it may be necessary to tap the cylinder cover on alternating sides, with a soft-faced mallet. Remove the nuts from the four tie rods. Remove the plastic tie rod washers and remove the rear head from the cylinder, using the lifting eyes. In some cases, the nuts may be seized onto the tie rods and the nut and tie rod may come out as a unit. Place the rear head on a clean protective surface.

Using the lifting eye remove the control spool guide plug (Fig. 33B) and place it on a clean protective surface.

Next, slide the control spool out of the cylinder (Fig. 33C). The spool should slide easily out of the cylinder, without the use of tools. If the spool is stuck or seized a mechanical puller may have to be used.

Figure 33B

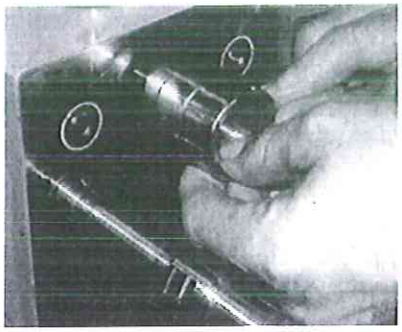


Figure 33C

Removing the Rear Head from the Cylinder:

⚠CAUTION

Do NOT use impact tools as this can damage the breaker.

Insert lifting eyes into the rear head and stand the breaker onto the safety stand.
Back off the tie rod nuts a couple of turns, this can be done using a torque multiplier if the breaker is standing up. If the breaker is lying down, use the sledge-wrench method. Then using the hoist, jerk the assembly upwards, which should loosen the rear head from the cylinder.

If the rear head is stuck, it may be necessary to tap the cylinder cover on alternate sides, with a soft-faced mallet. Remove the nuts from the four tie rods. Remove the plastic tie rod washers and remove the rear head from the cylinder, using the lifting eyes. In some cases, the nuts may be seized onto the tie rods and the nut and tie rod may come out as a unit.
Place the rear head on a clean protective surface.

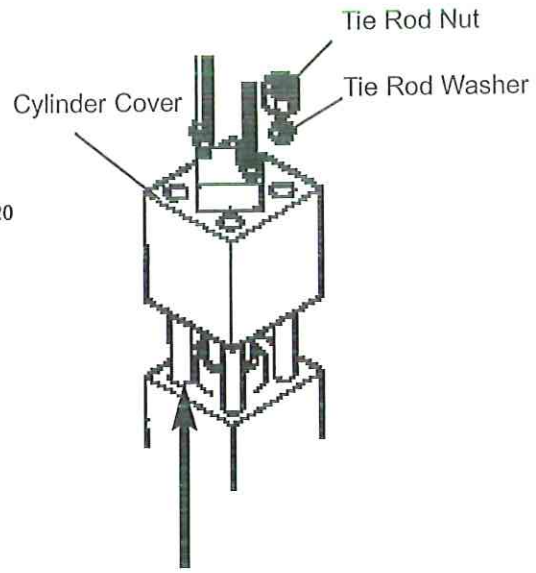


Figure 20

Removing the Piston:

Install a lifting eye into the top of the piston, and lift the piston straight up and out of the cylinder to avoid scratching its polished surface. Tapping the cylinder with a soft-faced mallet may ease the removal of the piston. The seal bushing will come out with the piston.

Place the piston on a clean protective surface.

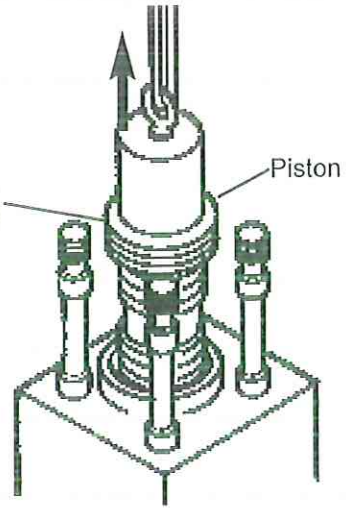


Figure 21

Removing the Tie Rods:

⚠CAUTION

Use hand tools to loosen the tie rods; impact tools will damage the thread inserts in the front head.

To loosen the tie rods it may be necessary to secure the front head to prevent it from rotating.

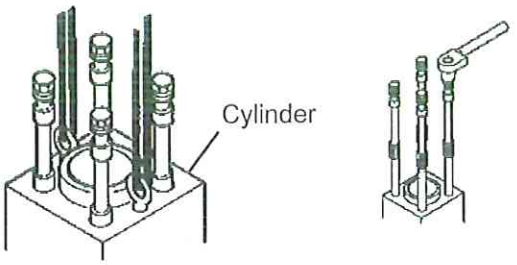
Loosen the tie rods by rotating them counter-clockwise. Use an adjustable wrench and a soft-faced mallet or a sledge wrench on the tie rod flats to loosen the tie rods.

Removing the cylinder involves installing two lifting eyes into the threaded holes in the top of the cylinder and lifting the cylinder straight up off the tie rods.
The cylinder should slip easily out of the front head. If not, tap the front head with a soft-faced, until the cylinder and front head come apart.

Place the cylinder on clean protective material.

Remove the four tie rods. Place the tie rods on clean protective material.

Figure 22



Removing the Tappet Bushing:

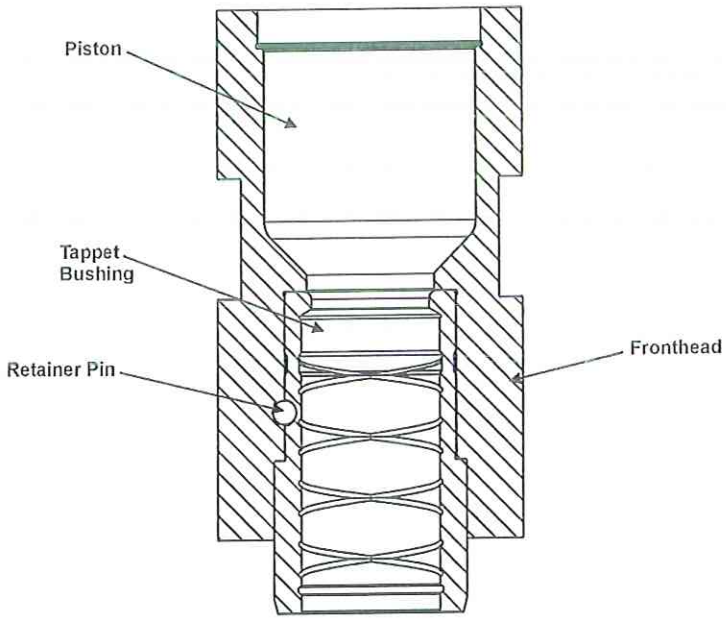
⚠CAUTION

Do not gouge out the bushings with a torch.

Unfasten the tie rods from the fronthead from the cylinder body assembly.

The tappet bushing is held in position by one retainer pin. Remove this pin by driving it out with a drift, from the opposite side of the stopper plug.

Carbon arc and heat the bushing to aid in the removal. Using a small press or jack press out the tappet guide bushing.



Installing the Tappet Bushing:

Check the inside of the front head for damage, and repair or replace as required.

Extreme care must be taken when installing the tappet bushing in the front head. Because the bushing is a shrink fit, the front head must be heated, so that it will expand, and the bushing placed in liquid nitrogen, so it contracts. As the pieces return to room temperature, they become tightly fitted together. If the bushing is not installed properly before this point is reached, it must be taken out and replaced with a new one. With liquid nitrogen you have about 7 seconds to align the retainer so the procedure must be done quickly.

Clean the inside of the front head thoroughly, and use a wire rotary brush to clean and smooth the surfaces in the areas where the bushing seats. If the front head has cooled, it must be heated with a torch to 300°F, (150°C). This will expand the housing a small amount. Then line up the slot in the bushing with the retainer hole.

When fully inserted, the tappet bushing will seat against a step in the bore of the front head. Care must be taken to ensure that the grooves in the tappet bushing line up with the retainer-pin hole in the front head. Do not install the stopper plug until the front head has cooled to room temperature.

Apply a coat of Never-seize to the retaining pin, and fully insert it into the retaining pin hole.

Inspecting the Seal Bushing:

Start by cleaning, and inspecting the cylinder seal bushing.

The seal bushing carries several specially designed seals. Careful attention should be paid to the condition and orientation of the old seals as they are removed. This may help to identify any operating problems that the breaker had before it was disassembled.

All parts should be thoroughly washed in clean solvent and dried with compressed air.

Once the seal bushing is clean and dry, protect it from dirt and set it aside.

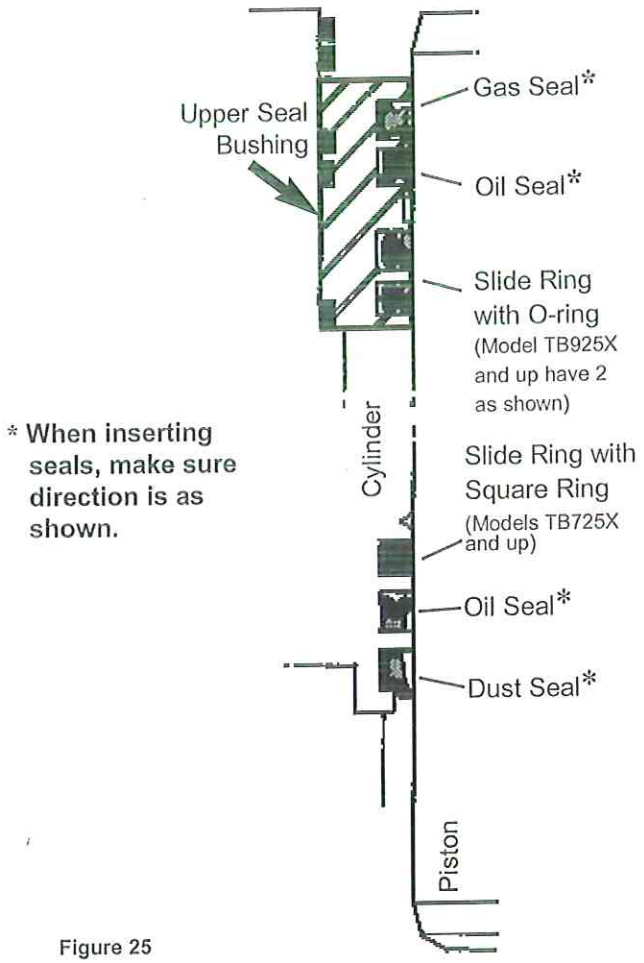


Figure 25

Inspecting the Piston:

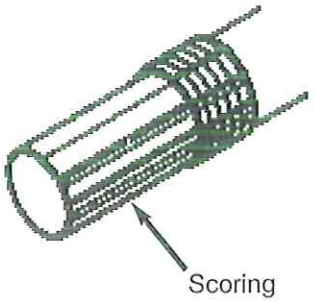
The piston should be carefully cleaned and inspected for corrosion, cavitation, pitting, and scoring.

Check the grooves in the piston for metal that has been pulled in due to galling. If this has occurred clean the grooves. Small marks can be removed with an oilstone or fine emery cloth and oil.

Excessive deformation of the piston, tappet and striker plate will prevent the breaker from firing. At this point these parts will have to be replaced.

Thoroughly dry the piston, protect it from dirt, and set it aside.

If the piston is not going to be installed immediately, coat it with oil and store it protected, in a clean dry place.



Inspecting the Piston:

Thoroughly clean the cylinder bore, and remove the dust seal, oil seal, and slide ring. Check the seals for signs of excessive wear conditions.

Thoroughly inspect the inside walls of the cylinder for corrosion, cavitation, or scoring.

Check grooves above seal area for small pieces of metal, due to galling. If these are not cleaned out they will chip off and go between the piston and cylinder, and galling will occur again.

Also inspect the main inlet and outlet adapter threads for damage. Always replace the seals and ensure that the adapters are not interchanged if they are removed. The cylinder is marked with a "P" beside the pressure adapter and a "T" beside the tank adapter. The Pressure adapter has a smaller hole than the tank adapter.

Check for any damage to the threaded inserts that hold the control valve, and repair or replace as necessary to ensure secure control valve mounting.

Thoroughly dry the cylinder and protect it from dirt.

Inspecting the Piston:

Inspect the control valve spool for any signs of scoring, binding and cavitation. Pay particular attention to the spool holes. Small scratches and marks may be removed with a fine oilstone or fine emery cloth and oil. Also check the control valve cap and valve body for marks or scratches, and remove them if they are not too severe. If the score marks are too deep or large, the complete control valve assembly must be replaced.

Examine the control valve ports for cavitation and erosion. Check all the oil passage holes in the control valve and be sure they are not plugged. Clean them with a fine wire if necessary to remove any dirt particles.

Clean all parts of the control valve in clean solvent and dry them with compressed air.

Inspecting the Gas Valve:

Remove the gas valve plug and the gas valve from the rear head. Thoroughly clean the cover and valve and inspect them for damage. Cover the gas valve threads with a good quality thread sealer. Reinstall the gas valve and seal, and tighten the valve to 61½ foot-pounds. Insert the gas valve plug and just hand tighten it for now.

Installing the Tie Rod:

Inspect the tie rod threads. If they are damaged beyond repair, the tie rods must be replaced.

Lubricate the tie rods thoroughly using a moly-based grease or Never Seize.

The tie rods should turn smoothly and easily until they bottom out in the holes. If they do not bottom out, or there is excessive resistance, the threads on the tie rods or the helisert inserts may be damaged.

Remove damaged heliserts and restore the front head threads with conventional thread chasers and taps. Insert new heliserts with the appropriate tool.

Torque tie rods to the specifications on page 47-49.

Installing the Cylinder:

Liberally oil the inside surface of the cylinder and the new seals, and install the seals and rings into the grooves at the lower end of the cylinder. Pay close attention to the correct placement and orientation of the seals. Improper seal installation will cause premature leakage and premature wear.

Apply some grease to the rubber pieces on the tie rods so the cylinder will slide on easily. Lower the cylinder carefully onto the tie rods. The control valve mounting holes on the cylinder should face the same direction as the grease fitting on the front head.

Re-Sealing the Seal Bushing:

Oil the seal bushing and seals, and install the seals and rings in the correct positions and orientations.

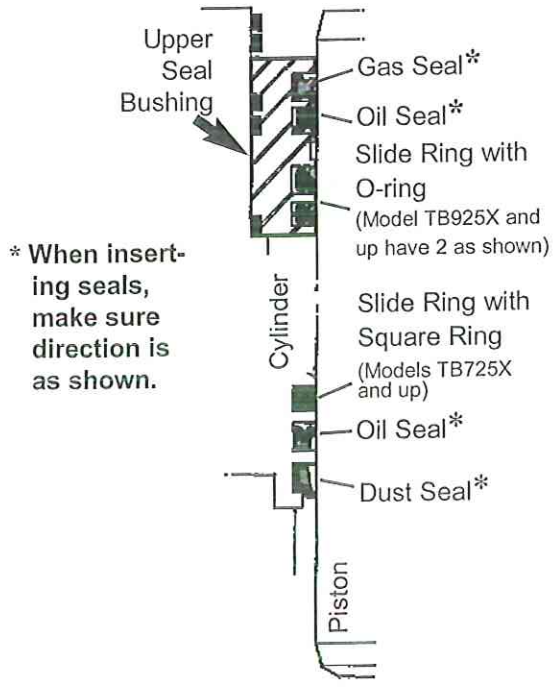


Figure 31

Installing the Piston:

Replace the o-ring in the top of the cylinder. Lubricate the top end of the piston, and slide the seal bushing into place, with the chamfer or step towards the center of the piston.

Lift the piston with the lifting eye, lubricate it thoroughly, and lower it carefully into the cylinder. It may need a tap to push it through the lower seals.

When the piston is all the way into the cylinder bore, use a soft mallet to tap the seal bushing into position in the cylinder. The bushing will stop when it reaches the support flange inside the cylinder bore.

Replace the o-rings and backup rings on the top of the cylinder where the rear head makes contact.

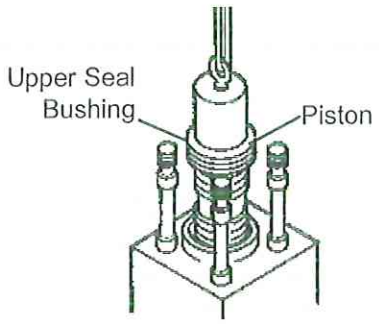


Figure 32

Installing the Rear Head:

The cushion chamber in the rear head needs a small amount of oil for proper operation. Just before you install the rear head, make a circular grease dam on the top of the piston, just high enough to contain the required amount of oil. The amount of oil needed can be obtained from the chart on page 51-53.

Lower the rear head over the tie rods. The gas valve should face the same direction as the control valve bolt holes on the cylinder.

Install new tie rod washers. Lubricate the tie rod nuts with Never Seize, and tighten them in a crossing pattern to draw the breaker components together evenly. Finish tightening the nuts to the correct torque in four stages, using the same crossing pattern.

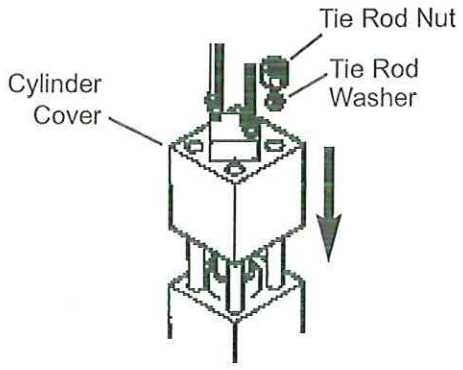


Figure 33

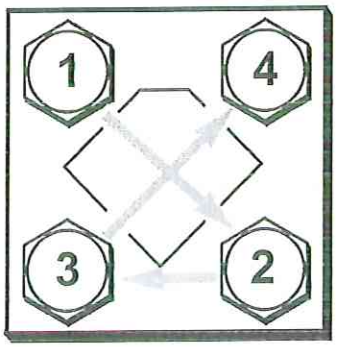


Figure 34

Installing the Control Valve:

Ensure the control valve spool is clean and insert it back into the cylinder body. (Fig. 34B)

Lubricate the seals on the control spool guide, ensuring that the guide is clean and insert it into the cylinder body. The guide should slide easily but if tools are required make sure the guide is squarely in the cylinder body and tap it into position using a soft-faced mallet. (Fig. 34C)

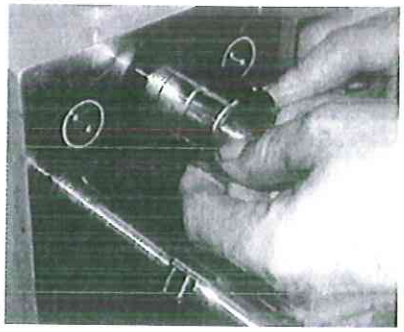


Figure 34B

Figure 34C

⚠CAUTION

Recharging the Cushion Chamber:

⚠CAUTION

This gas is stored under high pressure. Caution is advised when handling.

Remove the gas valve plug from the gas valve. Attach one end of the charging hose to the gas regulator and attach the charging adapter to the other end of the hose.

With the charging adapter inserted into the gas valve and the nitrogen tank valve open, adjust the regulator handle slowly to build the pressure to the value specified in the service manual. If the piston is not at the bottom of its stroke the pressure will move it down to rest on the inside of the front head. Be aware that if the tool is installed at this stage, it may accelerate dangerously out of the cylinder when the cushion chamber is being pressurized.

To check the cushion chamber pressure, remove the charging adapter from the end of the hose and put it on the pressure gauge. Insert the adapter into the gas valve and observe the pressure reading. If the reading is too high, bleed off a small amount of gas to make the final adjustment, and test again. If the pressure is too low, reinsert the charging adapter, and build pressure to the required value.

When the pressure is at the correct value, (refer to the "Cushion Chamber" Pressure on the General Specification Chart on page 55), install the gas valve plug, using a new o-ring, and tighten to 8.7 foot-pounds torque. Take care not to cut the o-ring.

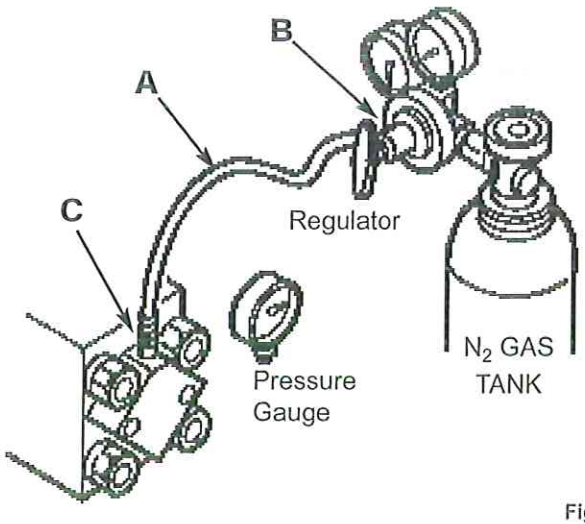


Figure 35

Oil Leakage:

If oil leakage develops, it may not be necessary to replace parts. Check the following points in the chart below before calling your BTI representative. A slight amount of oil seepage around the breaker connecting parts is normal during the first 200 hours of operation.

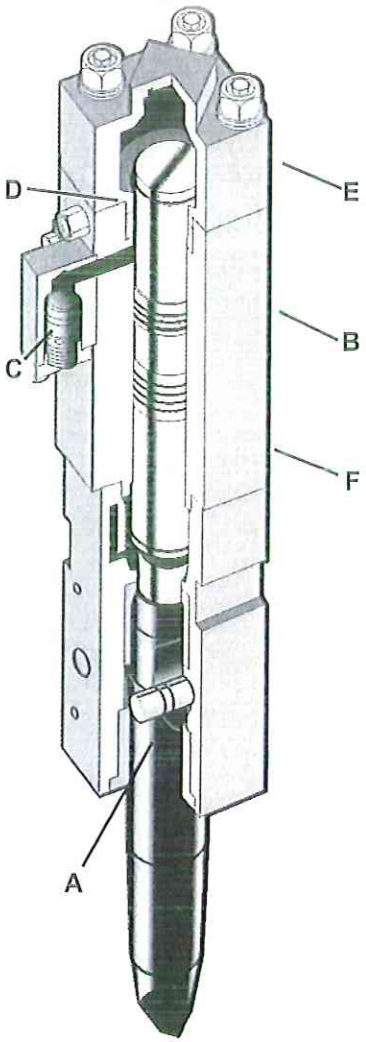


Figure 40

Area of Leakage	Condition	Corrections
A. The space between the tool and bushing	Large amounts of oil coming out.	Damaged seals. Re-seal as necessary.
B. Oil over the surface of the breaker.	Possible loose hoses or adapter fittings.	Check condition of hoses and fittings, tighten as necessary.
C. Control valve cap bolts.	Oil ooze after overhaul of unit.	Normal oozing of assembly lubricants.
D. Between control valve and surface of cylinder.	Oil ooze after breaker overhaul	Normal oozing of assembly lubricants.
E. Joining surface of cylinder and rear head.	Oil oozing New oil leaking	Loose tie rod nut, re-tighten Damaged O-ring, replace.
F. Joining surface of cylinder and front head.	New oil leaking	Loose plugs on face of cylinder, retighten. Damaged seals in the cylinder, replace as necessary.

Poor Breaker Performance:

CONDITION	CAUSE	CORRECTION
Does not hammer	Base carrier selector valve does not operate properly.	Check connection from cab controls to the selector valve.
	Poor performance of the hydraulic pump.	Check pump output. Repair or replace.
	Pressure relief valve set too low.	Check relief settings and adjust.
	Clogged or restricted hoses.	Clean or replace.
	Cushion chamber fills with oil.	Replace seals.
	Seizure of breaker.	Overhaul and replace worn parts.
Erratic Hammering	Hyd. oil temperature too high.	Oil temperature must not exceed 170 deg.F (77 deg. C).
	Insufficient oil flow and/or pressure.	Check base carrier hydraulic system.
	Clogged or restricted hoses, or pipes.	Clean or replace.
	Not enough down force on the tool.	Increase the down pressure acting on the tool.
	Pressure too high in cushion chamber.	Adjust pressure.
	Too much grease in the impact chamber.	Remove tool from front head and clean out excess grease. Follow proper greasing instructions.
	Excessive clearance between tool and tool bushing.	Check clearance and replace worn parts.
	Excess wear at top of tool.	Remove and inspect the tool. Replace if necessary.
	Foreign matter in the breaker control valve.	Disassemble and clean.
	Seizure of piston and cylinder.	Overhaul the breaker.

CONDITION	CAUSE	CORRECTION
Lack of Power	Insufficient oil flow or oil pressure.	Check hydraulics of the base carrier.
	Broken tool	Replace tool, check piston for damage.
	Cushion chamber gas pressure is too low.	Check and adjust.
Mushrooming of Tool	Continuous hammering in one place.	Use short bursts. Re-position breaker every 30 seconds.
Rapid increase in Oil Temperature	Insufficient oil cooling. Insufficient oil flow. Incorrect oil pressure.	Check oil cooler. Check pump output. Check relief valve setting.
Emulsification of Oil	Oil contaminated with water.	Locate source of water and repair. Replace oil

Kentucky Geological Survey
Donald C. Haney, State Geologist and Director
UNIVERSITY OF KENTUCKY, LEXINGTON

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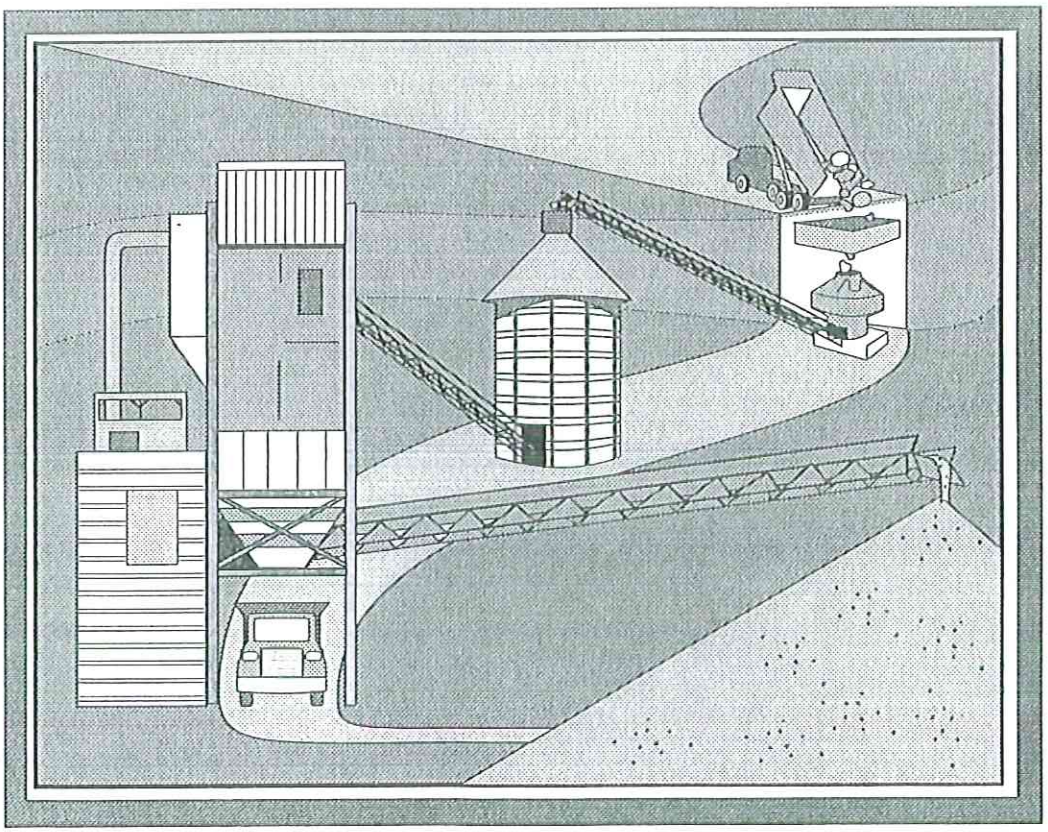
High-Carbonate, Low-Silica, High-Calcium STONE

in the High Bridge Group (Upper Ordovician)

Mason County, North-Central Kentucky

Warren H. Anderson
and
Lance S. Barron



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Donald C. Haney, State Geologist and Director
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HIGH-CARBONATE, LOW-SILICA, HIGH-CALCIUM STONE IN THE HIGH BRIDGE GROUP (UPPER ORDOVICIAN), MASON COUNTY, NORTH-CENTRAL KENTUCKY

Warren H. Anderson
and
Lance S. Barron

INFORMATION CIRCULAR 53

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HIGH-CARBONATE, LOW-SILICA, HIGH-CALCIUM STONE IN THE HIGH BRIDGE GROUP (UPPER ORDOVICIAN), MASON COUNTY, NORTH-CENTRAL KENTUCKY

Warren H. Anderson
and
Lance S. Barron

ABSTRACT

The High Bridge Group (Middle Ordovician) of northeastern Kentucky is a major source of limestone and dolomite for construction, agricultural, and industrial stone. These industries require carbonate rocks of high chemical purity. Chemical analyses of foot-by-foot samples from a Mason County core show that three zones of high-calcium and several thick zones of high-carbonate and low-silica stone are present in the High Bridge at a mineable depth. Mason County is located in northeastern Kentucky, on the Ohio River, and offers river access to transportation to the metropolitan Covington–Cincinnati market and the northern portion of the Eastern Kentucky Coal Field for mine-related markets.

INTRODUCTION

The Kentucky Geological Survey is conducting a regional study of the High Bridge Group (Upper Ordovician) to determine its chemical characteristics and to outline the occurrence of deposits suitable for industrial uses requiring carbonate rocks of high chemical purity. This is the third publication in a series of reports on the chemical characteristics of High Bridge carbonate rocks; analyses of foot-by-foot samples from Boone and Fayette County cores were previously published (Dever, 1974, 1981).

This report presents the chemical analyses of foot-by-foot samples of the High Bridge section from a core taken in Mason County. The core contains three zones of high-calcium and several thick zones of high-carbonate and low-silica stone.

The High Bridge Group (Middle Ordovician) is a thick (430 to 570 feet), widespread body of limestone and dolomite that is at a mineable depth beneath a large area of central and north-central Kentucky. It is being mined for construction and agricultural stone, for the production of lime for flux, and for flue-gas desulfurization (FGD). Lime is also used for rock dust, to neutralize acid mine drainage from coal mines, and in chemical industries. The High Bridge Group is being mined at two sites along the Ohio River in north-central Kentucky by the Dravo Lime Company: the Cabin Creek Mine at Springdale near Maysville in Mason County and the Black River Mine at Carntown in Pendleton County.

The Mason County core was given to the Kentucky Geological Survey by Cominco American, Inc. It is on file and available for inspection at the Survey's Well Sample and Core Repository. The interval from 474 to 1,093 feet was split and sampled for analysis. Laboratory analyses were performed under the supervision of Lance S. Barron, Kentucky Center for Energy Research Laboratory (KCERL) (now known as the University of Kentucky Center for Applied Energy Research), and Henry E. Francis, Kentucky Geological Survey (KGS), University of Kentucky. Catherine Crace (KCERL) and Mark Thompson (KGS) performed the actual laboratory analyses.

GEOGRAPHIC AND GEOLOGIC SETTING

The Cominco American core was drilled at a site in northwestern Mason County near the community of Minerva, approximately 2.5 miles east of the Mason–Bracken county line (Fig. 1). The core hole is on the east

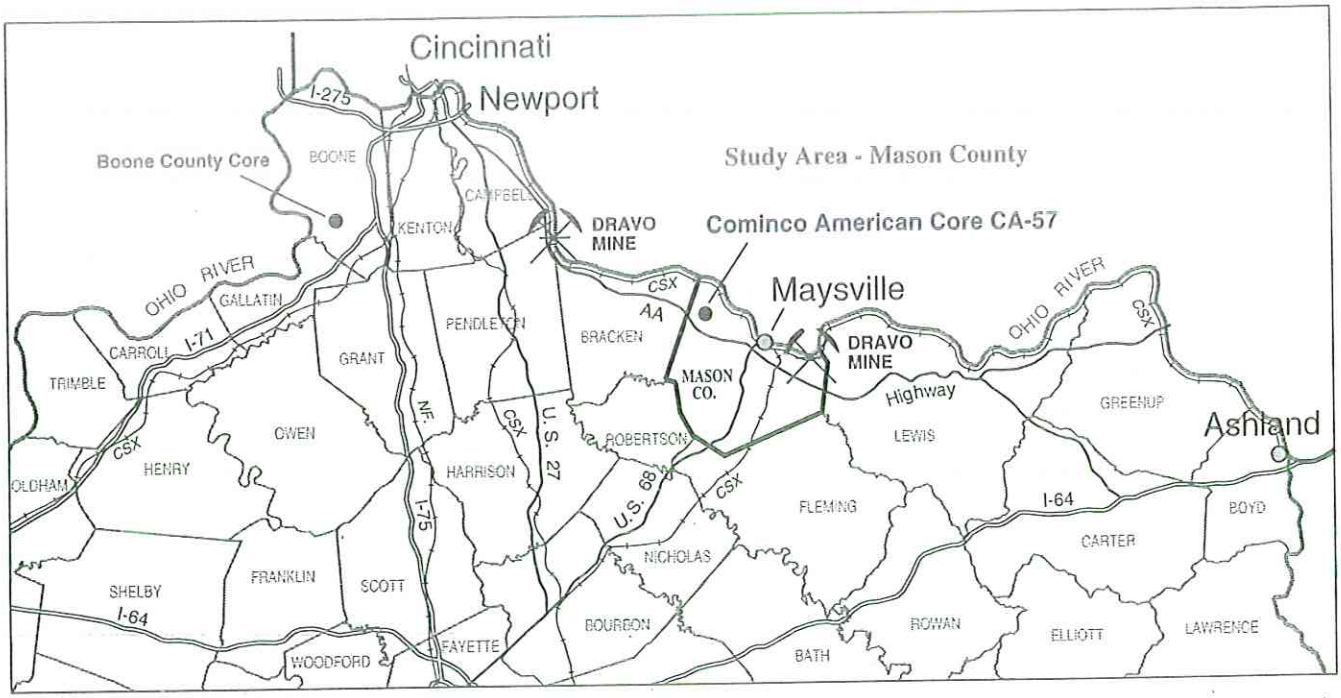

Figure 1. Generalized map of northern Kentucky showing locations of existing mine operations and Boone and Mason County cores, and major highways and railroads.

side of Kentucky Highway 435, 1.5 miles east of Minerva along an unnamed tributary of Lee Creek. The immediate area is covered by the Germantown topographic and geologic (Outerbridge, 1971) quadrangle maps, both at a scale of 1:24,000.

The core hole is located 2 miles from the Ohio River, and river access is readily available via state highways. Kentucky Highways 435 and 546 ("AA" Highway) furnish access to the network of Federal and State highways in Mason County. The county is served by the CSX System Railroad, which runs from Covington to Ashland through Maysville. The TransKentucky Transportation Inc. Railroad, a subsidiary of CSX Transportation, runs from Maysville to Paris, where it connects with additional CSX systems.

The core hole is in the Outer Blue Grass Region, near the southern extent of Pleistocene glaciation. Topography is flat to moderately rolling hills along the Ohio River. The elevation of the collar of the drill hole is 718 feet above sea level, which is about 225 feet above the Ohio River.

The site is on the eastern flank of the Cincinnati Arch (Fig. 2). Some faults occur to the east along the Lewis–Mason county line (Schilling and Peck, 1967), but no known faults exist in the vicinity of the core hole. Surface rocks in the immediate area are principally limestone and shale of the Upper Ordovician Kope Formation, Fairview Formation, and the Grant Lake Limestone (Outerbridge, 1971). Pleistocene glacial outwash occurs as sand and gravel deposits along the Ohio River.

HIGH BRIDGE GROUP

General

The High Bridge Group consists of three formations, which are, in descending order, the Tyrone Limestone, Oregon Formation, and Camp Nelson Limestone (Fig. 3). Total thickness of the High Bridge in the Mason County core is 510.5 feet, of which the Tyrone is 146.6 feet, the is Oregon is 7.4 feet, and the Camp Nelson is 357.5 feet. The Tyrone consists of micrograined limestone, and the Oregon consists of very finely crystalline dolomite. The Camp Nelson is a micrograined limestone, partly mottled with finely crystalline dolomite. The depositional environments of the Tyrone, Oregon, and upper Camp Nelson have been interpreted by Cressman and Noger (1976), Horrell (1981), Kuhnhenn and others (1981), Lazarsky (1983), and Gorman (1984).

Several thin bentonites serve as useful markers for local and regional correlation in the High Bridge. The two most prominent bentonites occur in the upper Tyrone, and their regional association has been discussed in Huff and Kolata (1990). They are the Millbrig or "Mud Cave," present locally at or near the top of the formation, and the Deicke or "Pencil Cave," present across the region, 15 to 30 feet below the top of the Tyrone (Wolcott and others, 1972). In the Mason County

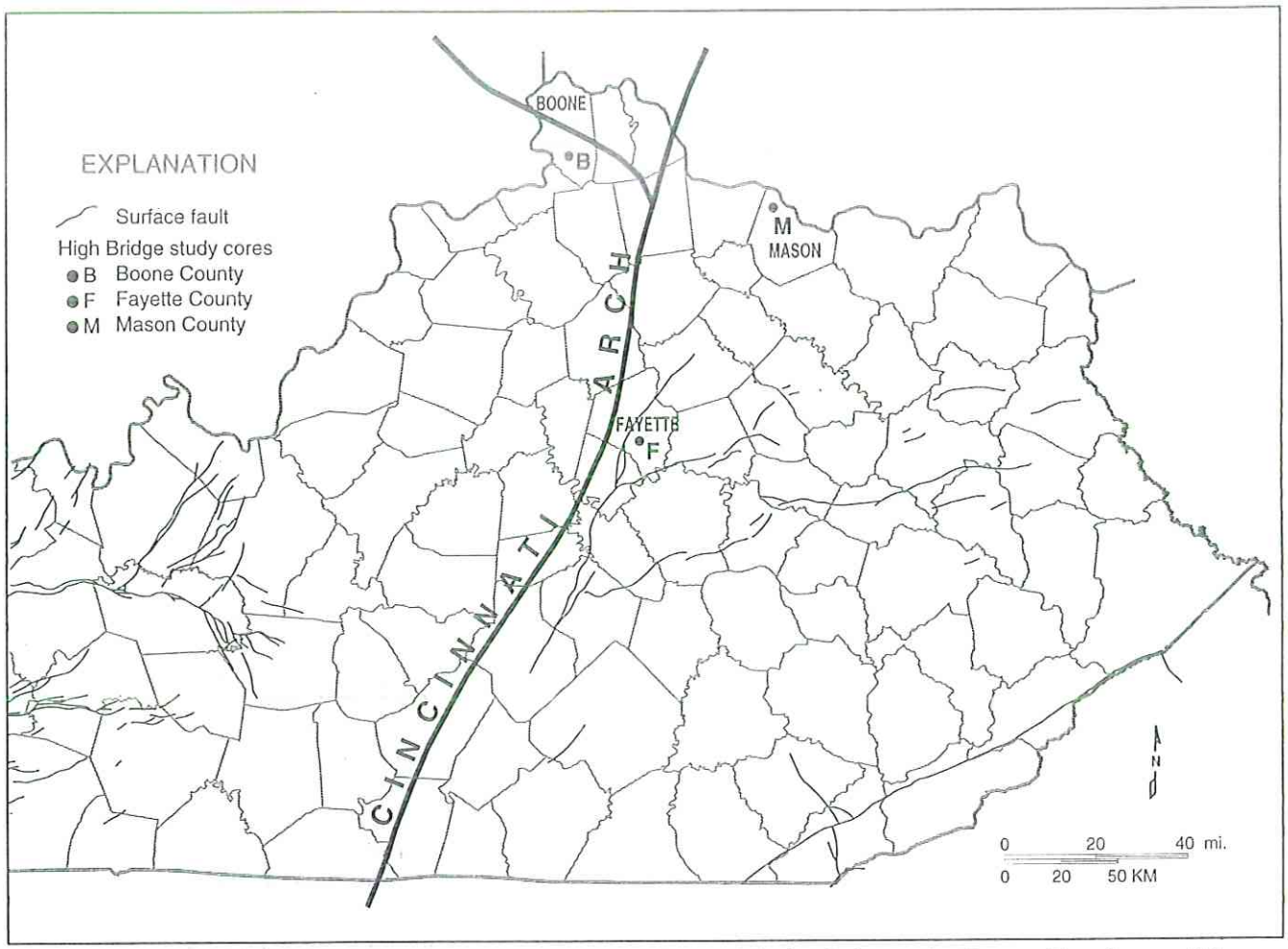

Figure 2. Structural features in central and eastern Kentucky, and their relation to the Boone, Fayette, and Mason County cores.

core, two additional thin bentonites are present, one about 51 feet above the base of the Tyrone and another about 132 feet below the top of the Camp Nelson.

The Tyrone is overlain by the Lexington Limestone, a coarse, crystalline, fossiliferous limestone. The Camp Nelson is underlain in turn by the Wells Creek Dolomite and, where present, the St. Peter Sandstone. In this core, the Wells Creek rests unconformably upon the Knox Group. The contact between the micrograined limestone of the Tyrone and the bioclastic limestone of the basal Lexington is distinct, but the contact between the Camp Nelson and Wells Creek is gradational. The lower Camp Nelson in the Mason County core is mainly limestone (in part slightly dolomitic) and shale; the Wells Creek is an interbedded dolomite and shale and the basal portion is a sandy dolomite. In this study, the contact between the Camp Nelson and Wells Creek has been placed below the lowest occurrence of micrograined limestone, a characteristic High Bridge lithology.

Potential Industrial Uses

The Federal Clean Air Act Amendments of 1990 (Public Law 101-549), also known as the Acid Rain Bill, will create a large demand for limestones and lime for reducing sulfur dioxide emissions from coal-burning power plants. Sulfur sorption techniques (Fluidized Bed Combustion [FBC] or Flue Gas Desulfurization [FGD]) generally require the use of limestone or lime, which react with the combustion coal gases. This reaction by-product is then a disposable commodity. In an FBC method, coal is burned on a bed of limestone or dolomite that is suspended or "fluidized" by an upward flow of air (Dever, 1990). As the coal burns, sulfur (SO_2) is released and reacts with the calcined limestone or dolomite and forms the by-product calcium sulfate ($CaSO_4$, gypsum). When the FGD method is used in existing plants, a hydrous lime mixture is sprayed into the flue gases to form a similar chemical reaction between sulfur and limestone (Cobb and Eble, 1992).

With an increased reliance on the use of coal to meet the energy requirements of the United States, greater quantities of stone will be needed for sulfur sorption capabilities such as fluidized bed combustion and flue-gas desulfurization. Limestone and lime are used for rock dust, spoil-bank reclamation, and acid-mine-drainage neutralization in coal mining. The High Bridge is also a source of construction and agricultural stone for the area's mixture of agricultural and expanding urban markets near Cincinnati.

Chemically pure limestone and dolomite have industrial uses such as raw material for the production of lime, portland cement, agricultural lime products, and chemical products; and flux for steel and other metallurgical industries and fillers. Specifications for many of these industrial uses require that the stone be essentially free of non-carbonate constituents such as silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), sulfur (S), and phosphorus (P). For certain industrial uses, magnesium carbonate ($MgCO_3$) is a deleterious constituent (Dever, 1981).

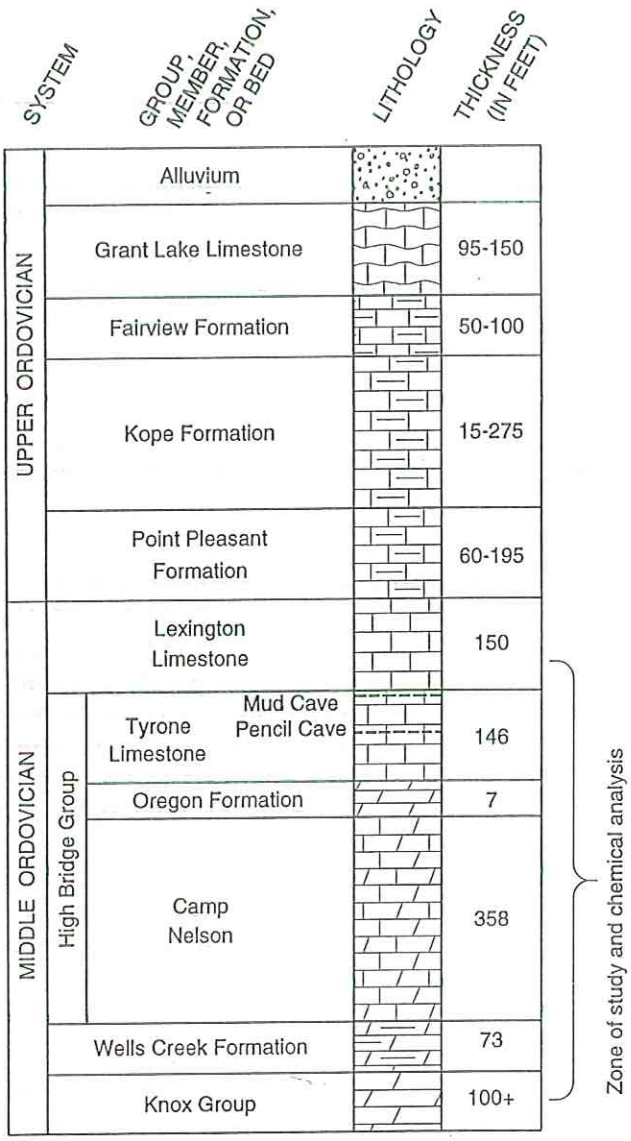

Figure 3. Generalized stratigraphic section for Mason County.

The term "high-calcium limestone" designates carbonate rocks composed of 95 percent or more calcium carbonate ($CaCO_3$). Carbonate rocks of high chemical purity are described by Dever (1974, 1981, 1990) and Dever and others (1991, 1992). These reports also provide a summary of several potential uses for high-carbonate and low-silica stone. The term "high-carbonate stone" designates carbonate rocks composed of 95 percent or more total carbonates—calcium carbonate plus magnesium carbonate ($CaCO_3 + MgCO_3$). The term "low-silica stone" designates carbonate rocks with a total (free and combined) silicon dioxide (SiO_2) content of 4 percent or less (Dever, 1981).

DISCUSSION OF ANALYTICAL DATA

In the Mason County core, a 10-foot-thick zone of high-calcium limestone occurs in the Tyrone, between the Mud Cave and Pencil Cave bentonites (Fig. 4). A thicker zone of high-calcium limestone can be obtained when averaged over an 18-foot interval (Table 1). This 18-foot-thick zone is not present in the Boone County core (Dever, 1974) and may be restricted to northeastern Kentucky. This zone could be worthy of exploration for high-calcium stone since it has a depth of approximately 500 feet, although the magnesium and silica contents (Table 1 and Appendix A) may restrict its use as a source of lime (John Ames, oral communication). Additional zones of high-calcium limestone in the core are only 1 to 2 feet thick and occur in the Camp Nelson. Several zones of high-carbonate stone, 12 to 61 feet thick, are present in the Mason County core (Fig. 4, Table 1, Appendix A); the zones are in the Camp Nelson and show a close correlation with the stratigraphic position of the high-carbonate zones of the Camp Nelson in the Boone County core, 50 miles to the northwest (Fig. 2).

The High Bridge is being mined at two sites on the Ohio River in north-central Kentucky for the production of lime. The Dravo Lime Company's Cabin Creek Mine in Mason County is producing a low-magnesium lime (MgO) for stack-gas scrubbing (Mining Engineering, 1977). The Cabin Creek Mine also produces limestone for FBC. Dravo's Black River Mine at Carntown in Pendleton County produces a high-calcium quicklime for FGD, steel-furnace flux, and chemical industries, and a hydrated lime for chemical industries and

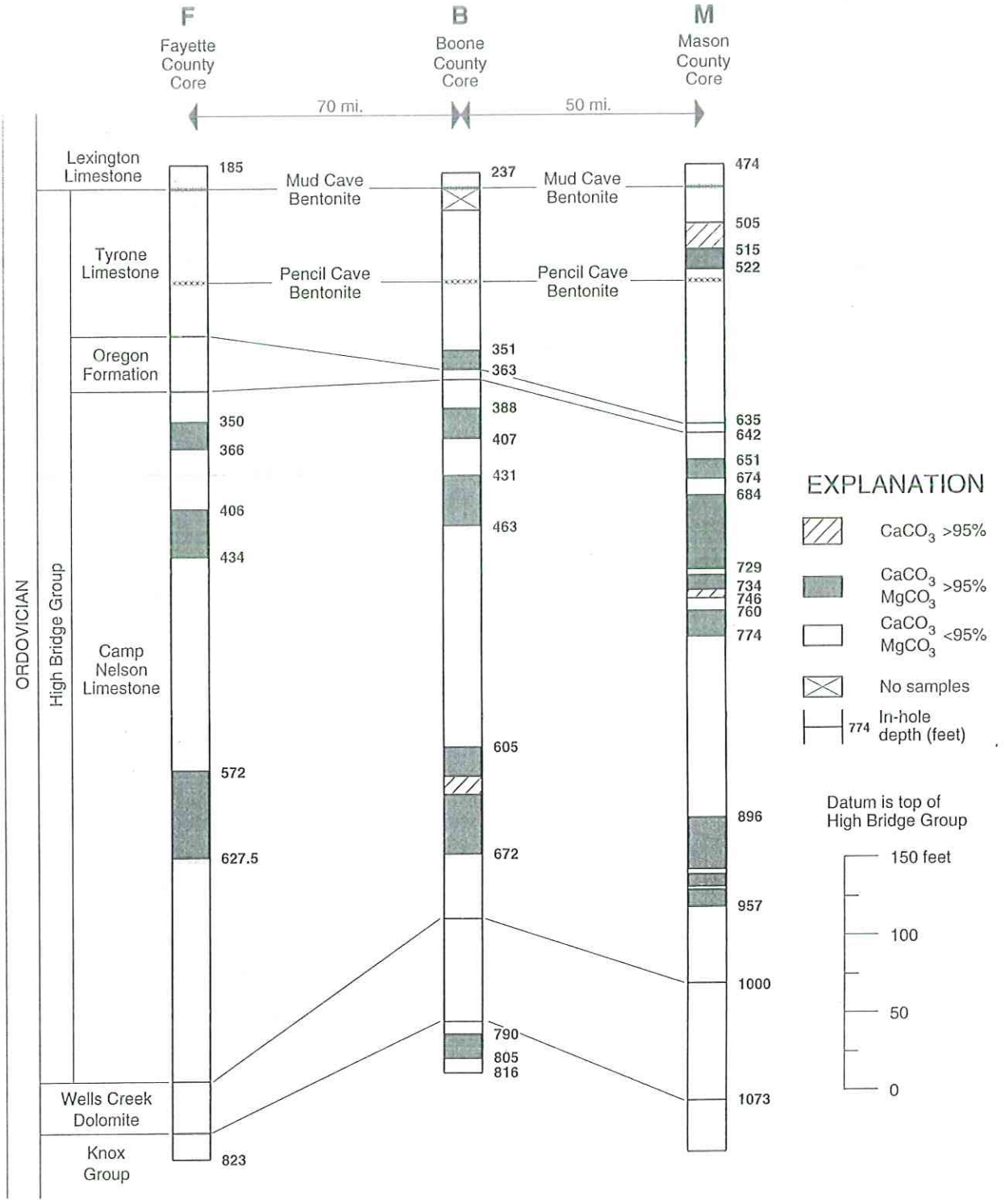

Figure 4. Zones of high-carbonate and high-calcium stone, and stratigraphy of analyzed sections in cores from Fayette, Boone, and Mason Counties. Section from Fayette County to Boone County is along the Cincinnati Arch, and section from Boone County to Mason County is across the arch and into the Appalachian Basin. Modified from Dever (1981).

water treatment (John Ames, oral communication). Limestone from the Pendleton County mine also is marketed for the production of rock dust for coal mines (Dever, 1981).

Most of the limestone in the Camp Nelson appears suitable for construction stone. A zone of argillaceous limestone and shale in the uppermost Camp Nelson of central Kentucky is not present in the Mason County or Boone County cores, correlative with the approximate interval from 670 to 690 feet in the Cominco American core (Appendix A). Rock in this zone in central Kentucky does not meet specifications for construction stone.

Limestone and dolomite samples from Kentucky have been tested in an atmospheric fluidized bed combustion pilot plant at the Kentucky Center for Energy Research Laboratory (now University of Kentucky Center for Applied Energy Research) (Barron and others, 1991). One of the samples studied by Barron and others (1991) was from the Oregon Formation. Barron and others (1991) found that dolomites or calcareous dolomites such as those in the Oregon have a greater sulfur sorption capacity and calcium utilization potential than the limestones in this study. The Oregon dolomite in the study by Barron and others (1991) was obtained from stockpiles at the Vulcan Materials Central Mine, Fayette County. Dolomitic limestone from Dravo's Cabin Creek Mine is also being used in FBC (Dever, 1990).

Structure contours on the top of the Tyrone in north-central Kentucky (top of High Bridge) have been compiled by Potter (1993) in a map covering a large area of north-central Kentucky (Fig. 5). Depth to the top of the High Bridge is generally less than 800 feet along the Ohio River in northern Kentucky. Wolcott and others (1972) used a trend-surface statistical analysis to predict thickness trends in the High Bridge of central and north-central Kentucky. This information could benefit exploration for additional mine sites.

CONCLUSIONS

Thick deposits of chemically pure carbonate rock are present in the High Bridge Group in north-central Kentucky. Regional stratigraphic correlation between deposits across northern Kentucky suggests that the deposits are widespread and represent large reserves of stone for industrial use. The High Bridge of north-central Kentucky along the Ohio River has potential for the production of limestone and lime for various industrial and agricultural uses. These carbonate rocks are being used for the production of lime for flue-gas desulfurization and as sorbent stone in a fluidized-bed combustion system.

ACKNOWLEDGMENTS

Appreciation is extended to Garland R. Dever, Jr., who contributed much of the work and analytical data on limestones in Kentucky. Without his advance work, knowledge, and stimulating discussions, this publication would not have been possible.

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Table 1. Average chemical analysis of high-calcium and high-carbonate zones.

Footage	Thickness	Total Carbonate	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	Total
High-calcium zone										
504-522	18 ft.	97.28	95.49	1.79	1.60	0.64	0.22	0.24	0.05	100.03
High-carbonate zone										
651-674	23 ft.	96.27	91.04	5.23	1.67	0.36	0.18	0.21	0.05	98.76
684-729	46 ft.	96.41	88.47	7.94	2.23	0.25	0.17	0.13	0.07	99.26
734-746	12 ft.	97.27	91.53	5.74	1.39	0.20	0.13	0.10	0.06	99.16
760-774	14 ft.	95.68	90.44	5.24	3.17	0.54	0.34	0.41	0.19	100.33
896-957	61 ft.	96.59	84.66	11.93	1.65	0.14	0.17	0.16	0.08	98.79

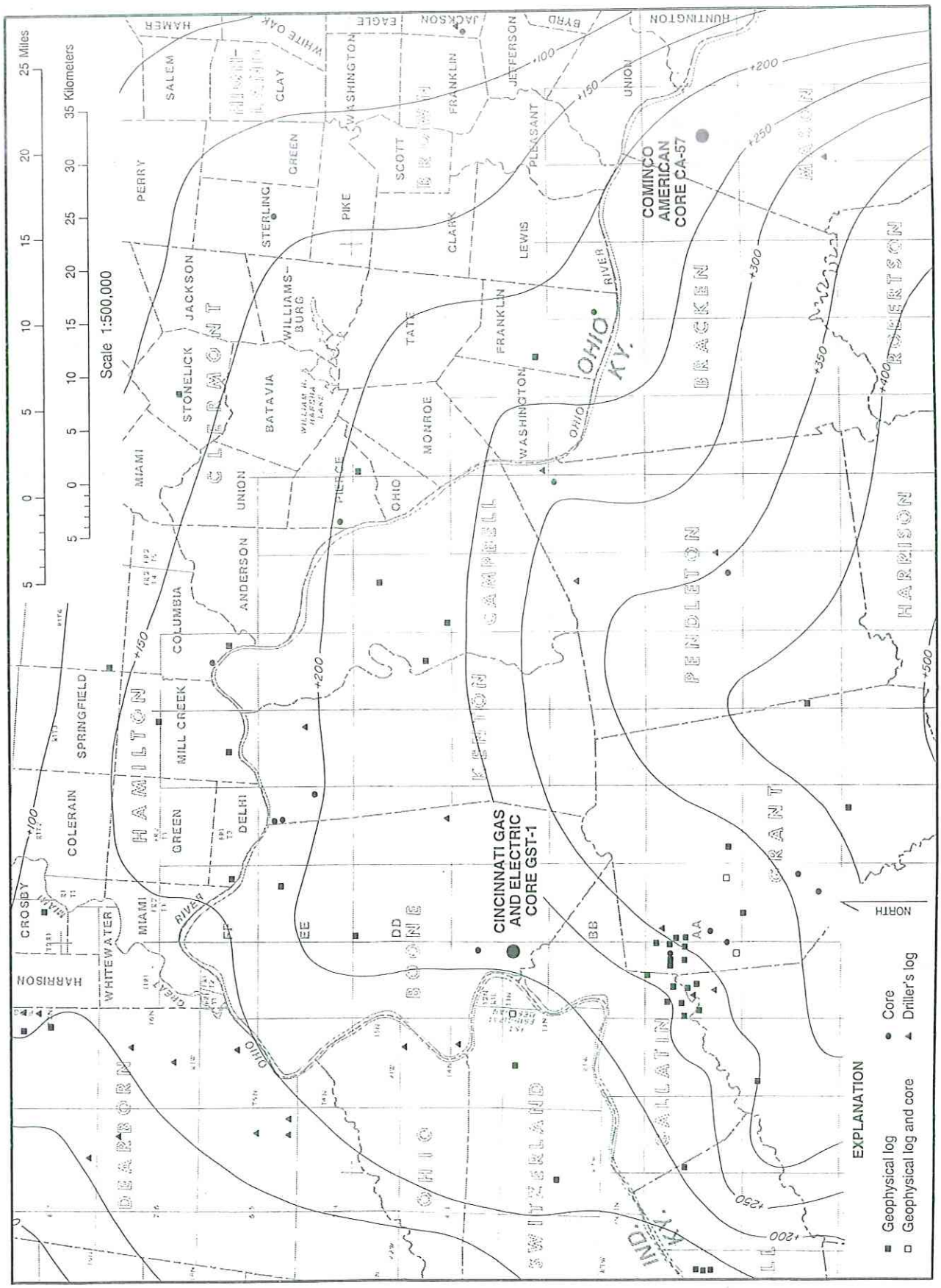

Figure 5. Structure-contour map on top of the High Bridge/Black River Groups. Modified from Potter (1993).

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APPENDIX A:
Major-Element Analyses and Lithologic Descriptions of Cominco American Inc. Core CA-57, Mason County, Kentucky

County: Mason
Operator: Cominco American Inc.
Carter Coordinate Location: sec. 14-AA-68 (Germantown Quadrangle)

Chemical Analysis							
% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
78.30	1.81	15.98	1.53	0.50	0.42	0.39	98.93
85.58	1.14	10.29	0.81	0.48	0.16	0.11	98.57
77.07	2.70	14.97	2.34	0.87	0.73	0.43	99.11
67.17	1.83	26.99	1.15	0.64	0.42	0.29	98.49
82.89	1.09	11.70	1.85	0.92	0.32	0.17	98.94
89.65	0.77	7.09	1.15	0.26	0.22	0.10	99.24
81.95	1.15	13.70	0.17	0.32	0.57	0.22	98.08
93.90	0.96	3.80	1.19	0.18	0.36	0.07	100.46
92.61	1.00	4.46	1.15	0.20	0.32	0.08	99.82
92.17	0.60	4.35	0.87	0.26	0.22	0.06	98.53
90.48	0.77	6.17	1.53	0.26	0.46	0.11	99.78
90.06	0.65	6.01	1.26	0.39	0.33	0.07	98.77
87.96	0.56	7.93	1.26	0.32	0.43	0.17	98.63
83.81	0.91	11.39	3.14	0.32	1.03	0.20	100.80
85.29	0.99	9.94	1.98	0.23	0.66	0.11	99.20
61.09	0.82	35.06	0.85	0.24	0.22	0.06	98.34
70.92	1.38	24.04	1.49	0.35	0.57	0.06	98.81
85.86	2.06	8.40	1.45	0.32	0.58	0.05	98.72
90.50	1.32	6.25	1.15	0.27	0.29	0.05	99.83
94.93	0.96	2.32	1.21	0.12	0.40	0.05	99.99
94.80	0.91	1.80	0.83	0.22	0.16	0.04	98.76
93.60	1.47	2.68	1.00	0.20	0.20	0.04	99.19
94.24	0.95	2.41	1.20	0.28	0.23	0.05	99.36
95.08	0.63	2.43	1.13	0.25	0.20	0.07	99.79
92.32	1.01	3.55	1.79	0.37	0.40	0.09	99.53
93.95	0.74	2.13	1.44	0.23	0.18	0.05	98.72
87.20	1.86	6.52	3.20	0.81	0.68	0.09	100.36
90.01	1.72	4.31	2.55	0.52	0.47	0.07	99.65
89.64	1.72	4.27	2.09	0.72	0.47	0.07	98.98
88.10	1.90	5.35	2.54	0.70	0.68	0.11	99.38
93.44	1.29	2.16	0.68	0.39	0.35	0.05	98.36
97.97	0.34	0.73	0.30	0.06	0.06	0.06	99.52
98.07	0.73	0.72	0.48	0.09	0.16	0.04	100.29
98.11	0.70	0.41	0.39	0.25	0.09	0.03	99.98
97.75	0.74	0.28	0.45	0.11	0.08	0.03	99.44
97.00	1.40	0.83	0.42	0.07	0.08	0.03	99.83
96.55	1.85	0.98	0.43	0.09	0.08	0.03	100.01
96.01	2.08	1.43	0.60	0.13	0.19	0.03	100.47
96.17	2.01	1.39	0.66	0.10	0.22	0.03	100.58
96.99	1.55	1.37	0.53	0.11	0.15	0.03	100.73
96.80	0.86	1.76	0.85	0.13	0.38	0.03	100.81
94.57	2.90	1.87	0.76	0.50	0.28	0.04	100.92
91.40	2.91	3.19	1.19	0.39	0.53	0.05	99.66
92.80	2.62	3.15	1.20	0.36	0.50	0.12	100.75
92.41	2.71	2.51	0.68	0.27	0.30	0.06	98.94
94.40	2.09	1.69	0.43	0.17	0.17	0.04	98.99
96.39	1.90	1.39	0.38	0.14	0.14	0.04	100.38
92.01	3.50	3.01	1.04	0.67	0.55	0.07	100.85
85.90	3.56	6.73	2.14	0.82	0.70	0.09	99.94
86.93	3.22	5.54	1.78	0.67	0.68	0.07	98.89
88.62	1.57	6.27	1.60	0.35	0.87	0.07	99.35
97.42	1.27	1.34	0.51	0.16	0.20	0.03	100.93

Sampled and Described By: Warren H. Anderson and Lance S. Barron
Analyzed By: Kentucky Center for Energy Research Laboratory and Kentucky Geological Survey
Date Sampled: August 10-11, 1993

Description		
Footage (feet)	*Thickness (feet)*	*Formation and Lithology*
474.4-489.4	15	**Lexington Limestone** Limestone, light- to medium- to light-olive-gray, moderately to coarsely crystalline; becomes finely to moderately crystalline in lower 6 ft.; scattered bioskeletal debris; some shale and argillaceous partings; blue porcelaneous chert at 475.4 ft.; blue porcelaneous chert with relict bioclastic texture in basal 0.6 ft.
		High Bridge Group
		Tyrone Limestone
489.4-490.4	1	**Mud Cave** Bentonite; green shale with biotite flakes.
490.4-499.7	9	Limestone, light-gray; becomes light-olive-gray in lower part; micrograined; in part moderately crystalline; floating bioskeletal debris, pellets, shell fragments, bryozoans, trilobites, scattered shale partings; stylolites.
499.7-504.6	5	Limestone, light-olive-gray to yellowish-gray; in part medium-gray; micrograined, in part with birdseye calcite; bioclastic calcilutite from 500 to 501.1 ft.; mottled with medium-gray and light-olive-green burrowing at 501.1 ft.
504.6-516.1	11	Limestone, yellowish-gray to light-olive-gray, with scattered medium-gray mottling; micrograined; birdseye calcite in upper 3 ft; some stylolites; in part with coarsely crystalline calcite veinlets; iridescent pyrite at 505.5 ft.; shale partings at 507.1 ft.
516.1-525.5	9	Limestone, yellowish-gray to light-olive-gray; in part brownish-gray; micrograined, with birdseye calcite; medium-gray burrows and mottling; numerous shale and argillaceous partings; greenish-gray, ar gillaceous limestone from 522.6 to 524.7 ft.
525.4-525.5	0.1	**(Pencil Cave)** Bentonite; green shale with biotite flakes.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
97.00	1.21	1.75	0.30	0.12	0.10	0.03	100.51
94.16	1.65	1.56	0.38	0.37	0.11	0.04	98.27
93.66	1.95	2.25	0.54	0.36	0.16	0.04	98.96
92.02	3.75	2.67	1.02	0.39	0.22	0.05	100.12
90.01	3.85	3.04	1.17	0.38	0.25	0.05	98.75
84.77	5.80	5.56	2.03	0.68	0.55	0.06	99.45
86.56	4.46	5.77	2.04	0.72	0.50	0.09	100.14
90.20	3.56	4.53	1.62	0.55	0.42	0.06	100.94
90.25	3.50	4.46	1.66	0.55	0.40	0.06	100.88
82.10	4.01	8.22	2.73	1.00	0.64	0.10	98.80
85.50	3.47	5.98	1.96	0.71	0.51	0.08	98.21
94.00	2.50	1.80	0.60	0.21	0.10	0.03	99.24
94.03	2.25	1.64	0.57	0.20	0.10	0.03	98.82
74.90	4.45	12.00	5.11	1.39	0.87	0.16	98.88
82.25	2.65	8.50	3.50	0.90	0.64	0.12	98.56
81.40	2.85	9.01	3.75	1.07	0.74	0.13	98.95
74.71	4.02	13.56	4.09	1.65	1.00	0.19	99.22
75.69	4.15	11.90	4.53	1.37	0.85	0.17	98.66
84.45	3.85	7.50	2.40	1.00	0.65	0.10	99.95
85.09	3.12	7.00	2.08	0.79	0.58	0.10	98.76
87.82	2.73	5.41	1.72	0.75	0.51	0.09	99.03
89.95	2.10	3.97	1.32	0.56	0.20	0.07	98.17
88.75	3.30	5.20	1.66	0.77	0.50	0.08	100.26
86.41	2.79	6.75	2.04	0.84	0.62	0.09	99.54
87.34	3.34	5.41	1.60	0.67	0.50	0.12	98.98
85.00	3.46	7.20	2.00	0.84	0.70	0.15	99.35
77.40	4.89	11.60	3.70	1.36	0.86	0.17	99.98
86.65	4.20	5.60	1.74	0.72	0.58	0.10	99.59
93.57	2.69	1.43	0.40	0.26	0.12	0.05	98.52
90.45	5.27	1.80	0.55	0.33	0.23	0.06	98.69
88.20	4.53	4.06	0.85	0.49	0.45	0.07	98.65
89.98	4.39	3.21	0.42	0.30	0.28	0.07	98.65
88.99	4.54	3.66	0.60	0.31	0.33	0.07	98.50
86.83	4.80	5.09	1.42	0.73	0.51	0.11	99.49
84.30	3.99	6.95	1.96	0.67	0.57	0.12	98.56
66.45	12.40	14.86	2.66	1.64	1.12	0.19	99.32
67.90	10.57	14.00	3.98	1.57	0.94	0.19	99.15
58.61	11.98	15.99	7.74	2.00	1.63	0.21	98.16
70.18	13.50	10.50	2.00	1.35	0.70	0.22	98.45
92.07	3.57	1.60	0.36	0.18	0.23	0.07	98.08
91.93	3.65	1.66	0.60	0.20	0.24	0.06	98.34
90.97	3.60	3.06	0.68	0.25	0.39	0.06	99.01
87.14	4.31	4.80	1.18	0.54	0.48	0.08	98.53
80.60	14.40	3.56	0.89	0.44	0.35	0.08	100.32
68.90	24.77	3.00	0.38	0.86	0.32	0.07	98.30
79.45	14.50	3.12	0.56	0.43	0.35	0.08	98.49
81.02	12.80	3.25	0.62	0.44	0.37	0.08	98.58
90.14	5.11	2.25	0.36	0.17	0.11	0.04	98.18
89.66	5.19	1.91	0.44	0.86	0.20	0.04	98.30
78.49	15.00	2.78	0.76	0.48	0.43	0.07	98.01
87.49	5.10	3.87	1.45	0.49	0.62	0.08	99.10
88.80	5.25	2.76	0.94	0.44	0.50	0.06	98.75
89.40	5.20	3.50	0.99	0.40	0.60	0.07	100.16
87.84	4.76	3.60	1.08	0.43	0.73	0.06	98.50
72.97	14.39	8.50	1.83	0.72	0.90	0.09	99.40
77.28	14.57	4.46	0.94	0.47	0.57	0.06	98.35
88.25	3.85	4.65	1.14	0.42	0.58	0.07	98.96
85.20	3.03	7.79	2.08	0.52	0.97	0.06	99.65
76.60	9.50	10.00	1.75	0.63	1.32	0.09	99.89
90.70	5.66	1.99	0.34	0.17	0.22	0.02	99.10

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
525.5-531.6	6	Limestone, yellowish-gray to light-olive-gray; micrograined; gray laminated and argillaceous mottling and partings; some coarsely crystalline veinlets.
531.6-539.1	8	Limestone, yellowish-gray to light-olive-gray; micrograined; in part very fine grained; mottled with shale; stylolitic; irregular bodies of light-olive-gray to greenish-gray, finely crystalline dolomite; dark shale partings from 532.1 to 537.2 ft.; brownish-gray limestone, in part with moderately crystalline calcite, in basal foot.
539.1-565.7	26	Limestone, yellowish-gray to light-olive-gray to greenish-gray, micrograined to very fine-grained, in part argillaceous, with abundant dark-gray, silty shale partings; some scattered floating bioskeletal debris, in part with yellowish-gray, micrograined limestone; 0.25-in. pyrite cube at 539.5 ft.; dolomite mottling at 543.7 ft.; birdseye texture from 554.5 to 559.9 ft.; algal laminations at 561.4 ft.; varved, argillaceous, laminated, and composed of intercalated greenish-gray shale and limestone, with some birdseye calcite in basal 5 ft.
565.7-585.6	19	Limestone, yellowish-gray to light-olive to pinkish-gray, with gray and brown coloration, some black mottling in lower part; micrograined, with birdseye calcite; in part fine-grained; argillaceous laminations; pyrite at 569.5 ft.; 0.5 ft. of shaly, argillaceous partings at 569.8 ft.; scattered shale partings; stylolites in lower 2 ft.
585.6-585.9	0.3	Bentonite; green shale with some biotite flakes and iridescent pyrite.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
88.15	2.70	6.38	0.64	0.15	0.17	0.04	98.23
86.89	5.00	5.10	1.17	0.58	0.51	0.11	99.36
87.70	5.60	5.01	1.06	0.58	0.50	0.09	100.54
90.78	3.26	2.76	0.59	0.30	0.26	0.10	98.05
93.01	2.46	3.09	0.93	0.55	0.38	0.08	100.50
88.52	3.61	4.15	0.81	0.54	0.40	0.09	98.12
68.80	11.00	16.02	2.49	1.45	0.79	0.18	100.73
86.91	5.01	4.01	1.73	0.90	0.70	0.15	99.41
87.09	5.60	3.11	0.93	0.86	0.41	0.08	98.08
96.09	1.71	1.05	0.19	0.11	0.13	0.03	99.31
96.45	0.82	0.80	0.11	0.10	0.08	0.06	98.42
92.57	0.94	2.86	0.81	0.12	0.66	0.08	98.04
96.99	1.20	1.58	0.30	0.11	0.24	0.04	100.46
88.44	8.13	1.81	0.42	0.05	0.24	0.04	99.13
90.20	6.25	2.05	0.40	0.08	0.26	0.05	99.29
89.93	5.40	2.00	0.36	0.06	0.25	0.04	98.04
90.03	5.27	2.00	0.40	0.28	0.26	0.05	98.29
87.99	7.05	2.09	0.43	0.26	0.26	0.05	98.13
86.06	8.80	2.30	0.50	0.30	0.28	0.05	98.29
88.88	6.90	1.80	0.50	0.36	0.27	0.12	98.83
91.83	4.30	1.75	0.30	0.25	0.17	0.07	98.67
93.12	3.15	1.81	0.15	0.13	0.11	0.05	98.52
93.18	3.45	1.72	0.47	0.26	0.20	0.07	99.35
93.30	3.60	2.31	0.79	0.42	0.35	0.07	100.84
90.98	5.70	1.25	0.23	0.15	0.13	0.04	98.48
90.85	5.75	1.00	0.19	0.12	0.10	0.04	98.05
90.70	5.92	1.66	0.45	0.22	0.21	0.04	99.20
90.10	5.40	1.78	0.47	0.21	0.19	0.04	98.19
89.77	6.48	1.30	0.21	0.14	0.12	0.04	98.06
88.20	9.05	1.00	0.17	0.15	0.10	0.05	98.72
88.69	8.31	0.95	0.19	0.13	0.10	0.06	98.43
89.66	6.75	1.50	0.34	0.18	0.23	0.07	98.73
84.96	6.67	4.26	1.00	0.50	0.57	0.17	98.13
89.22	6.63	2.13	0.42	0.23	0.17	0.04	98.84
85.45	9.14	2.78	0.59	0.29	0.26	0.10	98.61
86.91	7.79	2.68	0.57	0.35	0.25	0.11	98.66
79.70	13.18	4.14	0.91	0.46	0.40	0.13	98.92
82.02	12.04	2.95	0.46	0.28	0.24	0.06	98.05
84.11	11.90	2.15	0.30	0.17	0.16	0.06	98.85
82.90	11.87	3.39	0.77	0.38	0.36	0.11	99.78
80.50	10.77	5.71	1.00	0.14	0.40	0.09	98.61
80.70	11.00	4.88	0.85	0.43	0.36	0.09	98.31

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
642.4-666.7	24	**Camp Nelson Limestone** Limestone, light-olive-gray to pale-yellowish-brown, with dark-gray mottling, micrograined, with birds-eyes and veinlets of calcite; mottled with irregular bodies of greenish-gray, finely crystalline dolo mite, in part medium-light-gray calcarenite from 663 to 666.7 ft.; white agate chert at 664.4 ft.; stylolites.
666.7-684.4	18	Limestone, light-olive-gray to yellowish-gray, micrograined; with yellowish-gray to light-olive-gray to olive-gray, finely crystalline dolomite; thin zones of calcarenite, in part dark-greenish-gray, stylolites; argillaceous and shaly partings at 678.5 and 682.9 ft.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
85.40	9.72	2.25	0.30	0.36	0.16	0.07	98.26
83.20	12.06	2.53	0.36	0.43	0.19	0.07	98.84
83.89	11.78	2.00	0.25	0.15	0.13	0.07	98.27
87.30	8.82	1.63	0.15	0.14	0.12	0.08	98.24
91.25	4.26	2.00	0.20	0.15	0.11	0.05	98.02
89.82	6.60	1.55	0.20	0.15	0.10	0.05	98.47
88.90	7.65	1.30	0.12	0.11	0.07	0.05	98.20
87.80	7.59	2.70	0.43	0.23	0.18	0.04	98.97
85.00	8.84	4.07	0.43	0.22	0.18	0.04	98.78
90.00	5.83	3.11	0.28	0.15	0.12	0.04	99.53
88.26	6.45	3.29	0.32	0.18	0.14	0.07	98.71
85.23	9.39	2.79	0.32	0.20	0.14	0.05	98.12
88.74	8.00	2.34	0.25	0.23	0.13	0.06	99.75
79.97	11.20	7.28	0.36	0.29	0.19	0.10	99.39
90.09	7.60	1.33	0.19	0.17	0.12	0.09	99.59
86.96	7.70	3.59	0.21	0.13	0.12	0.09	98.80
84.68	8.98	4.96	0.21	0.15	0.12	0.10	99.20
86.88	8.91	1.97	0.28	0.17	0.16	0.09	98.46
88.00	8.75	2.37	0.45	0.25	0.20	0.07	100.09
91.58	6.26	1.57	0.23	0.13	0.10	0.09	99.96
91.67	4.79	2.07	0.11	0.12	0.08	0.08	98.92
91.50	6.32	1.87	0.19	0.11	0.10	0.09	100.18
89.00	8.01	2.60	0.40	0.19	0.18	0.07	100.45
88.01	8.57	1.61	0.25	0.14	0.10	0.07	98.75
89.33	7.61	1.57	0.15	0.08	0.07	0.05	98.86
91.60	5.85	1.70	0.23	0.11	0.12	0.05	99.66
88.50	8.54	2.12	0.42	0.22	0.17	0.05	100.02
90.56	7.25	1.31	0.17	0.10	0.07	0.04	99.50
91.03	7.01	1.38	0.19	0.12	0.07	0.04	99.84
89.81	8.25	1.94	0.34	0.15	0.12	0.06	100.67
88.56	8.72	1.89	0.28	0.16	0.14	0.08	99.83
88.96	7.12	1.79	0.17	0.17	0.13	0.09	98.43
89.01	6.99	1.57	0.17	0.18	0.13	0.07	98.12
92.08	6.10	1.53	0.19	0.11	0.12	0.07	100.20
91.53	6.75	1.43	0.17	0.13	0.11	0.07	100.19
93.55	4.01	1.40	0.25	0.11	0.10	0.08	99.50
91.80	7.01	1.27	0.23	0.09	0.09	0.04	100.53
92.14	6.00	1.28	0.17	0.10	0.10	0.06	99.85
92.90	5.50	1.84	0.26	0.15	0.14	0.09	100.88
88.60	9.20	1.83	0.34	0.25	0.17	0.15	100.54
66.80	26.66	5.68	0.34	0.23	0.15	0.10	99.96
90.61	4.91	1.69	0.28	0.50	0.12	0.17	98.28
89.56	6.95	1.59	0.23	0.09	0.10	0.04	98.56
89.99	6.02	1.60	0.19	0.15	0.09	0.08	98.12
89.00	9.36	1.56	0.15	0.12	0.08	0.05	100.32
90.49	5.26	1.94	0.19	0.15	0.12	0.07	98.22
78.00	3.60	15.97	0.11	0.29	0.17	0.10	98.24
91.73	5.79	1.55	0.21	0.13	0.09	0.06	99.56
89.07	9.03	1.47	0.15	0.16	0.06	0.06	100.00
86.99	5.29	5.63	0.16	0.16	0.06	0.04	98.33
91.36	5.31	1.29	0.15	0.11	0.06	0.03	98.31
91.95	4.39	1.37	0.13	0.13	0.07	0.05	98.09
93.75	3.31	1.19	0.25	0.10	0.09	0.07	98.76
94.62	2.19	1.15	0.17	0.09	0.09	0.06	98.37
95.40	3.56	0.99	0.11	0.07	0.06	0.05	100.24
92.71	5.85	1.10	0.17	0.11	0.09	0.06	100.09
87.26	10.40	1.19	0.17	0.12	0.11	0.06	99.31
84.29	12.70	1.40	0.23	0.13	0.12	0.10	98.97
94.44	3.73	1.41	0.17	0.16	0.10	0.06	100.07
90.38	6.22	1.26	0.28	0.16	0.14	0.05	98.49
92.17	3.97	2.09	0.28	0.17	0.15	0.07	98.90
90.01	7.30	2.20	0.34	0.18	0.17	0.06	100.26
87.39	6.20	3.20	0.63	0.30	0.31	0.15	98.18
86.97	8.06	2.76	0.39	0.19	0.25	0.16	98.78
77.97	12.49	5.43	0.92	0.37	0.70	0.24	98.12
82.19	10.94	4.00	0.44	0.13	0.32	0.19	98.21

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
684.4-743.4	59	Limestone, light-olive-gray to yellowish-gray, micrograined, birdseye calcite, in part with floating bioclastic debris; with greenish-gray to light-olive-gray dolomite; scattered tripolitic chert; birdseye calcite; stylolites, vertical fracture with argillaceous parting at 727 ft.; chert with relict bioclastic texture at 731.2 ft.; thin zones of light-brownish-gray, bioclastic calcilutite from 738 to 741 ft.; very light-gray, with dark mottling, earthy texture in basal 0.5 ft.
743.4-749.9	6	Limestone, light-olive-gray to olive-gray, fine- to medium-grained; thin zones of calcilutite with floating and bioclastic calcarenite; dolomite stringers at 743.4 and 747 ft.; mainly yellowish-gray to light-olive-gray, micrograined, with birdseye and veinlets of calcite, stylolites in lower 3 ft.; in part medium-dark-gray, fine-grained, argillaceous with floating bioclastic grains in lower 3 ft.; mottled with irregular bodies of greenish-gray, fine-grained dolomite at 749 ft.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
92.48	4.91	2.18	0.29	0.08	0.26	0.16	100.36
92.39	4.11	2.13	0.39	0.12	0.30	0.14	99.58
95.15	3.50	1.15	0.15	0.09	0.09	0.08	100.21
95.83	1.50	0.89	0.13	0.09	0.09	0.06	98.59
95.55	2.91	0.75	0.10	0.09	0.10	0.06	99.56
95.00	3.37	0.77	0.21	0.11	0.12	0.07	99.65
91.90	4.35	2.96	0.70	0.12	0.36	0.11	100.50
86.40	6.90	4.51	1.33	0.13	0.65	0.19	100.11
88.06	6.30	3.80	0.90	0.47	0.43	0.22	100.18
91.95	3.79	3.25	0.49	0.28	0.27	0.12	100.15
91.40	5.30	2.71	0.30	0.24	0.36	0.14	100.45
92.16	4.50	2.50	0.38	0.22	0.34	0.11	100.21
95.67	2.40	1.61	0.25	0.14	0.23	0.09	100.39
91.03	2.26	4.85	0.87	0.42	0.87	0.29	100.59
95.14	2.18	2.12	0.36	0.18	0.31	0.13	100.42
91.26	4.47	3.43	0.68	0.38	0.49	0.27	100.98
93.18	4.13	1.88	0.26	0.18	0.22	0.09	99.94
82.16	9.55	4.96	0.80	0.39	0.75	0.36	98.97
89.48	6.00	3.40	0.53	0.25	0.50	0.27	100.43
90.08	5.90	3.30	0.44	0.23	0.37	0.19	100.51
87.58	7.50	3.45	0.70	0.47	0.35	0.23	100.28
88.02	7.29	3.47	0.80	0.41	0.37	0.20	100.56
87.07	8.06	3.44	0.70	1.00	0.33	0.17	100.77
76.80	7.20	11.59	2.55	0.50	1.71	0.47	100.82
85.99	5.00	4.97	1.26	0.26	0.73	0.29	98.50
90.03	5.75	2.26	0.47	0.17	0.63	0.21	99.52
92.09	5.09	1.38	0.26	0.27	0.74	0.26	100.09
91.57	5.08	1.01	0.19	0.24	0.07	0.05	98.21
87.84	7.59	2.47	0.42	0.13	0.10	0.06	98.61
83.64	8.80	3.94	0.91	0.22	0.43	0.17	98.11
82.20	10.97	2.97	1.34	0.49	0.56	0.27	98.80
85.29	8.97	3.00	0.70	0.79	0.29	0.19	99.23
87.23	6.81	2.99	0.61	0.49	0.30	0.17	98.60
71.73	14.29	8.94	2.26	0.50	0.36	0.19	98.27
70.75	14.63	8.28	2.17	1.15	0.80	0.53	98.31
72.69	13.25	9.51	2.25	1.17	0.90	0.41	100.18
88.42	8.04	1.80	0.47	1.11	0.13	0.06	100.03
88.77	8.16	2.10	0.30	0.21	0.16	0.10	99.80
88.94	6.99	2.13	0.26	0.29	0.26	0.14	99.01
90.34	6.57	1.30	0.17	0.24	0.12	0.07	98.81
92.89	3.77	1.19	0.09	0.19	0.07	0.09	98.29
90.60	6.00	2.09	0.25	0.15	0.17	0.12	99.38
86.99	8.68	2.33	0.47	0.23	0.27	0.17	99.14
82.48	9.65	4.03	1.02	0.39	0.56	0.34	98.47
87.31	4.14	4.59	1.02	0.40	0.59	0.37	98.42
79.88	10.25	5.71	1.40	0.54	0.65	0.41	98.84
90.79	3.49	2.47	0.59	0.26	0.34	0.19	98.13
88.22	3.28	4.29	1.02	0.41	0.60	0.43	98.25
89.95	4.25	2.60	0.50	0.30	0.27	0.20	98.07
91.95	3.65	3.26	0.25	0.17	0.13	0.11	99.52
83.36	8.05	4.60	1.15	0.53	0.40	0.30	98.39
87.31	4.31	4.71	1.30	0.59	0.53	0.36	99.11
90.50	3.00	2.98	0.75	0.34	0.30	0.21	98.08
94.35	1.60	1.75	0.34	0.17	0.16	0.08	98.45
94.07	1.36	1.89	0.34	0.18	0.17	0.11	98.12
92.87	1.81	3.00	0.30	0.20	0.23	0.11	98.52
90.49	3.29	2.97	0.75	0.20	0.26	0.10	98.06
90.01	3.08	3.19	0.87	0.41	0.37	0.24	98.17
73.70	12.36	9.53	1.59	0.50	0.84	0.42	98.94
88.53	4.43	4.74	0.81	0.31	0.59	0.39	99.80

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
749.9-785.9	36	Limestone, olive-gray, fine- to medium-grained; bioclastic calcilutite to calcarenite with floating bioclastic debris, burrows, scattered shale partings, and floating brachiopod fragments; light-olive-gray, micrograined with some birdseye calcite from 763.3 to 769 ft.; brachiopod fragments at 756.5 ft.; yellowish to greenish dolomite mottling from 769.2 to 785.9 ft.; scattered shale parting and some dark mottling in basal 4 feet; green bentonite shale from 774.5 to 774.9 ft. with biotite and some calcite.
785.9-788.1	3	Limestone, medium-gray to light-bluish-gray, fine-grained, with light-yellow dolomite mottling; with shaly partings.
788.1-812.6	24	Limestone, light-olive-gray to yellowish-gray, micrograined; fossiliferous; with irregular bodies of yellow dolomite; thin zones of calcarenite; some gastropods; light-olive-gray to yellowish-gray, medium-grained with occasional shale partings from 798.6 to 805 ft.; brownish-gray to olive-gray, micrograined, with birdseye calcite, and dark-gray dolomite-burrow mottling at base.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
77.02	9.51	9.49	1.32	0.40	0.89	0.61	99.24
80.28	6.26	8.28	1.32	0.48	0.80	0.58	98.00
81.21	8.50	7.07	1.25	0.41	0.65	0.44	99.53
90.56	2.85	3.09	0.72	0.28	0.44	0.21	98.15
84.46	5.44	6.16	1.06	0.35	0.66	0.25	98.38
84.64	5.96	6.23	1.17	0.39	0.69	0.22	99.30
93.60	2.90	2.70	0.45	0.15	0.35	0.14	100.29
94.01	1.80	2.73	0.59	0.20	0.41	0.17	99.91
86.01	4.25	5.52	1.17	0.43	0.66	0.44	98.48
90.97	2.21	3.31	0.55	0.18	0.62	0.35	98.19
86.51	4.50	5.16	0.96	0.27	0.62	0.37	98.39
89.40	3.51	3.99	0.70	0.24	0.60	0.45	98.89
94.04	1.64	1.72	0.25	0.20	0.25	0.13	98.23
93.03	1.56	2.58	0.38	0.15	0.35	0.14	98.19
90.05	1.85	5.32	1.00	0.36	0.64	0.24	99.46
80.95	6.34	8.64	1.59	0.48	0.71	0.39	99.10
84.80	4.56	5.95	0.96	0.32	1.00	0.77	98.36
82.64	6.03	7.85	1.59	0.54	0.90	0.71	100.26
83.07	3.93	9.60	1.70	0.53	0.96	0.54	100.33
73.89	2.90	18.56	1.97	0.49	1.59	0.78	100.18
65.04	3.10	24.96	2.36	0.47	1.81	0.94	98.68
90.30	3.09	4.08	0.49	0.13	0.43	0.20	98.72
84.96	4.38	6.59	0.89	0.28	0.67	0.28	98.05
85.49	3.25	7.20	1.49	0.59	0.90	0.53	99.45
85.94	9.05	2.79	0.55	0.16	0.40	0.11	99.00
89.36	4.68	2.79	0.44	0.38	0.29	0.13	98.07

Description

Footage (feet)	*Thickness (feet)*	*Formation and Lithology*
812.6-838	26	Limestone, light-greenish-gray to brownish-gray, in part olive-black to yellowish-gray; calcilutite and bioclastic calcisiltite; scattered specks of pyrite, chalcopyrite, and veinlets of calcite; scattered shale partings; thin zones of olive-gray, with black mottling, calcilutite; 1-in. green shale with rounded calcilutite fragments at base.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
88.84	6.04	2.59	0.53	0.17	0.38	0.12	98.67
90.90	5.70	1.10	0.17	0.13	0.11	0.08	98.19
92.73	3.96	0.95	0.10	0.13	0.10	0.08	98.05
93.07	5.02	0.85	0.09	0.11	0.09	0.06	99.29
79.30	14.88	2.75	0.49	0.26	0.35	0.15	98.18
86.56	9.25	1.80	0.25	0.20	0.18	0.10	98.34
94.27	2.09	1.95	0.34	0.15	0.11	0.07	98.98
93.09	3.41	2.26	0.43	0.20	0.30	0.19	99.88
83.29	9.98	3.74	0.90	0.31	0.52	0.27	99.01
83.69	11.02	3.35	0.94	0.25	0.42	0.22	99.89
89.09	6.60	2.88	0.69	0.25	0.39	0.21	100.11
84.76	5.34	5.25	1.66	0.42	0.85	0.37	98.65
86.70	4.21	4.45	1.42	0.36	0.65	0.25	98.04
83.64	3.80	7.95	2.08	0.55	0.80	0.17	98.99
85.68	3.06	6.25	1.70	0.49	0.80	0.20	98.18
89.62	2.96	3.74	0.94	0.28	0.75	0.30	98.59
85.04	6.55	4.90	1.27	0.39	0.51	0.20	98.86
92.08	3.43	2.00	0.34	0.14	0.20	0.09	98.28
90.02	4.76	2.89	0.57	0.18	0.34	0.05	98.81
87.01	6.89	3.98	1.00	0.28	0.56	0.10	99.82
87.97	5.01	3.79	0.95	0.35	0.53	0.20	98.80
86.91	4.83	3.96	1.10	0.36	0.58	0.37	98.11
82.68	6.33	7.72	2.08	0.53	0.80	0.41	100.55
84.71	5.10	5.59	1.74	0.44	0.68	0.20	98.46
73.99	8.53	10.94	3.21	0.80	1.40	0.20	99.07
86.90	4.58	4.55	1.23	0.33	0.56	0.24	98.39
90.90	5.17	2.00	0.42	0.19	0.24	0.11	99.03
90.45	5.01	2.29	0.70	0.39	0.42	0.27	99.53
92.88	5.11	1.61	0.26	0.17	0.16	0.09	100.28
89.40	6.73	2.97	0.74	0.29	0.44	0.21	100.78
86.19	5.67	4.58	1.32	0.44	0.59	0.37	99.16
86.80	5.30	5.32	1.47	0.42	0.69	0.40	100.40
90.03	3.34	4.30	1.25	0.39	0.52	0.30	100.13
81.14	4.69	9.99	2.46	0.71	1.00	0.35	100.34
83.10	5.65	7.87	1.93	0.61	0.71	0.37	100.24
90.00	2.76	4.31	1.23	0.43	0.49	0.20	99.42
92.66	2.20	2.19	0.64	0.20	0.09	0.10	98.08
84.60	3.98	6.43	2.15	0.63	0.21	0.15	98.15
83.56	6.39	6.17	1.98	0.55	0.17	0.13	98.95
88.61	2.59	5.25	1.72	0.51	0.10	0.05	98.83
88.37	2.79	4.89	1.49	0.41	0.31	0.19	98.45
84.91	6.37	4.41	1.47	0.47	0.29	0.24	98.16
85.17	11.47	0.89	0.38	0.15	0.17	0.07	98.30
86.50	11.90	0.75	0.47	0.16	0.11	0.04	99.93
84.77	11.69	1.35	0.36	0.20	0.17	0.13	98.67
83.70	11.55	2.60	0.82	0.41	0.39	0.05	99.52
91.01	6.00	2.30	0.68	0.29	0.35	0.03	100.66
89.06	5.81	2.06	0.62	0.28	0.32	0.08	98.23
89.33	5.82	3.26	1.09	0.45	0.46	0.05	100.46
91.90	5.50	1.52	0.59	0.22	0.25	0.04	100.02
89.34	7.41	2.02	0.53	0.28	0.35	0.02	99.95
86.14	6.83	4.00	0.38	0.34	0.70	0.03	98.42
88.61	4.39	3.59	1.06	0.36	0.65	0.04	98.70
87.82	10.29	1.00	1.17	0.13	0.20	0.03	100.64
NO ANALYSIS							

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
838-881.3	43	Limestone, light-brownish-gray to yellowish-gray to light-olive-gray, with irregular black mottling, micrograined; in part with irregular bodies of light-olive-gray dolomite and thin zones of bioclastic calcarenite and calcilutite with floating bioclastic grains; birdseyes and veinlets of calcite; scattered pyrite and shale partings; medium-gray to brownish-gray micrograined, with scattered shaly dolomitic zones in lower 18 ft.
881.3-892.1	10	Limestone, yellowish-gray to olive-gray, with black mottling, micrograined; in part with irregular bodies of dark-yellowish-gray dolomite; birdseyes and veinlets of calcite; stylolites.
892.1-896.1	4	Core loss.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
84.02	12.01	1.70	0.44	0.21	0.33	0.05	98.76
84.13	12.17	2.14	0.59	0.30	0.40	0.07	99.80
85.49	11.08	0.98	0.18	0.14	0.17	0.07	98.11
84.81	12.05	0.80	0.09	0.29	0.12	0.06	98.22
88.70	9.70	0.83	0.08	0.10	0.09	0.05	99.55
84.18	11.28	1.61	0.75	0.11	0.11	0.07	98.11
82.74	12.98	1.88	0.17	0.14	0.16	0.05	98.12
82.43	14.39	1.90	0.49	0.24	0.36	0.11	99.92
83.36	13.48	1.53	0.50	0.18	0.09	0.05	99.19
86.15	12.08	0.85	0.15	0.13	0.14	0.04	99.54
83.68	12.98	0.98	0.10	0.15	0.10	0.07	98.06
84.51	12.45	0.93	0.08	0.13	0.09	0.05	98.24
83.99	13.15	0.66	0.06	0.11	0.08	0.04	98.09
85.09	11.86	0.75	0.09	0.13	0.09	0.06	98.07
86.20	10.12	1.24	0.25	0.15	0.25	0.07	98.28
85.20	11.30	1.59	0.08	0.19	0.28	0.04	98.68
81.17	12.40	3.39	0.16	0.35	0.61	0.11	98.19
84.87	12.03	1.52	0.31	0.16	0.23	0.09	99.21
85.55	11.49	0.89	0.14	0.13	0.12	0.07	98.39
85.72	11.66	0.58	0.08	0.11	0.11	0.05	98.31
85.97	11.13	0.59	0.09	0.11	0.10	0.07	98.06
83.64	12.95	1.60	0.45	0.12	0.25	0.10	99.11
83.22	12.58	1.55	0.21	0.13	0.29	0.09	98.07
82.82	13.15	1.04	0.39	0.22	0.27	0.19	98.08
84.25	12.36	0.70	0.16	0.13	0.30	0.13	98.03
88.01	7.89	1.63	0.07	0.21	0.31	0.19	98.31
86.89	7.87	3.26	0.11	0.09	0.05	0.05	98.32
89.24	7.99	1.13	0.08	0.24	0.05	0.10	98.83
89.31	6.83	2.07	0.09	0.24	0.36	0.23	99.13
89.08	6.53	1.90	0.20	0.17	0.12	0.15	98.15
84.48	12.62	0.68	0.18	0.10	0.07	0.10	98.23
86.55	11.62	0.39	0.08	0.10	0.07	0.03	98.84
77.39	19.80	0.50	0.06	0.13	0.11	0.07	98.06
82.23	17.07	0.52	0.07	0.15	0.11	0.05	100.20
84.98	9.95	2.28	0.11	0.32	0.30	0.15	98.09
88.02	4.78	3.68	0.17	0.49	0.59	0.34	98.07
85.41	8.25	3.73	0.11	0.25	0.22	0.14	98.11
87.31	8.10	4.03	0.03	0.18	0.17	0.11	99.93
88.75	7.03	3.36	0.05	0.11	0.06	0.05	99.41
89.01	6.62	3.55	0.03	0.10	0.10	0.06	99.47
82.05	14.03	3.57	0.02	0.12	0.11	0.04	99.94
81.77	14.65	3.59	0.02	0.17	0.09	0.02	100.31
87.65	8.01	3.45	0.04	0.08	0.07	0.03	99.33
83.75	11.45	4.03	0.03	0.16	0.18	0.10	99.70
75.46	18.82	4.11	0.04	0.18	0.20	0.10	98.91
82.88	13.68	3.50	0.04	0.14	0.15	0.03	100.42
79.40	17.60	1.71	0.07	0.16	0.10	0.03	99.07
80.83	16.03	1.37	0.04	0.07	0.03	0.03	98.40
82.30	16.77	0.42	0.03	0.10	0.06	0.05	99.73
81.93	18.08	0.54	0.02	0.13	0.07	0.05	100.82
81.64	15.59	0.59	0.09	0.13	0.08	0.05	98.17
80.49	16.57	0.77	0.09	0.14	0.11	0.10	98.27
81.36	15.83	0.69	0.05	0.11	0.08	0.05	98.17
79.15	18.26	0.47	0.04	0.14	0.05	0.05	98.16
86.38	12.21	0.36	0.03	0.11	0.03	0.01	99.13
81.15	18.08	0.54	0.02	0.15	0.08	0.04	100.06
81.55	16.92	0.79	0.03	0.16	0.10	0.07	99.62
93.20	3.21	1.04	0.10	0.23	0.15	0.09	98.02
93.86	2.06	1.59	0.08	0.37	0.09	0.06	98.11
93.92	1.72	2.00	0.09	0.23	0.27	0.10	98.33
86.31	4.80	5.90	0.05	0.65	1.34	0.67	99.72
90.06	4.24	5.23	0.04	0.53	0.59	0.13	100.82
89.99	5.07	1.76	0.08	0.57	0.46	0.16	98.09
90.48	4.87	1.89	0.06	0.49	0.19	0.09	98.07
91.39	4.65	1.46	0.06	0.21	0.18	0.15	98.10

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
896.1-962.6	67	Limestone, yellowish-gray to light-olive-gray, micrograined to fine-grained with irregular bodies of yellowish-gray to greenish-gray, medium-grained dolomite; in part with floating bioskeletal debris and some birdseye calcite; stylolites; in part medium-dark-gray, micrograined with traces of organic matter from 922.5 to 925.6 ft.; brownish-gray micrograined with birdseye texture at 955.2 ft.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
90.00	4.88	2.39	0.03	0.33	0.74	0.39	98.76
87.06	6.09	5.08	0.01	0.58	0.90	0.26	99.97
79.50	9.85	8.10	0.02	0.79	1.12	0.50	99.88
93.82	5.02	1.40	0.02	0.21	0.16	0.07	100.70
84.50	11.41	3.20	0.02	0.74	0.11	0.05	100.03
85.60	8.72	4.69	0.08	0.51	0.19	0.09	99.88
82.13	8.75	6.87	0.15	0.52	0.22	0.13	98.77
75.50	6.25	12.46	2.77	1.01	0.63	0.51	99.13
66.40	15.43	13.60	3.09	1.11	0.48	0.32	100.43
74.57	8.21	13.66	0.39	1.09	0.32	0.24	98.48
75.75	8.42	12.71	0.27	1.09	0.25	0.11	98.60
85.86	5.72	6.79	0.10	0.66	0.09	0.07	99.29
70.94	8.86	13.99	3.49	1.39	0.79	0.53	99.99
95.01	3.40	1.84	0.02	0.26	0.05	0.03	100.61
94.91	3.52	1.57	0.04	0.30	0.05	0.04	100.43
95.95	2.20	1.50	0.09	0.22	0.04	0.03	100.03
93.20	4.18	1.11	0.30	0.17	0.00	0.00	99.00
92.00	4.71	1.40	0.36	0.17	0.00	0.00	98.70
93.40	3.02	1.50	0.47	0.17	0.00	0.00	98.60
88.20	5.41	2.86	0.82	0.27	0.00	0.00	97.60
55.80	12.00	16.20	2.79	1.67	0.00	0.00	88.50
92.20	3.73	1.89	0.49	0.18	0.00	0.00	98.50
85.50	5.91	4.34	1.17	0.42	0.00	0.00	97.30
67.60	11.30	11.20	2.60	1.04	0.00	0.00	93.70
76.80	8.86	7.47	1.84	0.64	0.00	0.00	95.60
91.90	3.69	1.82	0.45	0.17	0.00	0.00	98.00
66.30	12.50	11.20	2.36	1.00	0.00	0.00	93.40
59.80	14.80	13.50	2.40	1.22	0.00	0.00	91.70
61.90	9.62	14.10	2.48	1.20	0.00	0.00	89.30
65.80	8.64	13.30	2.84	1.24	0.00	0.00	91.80
85.80	4.25	4.57	1.12	0.38	0.00	0.00	96.20
85.70	4.25	4.96	1.15	0.37	0.00	0.00	96.40
87.70	3.83	4.11	0.95	0.29	0.00	0.00	96.90
76.80	6.72	8.10	1.76	0.62	0.00	0.00	94.00
85.50	4.33	5.14	1.01	0.29	0.00	0.00	96.30
81.40	5.35	7.20	1.30	0.43	0.00	0.00	95.70
76.00	9.66	7.84	1.40	0.54	0.00	0.00	95.40
62.30	25.30	7.57	1.07	0.53	0.00	0.00	96.70

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
962.6-999.9	38	Limestone, light-olive-gray to brownish-gray, with black mottling, micrograined; in part laminated with thin shale partings, interbedded with several 2- to 4-in. green dolomitic shales; dolomitic in basal foot.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
52.20	22.10	14.80	2.18	1.20	0.00	0.00	92.50
28.30	4.34	5.32	15.90	1.55	0.00	0.00	55.40
47.90	30.60	13.90	1.49	1.02	0.00	0.00	94.90
44.40	29.90	15.90	1.61	1.45	0.00	0.00	93.30
51.80	32.90	11.10	1.21	0.68	0.00	0.00	97.70
53.70	34.90	9.04	0.99	0.66	0.00	0.00	99.30
56.10	34.40	7.53	0.78	0.57	0.00	0.00	99.40
50.40	36.90	10.00	1.01	0.78	0.00	0.00	99.10
47.50	32.50	12.90	1.48	1.19	0.00	0.00	95.60
53.30	35.10	8.81	1.07	0.71	0.00	0.00	99.00
45.90	28.40	16.00	1.62	1.44	0.00	0.00	93.30
55.40	31.80	9.73	1.01	0.76	0.00	0.00	98.80
60.90	32.10	5.22	0.59	0.49	0.00	0.00	99.20
53.40	31.90	11.60	0.88	0.67	0.00	0.00	98.50
55.80	32.00	8.66	0.70	0.56	0.00	0.00	97.70
52.40	34.10	9.62	1.19	0.86	0.00	0.00	98.20
50.40	36.00	9.22	1.30	0.91	0.00	0.00	97.80
41.80	28.10	17.50	1.54	2.03	0.00	0.00	91.00
50.60	33.70	10.40	1.49	0.93	0.00	0.00	97.10
47.50	29.50	13.90	1.73	1.18	0.00	0.00	93.90
47.40	30.00	14.20	1.81	1.27	0.00	0.00	94.80
49.50	31.30	12.90	1.67	1.18	0.00	0.00	96.60
50.80	32.50	12.40	1.32	0.96	0.00	0.00	97.90
51.00	31.40	13.10	1.03	0.84	0.00	0.00	97.40
50.90	31.60	11.30	1.43	0.82	0.00	0.00	96.10
49.40	31.80	12.70	1.62	1.07	0.00	0.00	96.70
49.80	32.70	11.10	1.34	0.89	0.00	0.00	95.80
53.40	32.60	10.50	0.85	0.67	0.00	0.00	98.00
49.90	32.30	11.30	1.37	0.91	0.00	0.00	95.80
47.20	30.90	13.40	1.60	1.13	0.00	0.00	94.30
51.00	31.80	11.90	1.14	0.80	0.00	0.00	96.70
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47.70	31.50	13.50	1.68	1.19	0.00	0.00	95.50
38.40	25.10	19.60	1.02	2.61	0.00	0.00	86.70
46.10	30.70	15.10	1.72	1.48	0.00	0.00	95.10
51.00	34.80	10.90	1.09	0.87	0.00	0.00	98.60
43.60	26.60	17.70	1.75	1.77	0.00	0.00	91.30
40.70	22.70	20.90	1.50	2.18	0.00	0.00	88.00
48.80	29.20	15.90	1.53	1.22	0.00	0.00	96.60
47.90	26.00	17.30	1.85	1.44	0.00	0.00	94.40
46.70	26.60	16.60	1.86	1.38	0.00	0.00	93.20
46.80	28.60	15.90	1.86	1.44	0.00	0.00	94.60
42.90	24.10	19.10	1.71	1.86	0.00	0.00	89.70
46.30	27.90	15.20	1.62	1.13	0.00	0.00	92.20
46.30	30.80	14.00	1.62	1.34	0.00	0.00	94.00
43.10	27.00	17.30	1.65	1.84	0.00	0.00	90.80
49.40	31.10	13.30	1.39	0.92	0.00	0.00	96.20
47.10	32.00	14.80	1.60	1.20	0.00	0.00	96.60
45.50	29.50	15.80	1.65	1.30	0.00	0.00	93.70
42.80	26.80	17.10	1.52	1.65	0.00	0.00	89.90
41.20	28.30	18.30	1.54	2.17	0.00	0.00	91.50
46.40	31.20	14.90	1.71	1.27	0.00	0.00	95.50
50.20	33.90	11.80	1.17	0.90	0.00	0.00	98.00
50.10	34.40	12.10	1.16	0.90	0.00	0.00	98.60
47.20	30.40	14.90	1.47	1.11	0.00	0.00	95.10
43.30	27.60	17.40	1.63	1.62	0.00	0.00	91.50
45.50	32.90	14.40	1.75	1.49	0.00	0.00	96.00
48.00	32.40	13.00	1.65	1.32	0.00	0.00	96.30
47.10	31.80	13.90	1.48	1.33	0.00	0.00	95.60
41.50	28.90	18.50	1.44	2.03	0.00	0.00	92.30
34.10	21.30	23.20	0.07	3.15	0.00	0.00	81.80
46.80	33.10	13.70	1.34	1.29	0.00	0.00	96.20
45.20	31.60	15.20	1.51	1.33	0.00	0.00	94.90

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
999.9–1073.5	73	**Wells Creek Formation** Dolomite, light-gray to olive-gray to greenish-gray to light-bluish-gray, with black mottling, micrograined to fine-grained, earthy, porcelaneous chert, irregularly laminated with shale and argilla ceous partings; dolomite of upper 1.75 ft. grades downward into green shale from 1001.9 to 1003.3 ft.; in part intercalated with green silty shales; interbedded with several 2- to 12-in. green silty shales; scattered quartz sand from 1037 to 1038 ft.; argillaceous with scattered quartz sand in lower 4 ft.; clasts of Knox dolomite and abundant quartz sand in basal foot.

Chemical Analysis

% $CaCO_3$	% $MgCO_3$	% SiO_2	% Al_2O_3	% Fe_2O_3	% K_2O	% Na_2O	% Total
43.50	28.50	17.20	1.74	1.58	0.00	0.00	92.50
45.30	30.30	15.70	1.63	1.41	0.00	0.00	94.40
45.40	31.60	14.80	1.48	1.19	0.00	0.00	94.50
44.20	28.00	16.30	1.74	1.32	0.00	0.00	91.50
44.70	29.10	15.90	1.61	1.23	0.00	0.00	92.50
47.20	32.60	13.10	1.37	0.98	0.00	0.00	95.30
44.80	30.00	15.20	1.52	1.19	0.00	0.00	92.70
46.20	32.10	13.80	1.29	1.11	0.00	0.00	94.50
44.10	31.40	15.40	1.71	1.29	0.00	0.00	93.90
47.70	32.60	13.30	1.03	0.71	0.00	0.00	95.40
53.80	42.30	3.02	0.53	0.46	0.00	0.00	100.10
53.60	41.30	3.19	0.69	0.48	0.00	0.00	99.30
51.10	36.70	8.93	0.91	0.61	0.00	0.00	98.30
48.30	32.70	13.10	1.12	0.65	0.00	0.00	95.90
51.50	38.60	7.48	0.70	0.44	0.00	0.00	98.70
50.40	34.10	12.00	0.90	0.53	0.00	0.00	98.00
50.40	33.90	11.30	0.97	0.50	0.00	0.00	97.10
51.60	39.10	6.98	0.77	0.51	0.00	0.00	98.90
51.50	38.20	8.46	0.77	0.54	0.00	0.00	99.50
52.60	36.80	7.73	0.92	0.48	0.00	0.00	98.50
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53.70	42.90	2.37	0.66	0.48	0.00	0.00	100.10
52.60	40.70	4.83	0.84	0.49	0.00	0.00	99.40
50.60	35.50	11.40	0.81	0.52	0.00	0.00	98.80
49.00	34.50	12.80	0.74	0.48	0.00	0.00	97.60
47.30	29.20	17.80	1.00	0.61	0.00	0.00	95.90
48.70	31.20	14.20	0.94	0.52	0.00	0.00	95.50
49.90	33.50	12.00	0.73	0.50	0.00	0.00	96.70
50.90	34.60	10.30	0.79	0.41	0.00	0.00	97.00
50.70	35.10	9.95	0.94	0.38	0.00	0.00	97.00
51.20	37.10	7.49	0.81	0.28	0.00	0.00	96.80
51.40	36.00	7.95	0.75	0.32	0.00	0.00	96.50
50.70	33.20	10.50	0.86	0.38	0.00	0.00	95.70
48.60	33.70	13.10	0.98	0.58	0.00	0.00	96.90
47.80	32.20	14.10	1.09	0.69	0.00	0.00	95.90
48.80	31.80	14.90	0.95	0.63	0.00	0.00	97.20
50.70	34.20	12.20	0.69	0.41	0.00	0.00	98.20
48.30	30.00	17.90	0.87	0.72	0.00	0.00	97.80
52.80	40.80	4.25	1.13	0.52	0.00	0.00	99.50
52.90	40.60	3.70	0.94	0.32	0.00	0.00	98.50
52.30	39.30	4.92	1.04	0.33	0.00	0.00	97.90
51.90	39.60	6.23	0.83	0.41	0.00	0.00	99.00
53.20	41.40	3.02	0.49	0.19	0.00	0.00	98.20
54.10	41.30	1.55	0.24	0.16	0.00	0.00	97.30
53.80	39.80	2.94	0.33	0.18	0.00	0.00	97.10
53.10	38.00	5.25	0.28	0.19	0.00	0.00	96.80
51.80	37.70	8.08	0.29	0.24	0.00	0.00	98.10
51.00	34.30	11.60	0.42	0.32	0.00	0.00	97.40
48.90	31.40	16.10	0.45	0.47	0.00	0.00	97.32

Bottom of sampled interval

Description

Footage (feet)	Thickness (feet)	Formation and Lithology
		Wells Creek Formation (continued)
1073.5-1113.6	40	**Knox Group** **Kingsport Formation** Dolomite, very light-gray to light-gray, in part light-olive-gray, finely crystalline; scattered quartz sand; abundant quartz sand in upper 2 ft.; tripolitic chert with dolomoldic texture; clasts of Wells Creek and Knox dolomite at top; stylolites; in part vuggy and fractured; some oil staining and pyrite; scattered shale laminations at 1089.2, 1099, and 1101.4 ft.

Subsidence Control Compliance

The May 14, 1998 Agreed Order (File No. NCP-23849-043) stipulates certain actions concerning the subsidence control plan that must be followed by Sterling Ventures, LLC. These actions include:

> *Prior to excavation of the production workings, Sterling shall submit as a permit revision a subsidence control plan which will define the layout and characteristics of the underground workings. The plan shall be designed to provide a long-term safety factor, during and after mining, equal to or better than 1.75. The safety factor shall be calculated using accepted engineering practice. Any changes to the mining method or mine layout will require submission of a revised subsidence control plan as a permit modification.*

Subsidence Control Plan
A subsidence control plan was submitted in the renewal application issued on November 14, 2002. Since that time, the mining plan has changed. Therefore, a new subsidence plan is being submitted with this application.

The original mine plan called for the alignment of entries and stacking of pillars on three levels: ventilation, Tyrone and the Camp Nelson. The new plan calls for the offsetting of entries while maintaining the original pillar stacking concept.

	Original Mine Plan				New Mine Plan			
	Pillar Size	Entry Width	Mine Height	Entry	Pillar Size	Entry Width	Mine Height	Entry
Ventilation	50'x50'	50'	20'	In Line	60'x60'	30'	20'	Offset
Tyrone	50'x50'	50'	25'	In Line	50'x50'	40'	25'	Offset
Camp Nelson	50'x50'	50'	30'	In Line	50'x50'	40'	30'	Offset

For details on the current mine plan, please see Page 9 for a detailed schematic of the current mine plan and drawing SM-5.

The Camp Nelson pillar was chosen for analysis since it has the greatest vertical stress and the lowest width-height ratio.

Based on the current mine plan, the Camp Nelson pillar is calculated to have a safety factor of about 4.0. Refer to page 8 for this analysis. This evaluation is based on the Tributary Area Theory that is recommended in the document titled *Pillar Design Issues in Underground Stone Mines* by A.T. Iannacchione.

The mine will continue to be monitored for geologic discontinuities that may lead to possible pillar failure.

Pillar Evaluation

Sterling Materials

Jul-03

Input	
Pillar Width (ft)	50
Pillar Length (ft)	50
Pillar Height (ft)	30
Seam Base Elevation (ft)	-171
Entry Width (ft)	40
Max. Topo Elevation (ft)	800

Output	
Overburden Height (ft)	941
Extraction Ratio	69%
Width-Height Ratio	1.67 *if >1.4, use 1.4*

From Figure 7

Pillar Strength (psi)	12000
Pillar Stress (psi)	3000

Safety Factor	4.00

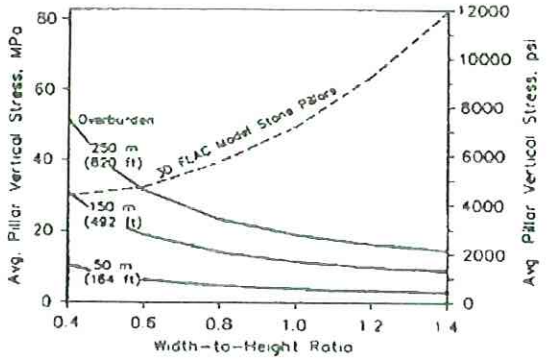


Figure 7 - Changes in stone pillar strength at width-to-height ratios ranging from 0.4 to 1.4.

Figure 7 is from *Pillar Design Issues in Underground Stone Mines* by A.T. Iannacchione

Comments

Sterling Materials mines about 25 feet in the Tyrone seam and about 30 feet in the Camp Nelson seam. The base elevation for the Tyrone seam ranges from -47 to -27 msl, while the base elevation for the Camp Nelson seam ranges from -191 to -171 msl. The pillars overlie one another.

This analysis applies to the Camp Nelson level only, since it is the lowest level and has the smallest pillar size. See page 9 of this report for a skematic of the mining levels.

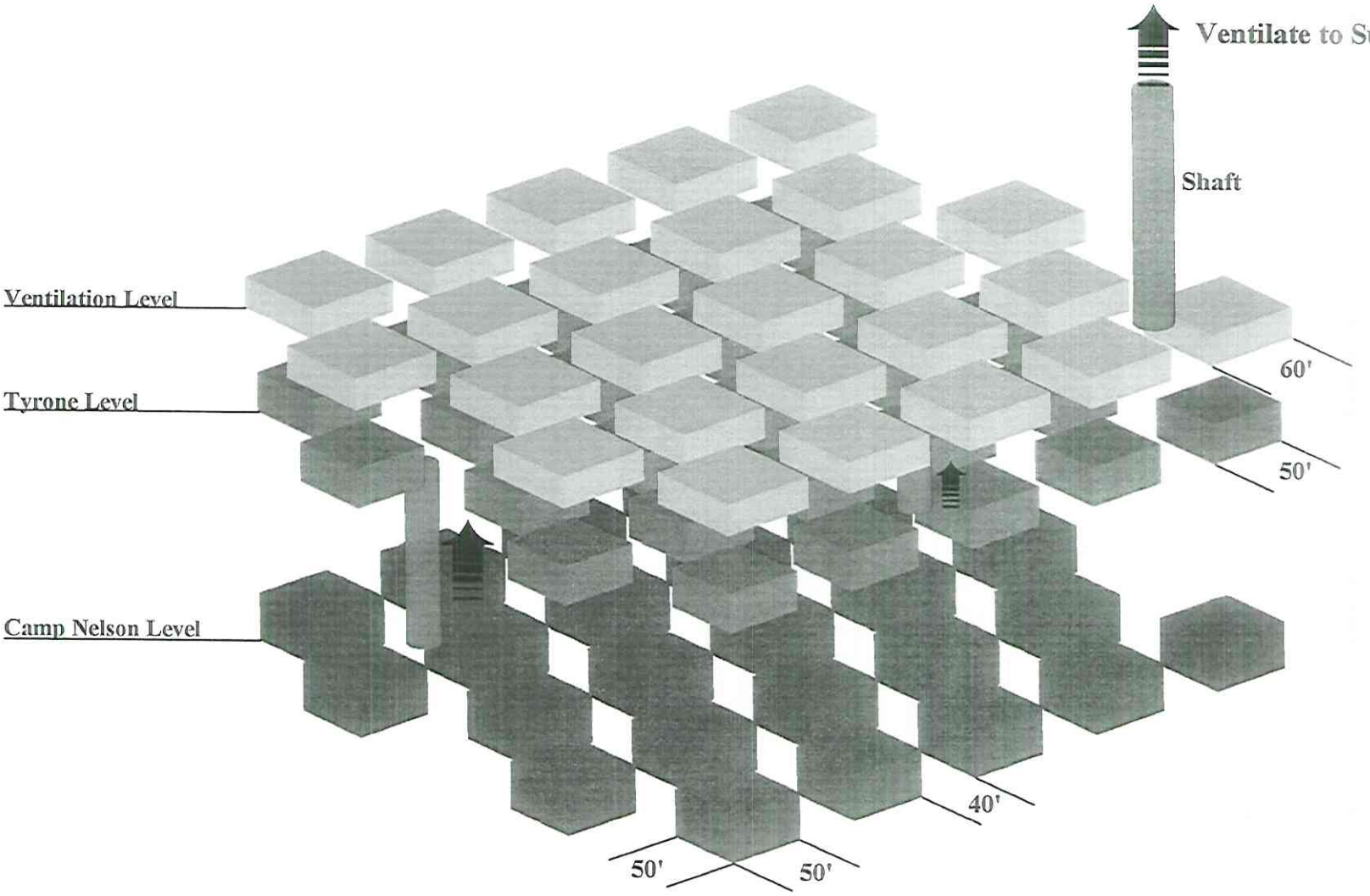
NOTES:

This evaluation uses the ***Tributary Area Theory***

Pillar Assumptions:

1) Stiffness = 6,000,000 psi
2) Friction Angle = 40 degrees
3) Cohesion = 1000 psi
4) No geologic discontinuities

Morgan Worldwide Consultants



MORGAN WORLDWIDE CONSULTANTS
P.O. Box 888
Lexington, Kentucky 40588

Drawn by: JB

Date: 07/22/03

NTS

Sterling Materials

Schematic of Underground Mine Plan

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
and Prevention (CDC)
National Institute for Occupational
Safety and Health
Pittsburgh Research Laboratory
P.O. Box 18070
Pittsburgh, PA 15236-0070

January 9, 2006

Mr. Sam Van
Sterling Materials
100 Sierra Drive
Verona, KY 41092

Dear Mr. Van,

NIOSH Research into Roof Span and Pillar Design for Underground Limestone Mines

We have collected data on pillar and roof conditions at 17 different limestone operations in the Eastern United States since the beginning of 2005. We thank you for the opportunity to have collected data at the Sterling Mine during June 2005. The mine visits have provided valuable information for developing design guidelines based on actual mine performance. The purpose of this letter is to provide brief summaries of the collected data to mines that participated in this study.

The data are presented in the attached tables and a chart which list the mines visited in numerical order. Your mine is represented by No. 13 in the tables and chart. There are a total of 54 observations at present. Note that the observations do not necessarily represent current mining practice because we also visited some mining areas that had been abandoned.

Table 1 summarizes the actual pillar dimensions measured at the mine sites. You will see that we measured pillar length/width/height. The results show that the average pillar height on development is 25.1 ft and it increases to 38.3 ft after floor benching. About 43% of the areas visited had been benched.

We are particularly interested in the performance of pillars with width-to-height ratios of less than 1.5. Table 1 shows that 30 of the 54 areas visited (55%) had width-to-height ratios of less than 1.5. The pillars with lower width-to-height ratios were typically formed after benching. We saw a few unstable pillars. Unstable pillars are defined as pillars that required rib support, were abandoned because of rib instability or collapsed. Only one collapsed pillar was observed.

Table 1: Pillar Data

Mine No	Pillar Height (ft)	Pillar Width A (ft)	Pillar Width B (ft)	Width to Height ratio	Layout Type	Cover depth (ft)	Bench-ed?	Develop height (ft)	Local Extraction Ratio†	Pillar Load (psi)
1	28	36	36	1.3	Square	150	N	27	80%	894
1	61	34	32	0.6	Square	320	Y	27	83%	2,243
1	60	50	75	0.8	Offset	380	Y	31	69%	1,466
1	26	31	35	1.2	Square	320	N	26	82%	2,170
1	27	35	37	1.3	Square	320	N	27	80%	1,902
1	60	35	37	0.6	Square	320	Y	28	80%	1,902
2	28	56	44	2.0	Offset	300	N	28	76%	1,515
2	29	43	55	1.5	Offset	100	N	28	78%	545
3	18	17	55	0.9	Square	200	N	18	84%	1,480
3	18	20	55	1.1	Square	230	N	18	82%	1,500
3	16	20	47	1.3	Square	80	N	16	76%	393
4	50	41	37	0.8	Square	400	Y	28	80%	2,408
4	27	36	40	1.3	Square	300	N	27	77%	1,584
4	27	35	37	1.3	Square	275	N	27	79%	1,572
5	16	46	56	2.8	Square	300	N	16	75%	1,455
5	18	65	66	3.5	Square	100	N	18	69%	386
5	17	54	82	3.2	Square	250	N	17	69%	960
6	30	37	55	1.2	Square	290	N	29	69%	1,124
6	26	37	70	1.4	Square	270	N	26	64%	908
6	30	41	51	1.4	Square	230	N	29	70%	906
7	75*	94	94	1.3	Square	1,300	Y	26	54%	3,381
7	33*	77	81	2.4	Square	1,340	Y	26	59%	3,916
7	55*	80	100	1.5	Square	1,750	Y	26	58%	5,036
8	95	50	52	0.5	Square	260	Y	-	67%	956
8	43	60	60	1.4	Offset	477	Y	-	67%	1,718
8	47	60	60	1.3	Offset	557	Y	-	66%	1,994
9	48	70	70	1.5	Square	323	Y	28	67%	1,163
9	125	71	59	0.6	Offset	176	Y	28	55%	465
9	29	46	46	1.6	Square	368	N	29	75%	1,773
9	52	56	60	1.1	Offset	462	Y	28	73%	2,054
10	50	46	155	0.9	Offset	1,000	y	20	58%	2,825
10	50	49	155	1.0	Offset	1,000	y	20	58%	2,886
10	50	49	155	1.0	Offset	1,000	y	20	58%	2,886
11	24	36	49	1.5	Square	600	N	23	78%	3,216
11	50	36	49	0.7	Square	600	Y	23	78%	3,216
11	22	42	41	1.9	Square	600	Y	23	70%	2,362
11	50	42	41	0.8	Square	600	Y	23	70%	2,362
11	42	59	73	1.4	Offset	600	Y	23	60%	1,818
12	26	48	55	1.9	Square	900	n	26	68%	3,424
12	35	59	44	1.7	Square	900	n	35	70%	3,652
12	25	62	58	2.5	Square	900	n	25	64%	2,989
13	47	63	61	1.3	Offset	450	Y	26	58%	1,283
13	30	51	47	1.7	Offset	450	N	30	70%	1,789
13	27	54	52	2.0	Offset	480	N	27	66%	1,709

Mine No	Pillar Height (ft)	Pillar Width A (ft)	Pillar Width B (ft)	Width to Height ratio	Layout Type	Cover depth (ft)	Bench-ed?	Develop height (ft)	Local Extraction Ratio†	Pillar Load (psi)
14	28	47	42	1.7	Square	75	N	28	73%	329
14	26	42	41	1.6	Square	75	N	26	75%	357
15	62	49	48	0.8	Square	180	Y	27	75%	853
15	30	48	47	1.6	Square	280	N	27	75%	1,350
15	28	44	48	1.6	Square	180	N	27	76%	903
16	24	49	45	2.1	Square	200	N	23	75%	951
16	49	52	45	1.0	Square	200	Y	23	74%	908
16	25	51	44	2.0	Square	280	N	23	72%	1,216
17	27	60	58	2.2	Offset	120	N	25	72%	520
17	27	50	48	1.8	Square	200	N	25	76%	1,019
Average	**38.3**	**48.5**	**59.0**	**1.5**		**445**		**25.1**	**71%**	**1,752**

*Average height of low/high side of pillar in dipping formation
†Extraction ratio based on local pillar and room dimensions – not "planned" extraction

Table2: Roof Data

Mine No	Room Width (ft)	Inter-section span (ft)	Roof Instability?	Roof fall type*	Roof Support
1	44.0	72.0	Yes	H-stress	Spot
1	47.0	69.0	Yes	H-stress	Pattern
1	48.0	-	None	-	Spot
1	45.6	79.4	None	-	Pattern
1	44.6	69.9	None	-	Pattern
1	44.6	69.9	Yes	H-stress	Pattern
2	52.0	-	None	-	None
2	55.0	-	None	-	None
3	42.0	58.7	None	-	Pattern
3	42.3	64.0	Yes	Beam	Pattern
3	29.8	59.9	None	-	Pattern
4	47.9	68.9	None	-	None
4	41.3	64.9	Yes	Struc	Spot
4	42.6	66.6	None	-	Spot
5	51.5	83.0	None	-	None
5	51.8	73.5	None	-	None
5	51.8	81.0	Yes	Struc	None
6	35.4	63.6	None	-	None
6	33.5	71.5	None	-	None
6	37.1	70.2	None	-	None
7	44.3	-	Yes	Struc	None
7	44.3	-	None	-	None
7	48.9	-	None	-	None
8	38.4	68.9	None	Spall	Pattern
8	44.0	-	None	-	Pattern
8	43.6	-	Minor	Blocky	Pattern
9	51.2	-	None	-	Pattern
9	31.2	-	None	-	None
9	45.9	80.4	None	-	Spot
9	53.8	-	None	-	Pattern
10	40.0	-	Yes	H-stress	Pattern
10	43.3	-	None	-	Pattern
10	43.3	-	None	H-stress	Pattern
11	46.6	68.6	Minor	Spall	Pattern
11	46.6	68.6	None	-	Pattern
11	33.8	59.4	Yes	Beam	Pattern
11	33.8	59.4	Yes	-	Pattern
11	38.4	-	Minor	Spall	Pattern
12	40.0	71.5	Yes	H-stress	None
12	42.3	71.8	None	-	None
12	39.7	73.8	Yes	Beam	None

Mine No	Room Width (ft)	Inter-section span (ft)	Roof Instability?	Roof fall type*	Roof Support
13	33.5	-	None	-	None
13	40.0	-	None	-	None
13	38.4	-	None	-	None
14	40.3	63.3	None	-	None
14	41.3	59.4	None	-	None
15	47.9	75.1	None	-	Pattern
15	47.9	52.8	None	-	Pattern
15	47.9	71.5	Yes	Beam	Spot
16	46.6	58.0	None	-	Pattern
16	45.6	74.8	None	-	Pattern
16	42.6	72.8	None	-	Pattern
17	53.1	68.9	Yes	Beam	Spot
17	51.8	83.3	None	-	Spot
Ave:	**43.7**	**69.1**			

*H-Stress: Roof instability induced by horizontal stress
Beam: Bedding plane beam failed
Blocky: Unfavorable joints or slips
Struc: Major faults or slips caused instability

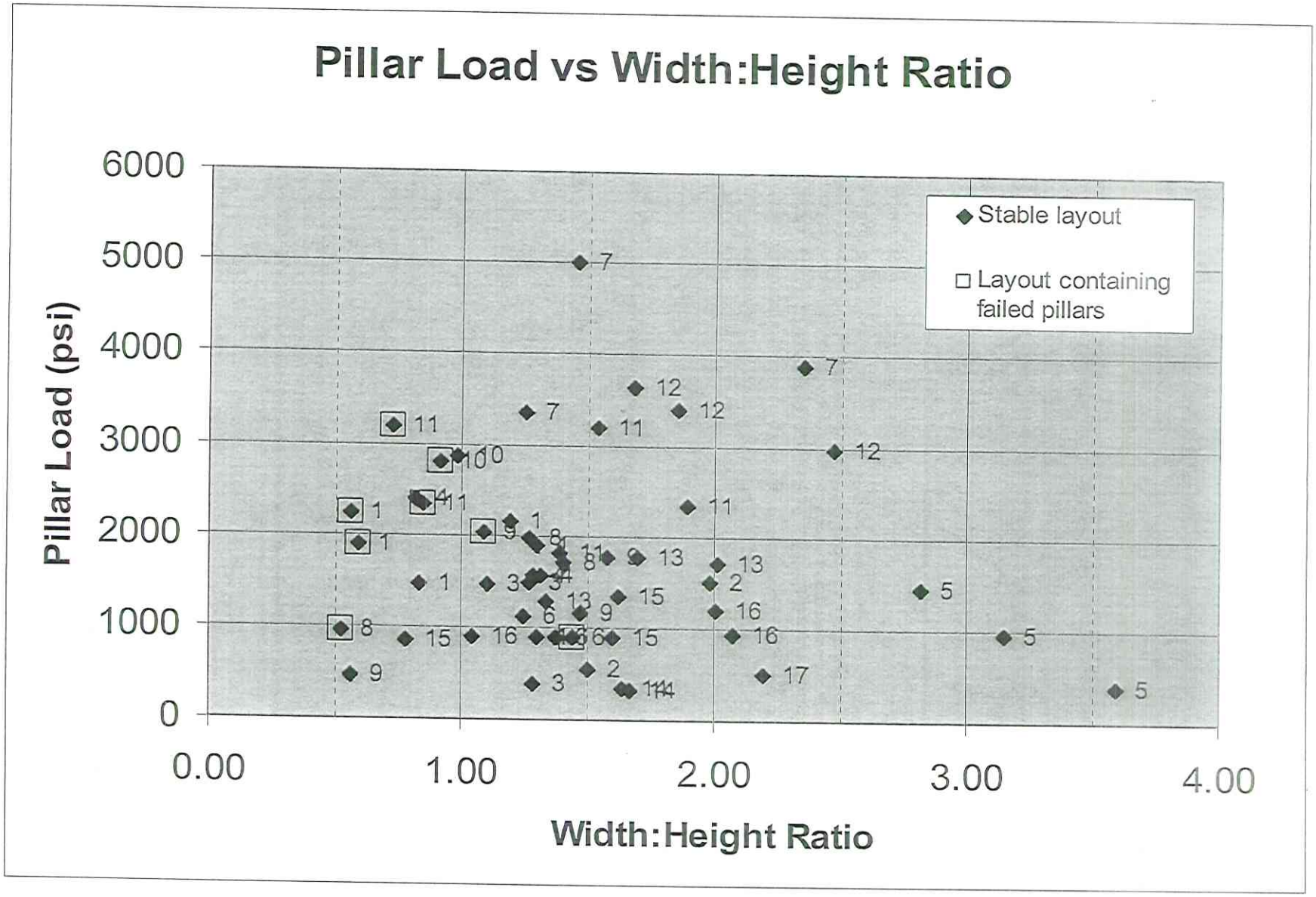


Figure 1: Pillar Load vs width-to-height ratio

Figure 1 shows the relationship between pillar width-to-height ratio and pillar load. The Figure also shows pillar layouts that contained one or more unstable pillars. We intend to add more points to this chart during 2006 so that we can develop guidelines relating pillar load to width-to-height ratio. The approximate pillar load was calculated as:

$$Load = \frac{1.2 \times h}{(1-e)} \quad (psi)$$

Where h is the depth of cover in feet and e is the extraction ratio.

We also collected data on roof stability, which is summarized in Table 2. We measured room widths as well as the diagonal distance across intersections, measured from pillar corner-to-corner in mines that have a square pillar layout. This gives us an indication of the maximum roof span in the workings. Almost every mine visited had some occurrences of roof falls. The falls were mostly caused by local geological structure such as faults, major slips or joints. Signs of roof damage caused by high horizontal stress were observed in four mines. We intend to investigate the horizontal stress issue in greater detail in 2006 and 2007. Regular roof support was used in 46% of the areas visited, while the remainder either did not use any roof support (39%), or used spot bolting (15%), as required.

I trust this information is of value to you. We enjoyed the site visits and the opportunity to interact with you. We appreciate your assistance with this project.

Sincerely

G.S. (Essie) Esterhuizen
Senior Service Fellow
NIOSH Pittsburgh Research Laboratory
Tel: 412-386-5207

Attachments.

30 CFR Metal and Nonmetal Mines, Part 57, Subpart B Ground Control:

§57.3200 Correction of hazardous conditions.

Ground conditions that create a hazard to persons shall be taken down or supported before other work or travel is permitted in the affected area. Until corrective work is completed, that area shall be posted with a warning against entry and, when left unattended, a barrier shall be installed to impede unauthorized entry.

§57.3201 Location for performing scaling.

Scaling shall be performed from a location which will not expose persons to injury from falling material, or other protection from falling material shall be provided.

§57.3202 Scaling Tools.

Where manual scaling is performed, a scaling bar shall be provided. This bar shall be of a length and design that will allow the removal of loose material without exposing the person performing the work to injury.

§57.3203 Rock Fixtures.

(a) For rock bolts and accessories addressed in ASTM F432-95, "Standard Specification for Roof and Rock Bolts and Accessories," the mine operator shall-

(1) Obtain a manufacturer's certification that the material was manufactured and tested in accordance with the specifications of ASTM F432-95; and

(2) Make the certification available to an authorized representative of miners.

(b) Fixtures and accessories not addressed in ASTM F432-95 may be used for ground support provided they-

(1) Have been successful in supporting the ground in an area with similar strata, opening dimensions and ground stresses in any mine; or

(2) Have been tested and shown to be effective in supporting ground in an area of the affected mine which has similar strata, opening dimensions, and ground stresses as the area where the fixtures are expected to be used. During the test process, access to the test area shall be limited to persons necessary to conduct the test.

(c) Bearing plates shall be used with fixtures when necessary for effective ground support.

(d) The diameter of the finishing bits shall be within a tolerance of plus or minus 0.030 inch of the manufacturer's recommended hole diameter for the anchor used. When separate finishing bits are used, they shall be distinguishable from other bits.

(e) Damaged of deteriorated cartridges of grouting material shall not be used.

(f) When rock bolts tensioned by torqueing are used as a means of ground support.

(1) Selected tension level shall be-

(i) At least 50 percent of either the yield point of the bolt or anchorage capacity of the rock, whichever is less; and

(ii) No greater than the yield point of the bolt or anchorage capacity of the rock.

(2) The torque of the first bolt, every tenth bolt, and the last bolt installed in each work area during the shift shall be accurately determined immediately after installation. If the torque of any fixture tested does not fall within the installation torque range, corrective action shall be taken.

(g) When grouted fixtures can be tested by applying torque, the first fixture installed in each work place shall be tested to withstand 150 foot-pounds of torque. Should it rotate in the hole, a second fixture shall be tested in the same manner. If the second fixture also turns, corrective action shall be taken.

(h) When other tensioned and non-tensioned fixtures are used, test methods shall be established and used to verify their effectiveness.

(i) The mine operator shall certify that tests were conducted and make the certification available to an authorized representative of the Secretary.

§57.3360 Ground support use.

Ground support shall be used where ground conditions, or mining experience in similar ground conditions in the mine, indicate that it is necessary, the support system shall be designed, installed, and maintained to control the ground in places where persons where performing their assigned tasks. Damaged, loosened, or dislodged timber use for ground support which creates a hazard to persons shall be repaired or replaced prior to any work or travel in the affected area.

§57.3400 Secondary Breakage.

Prior to secondary breakage operations, the material to be broken, other than hanging material, shall be positioned or blocked to prevent movement which would endanger persons in the work area. Secondary breakage shall be performed from a location which would not expose persons to danger.

§57.3401 Examination of ground conditions.

Persons experienced in examining and testing for loose ground shall be designated by the mine operator. Appropriate supervisors or other designated persons shall examine and, where applicable, test ground conditions in areas where work commencing, after blasting, and as ground conditions warrant during the work shift. Underground haulageways and travelways and surface area highwalls and banks adjoining travelways shall be examined weekly or more often if changing ground conditions warrant.

§57.3430 Activity between machinery or equipment and the highwall of bank.

Persons shall not work or travel between machinery or equipment and the highwall or bank where the machinery or equipment may hinder escape from falls or slides of the highwall or bank. Travel is permitted when necessary for persons to dismount.

§57.3460 Maintenance between machinery or equipment and ribs.

Persons shall not perform maintenance work between machinery or equipment and ribs unless the area has been tested and, when necessary, secured.

§57.3461 Rock bursts.

(a) Operators of mine which have experienced a rock burst shall-

(1) Within twenty four hours report to the nearest MSHA office each rock burst which:

(i) Causes persons to be withdrawn;

(ii) Impairs ventilation;

(iii) Impedes passage; or

(iv) Disrupts mining activity for more than one hour.

(2) Develop and implement a rock burst control plan within 90 days after a rock burst has been experienced.

(b) Then plan shall include-

(1) Mining and operating procedures designed to reduce the occurrence of rock bursts;

(2) Monitoring procedures where detection methods are used; and

(3) Other measures to minimize exposure of persons to areas which area prone to rock bursts.

(c) The plan shall be updated as conditions warrant.

(d) The plan shall be available to an authorized representative of the Secretary and to miners or their representatives.