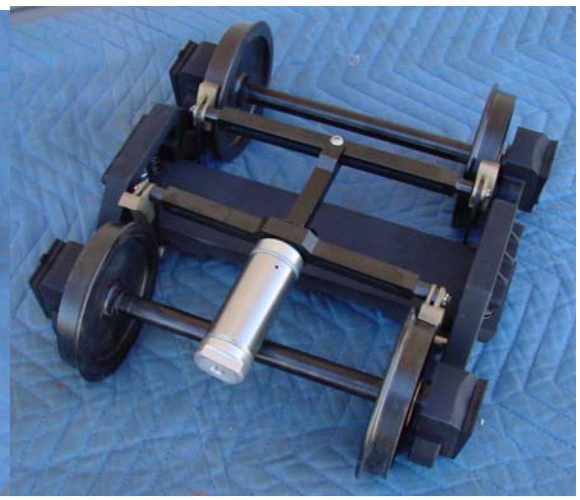
Air Brakes From Real Trains

Real Trains has been producing air brake systems for our 1 1/2" scale trucks for more than seventeen years. In this time over 100 pairs of trucks equipped with air brakes have been sold to modelers all over the world. The original design of this system is still what is offered today, a proven, reliable system.

On freight car trucks the cylinders operate to directly spread the brake beams apart, applying the brakes by pressing the shoes against the wheels. Our passenger trucks differ in that the brake beams are mounted beyond the wheels (referred to as "outside hung") but the cylinders operate to pull the brake beams together, otherwise being the same as the freight trucks.

It is important to realize that trucks must flex to follow uneven track. Our brakes do not limit the motions of the wheels and flex with the truck even while being applied.

Top View



Bottom View

Matching of Brake Forces to Cars

The ideal configuration for any brake system is to have all cars of the same type and about the same load. If the brakes on these cars are controlled separately from the locomotive they will then only need to have one size of brake cylinder. The selection of this cylinder is based on the expected average weight.

Where a mixed consist of cars having various weights is present, or where brake systems from various manufacturers are used, or where the car brakes are controlled by the same system as the locomotive brakes, it is necessary to carefully balance the brake forces for each brake system.

Real Trains®

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Real Trains understands this need to provide a wide range of brake forces. A “one size fits all” approach is not viable. In order to do this we stock and ship brake cylinders in the following diameters:

- 7/16”
- 1/2”
- 5/8”
- 3/4”
- 7/8”
- 1 1/16”
- 1 1/4”
- 1 1/2”

This range of products allows us to match brake forces exactly to each car. We have long supported this idea of balanced system and encourage all modelers to configure their systems for best operation. In support of this we offer a cylinder exchange program where, for a low cost, you may exchange our brake components for another size after you have tried them on your train.

Single versus Double Acting Air Cylinders

Real Trains supplies a full range of air brake cylinder diameters in both single acting and double acting versions. A single acting cylinder applies air on only one side of the piston (most commonly on the side that makes the rod extend) to apply the brakes. They use a spring to move the piston back to its initial position when the brakes are to be released. A vent allows air on the spring side of the piston to move in and out as needed.

Double acting cylinders do not contain a spring. They apply air to each side of the piston separately. The ratio of the pressures between the two sides of the piston determines in which direction it moves These double acting cylinders allow the simple construction of automatic (safety) air brakes.

Basics of Straight Air Brakes

A straight air brake system (see Figure 1) uses air pressure to move a piston that makes the system apply the brakes. Depending on design details the air cylinder may use linkages, beams, etc. to apply the braking force to one or more of the shoes. The linkage, if used, may also multiply or divide the piston force by some fixed ratio.

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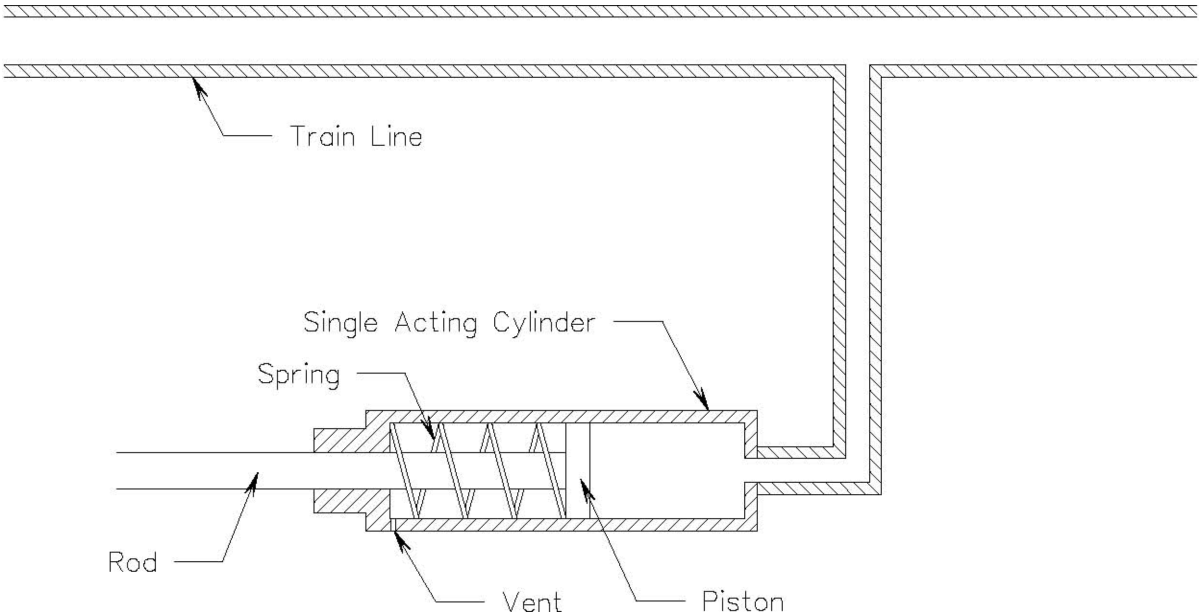

Figure 1 – Straight Air Brake System

In the case of Real Trains brakes the cylinder is mounted to one brake beam and the rod applies force to the other brake beam with a pivoting clevis. This allows all four brake shoes to move independently to adjust to wheel movement due to spring travel and for wear. To calculate this force we use the equation:

$$F = (LP * PI * (CD / 2)^2) – SF$$

Where:

F = force in pounds generated against brake beam
LP = train line pressure in psi
PI = 3.1415
CD = diameter of cylinder bore in inches
SF = force of return spring when compressed in pounds

Since the force of the piston is directly applied to the brake beam that connects two brake shoes, this means that one half of the force is applied to each shoe. The force per shoe is then one-half of the value "F".

If we assume two four wheel trucks with one shoe per wheel the total shoe force is eight times this individual force and the brake ratio is this total shoe force divided by the weight of the car and then expressed as a percentage. As an equation this is:

$$BR = ((F / 2) * 8) / WC * 100\%$$

Where:

BR = brake ratio as a percentage
F = force from equation above
WC = weight of car in pounds

The spring pressure at full travel is used because that is the worst case condition reached when, due to wear, the cylinder must extend as far as possible. These spring forces are standard between most manufacturers. Unlike the prototype, our model brakes do not have enough weight to overcome friction and return to their released position without the use of a spring.

Automatic Air Brakes

Automatic air brakes offer the increased protection of automatic application whenever the train line (main air brake line between cars) fails, or is separated in an accident. Their disadvantage is increased maintenance and a need for operator understanding of their limitations.

Automatic system all use control valves, regulators, etc. mounted on each car. Each of these items requires periodic inspection and maintenance to assure ongoing reliable operation. Unlike a locomotive which is usually serviced before each run day, cars are often simply pulled out and coupled up to run. A club must decide if its maintenance personnel will insure that the cars get proper service to allow the automatic systems to provide the safety expected from them. Nothing is worse than an expected safety system that does not work when it is finally needed. In the experience of Real Trains automatic systems are more common on privately owned cars where the person running them is interested in the brakes and spends the time to make them run right.

Automatic systems also require knowledge of their limitations by the engineer. Repeated partial applications along with the leakage that is normal with wear can slowly reduce the reservoir pressure to a point that an emergency full application may not be possible.
attached to the cars. Most safety chains are attached off to one side of the coupler and run diagonally under the coupler to their attachment, again off to the side of the centerline, on the other car. When the coupler fails or disengages the chain is pulled tight and applies a sideways force to both of the cars due to the off center attachment. This can derail other cars in the train not involved in the initial problem.

This is not the case with a drawbar. Properly designed drawbars allow the necessary movements while remaining on the centerline of the car. A drawbar is no more likely to cause a derailment than a coupler that remains coupled. While you can certainly find a case where a drawbar was not as good as an uncoupled coupler, you can also find many cases where couplers caused an accident (for example a separated rear section ramming into a stopped front section).

Automatic Air Brakes Without Special Parts

An automatic air brake system can be built using industry standard parts that are easily replaced as shown in Figure 2.

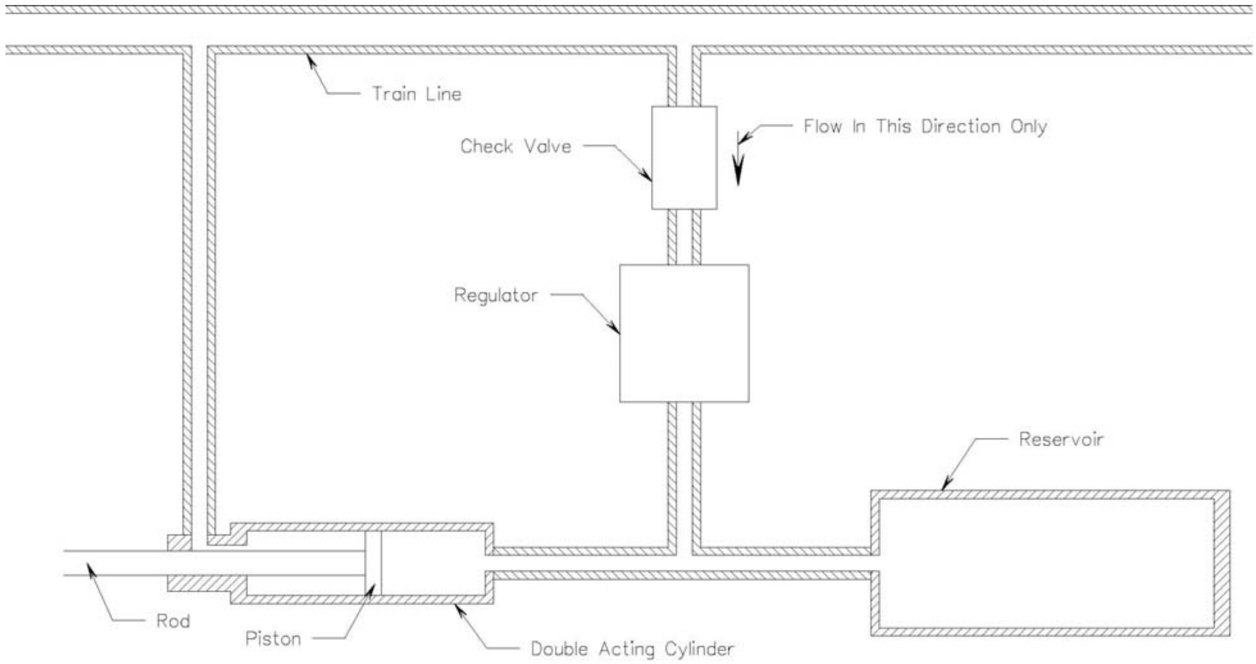

Figure 2 – Automatic Air Brake System

This system operates by using air pressure in the train line to release the brakes and pressure in the reservoir (supply tank) to apply them. It is important to understand that the balance between the forces on the piston and rod will make them move in one direction or the other and apply or release the brakes. Note here that we say the forces, not the pressures. In a double acting cylinder the same air pressure applied to both sides will always make the rod fully extend. This is due to the fact that the area on non-rod side is equal to the area of the piston while the area on the rod side is the area of the piston minus the area of the rod.

This means that, to remain in a balanced position, the pressure on the non-rod side must always be less. This is the reason for the pressure regulator in this system. If we assume a 7/8" diameter cylinder the area of the piston is 0.6013 square inches. Since the rod in this size cylinder is 1/4" in diameter its area is 0.0491 square inches. This results in an effective area on the rod side of 0.5522 square inches. With a maximum train line pressure of 85psi the force acting to release the brakes is 46.94 pounds.

To produce this same force on the other side of the cylinder requires approximately 78psi. This means that if we allow the reservoir pressure to rise above this value the train line pressure cannot release the brakes. In an actual system friction must be overcame to start movement and so we usually allow three or four psi below this value, say 74psi. The is the pressure that the regulator would be set for.

The check valve is needed because most regulators will reduce the pressure on their outlet when the input pressure is lowered. Since the brakes are applied by reducing the inlet pressure the check valve holds full pressure in the reservoir. In a practical system a dump valve to release the pressure and allow car movement would also be included.

In the work above we calculated a force on the rod. However, this is not the force available to operate the brakes. Once the check valve closes that part of the system becomes closed and has only the air volume that it contains to work with. When the cylinder extends to apply the brakes the total volume of the system will increase and the pressure will decrease. If we assume a reservoir volume of five times the cylinder volume, and the volume of the rest of the system after the check valve equal to the cylinder volume the pressure in the cylinder when extended will be 6/7ths of the initial pressure. Starting with 74psi this will give us approximately 38 pounds applied to the brake beam.

Please note that this applies to all automatic air brake systems. Failure to understand these issues leads to unobtainable values of brake ratio.

For an automatic air brake system the force equation becomes:

$$F = ((LP - FP) * PI * ((CD / 2)^2 - (RD / 2)^2)) * VR$$

Where:

F = force in pounds generated against brake beam
LP = train line pressure in psi
PI = 3.1415
CD = diameter of cylinder bore in inches
RD = diameter of rod in inches
FP = air pressure needed to overcome friction, assumed to be 4psi
VR = ratio of volumes of reservoir and piping to reservoir, piping and extended cylinder

Calculation of brake ratios is the same as presented before. You do not need to calculate these values, tables for each of the cylinder sizes that we use are presented at the end of this report

Train Line Pressures

After selling many system we have found that most customers use a train line pressure in the 80 to 85psi range. While most of the commonly available air fittings and cylinders are designed for pressures up to 250psi there are reasons why these pressures are not used.

The most common limitation is the compressors available. Finding reliable air compressors that will fit the size limitations of our trains and that operate off of 12 volts DC is difficult. Most of these small compressors state that they are capable of pressures up to 150psi. It is important to understand what this pressure means.

In a compressor of the type we most commonly will use the air is compressed by a piston or a diaphragm. Since both operate the same we will focus on the piston type. With the piston at the bottom of its stroke its cylinder is at maximum volume. At the top of the stroke the volume is now minimum. It is important to realize that the minimum volume is never zero. There are spaces around the piston and passages to the valves that always have some volume.

Normal air pressure at sea level is 14.7psi (this is in reference to an absolute pressure of zero, the gauges we use read in "gauge" air pressure where zero is equal to this atmospheric pressure). If a compressor has a compression ratio of 10 to 1 it will compress the air to one-tenth its initial volume and raise the pressure by 10 times.

If you ask such a compressor to produce a higher pressure it cannot. If the pressure in the system beyond the compressor is more than this the compressor cannot ever compress the air enough to open its outlet check valve and its output volume will be zero. This zero output is reached gradually with the compressor putting out less and less air as its limit is approached. In small compressors the ratio of the maximum to minimum volumes during the piston stroke are more limited than in larger systems. Most small compressors start to have problems producing much over 100psi.

In a practical system an air tank is usually used. The volume of this tank prevents the compressor from having to start and stop all the time. Usually a pressure switch is used to start and stop the compressor as needed to keep the tank pressure above some minimum value. Since the start and stop pressures must be different it is common to have a minimum tank pressure of 90psi. Given allowance for flow restrictions and errors in setup a train line pressure of 85psi seems to be a good compromise.

Brake Ratios for Real Trains Air Brakes

The following pages show the brake ratios for our systems. Note that these are done at train line pressures of 85psi, 100psi, and 125 psig.

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Straight Air Brakes - Single Acting Cylinders

Train Line
Pressure = 85

		Brake Ratio for Car Weight of:														
Cylinder Diameter	Spring Force (maximum)	100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	2	86%	43%	29%	22%	17%	14%	12%	12%	10%	9%	8%	7%	7%	6%	6%
1/2	2	118%	59%	39%	29%	24%	20%	17%	17%	13%	12%	11%	10%	9%	8%	8%
9/16	4	137%	68%	46%	34%	27%	23%	20%	20%	15%	14%	12%	11%	11%	10%	9%
5/8	6	161%	80%	54%	40%	32%	27%	23%	23%	18%	16%	15%	13%	12%	11%	11%
3/4	6	252%	126%	84%	63%	50%	42%	36%	36%	28%	25%	23%	21%	19%	18%	17%
7/8	6	361%	180%	120%	90%	72%	60%	52%	52%	40%	36%	33%	30%	28%	26%	24%
1 1/16	6	555%	277%	185%	139%	111%	92%	79%	79%	62%	55%	50%	46%	43%	40%	37%
1 1/4	15	714%	357%	238%	179%	143%	119%	102%	102%	79%	71%	65%	60%	55%	51%	48%
1 1/2	12	1106%	553%	369%	276%	221%	184%	158%	158%	123%	111%	101%	92%	85%	79%	74%

Straight Air Brakes - Single Acting Cylinders

Train Line
Pressure = 100

		Brake Ratio for Car Weight of:														
Cylinder Diameter	Spring Force (maximum)	100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	2	104%	52%	35%	26%	21%	17%	15%	15%	12%	10%	9%	9%	8%	7%	7%
1/2	2	141%	71%	47%	35%	28%	24%	20%	20%	16%	14%	13%	12%	11%	10%	9%
9/16	4	167%	83%	56%	42%	33%	28%	24%	24%	19%	17%	15%	14%	13%	12%	11%
5/8	6	197%	99%	66%	49%	39%	33%	28%	28%	22%	20%	18%	16%	15%	14%	13%
3/4	6	305%	153%	102%	76%	61%	51%	44%	44%	34%	31%	28%	25%	23%	22%	20%
7/8	6	433%	217%	144%	108%	87%	72%	62%	62%	48%	43%	39%	36%	33%	31%	29%
1 1/16	6	661%	331%	220%	165%	132%	110%	94%	94%	73%	66%	60%	55%	51%	47%	44%
1 1/4	15	862%	431%	287%	215%	172%	144%	123%	123%	96%	86%	78%	72%	66%	62%	57%
1 1/2	12	1318%	659%	439%	329%	264%	220%	188%	188%	146%	132%	120%	110%	101%	94%	88%

Straight Air Brakes - Single Acting Cylinders

Train Line
Pressure = 125

Cylinder Diameter	Spring Force (maximum)	Brake Ratio for Car Weight of:														
		100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	2	67%	34%	22%	17%	13%	11%	10%	10%	7%	7%	6%	6%	5%	5%	4%
1/2	2	90%	45%	30%	23%	18%	15%	13%	13%	10%	9%	8%	8%	7%	6%	6%
9/16	4	108%	54%	36%	27%	22%	18%	15%	15%	12%	11%	10%	9%	8%	8%	7%
5/8	6	129%	65%	43%	32%	26%	22%	18%	18%	14%	13%	12%	11%	10%	9%	9%
3/4	6	197%	98%	66%	49%	39%	33%	28%	28%	22%	20%	18%	16%	15%	14%	13%
7/8	6	277%	138%	92%	69%	55%	46%	40%	40%	31%	28%	25%	23%	21%	20%	18%
1 1/16	6	419%	210%	140%	105%	84%	70%	60%	60%	47%	42%	38%	35%	32%	30%	28%
1 1/4	15	554%	277%	185%	138%	111%	92%	79%	79%	62%	55%	50%	46%	43%	40%	37%
1 1/2	12	836%	418%	279%	209%	167%	139%	119%	119%	93%	84%	76%	70%	64%	60%	56%

Automatic Air Brakes - Double Acting Cylinders

Train Line Pressure = 85

Volume Ratio = 6/7

		Brake Ratio for Car Weight of:														
Cylinder Diameter	Rod Diameter	100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	3/16	34%	17%	11%	9%	7%	6%	5%	5%	4%	3%	3%	3%	3%	2%	2%
1/2	3/16	47%	23%	16%	12%	9%	8%	7%	7%	5%	5%	4%	4%	4%	3%	3%
9/16	3/16	61%	31%	20%	15%	12%	10%	9%	9%	7%	6%	6%	5%	5%	4%	4%
5/8	1/4	72%	36%	24%	18%	14%	12%	10%	10%	8%	7%	7%	6%	6%	5%	5%
3/4	1/4	109%	55%	36%	27%	22%	18%	16%	16%	12%	11%	10%	9%	8%	8%	7%
7/8	1/4	153%	77%	51%	38%	31%	26%	22%	22%	17%	15%	14%	13%	12%	11%	10%
1 1/16	5/16	225%	112%	75%	56%	45%	37%	32%	32%	25%	22%	20%	19%	17%	16%	15%
1 1/4	7/16	299%	150%	100%	75%	60%	50%	43%	43%	33%	30%	27%	25%	23%	21%	20%
1 1/2	7/16	449%	224%	150%	112%	90%	75%	64%	64%	50%	45%	41%	37%	35%	32%	30%

Automatic Air Brakes - Double Acting Cylinders

Train Line Pressure = 100

Volume Ratio = 6/7

Cylinder Diameter	Rod Diameter	Brake Ratio for Car Weight of:														
		100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	3/16	40%	20%	13%	10%	8%	7%	6%	6%	4%	4%	4%	3%	3%	3%	3%
1/2	3/16	56%	28%	19%	14%	11%	9%	8%	8%	6%	6%	5%	5%	4%	4%	4%
9/16	3/16	73%	36%	24%	18%	15%	12%	10%	10%	8%	7%	7%	6%	6%	5%	5%
5/8	1/4	85%	42%	28%	21%	17%	14%	12%	12%	9%	8%	8%	7%	7%	6%	6%
3/4	1/4	129%	65%	43%	32%	26%	22%	18%	18%	14%	13%	12%	11%	10%	9%	9%
7/8	1/4	182%	91%	61%	45%	36%	30%	26%	26%	20%	18%	17%	15%	14%	13%	12%
1 1/16	5/16	267%	133%	89%	67%	53%	44%	38%	38%	30%	27%	24%	22%	21%	19%	18%
1 1/4	7/16	354%	177%	118%	89%	71%	59%	51%	51%	39%	35%	32%	30%	27%	25%	24%
1 1/2	7/16	532%	266%	177%	133%	106%	89%	76%	76%	59%	53%	48%	44%	41%	38%	35%

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Automatic Air Brakes - Double Acting Cylinders

Train Line Pressure = 125

Volume Ratio = 6/7

Cylinder Diameter	Rod Diameter	Brake Ratio for Car Weight of:														
		100	200	300	400	500	600	700	700	900	1000	1100	1200	1300	1400	1500
7/16	3/16	51%	25%	17%	13%	10%	8%	7%	7%	6%	5%	5%	4%	4%	4%	3%
1/2	3/16	70%	35%	23%	17%	14%	12%	10%	10%	8%	7%	6%	6%	5%	5%	5%
9/16	3/16	92%	46%	31%	23%	18%	15%	13%	13%	10%	9%	8%	8%	7%	7%	6%
5/8	1/4	107%	53%	36%	27%	21%	18%	15%	15%	12%	11%	10%	9%	8%	8%	7%
3/4	1/4	163%	81%	54%	41%	33%	27%	23%	23%	18%	16%	15%	14%	13%	12%	11%
7/8	1/4	229%	115%	76%	57%	46%	38%	33%	33%	25%	23%	21%	19%	18%	16%	15%
1 1/16	5/16	336%	168%	112%	84%	67%	56%	48%	48%	37%	34%	31%	28%	26%	24%	22%
1 1/4	7/16	447%	223%	149%	112%	89%	74%	64%	64%	50%	45%	41%	37%	34%	32%	30%
1 1/2	7/16	671%	335%	224%	168%	134%	112%	96%	96%	75%	67%	61%	56%	52%	48%	45%