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## Commercial Walk-Behind Lawn Mower Failure Analysis Case Study

By Dennis B. Brickman\*

### ABSTRACT

A failure modes and effects testing program was conducted to analyze the cause of a mid-size commercial walk-behind lawn mower accident in which the operator's foot came in contact with the rotating blade. Systematic analysis showed that the accident was caused by improper mower service and operator misuse of the mower. Testing results reveal that an alternative design proposal does not preclude this random event. Accident prevention countermeasures are explored.

### INTRODUCTION

#### Mower Description

The subject mid-size commercial walk-behind lawn mower depicted in Fig. 1 utilizes a pair of three position traction control levers at the operator's console as shown in Fig. 2. When both traction control levers are released into the traction engage position, the mower has straight forward propulsion without requiring the operator to maintain contact with the levers. When both traction control levers are fully squeezed, the wheel drive clutch is disengaged and a friction brake

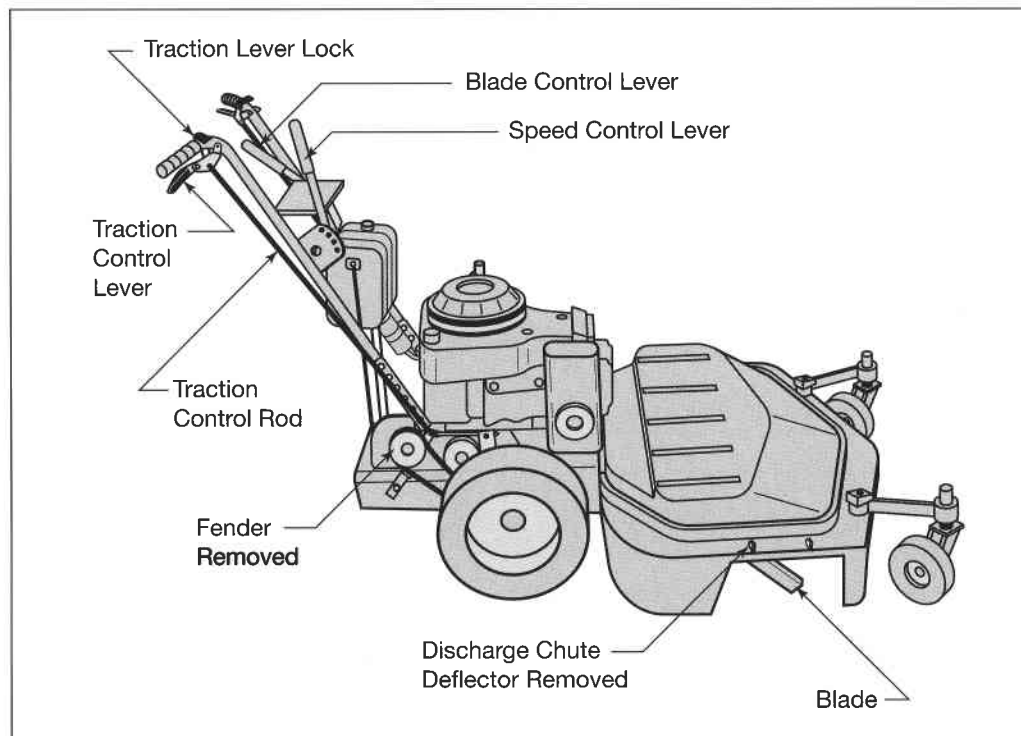


Figure 1 - Commercial Walk-Behind Lawn Mower

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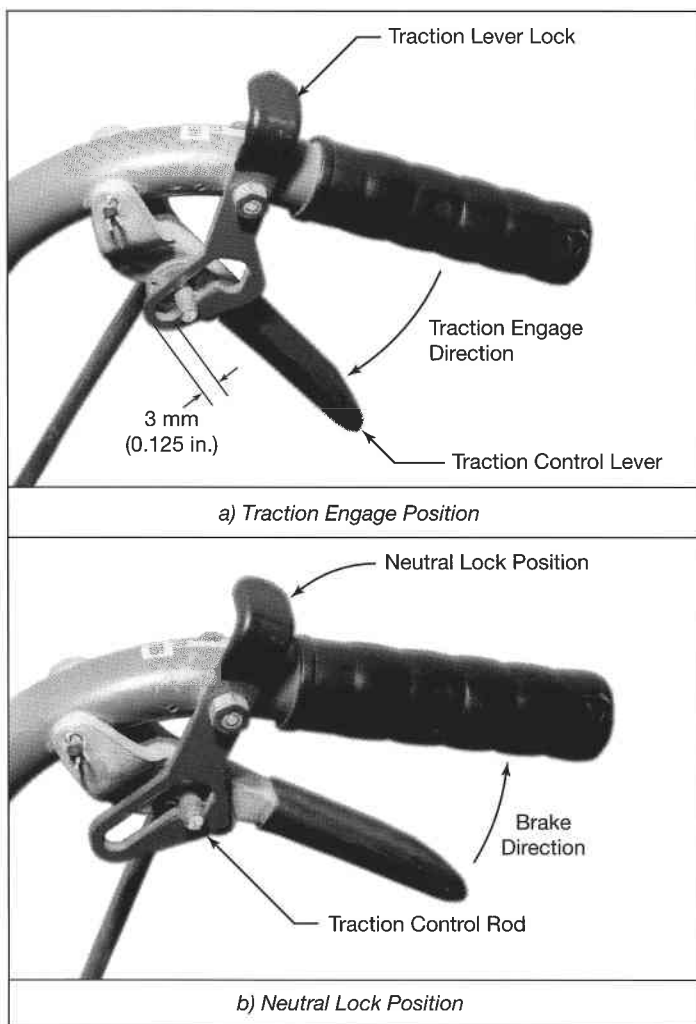


Figure 2 – Right Traction Control

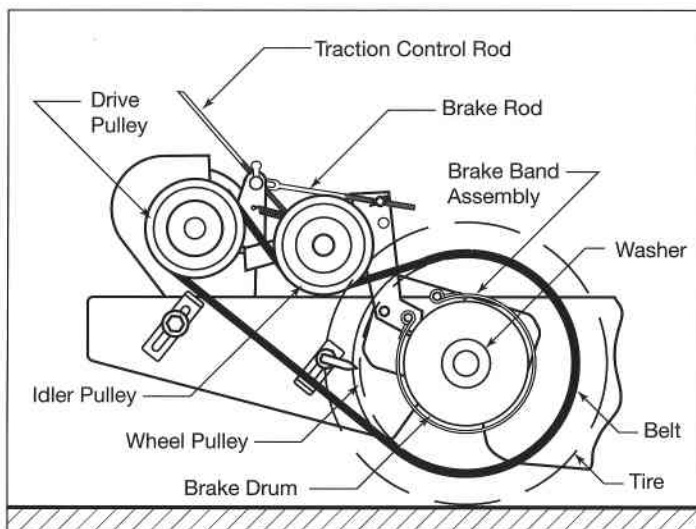


Figure 3 – Right Wheel Drive Clutch/Brake Assembly in Brake Position (Fender Removed)

is applied which stops the forward propulsion of the mower as illustrated in Fig. 3. When the traction control levers are placed into the intermediate neutral position by applying the traction lever locks, the mower's wheel drive is disengaged, but no additional braking is applied to the wheels. The mower utilizes a skid-steer concept for steering. In order to make a right turn, the right traction control lever is squeezed into the intermediate neutral or fully

squeezed brake positions while the left traction control lever remains in the traction engaged position. The sharpness of the turn is proportional to the degree of squeezing of the right traction control lever. When the right traction control is fully squeezed into the brake position, the right drive wheel stops rotating and the mower makes a sharp right turn about the right drive wheel. If the right traction control lever is placed into the neutral position, the right drive wheel continues to rotate as the mower makes a gradual right turn. Similarly, squeezing the left traction control lever while the right traction lever remains in the traction engaged position causes the mower to make a left turn.

### Accident Description

At the time of the accident, the mower operator was attempting to maneuver the mower around an evergreen tree on flat terrain by making a clockwise gradual right turn followed by a left turn. The mower propulsion speed was set at the fastest position. The operator attempted to release the slightly depressed right traction operator control lever and squeeze the left traction control lever. However, the mower made a sharp right turn while the operator continued walking straight ahead, resulting in the operator's left foot contacting the moving blade. The operator ended up on top of the mower and he was able to shut off the engine. It was alleged by the mower operator that the right traction control lever locked in the neutral position after he released his right hand from the lever which caused the mower to make a sharp right turn. The operator's employer, however, had to lock the traction locks in to start the mower following the accident.

### Mower History

Less than a week before the accident, the subject mower was brought into a lawn mower service shop because it was not driving and stopping properly due to a bent transmission shaft pulley and worn traction belts. According to the service order, the following service items were performed on the mower:

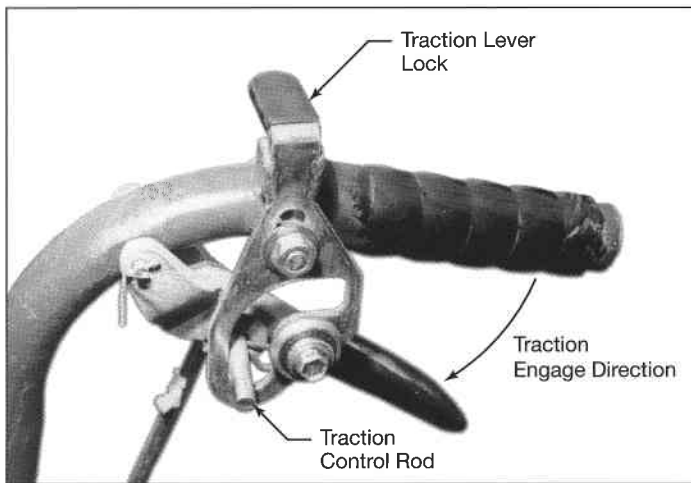
1. Replaced drive pulleys and belts.
2. Replaced brakes.
3. Replaced left and right wheel bearings.
4. Installed grease fitting on left and right wheels.
5. Greased machine.
6. Replaced traction levers and pins.

The mower was picked up by its owner the day before the accident after these service items were performed.

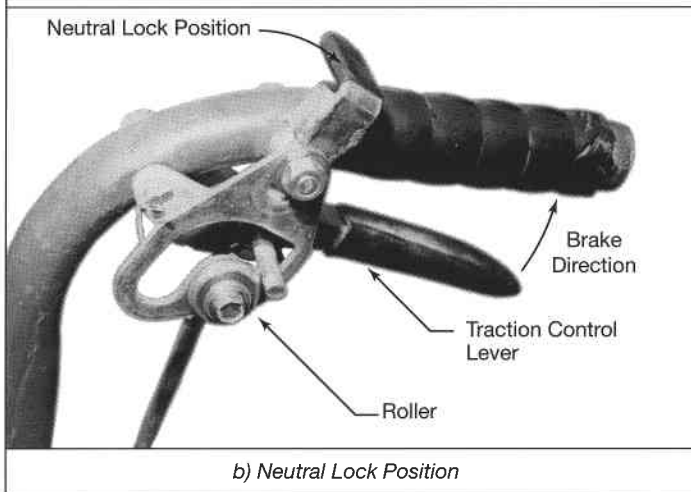
On the day of the accident, the operator felt the mower proceeding in a gradual right turn, comparable to an automobile that is pulling to the right. This pulling required constant corrective action with the left traction control. In addition, the operator experienced the mower making sharp right turns after releasing the right traction control lever when making 180 degree right turns on multiple occasions throughout the day of the accident. At lunch, the operator told his employer that he was having problems with the mower. Nevertheless, the operator continued to use the mower in its condition until his accident occurred.

Three to four weeks after the accident, the mower owner operated the subject mower and noticed that the mower pivoted to the right. After the accident, the mower owner sold the subject mower to another landscaper who also experienced the mower making sharp right turns three or four times after releasing the right traction control lever during 180 degree turns. The mower did not continue to make a sharp right turn when the new owner made a slight right turn.

A month after the accident, the new owner brought the subject mower back to the service shop for additional work. The following additional service work was performed:



a) Traction Engage Position



b) Neutral Lock Position

Figure 4 – Right Traction Control Position with Roller Lock

1. Installed new style roller locks.
2. Adjusted brakes and clutches.

It was alleged by the injured operator that his accident would not have occurred had the new style roller locks shown in Fig. 4 been equipped on the subject mower.

## ACCIDENT INVESTIGATION

After the accident, various investigators made the following observations regarding the subject mower:

1. With the traction control levers in the neutral position, the left wheel was in a free wheeling state as originally designed by the mower manufacturer while the right wheel was noticeably dragging.
2. The left and right brake assemblies were of totally different design fabrication.
3. The spacer washer that maintains proper clearance between the wheel and pulley component and the neighboring brake assembly was measured to be 6.35 mm (0.250 in.) thick on the left wheel as originally designed by the mower manufacturer and 4.76 mm (0.188 in.) on the right wheel.
4. There was considerable circular scoring present on the right brake band anchor plate at the radius of the brake drum.
5. There was a 3.18 mm (0.125 in.) indentation of the wheel pulley rim. In addition, a gouge mark was observed on the pulley caused by interference between the pulley indentation and the brake band pivot anchor.
6. Neither the originally equipped discharge chute deflector nor a grass catcher was present on the mower.

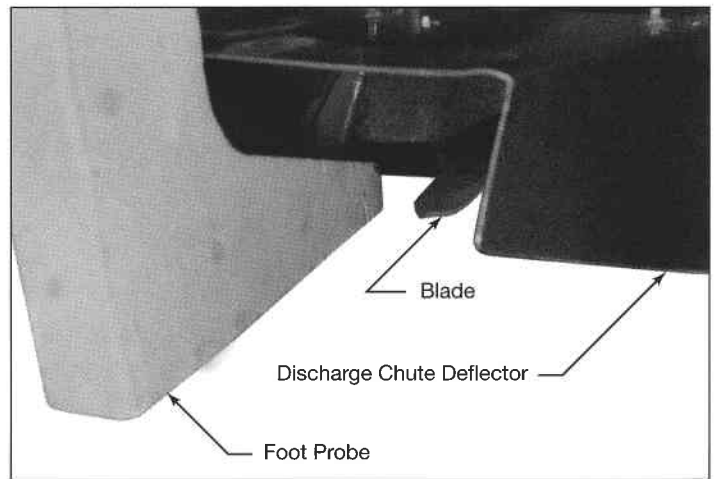


Figure 5 – ANSI B71.4-1984 Foot Probe Test

## TESTING PROGRAM

### Discharge Chute Testing

**ANSI B71.4-1984 Foot Probe Testing.** In accordance with the test protocol outlined in paragraph 8.3.2 of ANSI B71.4-1984 (1), the prescribed wooden foot probe was inserted into the discharge opening of an exemplar mower equipped with the original discharge chute deflector as shown in Fig. 5. The mower complied with the ANSI B71.4-1984 foot probe test acceptance requirement by not allowing the probe to enter the path of the blade. The foot probe test was repeated with the discharge chute deflector removed and the probe made contact with the blade. Finally, the probe was inserted under the front of the exemplar mower deck and the probe did not make blade contact. These tests were repeated using a live human foot wearing a sneaker and similar results were obtained.

**Stationary Mower - Dynamic Dummy Discharge Chute Testing.** A 1.73 m (68 in.) tall anthropomorphic dummy weighing 76.7 kg (169 lb) was swung in a pendulum fashion into the discharge chute deflector of the stationary exemplar mower. The feet of the dummy dynamically impacted against the discharge chute deflector at the bottom of the dummy's travel path. Tests were conducted multiple times with the dummy oriented perpendicular and parallel to the mower. The dummy's feet did not make blade contact and the discharge chute deflector remained in its original position during all the tests.

**Dynamic Mower - Stationary Dummy Discharge Chute Testing.** The path of the exemplar mower was set such that it made a right turn into the feet of a stationary anthropomorphic dummy. During the first test, the front of the mower deck contacted the dummy's feet. During the second test, the discharge chute deflector contacted the dummy's feet. The dummy's feet did not make blade contact and the discharge chute deflector remained in its original position during these tests.

### Dynamic Right Traction Control Testing

**Normal Mower Condition With Neutral Locks.** A properly adjusted exemplar mower equipped with the original neutral locks was tested to determine if the mower could make a sharp right turn under similar conditions to those that existed at the time of the accident. The following observations were made:

1. When the right traction control lever was slightly squeezed and the left traction control lever was in the traction engaged position, the mower made a slight right turn.
2. When the right traction control lever was fully squeezed and the left traction control lever was placed in the traction engaged position, the mower made a sharp right turn.

3. When the right traction control lever was locked into the neutral position and the left traction control lever was placed in the traction engaged position, the mower made a gradual right turn sharper than in case #1.
4. When the right traction control lever was slightly squeezed and then released and the left traction control lever was in the traction engaged position, the mower started to make a slight right turn and then proceeded straight forward.
5. No tests resulted in the right traction control locking into the neutral or fully braked position without operator intervention.

**Misadjusted Mower Condition With Neutral Locks.** In order to attempt to recreate the described behavior of the subject mower at the time of the accident, the exemplar mower was intentionally misadjusted as follows:

1. The left and right brake assemblies were of different designs as observed on the subject mower.
2. The right brake assembly was adjusted such that the right wheel was noticeably dragging.
3. The spacer washer between the right wheel and pulley and the neighboring brake assembly was 4.76 mm (0.188 in.) thick as was observed on the subject mower.
4. The right traction control rod end was touching the bottom of the neutral lock slot in the traction engaged position instead of having a 3.18 mm (0.125 in.) gap as specified in the mower manual. This condition produced right wheel drive slipping.

After the exemplar mower was intentionally misadjusted, the following test observations were made:

1. When both traction control levers were placed in the traction engaged position, the mower veered to the right requiring constant left traction control corrective action.
2. After making a right turn and releasing the right traction control lever, the mower continued to make a sharp right turn with the right drive wheel stationary on one occasion.
3. After making a right turn and releasing the right traction control lever, the mower continued to make a sharp right turn with the right drive wheel rotating on multiple occasions. This right turn was not as sharp as in case #2.
4. After making a right turn and releasing the right traction control lever, the mower continued traveling straight forward on multiple occasions.
5. Circular scoring was present on the right brake band anchor plate at the radius of the brake drum.

**Misadjusted Mower Condition With Roller Locks.** During this phase of the testing, roller locks were installed on the exemplar mower to determine if they would prevent the mower behavior described by the operator at the time of the accident. After the roller locks were installed, the mower was misadjusted as described in the aforementioned neutral lock section.

The following test observations were made:

1. When both traction control levers were placed in the traction engaged position, the mower veered to the right.
2. After making a right turn and releasing the right traction control lever, the mower continued to make a sharp right turn with the right drive wheel rotating on multiple occasions.
3. Circular scoring was present on the right brake band anchor plate at the radius of the brake drum.

## COMMERCIAL LAWN MOWER ACCIDENT STATISTICS

The Occupational Safety and Health Administration (OSHA) has conducted investigations of accidents associated with commercial lawn mowers (2). A review of these OSHA accident narratives reveals no other reported instances in which a blade contact injury

occurred due to a sharp right turn when a right traction control lever was released in the manner described by the mower operator. In addition, the manufacturer of the subject mower has not received any reports of similar accidents involving a sharp right turn after the operator released the right traction control lever.

## CONCLUSIONS

The following accident prevention countermeasures could have been utilized by the lawn mower service shop to prevent the subject accident:

1. The lawn mower service shop could have adjusted the subject mower properly according to the instructions in the manual just prior to the accident.
2. The lawn mower service shop could have properly tested the subject mower after servicing the mower just prior to the accident.
3. The lawn mower service shop could have installed a discharge chute deflector according to the on-product warning and in-manual warnings and instructions on the subject mower just prior to the accident.

The following accident prevention countermeasures could have been employed by the operator to prevent his injuries:

1. The operator could have operated the subject mower with a discharge chute deflector in place in accordance with the on-product warning and with the in-manual warnings and instructions.
2. The operator could have stopped using the subject mower.
3. The operator could have made left turns instead of right turns since he was only having problems making right turns.
4. The operator could have positioned himself to the left operator position so that if the mower made a sharp right turn he would be away from the rotation.
5. The operator could have maintained a firm grip on the left traction control lever to stop the propulsion of the mower.
6. The operator could have reduced the speed of the mower from its full fast speed selection.

Results from the testing program on the exemplar mower indicate the following:

1. The subject injury to the mower operator's foot would have been prevented had the discharge chute deflector been in place at the time of the accident.
2. With a properly adjusted mower, the mower will not make a sharp right turn after the right traction control lever is released from a slightly squeezed position as described by the mower operator at the time of his accident.
3. With an improperly adjusted right drive wheel clutch and brake assembly, the mower equipped with the original neutral locks can make a sharp right turn after the right traction control lever is released from a slightly squeezed position as described by the mower operator at the time of his accident.
4. With an improperly adjusted right drive wheel clutch and brake assembly, the mower equipped with the roller locks can still make a sharp right turn after the right traction control lever is released from a slightly squeezed position as described by the mower operator at the time of his accident.

## REFERENCES

1. "American National Standard for Commercial Turf Care Equipment - Safety Specifications," *ANSI B71.4-1984*, American National Standards Institute, New York, May 25, 1984.
2. "Mower Accident Search Detail," Occupational Safety and Health Administration, 1980-1998.