NEW YORK
state department of
HEALTH

FATALITY ASSESSMENT AND CONTROL EVALUATION

Operator Killed when Horizontal Auger Boring Machine Overturned Case Report 11NY043

CASE SUMMARY

In July 2011, a 46 year-old male equipment operator (victim) working for a trenchless utility installation contractor suffered fatal crushing injuries when a horizontal auger boring (HAB) machine overturned. At the time of the incident, the victim was installing three steel pipe casings using a trenchless method called pipe ramming at a municipal water project site. Each casing was 36 in (0.9 m) in diameter and 40 ft. (12 m) long. The casings were driven horizontally through the ground by a pneumatic ramming hammer. On the day of the incident, the victim was operating an HAB machine to bore inside the casings to remove earth material that filled the casings during installation. The machine was mounted on a track assembly and the track assembly was not anchored to the ground. The weight of the machine and the track assembly was 15,800 lbs. (7,167 kg). The victim was operating the machine at the operator's platform located on the left side of the machine (when facing the casing). The incident occurred shortly after 10:00 am when the auger string had advanced approximately 11 ft. (3.4 m) into the casing. The HAB machine along with the track assembly suddenly pitched to the left roughly 90 degrees counterclockwise (Photo 1). Unable to jump free, the victim was pinned by the machine against the ground before the machine swung back to the upright position. Immediately the machine pitched to the left a second time, crushing the victim, and swung back upright before it pitched the third time and rested on its left side with the motor running and the victim pinned underneath. A coworker immediately called 911. Meanwhile an equipment operator at the site used an excavator to move the machine off the victim. The workers were able to turn the machine off and free the victim. They performed CPR on the victim until the EMS arrived. The victim died on route to the hospital as a result of severe crushing injuries.

CONTRIBUTING FACTORS

- Auger boring was conducted without having a casing securely attached to the machine's master casing pusher: a bare auger string bored inside a preinstalled casing.
- Measures to stabilize the boring machine and prevent machine upset were not implemented.

KEY RECOMMENDATIONS

- ***Employers*** *should ensure that operators always bore with the casing securely attached to the HAB machine as required by the manufacturers and implement additional measures to stabilize the boring machine when necessary.*
- ***Employers*** *should provide employee training on precautions and measures for preventing boring machine upset.*
- ***Utility installation project designers, engineers and managers*** *should incorporate measures to prevent boring machine upset at the project design stage.*

- ***Boring machine manufactures*** *should consider the following measures to prevent machine overturn**:***
    - *Widen the base of the HAB machine with outriggers to increase stability;*
    - *Provide a remote control device for operating HAB machines;*
    - *Move the operator platform to the rear end of the machine;*
    - *Install rollover protection bars or a cage to protect the operator;*
    - *Install a torque meter or a RPM limiter and an interlock to shut down the machine when the output torque and RPM exceeds the safe limits;*
    - *Install a pressure meter on the machine base to monitor stability and an interlock to shut down the machine before it overturns;*
    - *Modify the machine base and track assembly design so that the machine can be anchored into the ground; and*
    - *Warn operators about the danger of boring inside a preinstalled casing without stabilizing the machine.*

Photo 1. Accident scene: the horizontal auger boring machine overturned to its left side (photo courtesy of OSHA).

INTRODUCTION

In July 2011, a 46 year-old male equipment operator (victim) of a trenchless utility installation contractor suffered fatal crushing injuries when a horizontal auger boring (HAB) machine overturned. New York State Fatality Assessment and Control Evaluation (NY FACE) staff learned of the incident from newspaper articles. A NY FACE investigator conducted an on-site investigation on August 11, 2011. During the site visit, the NY FACE investigator met with the owner of the contracting company, observed the incident site and examined the HAB machine that was involved in the incident. The case was reviewed and discussed with the compliance officer of the Occupational Safety and Health Administration (OSHA) who investigated the incident. Additional documents reviewed included the OSHA investigation report and the death certificate.

The trenchless utility installation contractor has been in business since 1995 specializing in utility installation and rehabilitation using trenchless technologies such as pipe ramming, pipe jacking and pipe bursting. At the time of the incident, the company employed three workers, including the victim, who was also the owner's brother. The victim had more than 11 years of experience in trenchless operations. He had completed over 200 pipe ramming projects with diameters up to 48 in (1.2 m). This was the company's first work-related fatality.

INVESTIGATION

At the time of the incident, the contractor was subcontracted to install 100 ft. (30.5 m) of 36-inch (0.9 m) diameter steel casings under a high speed rail line for a municipal water expansion project. The casing line would transfer water from a lake upgrade (grade: 8%) to a water treatment plant. The railway had to remain open during the construction. Pipe ramming, a trenchless method that is frequently used for horizontal pipe installations under railways and road embankments, was chosen by the engineering design firm for the project.

In a typical pipe ramming operation, a ramming tool and a steel casing are both placed in an insertion pit and lined up in the desired direction (Fig.1). The ramming tool that is attached to the rear of the casing drives it into the earth with repeated percussive blows. The next casing is welded to the end of the first casing and driven into the earth in the same manner followed by more casings to form a desired length. All casings have open ends; earth materials (soil and rocks) known to the industry as "spoils" fill the casings while they are driven through the earth. The spoils inside the casing line are then removed using compressed air, pressurized water or a HAB machine.

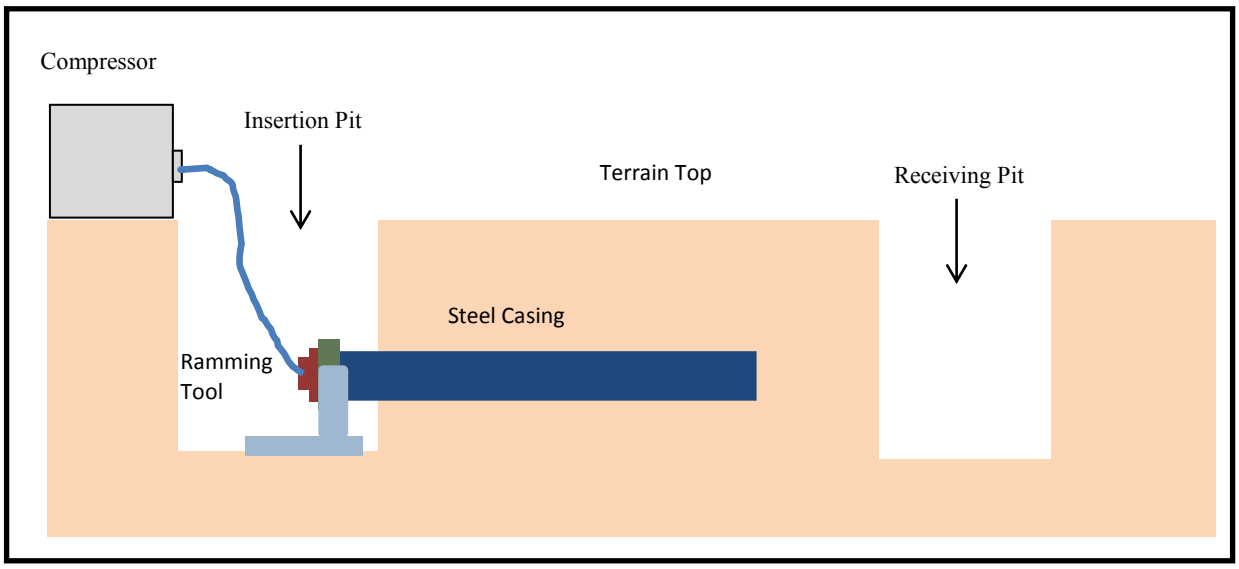

Figure 1. Typical pipe ramming setup (Courtesy of Trenchless Technology Center)

The pipe ramming operation started on Tuesday of the week prior to the incident. Three steel casings 36-inch (0.9 m) in diameter and 40 ft. (12.2 m) long were hammered consecutively into the earth (down grade) by a pneumatic ramming hammer. Except for an obstruction encountered at 40 ft. (12.2 m), the crew completed the ramming operation on Thursday without an incident. The HAB machine was set up on Friday and the spoil removal operation was to start the following Monday.

The contractor purchased the used HAB machine from an excavation company eight years prior to the incident. At the time of purchase, the contractor consulted the manufacturer of the machine and hired a technician from the manufacturer to provide training on proper machine operation and maintenance. Preventive maintenance including lubrication and tune up was completed in the spring prior to the July incident. The hour-meter on the machine read 172 hours of use at the time of the incident.

The HAB machine was equipped with a 98 horsepower (70 kilowatt), turbo-charged, air-cooled diesel engine with a 5-speed manual transmission. The maximum advance thrust was 500,000 lbs. (2,224,110.8 Newton) that was generated by the two hydraulic cylinders in the base push unit. The machine's output torques and speeds are presented in Table 1. The machine generates a maximum torque of 110,823 foot-pound (ft-lbf) or 150,276 newton meters (N-m) at 4 RPM in its first and reverse gears.

Table 1. HAB Machine Maximum Output Torques and Speeds

Gears	Speeds (RPM)	Output Torques (ft-lbf)	Output Torques (N-m)
1st	4	110,823*	150,276*
2nd	8	59,886*	81,205*
3rd	12	33,729	45,736
4th	20	20,375	27,628
5th	30	13,767	18,668
Reverse	4	110,823*	150,276*

**Output torque exceeds the Maximum Safe Operating Torque of 39,500 ft-lbf or 53,554 N-m (see Appendix).*

The machine was mounted on a track assembly comprised of two pairs of tracks connected by steel beams. The track assembly was approximately 32 ft. (9.8 m) long and 5 ft. wide. There were rectangular openings (holes) on the tracks. The base of the HAB machine had movable rectangular protrusions (hydraulic dogs) controlled by hydraulic power that can be locked into the holes on the tracks to prevent machine movement on the tracks (Photo 2). The dimensions of the machine were 60 in (1.5 m) wide, 144 in (3.7 m) long and 52.5 in (1.3 m) high. The centerline of the auger was 1.88 ft. above the ground. The combined weight of the machine and the track assembly (auger string excluded) was approximately 15,800 lbs. (7,167 kg).

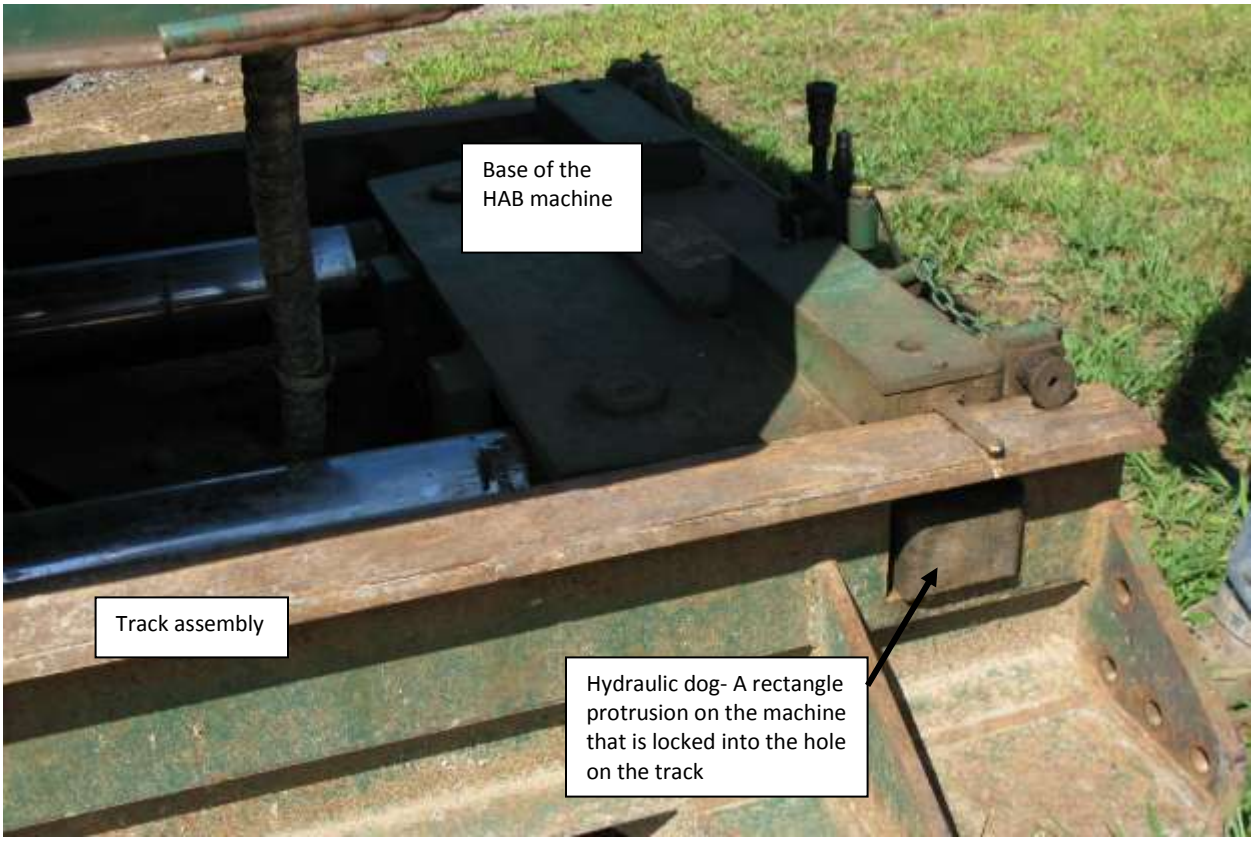

Photo 2. The HAB machine is locked to the track assembly by the rectangle protrusions engaged into the holes on the track assembly.

To set up the machine, workers placed one-inch thick steel plates 64 in x 108 in (1.6 m x 2.7 m) on compacted soil and placed the track assembly on top of the steel plates. The track assembly was aligned with the casing and the designed grade before the machine was mounted. The track assembly was not anchored to the ground.

On the day of the incident, the victim and a coworker arrived at the site at approximately 7:30 am to set up the spoil removal operation. Two 10-ft (3-m) long augers were connected by a 4 in (101.6 mm) hex shaft with cotter pins to form an auger string. The lead auger had a cutting head and the outside diameter of the auger was 34 in (0.9 m). The workers mounted the auger string onto the HAB machine. The soil was loam mixed with boulders and rocks.

The victim started the HAB machine at approximately 9:00 am. He was operating the machine from the operator's platform that was located on the left side of the machine (when facing the bore or

casing) where all the controls were. The coworker who worked in construction for 20 years including five years in trenchless operations stated that the operation was proceeding as planned. Although he noticed the noises of the machine striking rocks, he did not think that it was anything unusual.

The incident occurred shortly after 10:00 am when the auger string had advanced approximately 11 ft. (3.4 m) into the casing line. The HAB machine along with the track assembly suddenly pitched to the left roughly 90 degrees counterclockwise (Photo 1). Unable to jump free, the victim was pinned by the machine against the ground before the machine swung back to the upright position. Immediately the machine pitched to the left a second time crushing the victim and swung back to upright before it pitched the third time and rested on its left side with the motor running and the victim pinned underneath. The coworker immediately called 911. Meanwhile an equipment operator at the site used an excavator to move the machine off the victim. The workers were able to turn the machine off and free the victim. They performed CPR on the victim until the EMS arrived. The victim died on route to the hospital as a result of severe crushing injuries.

The post incident examination found that the HAB machine was operational resulting in no functional damage from the incident and the auger string was not out of alignment. The blades of the auger were bent during the incident (Photo 3) according to the owner of the company. It appeared that the auger was jammed by the spoils inside the casing. According to the OSHA investigation, there were rocky materials in the area being bored and large boulders and cobbles inside the pipe casing when the auger string was removed. The throttle position indicated that the machine was operating at or near full power when the machine overturned.

Photo 3. The bent auger blades indicate that the auger was caught by the spoils inside the casing.

The HAB machine manufacturer warned about the danger of machine upset (overturning) in the operator's manual and specified three risk factors: 1) operating the machine at full power in a low gear or reverse, 2) advancing into the earth face rapidly or erratically, or 3) encountering an obstruction that catches the auger. To prevent machine upset, the manufacturer recommended "cased bore". The HAB machine was equipped with a master casing pusher. During "cased bore", a casing with an auger inside is attached to the machine through the master casing pusher and boring is conducted simultaneously when the casing section is pushed into the earth. Since the casing is secured to the machine, the weight of the casing and the frictional ground resistance add stability to the machine and deters machine upset. The manufacturer specifically warned of the danger of free boring – boring with a bare auger increases the possibility of machine upset.

At the time of the incident, the master casing pusher was not installed on the machine and a bare auger string bored inside preinstalled casings. This method exposed workers to essentially the same hazards as free boring.

After the incident, the contractor switched to a different spoil removal method called the "shakedown" method by using a pneumatic hammer to shake and vibrate the casings at the exit end to remove the spoils by grade and gravity. The shake down method was reviewed and approved by the project engineer. The operation was completed without incident.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: ***Employers should ensure that operators always bore with the casing attached to the HAB machine as required by the manufacturers and implement additional stabilizing measures when necessary.***

Discussion: Earth boring machines are designed to bore through the earth with large forces and torques. As the rotating auger string thrusts into the earth, the boring machine "torques" as a reaction to the earth resistance encountered by the auger string. This reaction causes machine upset or overturn. The weight of the machine and the width of the machine base dictate the Maximum Safe Operating Torque (MaxSOT) of a HAB machine (see calculation in Appendix). As long as the machine output torques in all gears are within the limit of MaxSOT, the machine should remain upright. Otherwise, machine upset occurs.

The MaxSOT for this particular HAB machine is 39,500 ft-lbf (53,554 N-m). The machine output torques in first and reverse gears were 110,823 ft-lbf (150,276 N-m), exceeding MaxSOT by approximately 2.8 times. The output torque in second gear of 59,886 ft-lbf exceeds the MaxSOT as well. During the incident, the combined resistance generated by the machine weight, and additional stabilizing forces was not large enough to deter machine movement resulting in machine upset.

To prevent machine upset, manufacturers recommend "cased bore" only: always bore with a casing that is securely attached to the machine's master casing pusher. When boring with a casing, one end of the casing is secured to the machine and the other end is being held by the earth that stabilizes the machine. Meanwhile the friction between the casing bore and the casing deters the machine's rotational movement around the casing centerline. Employers should ensure that workers who operate earth boring machines strictly follow manufacturers' requirements, never bore with a bare auger string and always bore with casings that is securely attached to the machine's master casing pusher.

The HAB machine manufacturer specifically warned of the danger of free boring (boring directly into earth without a casing) that increases the possibility of machine upset. Although the HAB machine in this case bored inside a preinstalled pipe casing and the method was not technically "free boring", the hazards associated with machine torqueing are essentially the same. When operations associated with a high risk of machine upset have to be conducted, employers should consult project engineers and the HAB machine manufacturer to assess the hazards of machine overturning and implement additional stabilizing measures, such as anchoring and securing the machine track assembly to the ground.

A cautionary note should be made on "cased bore". Many factors such as friction coefficient (roughness of the contact surface) and soil conditions can influence the magnitude of the friction and the strength of the earth support. Engineers and contractors should be aware of the machine overturn risk and provide additional machine stabilizing mechanisms if necessary.

Recommendation #2: ***Employers should provide employee training on precautions and measures for preventing horizontal auger boring machine upset.***

Discussion: An earth boring machine is particularly at risk of machine upset when operating in low or reverse gears under soil conditions that require high torque to bore through, or encountering an obstruction that catches the auger string or cutting head. Employers should provide training to workers who work with or around HAB machines on precautions and measures for preventing machine upset. Workers should learn the risk factors, strictly follow manufacturers' requirements, and always bore with a casing that is secured to the machine's master casing pusher.

Recommendation #3: ***Utility installation project designers, engineers and managers should incorporate measures to prevent horizontal auger boring machine upset at the project design stage.***

Discussion: The trenchless method used in this case is accepted and frequently used by construction and utility contractors. The hazard associated with this method is potential HAB machine upset during the spoil removal operation when the machine bores inside the preinstalled casing with a bare auger string. Project designers, engineers and managers should be aware of this particular hazard and address specific prevention measures at the project design stage if a HAB machine is to be used. Boring without an attached casing should never be conducted unless the method is approved by the manufacturer and specific measures for preventing machine upset are implemented.

Recommendation #4: ***Horizontal auger boring manufacturers should consider adding additional safety features to prevent operator injury associated with machine upset.***

Discussion: Manufacturers should consider adopting the following measures to enhance HAB machine stability and prevent worker injuries:

1) ***Widen the base of the machine with outriggers to increase the machine's stability*** *(see Appendix).*
2) ***Provide a remote control device for operating HAB machines:*** Manufactures should provide a remote control device so that an operator can operate the machine from a safe distance.
3) ***Move the operator platform to the rear end of the machine.***
4) ***Install rollover protection bars or a cage to protect the operator.***
5) ***Install a torque meter or RPM limiter and an interlock to shut down the machine when the machine torque or RPM exceeds the safe limit.***

6) ***Install a pressure meter to monitor machine stability and an interlock to shut down the machine before it overturns.*** The HAB machine in this case was mounted on a pair of tracks. When the machine is stable and balanced, each track should bear approximately half of the machine weight. At the point of machine overturn, one track may bear approximately all the machine weight while the other may bear none. A pressure meter can monitor the weight distributions on the two tracks and an interlock can shut down the machine before it overturns.

7) ***Modify the machine base and track assembly design so that the machine can be anchored into the ground.***

8) ***Warn operators of the danger of boring inside a preinstalled casing without stabilizing the machine.*** It appeared that the method described in this case is frequently used by the industry. Manufacturers should specifically warn operators in the operators manual about the danger of machine upset when boring inside a preinstalled casing without taking measures to stabilize the machine.

Keywords: horizontal auger boring machine, earth boring machine, machine upset, machine torque, machine overturn, trenchless utility installation,

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Appendix
Maximum Safe Operating Torque (MaxSOT) and Minimum Safe Operating Width of Machine Base (MinSOW)

Maximum Safe Operating Torque (MaxSOT)

W - The weight of the machine including base unit, power unit, master track and two track extensions[1]:
W = 15,800 lbs. (7167 kg)

D - The width of the machine base[1]: D = 5.0 ft.

Dcg – Distance to the center of gravity[2]: Dcg = D/2 = 2.5 ft.

Maximum Safe Operating Torque (MaxSOT) = Dcg x Weight = 2.5 ft. x 15,800 lbs.

MaxSOT = 39,500 ft-lbf (53,554 N-m)

The risk of machine upset exists as soon as the machine's output torque exceeds the MaxSOT. The machine's output torques in first, second and reverse gears exceed MaxSOT. To prevent machine upset, the manufacturers should:

1) Limit the RPM (with an RPM limiter preferably) in each gear;
2) Limit the torque in each gear;
3) Modify the machine foundation so that it may be anchored to the ground; or
4) Widen the machine base with outriggers.

Minimum Safe Operating Width of Machine Base (MinSOW)

Minimum Safe Width of Machine Base (MinSOW) = 2 x Minimum Safe Distance to the Center of Gravity (MinSDcg) in each gear

$$\text{MinSDcg} = \frac{\text{Output Torque in each gear}}{\text{Machine Weight (15,800 lbs)}}$$

Gears	Speeds (RPM)	Output Torques (ft-lbs)	Output Torques (N-m)	MinSDcg in ft.
1st	4	110,823	150,276	7.01
2nd	8	59,886	81,205	3.79
3rd	12	33,729	45,736	2.13
4th	20	20,375	27,628	1.29
5th	30	13,767	18,668	0.87
Reverse	4	-110,823	150,276	-7.01

Minimum Safe Operating Width of Machine Base (MinSOW) = 2 x MinSDcg = 2 x 7.01 ft

MinSOW = 14.02 ft

The current machine base was 5 ft wide. In order to prevent machine upset at maximum torque output in first and reverse gears, the base needs to be widened to at least 14.02 ft.

[1] *The weight of the casing pusher (750 – 1185lbs.) was not included since it was not installed on the machine at the time of the incident.*

[2] *The center of gravity is assumed in the center and near the base of the machine and the machine is on level ground.*

The New York State Fatality Assessment and Control Evaluation (NY FACE) program is funded by the National Institute for Occupational Safety and Health and administered by the New York State Department of Health. NY FACE is a research program designed to study the causes of workplace fatalities and develop practical and effective prevention measures. NY FACE investigators evaluate information from multiple sources and provide recommendations for prevention in summary reports. These recommendations are distributed to employers, workers, and other organizations interested in promoting workplace safety. The NY FACE does not determine fault or legal liability associated with a fatal incident. Names of employers, victims and/or witnesses are not included in written investigative reports or other databases to protect the confidentiality of those who voluntarily participate in the program. Additional information regarding the NY FACE program can be obtained from:

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