Cost-effective Rollover Protective Structure (CROPS) for Wheeled Agricultural Tractors

Ford 4000 SERIES

TESTING INFORMATION

This testing report was updated in March 2021.

This report provides enhanced information on the testing procedures and data collected by NIOSH. Specific report updates include tractor chassis information, static testing information and the reasoning for the testing.
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Static testing of a fully assembled NIOSH CROPS was performed at the NIOSH Division of Safety Research laboratories in Morgantown, West Virginia, and in accordance with testing criteria outlined in SAE J2194. The main purpose of the static laboratory testing was to simulate field upset in a controlled and repeatable environment (SAE J2194). The static loading sequence consisted of four tests: (1) longitudinal loading, (2) 1st vertical crush loading, (3) transverse loading, and (4) 2nd vertical crush loading. During any of the four phases of static testing, the CROPS cannot be altered (e.g., bolts tightened, material repairs) and cannot touch or enter the operator clearance zone.

During the static laboratory testing, the loads were applied slowly over time, with the applied force and corresponding displacement collected. From these measurements, the energy absorbed by the CROPS was calculated (see graphs).

The photos show the condition of the tested CROPS at the beginning and the end of each of the four static tests.
CROPS Testing Information, Ford 4000 Series

General Testing Information

Date(s): CROPS Testing – 6/18/2008, 6/19/2008, 6/26/2008

Laboratory: NIOSH High Bay Lab
1095 Willowdale Rd
Morgantown, WV 26505

Conducted by: Division of Safety Research/Protective Technology Branch Engineering Staff

Machine manufacturer: Ford

ROPS manufacturer: NIOSH
1095 Willowdale Rd
Morgantown, WV 26505

Testing Background
An energy absorbing CROPS test was conducted between 06/18/2008 and 06/26/2008 following the industry standard that was current in 2008, SAE J2194. This test was a retest of the CROPS design with the main difference of reducing the base plates from ¾ in thickness to ½ in thickness. This change was performed to make the CROPS more manufacturable.
Specification of the Test Machine

Chassis: Ford 4600
Reference Mass (mt): 8400 lbs.

Specification of the CROPS

CROPS Identification: CROPS with ½ inch base plates
ROPS Design/Test Type: Energy-Absorbing

Required Energy Absorption:

| Longitudinal Loading: | E_{IL1} = (1.4) mt | 47212 in-lbs. |
| Side Loading:         | E_{IS} = (1.75) mt | 59015 in-lbs. |
| Vertical Crush Loading: | F_R = (20) mt | 17131 lbs. |

Test Equipment

Description of the load application devices:
The horizontal loads were applied by means of a hydraulic cylinder. The flow rate to the
hydraulic cylinder was controlled to maintain the static nature of the test, as described in SAE
J2194. The vertical crush load was applied with two hydraulic cylinders mounted on each end of
a steel I-beam that was installed across the top of the CROPS.

Description of the laboratory instrumentation:
The instrumentation used for this test was:

- A 20,000 lb. load cell attached to the end of a hydraulic cylinder, which was used to
  measure the force being applied to the CROPS for the longitudinal and transverse
  testing.
- Two 20,000 lb. load cells attached to the ends of separate hydraulic cylinders, which
  were used to measure the applied crushing loads in the vertical testing.
- An LVDT (linear variable differential transducer), which was used to measure
  displacement of the CROPS throughout the testing.
- An MTS 458.20 MicroConsole, which controlled the applied forces.

Data Collection and Computation

- The test LVDT measurements and energy calculation of the testing were performed
  by a LabView program. The Simpson rule for integration was used to calculate the
  energy for the testing and outputted the data to a CSV file for analysis.
- The permanent deflection distance data was recorded by hand.

CROPS test temperature and description of how CROPS temperature/material options were met,
the language below is taken from the SAE J2194 Standard, ROPS in this section is used
synonymously with CROPS:

All material used for the ROPS met the requirements of SAE J2194 6.9 Material Requirements.
The ROPS tests were performed at ambient temperature.

- All fasteners used to attach the ROPS to the tractor frame and to connect
  structural parts of the ROPS were SAE grade 5 through 8 or equivalent.
- All steel material used in the ROPS met the minimum Charpy V-notch impact
  energy requirements specified.
- All welding electrodes used in fabrication of structural members and mounts were
  compatible with the ROPS material.
Test Load Sequence

1. Longitudinal loading from the rear (left side of machine)
2. Vertical crush load
3. Transverse loading from the side (right side of machine)
4. Vertical crush load

Test Setup

The tractor was bolted to a 20,000-pound test bed via custom manufactured mounting structures to simulate the tractor wheel height and to keep the tractor from moving during the test procedure.

Between the testing sequence, the tractor was rotated such that the hydraulic cylinder could be positioned in the appropriate location for each of the 4 tests. This test set up is shown in the testing sequence pictures that follow.
Ford 4000 Longitudinal Test

Before

After
Ford 4000 Longitudinal Test

June 18, 2008

- Permanent Deflection: 11 inches
- Energy Criteria: 47,212 in-lbs
- Max Energy: 47,252 in-lbs

Distance (inches)

Energy (in-lbs)
Ford 4000 Vertical Crush #1
June 19, 2008

Load (Lbs)

Load Criteria
-17131 lbs
Max Load
-17,346 lbs

Vertical Crush Load

Data Points
Ford 4000 Transverse Test

Before

Ford 4000 Transverse Test

After
Ford 4000 Transverse Test

June 19, 2008

- Energy (in-lbs)
- Distance (inches)

Permanent Deflection 10.12 inches
Energy Criteria 59,015 in-lbs
Max Energy 59,021 in-lbs

Transverse Energy
Ford 4000 Vertical Crush #2
June 26, 2008

Load Criteria
-17,131 lbs

Max Load
-17,962 lbs

Vertical Crush Load

Data Points

Load (Lbs)
-20,000
-15,000
-10,000
-5,000
0
5,000
300 600 900 1200 1500 1800 2100 2400 2700
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