
Nail Penetration Test Rig

Overview. The proposed Nail Penetration Test Rig is a completely self-contained, integrated system designed to perform controlled nail penetration testing on batteries. The system combines a fire-rated test enclosure, a precision servo-driven penetration ram, and a local control package to provide safe, repeatable, and well-controlled test execution.

1. System Description

The test enclosure is an approximately 4 ft x 4 ft x 7 ft high shed constructed with fire-rated internal materials. A fire-rated rear access door is provided, and the roof may be propped open during testing to allow combustion products or vapors to vent safely during the penetration event. Fork pockets integrated into the base frame facilitate movement and positioning of the unit.

Three viewing ports are provided, each consisting of a fire-rated safety-glass window approximately 12 in x 12 in. A shelf below each viewing port is provided for mounting cameras, lighting, or other detection devices, and a sunshade above each window reduces glare during test observation and video recording.

A positioning table is installed within the enclosure and is manually adjustable along the X, Y, and Z axes using hand cranks. The table accommodates a minimum positioning envelope of 12 in x 12 in x 12 in and is constructed of fire-rated materials suitable for the test environment.

A laser alignment device mounted on the exterior of the enclosure is directed at the intended point of impact to assist the operator in positioning the test article accurately.

A servo-driven ram is mounted externally, with the rod penetrating the enclosure wall. The end of the ram rod is threaded to accept interchangeable tooling for holding one or more nails, depending on the specific test configuration.

The ram is driven through a servo motor and gear arrangement and incorporates an absolute encoder so that ram position is continuously known by both the servo controller and the PLC. This arrangement enables precise motion control and repeatable penetration profiles.

A control panel mounted on the exterior of the enclosure includes a 10 in HMI with sunshade, start and stop pushbuttons, the servo controller, power supply, and PLC. Through the HMI, the operator may manually stroke the ram and enter the required test parameters before initiating the test sequence.

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2. Servo Ram Characteristics

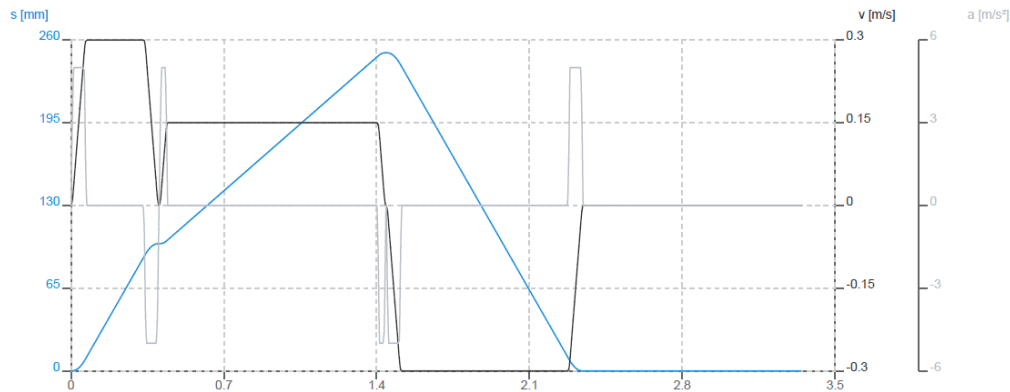
Parameter	Value
Maximum speed	0.3 m/s
Maximum acceleration	5 m/s ²
Maximum jerk	500 m/s ³
Maximum deceleration	5 m/s ²
Total cycle time	3.35 s
Maximum motor speed	3,600 rpm
Maximum motor torque	4.42 Nm
RMS motor torque	1.6 Nm
Maximum current	5.39 A
RMS current	1.95 A
Maximum power	1,020.52 W
RMS power	254.22 W
Emergency-stop deceleration	5 m/s ²
Displacement during emergency stop	9 mm
Current during emergency stop	1.62 A
Mass moment of inertia ratio	1.41
Servo drive workload (effective / maximum)	38% / 47%
Motor workload (effective / maximum)	51% / 47%
Actuator workload (effective / maximum)	39% / 59%
Guide workload (effective / maximum)	0% / 1%
Ball screw service life	1,698 km

Note: Servo performance values shown above are based on the proposed motion profile and are intended to define the operating capability of the penetration axis.

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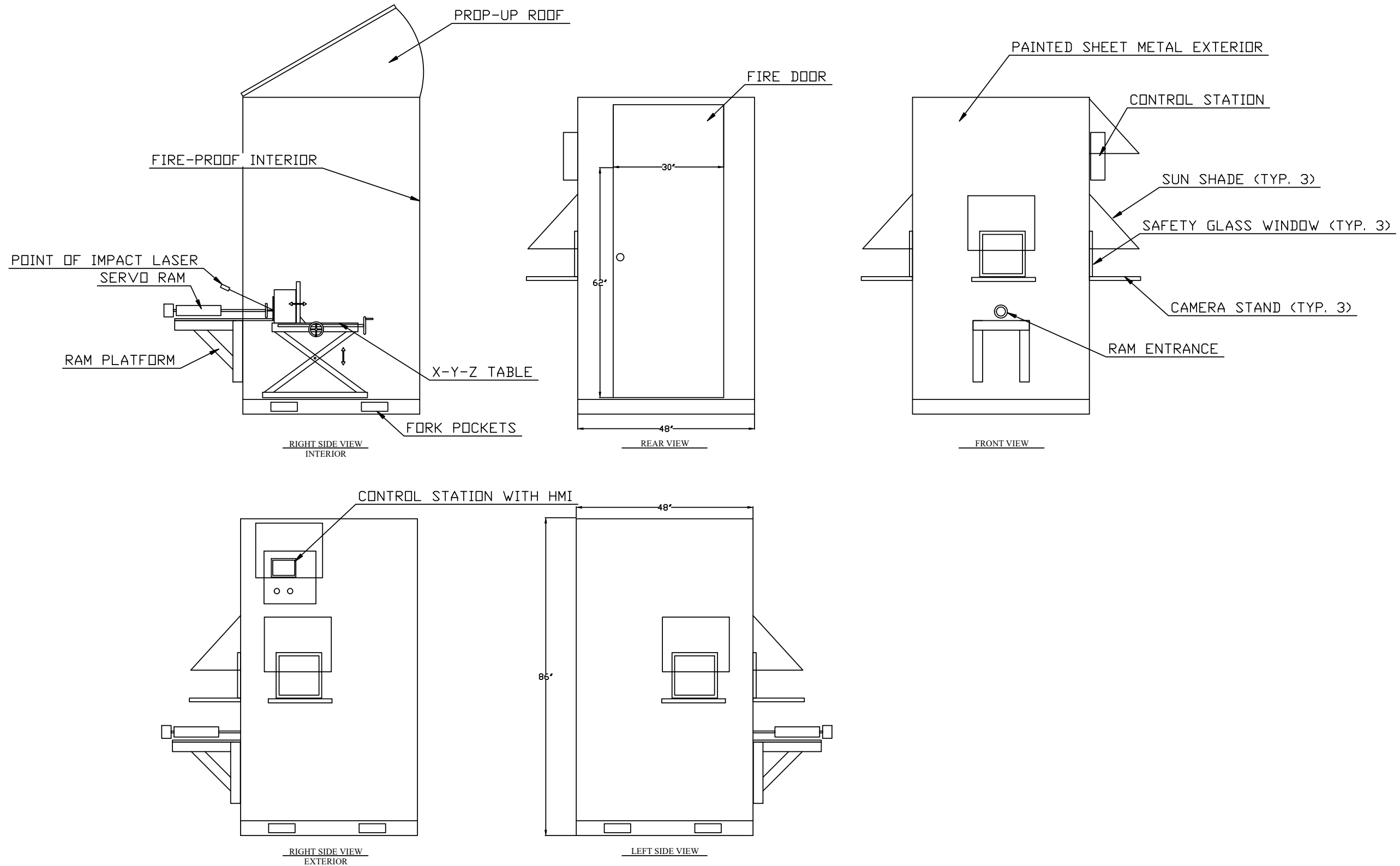
Motion profile

	Target position [mm]	Payload [kg]	External force [N]	Speed [m/s]	Acceleration [m/s ²]	Deceleration [m/s ²]	Travel time [s]	Pause time [s]
1	100.0	5.0	0.0	0.3	5.0	-5.0	0.40333	0.0
2	250.0	5.0	-3000.0	0.15	5.0	-5.0	1.03999	0.0
3	0.0	5.0	0.0	-0.3	-5.0	5.0	0.90333	1.0



3. Typical Operation

- The operator marks the battery at the desired point of impact.
- The appropriate nail tooling is attached to the ram, including any required selection for nail quantity and whether the tooling is to retract or remain in place after penetration.
- The battery is placed on the positioning platform and aligned so that the external laser coincides with the required point of impact.
- The enclosure roof is opened as required for venting, and the operator exits the immediate test area.
- Lighting, cameras, and any other monitoring or detection equipment are positioned at the viewing ports.
- The operator enters the required test parameters through the HMI, including forward speed, reverse speed, penetration depth, and the selected post-penetration action.
- The operator selects the command to move the ram to the start position. The ram then advances to a location sufficiently far from the test article to allow acceleration to the programmed speed before impact.
- The operator initiates the test using the start pushbutton. The ram penetrates the test article and retracts if that option has been selected.
- If required, the stop pushbutton may be used to command ram retraction and disable the axis.



LTR	DATE	BY	DESCRIPTION

REVISIONS			

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ENGINEER APPROVAL BY:	DATE:	
DRAWN BY:	DATE:	
	DATE:	

SCALE: NTS

CLIENT	
PROJECT TITLE	NAIL PENETRATION TEST RIG
LOCATION	

SHEET TITLE	PRELIMINARY GENERAL ARRANGEMENT	
SIZE	SHEET	NUMBER
B	1 OF 1	