Hudson University Rigging Inspection Report

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Executive Summary

This report was originally prepared for a college near Pittsburgh, PA. We have replaced all occurrences of the name of this college with *Hudson University*, a fictitious institution.

The stage rigging systems at Hudson University have a few critical issues and many important issues that need to be resolved for the safe continued function of the system. Immediate service is recommended from a qualified rigging contractor. The fire curtain repair will also involve an abatement contractor. While the bones of the system are good, many issues related to age and maintenance need to be addressed sooner rather than later.

Contents

1 Introduction

Hudson University is a small college located about half an hour from Pittsburgh, PA. The main theatre features a reasonably sized proscenium stage with a small house, a few catwalks, and a full counterweight rigging system. The rigging system features 21 linesets including three fixed electrics, a fire curtain, a full walking grid with upright head and loft blocks as well as a loading bridge. The system has seen very little rework from when it was originally installed in what we estimate to be the 60's or 70's.

An additional facility in the old elementary school offers a small deadhung rigging and lighting system, and is about a 3 minute drive from the main theatre.

Ben Peoples visited Hudson for a full rigging inspection on November 19th. Pittsburgh Hoist & Sandbag offers rigging inspections and specification and bidding assistance, but does not repair or install stage rigging systems. This report and its recommendations should be presented to rigging installers for repair quotation.

2 Issues Identified

Both spaces' rigging systems require significant amounts of both repair and replacement to become both safe and functional. Some of this is simply because the philosophy of what is safe has changed significantly since the theatre was built, some of this is because of the natural aging of the system, some of this is due to damage done to the system, either by poorly executed repairs or by actual damage done to the system.

While the theatres superficially appear to be in good working shape, a close inspection finds some problem with every single lineset in the theatre. The term *tension load path* will appear throughout this document. This refers to the components that are actually holding the load up, rather than simply making for smooth operation of the system. For instance, the guides that the counterweight arbors travel in are not in the tension load path. While a failure of a guide could cause significant problems, it would not in itself cause the load to drop. On the other hand, the cable lift line termination is in the tension load path, and a failure of this could itself cause the load to drop. See the appendix of this document for an overview of counterweight rigging systems to better understand the terms used throughout this document if you are not familiar with them yourself.

There is some question as to what the largest and most critical issue is. While there is a serious life safety issue involved in the fire curtain not operating, there are few theatres where the fire curtain has actually activated in an emergency. On the other hand, there is critically dangerous overhead hardware over the stage. This offers are much more immediate concern: a fire may happen in a theatre, but this hardware *will* fail if not attended to.

The small space over in the elementary school is using unrated chain for overhead attachments of track and light fixtures. I did not inspect above the drop ceiling to see what the attachment to structure looked like. In short, the entire rigging in the small theatre needs to be replaced with rated hardware. This is either chain rated for overhead use, or wire rope suspensions. In all cases the entire tension load path should be made up of rated hardware that deforms rather than breaks or drops the load in an overload condition.

2.1 Main Theatre

2.1.1 Fire safety curtain

The fire safety curtain most notably does not function. A fire curtain is used to block off the proscenium opening in the event of a fire preventing the spread of fire, smoke and panic from the stage to the audience giving audience members time to escape. It can also serve to contain fire damage to the stage, rather than spreading to the higher grade finishes in the auditorium.

It was not clear why the fire curtain was not operating, and it will likely require inspection with an aerial lift to establish what is required to make it functional.

Additional concerns with the fire safety curtain is that it is almost definitely made from asbestos. This is typical of curtains in this era, and the material looks correct. We were not able to get close enough to confirm, which should fall to an abatement contractor regardless. Modern fire curtains are made from a woven fiberglass material. While making the fire curtain operate, it would be prudent to replace the asbestos material with fiberglass.

More minorly, the tension block for the fire curtain operating line was not attached to the floor. The head, loft, and running rigging for the fire curtain did appear to be in good shape, despite not operating.

2.1.2 Electrics

The main theatre features three fixed electrics – these are battens with permanently installed electrical raceways. While these raceways are modern—installed in the last 15 years according to the user—they are both not properly installed to the battens and the battens are improperly installed.

The electrics have double pipe battens, meaning there is one pipe above the raceway that is hung from the rigging lines and a second pipe below the raceway. The general practice for this is to use a steel strap that supports the lower pipe *and* the raceway. When the raceways were replaced the existing brackets with unrated—unsafe—hardware were left in place, and the raceways simply attached to the bottom pipe. This has caused the raceways to rotate forward of the pipe, further bending the existing brackets and causing damage to the new raceways. Additionally, it puts more load on the old hardware.

The first electric suffers from the worst conditions. The batten terminations are original: see batten termination discussion below. The hanging hardware is unrated and unsafe. The tail ends of the batten are held up by cotton sash cord, which is not rated for this purpose. Failure of the cotton sash cord could cause a zipper failure of the batten hangers. The cable cradle for the power supply cable to the raceway is improperly terminated to its liftline.

The third electric has been re-rigged, but not in a way that is considered safe by either current standards or standards when the work was done. However, it still suffers from improper hanging hardware and improperly installed raceway. However, the cable cradle is also still improperly rigged to its liftline.

The second electric is in the best shape, but still dangerous. The rerigging appears similar to the third electric, but the trim chain termination lacks backup or mousing. See discussion of batten terminations below. The raceway has been attempted to be attached better to the pipes, and it certainly is, but the hanging hardware is not large enough to support the bottom batten, only the raceway. The bottom batten is still relying on the old rigging hardware for suspension.

2.1.3 Liftlines and termination

The original system terminated the liftlines at the batten with a clove hitch and two malleable wire rope clips.[1] The cable itself is rusty, which indicates that it was not Galvanized Wire Rope since the other galvanized hardware is still shiny, even adjacent to the cable. The arbor termination is two malleable wire rope clips with a thimble to a turnbuckle. A turnbuckle is a device that is used to finely adjust the length of a liftline, allowing battens to be carefully leveled. Turnbuckles must be locked off in some way to prevent them from loosening over time, eventually dropping the load. A very small percentage of turnbuckles were locked off.

Because the rust can hide defects, wire rope manufacturers suggest that "rusty rope may break without warning."

The clove hitch damages the wire rope by exceeding the minimum bend radius of the wires. While exactly difficult to define what an old clove hitch's rating should be, a new clove hitch is likely to be no stronger than a circus knot tied in the rope. A small sample of circus knots tested showed they generated approximately 75% of the breaking strength of the rope. Properly installed cable clips are considered to generate 80% of the breaking strength of the wire rope when new. Because of the physical proximity between these two terminations we can treat them as serial, meaning our *maximum* efficiency is 60%. Some sources suggest less than 50% for clove hitch and cable clips.

Some terminations have been replaced or reworked. Many of these changes have improved the situation, although in no case was a fully overhead-rated assembly found in the system. See the line-by-line survey for details. Many of these are poorly or barely installed, which has made things far worse. It also appears that some of the original cable clips on the arbors were installed backwards. Based on limited testing data available, this results in similar reduction in efficiency to the knot and cable clip system. Because the ends of the liftline can be treated individually, this does not present an additional derating of the liftline capacity, but it does present an equally unsafe situa-

[1] Cast or "malleable" wire rope clips are made from steel or iron that has been poured, liquid, into a mold. Unless each is x-rayed, they can easily contain voids in the casting. Additionally, the failure mode for a cast clip is snapping, not bending. This means that the first sign of a problem is the failure of the clip. The Wire Rope Users Manual says this: "Malleable clips are to be used for making eye termination assemblies only with right regular lay wire rope and only for light duty uses with small applied loads, such as hand rails, fencing, guard rails, etc." It specifically recommends the use of forged clips in support line use.

tion.

The electrics that have new cable terminations were swaged correctly—swage sleeves such as those used on this system are 100% efficient: no deration of the liftline is needed. However, the trim chains used are not rated for overhead use: they are Proof Coil Grade 30 Chain. The accepted practice in this case is to provide an additional secondary fixing of the chain using a rated bolt above the trim chain. This bolt was not provided. Additionally, the shackle pins used in the tension load path lack mousing: vibration can cause the pins to loosen over time, resulting in the failure of a liftline.

2.1.4 Arbors

The arbors hold counterweights that balance the weight of the battens, electrics, and equipment attached to the lines. The arbors were generally in good condition, but a few issues were identified.

The originally provided stage weight is cast iron (sometimes incorrectly called "pig iron"), which is not a problem in this case. However, the weight is designed with slots to go over the nuts on the bottom of the arbors. When properly installed, the weights sit fully on the base plate of the arbor. When installed upside down, the weights sit directly on the nuts. During normal operation this is not a problem. However, in the event of an accident called an "arbor crash" where an out-of-balance lineset runs away and the arbor slams into its end stops, this stress concentration could cause fracturing of the stage weight possibly causing fractured cast iron to fall from the loading bridge.

There are two systems that work together to keep the counterweights in the arbor in the event of a crash. The first of these is the shaft collars. These collars hold the top weight in place as the arbor hits the top stop. However, the rods that hold the weight in place can also bend, opening enough to allow weight to simply fall out. To prevent this, spreader plates are provided that should be evenly spaced throughout the weight stack—typically on 2 foot spacing—to hold the arbor rods together. On this system, standard length arbors are provided with two spreader plates, which is probably enough if properly distributed. The shaft collar design suggests a third may be necessary at the shaft collars. However, the electrics and the main drape are not provided with additional spreader plates, which means that in the best case the spreader plates will have to be spread apart much further than recommended. However, on many of these systems the spreader plates are buried under stacks of weight.

Additionally, most of the shaft collars were not tightened, basically negating their effectiveness.

2.1.5 Head and Loft Blocks

At the grid the head and loft blocks were in surprisingly good shape. The one exception to this is the first two head blocks which have slipped from their originally installed position. This has caused significant amounts of grinding on the head block grooves. The blocks may not need to be replaced, but it probably is not a bad idea.

2.1.6 Loading bridge

Weight was stacked on a chair on the loading bridge, placing it above the guards that prevent the weight from falling from the loading bridge. Stack weight only on the floor and do not exceed the height of the guards.

2.1.7 Sag bars

For proper operation, sag bars or idlers are required where the liftlines cross the grid. In addition to improving batten performance, sag bars prevent the cable from grinding on the structure. No sag bars are provided in this system.

2.1.8 Signage

Any operational signage was completely missing from the theatre. No safety instructions or even basic system signage was provided. Signage should, at a minimum, clearly indicate capacities of all of the linesets.

2.1.9 Curtain Tracks

The main curtain appears to have been re-rigged at some point, but the old batten was simply hung from the new batten without any attempt at leveling it. The main curtain does not operate smoothly because of this. Nothing looks like a safety issue in this rigging.

2.1.10 Temporary equipment

In any theatre, temporary equipment is attached to battens and building structure to support theatre operations. We do not individually inspect this equipment, but we do look at it. We have the following notes:

Speakers Speakers are hung on the face of the proscenium wall from unrated hooks from the speaker handles. This is not considered a suitable attachment in either case.

Safety cables Lighting fixtures are typically hung from cast iron clamps with a secondary cable suspension to prevent falling if the clamp fails. Exactly none of the lights over the stage had safety cables.

Projection screen Projection screen appears to be rigged with 1/8" cotton sash cord and is beginning to fall apart. Recommend re-rigging with rated hardware before the aluminum tube falls off.

Dog chain In a couple of places "dog chain" was used to hang equipment from battens. Lineset 11 is a notable case of being a little frighteningly rigged.

2.2 Elementary School Theatre

A small theatre is being used by Hudson University at the adjacent former Hudson Elementary School. Rigging here consists of double loop weldless chain suspending drapery tracks and PAR30 striplights.

The track and striplights appear to be in good condition, but the double loop chain is considered unrated and should be replaced.

Connections above the T-grid drop ceiling were not inspected.

3 System Survey Results

The following tables represent the survey results of our rigging inspection. They only call out significant problems in the system. See Recommendations for recommendations and the Issues Identified for discussion.

		Batten Termination						Arbor Termination					Arbor Itself							Accessories		
Lineset	Rusty Cable	Unrated batten suspension straps	Cable clips and clove hitch	Improperly installed cable clips	Improperly installed trim chain	Shackles need to be moused	Head block fleet angle	Cable clips — correct	Cable clips — reversed	Shackles need to be moused	Damaged turnbuckle	Turnbuckles need to be moused	Arbor has crashed	Loose Tie Rods	Loose shaft collars	Insufficient spreader plates	Weights improperly installed	Pipe weight not marked well	Spreader plates incorrectly installed	Poorly installed pipe extension	Improperly installed raceway	Badly rigged attached equipment
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4 Recommendations

The general recommendation for both theatres is to immediately rip out all of the unrated or unsafe hardware and replace it with properly rated equipment. While this would be best, it can be cost prohibitive, and a more balanced approach may be more appropriate, based on the relatively light use of the system.

In addition to suggested phased repairs listed below, a training program for the counterweight rigging and lighting systems should be implemented. See separate recommendation document not part of this rigging report.

4.1 User-serviceable elements

Prior to a rigging contractor being involved, the following actions can be performed by the user or college facilities management:

- Re-rig or remove any poorly installed equipment. Linesets 2, 4, 11, and 15 are noted for this.
- Tighten arbor rod nuts.
- Always tighten shaft collars tight to the top weight.
- Mouse all shackles and turnbuckles.
- Paint or otherwise identify the pipe weight on all arbors.

4.2 Critical elements

The fire curtain needs to be replaced and re-rigged for proper operation. There is no way around this, and it is going to involve both a rigging contractor and an asbestos abatement contractor. I would recommend using whatever abatement contractor the rigger recommends, since removal of a firecurtain can be dangerous in itself.

Again, a full rerope of the rusty cable is recommended. If this is not possible, improperly terminated cables on linesets 3, 9, 13, 16, 17, and 18 should be replaced. These cables should be sent to a testing facility to establish a sampling of breaking strength for the rusty cable. This does not guarantee safety, but should provide data for better rating of the system's current capacity.

The first electric should be reroped immediately to replace the bad terminations. All three electrics should have new hanging hardware fabricated to replace the bad suspension straps and better support the electrics.

The two damaged turnbuckles should be replaced.

4.3 Important elements

The remaining issues identified can be dealt with either concurrently with the reroping or can be dealt with as time and money allows. This includes readjustment of the two kicked headblocks, installation of sag bars, and other issues not super critical.

Signage is strongly recommended and your rigging contractor can provide signage that identifies the proper functioning of the system.

Appendix: Background

Counterweight rigging systems have been used in a relatively modern sense in theatres for about 150 years. Until about World War II, they mostly consisted of sandbags and natural fiber (hemp) ropes. These systems rather complicatedly allowed for the lifting of large loads over the stage with minimal effort by stagehands. Eventually, the sandbags were replaced with steel or cast iron bricks being placed into carriages that had fixed loops of ropes attached allowing them to move up and down and indirectly lift the loads.

While these systems have existed in some form or another for over 70 years, there was not any sort of industry standard for them until 2009 when the PLASA Technical Standards Program (TSP) published the Manual Counterweight Rigging ANSI standard. This standard codifies the current (as of 2009) industry best practices in a single document. Its introduction (not part of the normative standard) describes that systems installed prior to 2009 are not inherently unsafe. This, however, does not mean that all systems installed prior to 2009 are safe, simply that noncompliance with the standard does not necessarily mean a system is unsafe. A qualified rigger can inspect and evaluate a system and make the determination of what hardware is safe and what is not. A counterweight rigging system, in whatever form, is a machine. Like all machines it requires regular inspection and maintenance to remain safe and operational.

A counterweight rigging system, by its design, takes large steel weights and suspends them over the side of the stage area. These weights counteract the weight of the pipes over the stage. By lifting or lowering the weights, installed in what's known as an arbor, the pipes— known as battens or linesets– can be lowered and raised. While precise counterbalance is neither necessary nor achievable, it generally takes less than 20 pounds of pull on a rope to move what can be several hundred pounds of weight over the stage. It should become clear that the connections between these arbors and these battens are critically important to keep everything hanging where it is.

The most critical parts in a rigging system is the *Tension Load Path.* This refers to the components that are loaded in tension. Failure of these components can either directly drop the load or can cause *zipper failures* where the shock load from a component failing causes the next component in line to fail. In general, we like to have components in the tension load path deform noticeably when overloaded rather than snapping. This allows hardware that has been overloaded to be identified before it fails, rather than forensically after the fact. While other parts of the system (bearings, mounting clips, guide shoes) are critical to the operation of the system, the integrity of the tension load path is critical to the safety of the system.

There are several components commonly found in older rigging systems that are currently recommended for replacement. These include: unrated chain (including double loop weldless and proof coil chain if used in single-load path situations), cast wire rope clips, bolts below a Grade 5, and any sort of cast iron or cast steel hardware used in tension. All cast hardware will crack and fail without warning, forged or rolled hardware will deform prior to failure.

Additionally, like any machine, vibration can loosen hardware. Turnbuckles and shackle pins are the most notorious for this, as turnbuckles will loosen over time if not *moused*. Mousing refers to using either wire or plastic zipties to prevent the hardware from loosening. Nuts can be fixed with a locking compound or deformed thread locking hardware like a nylock nut.

In addition to our experience in the design, use and inspection of theatrical rigging systems, we rely on industry publications to provide insight to overall best practices. For modern installations and best practice documentation for new work, we use the *ANSI E1.4-2013 Entertainment Technology - Manual Counterweight Rigging Systems* . Fire curtains are covered by NFPA 80 and *ANSI E1.22-2009 Entertainment Technology - Fire Safety Curtain Systems*. For best practice regarding wire rope, we refer to the Wire Rope Users Manual, published by the Wire Rope Technical Board. This document clearly calls out the proper and improper use, inspection and maintenance of steel cable and its terminations. For stranger cases, we may refer to a plethora of test data that has been published by Delbert Hall.

4.4 Definitions

The following are definitions of rigging terms that you may find throughout this document. It is not intended to be complete or authoritative. Please feel free to contact us for clarification. Definitions are a subset of those found in ANSI E1.4-2009 and are ©2009 ESTA.

Batten A pipe that is secured to the lift lines. Battens are used for flying scenery, curtains, lighting and audio equipment …

Batten clamp A piece of rigging hardware, typically consisting of two pieces of metal bolted around a batten and having a hole for the attachment of a hanging curtain, turnbuckle assembly, or rope.

Block An assembly of one or more sheaves in a housing designed to support one or more lines to allow a change of direction.

Breaking strength The load at which failure will occur in a component.

Counterweight A weight used to balance the load on a line that is being raised, lowered, or held in position.

Counterweight arbor A movable rigid carriage assembly and inclusive guides that holds counterweights and is used to counterbalance a load.

Design factor A ratio of the design load limit to the ultimate breaking strength of a material or component.

Fleet angle The included angle between a line representing the travel of a rope, from the groove in a sheave, and a line drawn perpendicular to the axis of the sheave.

Guide shoe A device that connects a counterweight arbor or tension block to the guide rails in order to control the path of its travel.

Guide rails A means of guiding the counterweight arbor throughout its travel in the vertical plane, but which also prevents the horizontal or twisting motions of the arbor.

Head block The stationary sheave or block assembly directly above the counterweight arbor ... The head block permits lift lines to change direction. In wire rope systems, the head block is also grooved to allow the purchase line to change direction by 180 degrees.

Hemp rope Natural fiber rope made from a tree called the abaca.

Idler block a block designed to support only the self-weight of one or more lift lines, and guide those lines to a load bearing block without changing direction of the line. Idler blocks are used for the same purpose as sag bars.

Lift line Any rope or cable reeved through head blocks and loft blocks, and attached to a load. Lift lines operate singly, as spot lines, or in "sets" of several lift lines working together to support a load or a batten.

Line set A system of multiple lift lines, operated together to raise, lower, or suspend a load: All of the mechanical, component subsystems required for supporting, positioning, and operating those lift lines as a system.

Loading bridge An elevated area, located to permit counterweight loading and unloading at the arbor, while the battens are at low trim.

Locking collar A locking device, located on a counterweight arbor rod, designed to impede the unintended movement of counterweights from the arbor.

Locking rail A structural railing that supports the rope locks.

Loft block The overhead block through which one or more lift lines pass before being attached to the load being lifted or supported.

Purchase line The operating line attached to the top and bottom of a counterweight arbor, permitting an operator to raise and lower a batten.

Rigging General term for arrangements of hardware and systems for the raising, lowering, and suspension of scenery, properties, lighting, and similar loads used over performance areas.

Rope lock A positioning device, located on the locking rail, that grips or releases the purchase line of a counterweight set.

Sag bar A bar or other non-sheaved mechanism used to support the self-weight of one or more lift lines, as those lines extend to a load-bering block. A Sag bar is used for the same purpose as an idler block.

Spreader plate Plate that is installed between counterweight arbor rods to keep the rods from spreading during rapid travel or impact in order to prevent counterweights from falling out of the arbor.

T-bar or T-bar track A variation of guide rails employing T-shaped members.

Tension block A block designed to remove slack from a purchase line, prevent the purchase line from twisting in its travel, and from rubbing against wire ropes, structural framing, and adjoining equipment.

Tension load path The path of tension-only load that follows the axis of the rope or wire rope lift lines, including all connections and terminations along the path....

Thimble A grooved fitting around which a rope or cable is bent to form an eye. It supports and protects the rope or cable to prevent kinking and wear.

Trim chain A system employing a length of chain and fittings used to connect a lift line to a batten (or other load) and adjust its level.

Wire rope clip A device used for forming eye terminations on wire rope.

Working load limit The maximum recommended capacity of a component or system, during normal operating conditions.

Images

Our inspection reports include a section of images. They have been omitted from this sample report, since they will identify the theatre in question.

END OF REPORT