HISTORIC AMERICAN ENGINEERING RECORD

STEEL BRIDGE

This report is an addendum to a 7-page report previously transmitted to the Library of Congress in 1992

Location:	**Spanning the Willamette River on Oregon 99W, Portland, Multnomah County, Oregon** **UTM: 10/525930/5041420** **Quad: Portland, Oregon**
Date of Construction:	**1910-1912**
Structural Type:	**Double-deck, vertical lift bridge**
Engineer:	**Waddell & Harrington, Kansas City, MO**
Fabricator:	**American Bridge Company, Pittsburgh, PA**
Builder:	**Superstructure - Robert Wakefield & Co., Portland, OR; Substructure - Union Bridge & Construction Company, Kansas City, MO.**
Present Owner:	**Oregon-Washington Railroad and Navigation Company; Union Pacific and Southern Pacific; Union Pacific.**

Present Use:	**Lower deck - railroad; Upper deck - light rail, vehicular, and pedestrian traffic, rented by ODOT**
Significance:	**Significance: An early example of the Waddell-type vertical lift bridge, the Steel Bridge documents that, guided by Harrington, most features of the type achieved "standard" form by 1912. It also demonstrates Waddell & Harrington's virtuosity in developing the bridge type's rich potential: its lower, railroad deck may be lifted independently, telescoping into the trusses above, or both decks may be lifted together, a unique combination. Combined with its great weight and massive members, these features made it an essential case in subsequent engineering discussions.**
Historian:	**Researched and written by Judith A. McGaw**
Project Information:	**Project Documentation of the Steel Bridge is part of the Information: Willamette River Bridges Recording Project, conducted during the summer of 1999 under the co-sponsorship of HAER and the Oregon Department of Transportation in cooperation with Multnomah County. It extends preliminary work conducted under the Oregon Historic Bridge Recording Project with the same co-sponsors in the summer of 1990.**
Related Documentation:	**HAER No. OR-20; HAER No. OR-22**

Overview

From almost any perspective, Portland's Steel Bridge is remarkable. To begin with, it is the only bridge of its kind ever built: a lower, lifting deck that raises independently by telescoping its vertical hangers into the vertical members of the trusses above, combined with an upper, lift deck that also raises to provide additional clearance. Unlike most unique structures, which are simply anomalous, the Steel Bridge's design and construction display a careful working out of the vertical lift bridge's potential. In so doing the bridge manifests the prolific creativity of the consulting engineers, Waddell & Harrington, who essentially brought this type into being. Professional articles and engineering texts throughout the first half of the twentieth century recognized the bridge's exceptional importance; although their other examples might vary, when writing about the vertical lift bridge, they always featured Portland's Steel Bridge.[1]

The bridge itself conveys powerfully another distinctive feature emphasized in the literature, but hard to appreciate except through direct experience: the structure is massive. As late as mid-century its 9 million pounds total moving load made it one of the heaviest yet built. Its huge structural members, within which most people could fit easily, remain especially impressive. Built to carry the heaviest anticipated loads, it continues to perform that function; it readily accommodates the heaviest tractor trailers and the newest light rail vehicles on its vehicular deck while bearing modern freight and passenger trains below.[2]

The Steel Bridge also embodies some remarkable political maneuvers. Built by the Harriman roads at the height of Progressive Era hostility to railroads, the structure underwent repeated challenges before its construction began. Thereafter, it became the site of conflicts between the railroads and the various political entities that rented and policed its traffic deck: the City, County, and State at various times. Its ability to carry traffic has been dramatically altered through the resolution of additional political debates over its approaches and ramps.

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[1] To be precise, what the Steel Bridge represented was a working out of the potential of Waddell's pioneering *large-scale, high-clearance,* vertical lift bridge. Hereinafter the phrase "the vertical lift bridge" refers to this type.

Most of these contentions are documented in the text that follows. My observations about the Steel's centrality in professional discussions of the vertical lift bridge rest upon the following important works: George A. Hool and W. S. Kinne, eds., *Movable and Long-Span Steel Bridges* (New York: McGraw-Hill Book Company, Inc., 1943); Otis Ellis Hovey, *Movable Bridges* (New York: John Wiley & Sons, Inc., 1926), Vol I: Superstructure; Ernest E. Howard, "Vertical Lift Bridges," *Transactions of the American Society of Civil Engineers*, 84 (1921), 580-695 (including discussion) [Howard won the ASCE's Thomas Fitch Rowland Prize for this article]; Horatio P. Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," *Transactions of the American Society of Mechanical Engineers*, 40 (1918), 1017-1042 (including discussion). Also documenting the relative importance of the structure is the fact that J. A. L. Waddell in his classic *Bridge Engineering* (New York: John Wiley & Sons, 1925), devotes two full pages of text and two of illustrations to the Steel Bridge out of a thirty-page chapter on the vertical lift type; the only bridges he gives slightly more coverage are the South Halsted Street and Fratt (A.S.B.) bridges, those in which he personally played the central role.

[2] Hool and Kinne, *Movable and Long-Span Steel Bridges*, 168

Finally, the Steel Bridge is remarkable in surviving as a functioning bridge for nearly ninety years. Its history documents that, whatever its initial assets, no movable structure survives so long without consistent maintenance, intelligent operation, and creative repair. Life-sustaining alterations began early in its history. Consistent care, assured through long-tenured employees who have passed on an effective operating and maintenance tradition, accounts for the ease with which the aged structure performs its contemporary tasks.

The Railroads in Portland

Understanding the Steel Bridge begins with understanding its principal architects and operators: the railroads. Intent on fostering the economic development that would assure their financial survival and success, Oregon's various railroads became early and continuing proponents and exemplars of bridge building. The Portland, Dalles, and Salt Lake Railroad submitted the first Willamette River bridge plans to Portland's City Council in 1872. The effort proceeded as far as driving test piles and presenting the project to the U.S. Army Corps of Engineers, which exercised the responsibility to approve any structure over navigable waters within the United States.[3]

Although that structure never materialized, Portland's second Willamette River bridge was a railroad bridge. Henry Villard, one of several influential railroad promoters to leave his stamp on Oregon, proposed the bridge in 1883. Villard, a German-born American journalist, became interested in railroads while visiting German investors. As their representative, in 1874 he assumed control of the Oregon & California Railroad, the Oregon Central Railroad, and the Oregon Steamship Company. The railroads received Congressional authorization to bridge the Willamette the same year. Captivated by a vision of Oregon's enormous potential, Villard acquired additional transportation companies and eventually created the Oregon Railway and Navigation Company (O.R.& N.). To protect his interests, he also orchestrated the acquisition of the Northern Pacific Railroad in 1881. He completed its transcontinental line in 1883, although at such great cost that his various enterprises suffered financial setbacks; Villard resigned all his railroad positions in 1884.[4]

Villard's departure and the associated financial uncertainty delayed the start of the new bridge's construction until 1886 and its completion until 1888 for trains and 1889 for vehicular traffic. But Villard's grand (some said grandiose) vision was reflected in this, the first Steel

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[3] Fred Lockley, *History of the Columbia River Valley from The Dalles to the Sea* (Chicago: The S. J. Clarke Publishing Company, 1928), I: 534.

[4] E. Kimbark MacColl, *The Shaping of a City: Business and Politics in Portland, Oregon, 1885 to 1945* (Portland: The Georgian Press, 1976), 42-47; Jon Huibregtse, "Henry Villard," *American National Biography*, ed. John A. Garraty and Mark C. Carnes (New York: Oxford University Press, 1999), XXII, 362-363; Lockley, *Columbia River Valley*, 534-536; W. W. Cotton to J. P. O'Brien, General Manager, 1/29/1908, O.R.& N. Letterbooks, Union Pacific Collection, Oregon Historical Society (hereinafter, OHS).

Bridge. Villard's efforts had assured that Portland became the terminus of a transcontinental railroad. The Steel Bridge complemented that effort by carrying traffic from the east and south over the Willamette into downtown Portland. The bridge's design also reflected Villard's preference for going first class; he had, for example, proposed a new Union Station to be the work of the nationally prominent McKim, Mead and White. But while his Union Station became a casualty of Villard's financial reverses, his Steel Bridge plan survived to become a first class structure. George S. Morison, the nation's preeminent bridge engineer, served as consulting engineer. Morison was "the great pioneer" of steel bridge construction. In Portland he created the West Coast's first steel bridge. Morison's accomplishment was underwritten by the O.R.& N., the most powerful corporate entity in Portland, whose local real estate alone had an estimated value of $3 to $4 million. The locally dominant O.R.& N. was joined in the project by the nationally powerful Union Pacific, which purchased a majority of O.R.& N. stock the year the bridge was completed.[5]

Other, formal names were proposed for the new structure, but local people found Morison's innovative use of materials so striking that the bridge quickly became known as "the Steel Bridge," a name it eventually handed on to its successor. The first Steel Bridge created other precedents with which its successor also had to contend. It was a double-deck bridge, carrying railroad traffic on its lower deck and, on its upper deck, pedestrians, horse-drawn vehicles, and the city's first electric railway, the work of C. F. Swigert. And because Villard's financial failure had doomed the proposed east side repair shops and west side station his bridge was intended to link, its builders moved it upstream to the Willamette's narrowest Portland stretch near the heart of the city.[6]

Spurred by the economic development that Villard's bridge was intended to foster, by the

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[5] MacColl, *Shaping of a City*, 47, 80, 151-152, 223; J. I. P., "George Shattuck Morison," *Dictionary of American Biography*, ed., Dumas Malone (New York: Charles Scribner's Sons, 1934); James L. Ehernberger and Francis G. Gschwind, *Smoke along the Columbia: Union Pacific, Oregon Division* (Callaway, NE: E.G. Publications, 1968), 61.

[6] Completing the electric railway involved considerable innovation since the bridge's draw span was the longest yet to carry an electric street railway. Swigert had come to Portland to manage a local branch of his uncle's San Francisco-based Pacific Bridge Co. In that capacity he had help design and build Portland's first trans-Willamette bridge and he continued to be involved in local construction, including several additional trans-Willamette bridges. His street railway interests would certainly have been well served by moving the Steel Bridge closer to the population center and his expertise may well have enabled him to influence the decision. MacColl, *Shaping of a City*, 95, 153, 283-287; John T. Labbe, Fares, *Please!: Those Portland Trolley Years* (Caldwell, ID: The Caxton Printers, 1980), 66.

Villard had proposed a bridge between Albina, a community on the river's east bank later incorporated into northeast Portland, and 17th Street on the west bank, thus linking his proposed railroad shops on the east side with his proposed depot on the west. At least one account credits Potter, Union Pacific's Vice President, with the choice of a new location for the bridge. MacColl, *Shaping of a City*, 45-46, 151-152; Lockley, *Columbia River Valley*, 536; S. Gertsman, "Portland City of Bridges," *Oregonian*, 5/31/1931, p. 4; "Why It's Called Steel Bridge," *The Portland Journal*, 11/19/1962, p. 10.

early 20th century Portland's rail traffic boomed and its railroads flourished. Figures for 1910 show that every twenty-four hours 70 steam passenger trains and 164 electric railway trains entered and left Portland. In addition, roughly 220,000 freight cars moved in and out of the city each year. Freight trains brought in the 5.5 million bushels of wheat that allowed Portland to rank second only to New York City as a United States wheat exporting city and they carried the nearly one-quarter billion board feet of lumber that left Portland annually to build the cities of California and the East. They also transported roughly 1,000 head of livestock a day. Meanwhile, passenger trains had permitted Portland to grow by 129 per cent between 1900 and 1910, a rate exceeded by only two other cities, making the city rank 28th nationally in population. Mostly, the influx multiplied the city's homogeneous, largely Middle Western population, although the *Oregonian*, reflecting the onset of one of Portland's periodic vice crusades, asserted: "The trains are loaded with gamblers, macquereaux, touts, pimps, confidence men, common women . . . who have heard that the town is wide open, the pastures green, and the feeding good."[7]

The railroads were far from passive beneficiaries of this economic growth. E. H. Harriman, noted nationally for reorganizing and rebuilding the Union Pacific, played an especially important role. In 1898, in the midst of his tour of the newly reorganized railroad, Harriman stopped in Portland and wired his board of directors for $25 million to improve U.P. right-of-way and rolling stock throughout the system. In Portland and elsewhere, his commitment to capital improvement and maintenance paid off in profitable operations. To accommodate the potential growth he foresaw, the Union Pacific invested an additional $25 million in improvements. In consequence, by 1907 the railroad's freight cars' average capacity had grown from 20 to 34 tons and by 1909 its locomotives' had increased from 37 to 68 tons. Although bearing a separate name and boasting its own board of directors, Portland's O.R.& N. (since 1897 reorganized as he Oregon Railroad & Navigation Company) was essentially a piece of the Union Pacific system; Harriman controlled virtually all of its stock. By 1901, Harriman's Union Pacific had also acquired control of the Southern Pacific, which, in turn, controlled the railroads entering Portland from the south. Here, too, Harriman's policy was to upgrade equipment; $71 million spent on the Southern Pacific paid off in enhanced operations and economic performance.[8]

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[7] If anything, these various statistics minimize local economic activity. The electric train figures do not include service to nearby points such as St. Johns and Troutdale, the livestock figures are taken from a less busy month, and the lumber figures are only for wood exported by rail. Equal amounts of lumber were shipped from the port and retained for local building. The only U.S. cities to grow more rapidly during the decade were Seattle and Spokane; Los Angeles ranked next behind Portland with a growth of 113 per cent. The 1910 census showed Portland's population derived especially from Iowa, Illinois, Missouri, and Ohio, in that order. African-Americans, Indians, and Asians made up less that 3 per cent of the population. MacColl, *Shaping of a City*, 389-395; quotation from 402.

[8] Lloyd J. Mercer, "Edward Henry Harriman," in *American National Biography*; MacColl, *Shaping of a City, passim*; O.R.& N. Letterbooks, OHS; Ehernberber and Gschwind, *Smoke along the Columbia, passim.*

As the first decade of the 20th century drew to a close, then, Portland's Steel Bridge carried far more traffic than its builders had anticipated and far heavier loads than its designers had calculated. At the same time, its upper, vehicular deck struggled with the multiplication of novel, gasoline-powered vehicles which had not figured in the bridge's planning. Its 19' wide deck in particular was better suited to serve wagons than trucks.[9]

Other developments in the Union Pacific's regional system created more pressure for a new bridge. A Portland-Seattle line had been under development since 1890, although the 1893 panic and conflicts with the Northern Pacific had delayed its completion. Finally, in 1909 the U.P., N. P. and Great Northern signed an innovative trackage rights agreement that not only opened western Washington's major cities to the U.P., but also became the model for cooperative trackage rights agreements nationwide. The O.R.& N. could expect additional traffic from the north along two new routes, a loop line and a tunnel through the North Portland peninsula, currently under construction. When finished in 1910-11, these new routes would allow heavy freight trains to avoid the steep grade along Sullivan's Gulch on the direct route into Portland from the east. Also, since the completion of the first Steel Bridge, the area north of the Bridge in Albina, on the Willamette's east bank, had become the site of the Union Pacific's major Pacific Northwest car shops, providing another demand for passage north to and from the Bridge's east portal. None of this new traffic could use the old Steel Bridge. In setting the span at the Willamette's narrowest point, its builders had also placed it where its east approach encountered a high embankment too near the river to allow space for trains to turn to the north.[10]

For a multitude of reasons, then, by late 1907 O.R.& N. management knew they would need to replace the Steel Bridge. As their plans matured, two engineers especially helped shape the final structure. Leading the effort was George W. Boschke, Chief Engineer. Boschke completed his formal education in the Boston public schools and at Wilson College. He began his career immediately thereafter, in 1886, with the engineering department of Southern Pacific in Texas. While there he simultaneously undertook a three-year project building Galveston's seawall, a remarkable piece of engineering that later successfully withstood a tidal wave topping it. After a stint with S.P. in California, Boschke came to Portland in 1904. By the time he began work on the Steel Bridge, he had supervised or was supervising construction of several major eastern and central Oregon branch lines as well as the many shorter projects that constituted Harriman's improvement program. And to Boschke, supervision was a hands-on job. As the U.P. raced to counter James J. Hill's central Oregon initiative by building a railroad along the Deschutes River to Bend, the Chief Engineer took up residence in a tent alongside his

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[9] W. P. Hardesty, "The New O.-W.R.& N. Bridge at Portland, Oregon," *Engineering News*, 68 (1912), 1100; MacColl, *Shaping of a City*, 152. Hardesty's 19' figure probably refers to the width of the vehicular traffic area. Howard, "Vertical Lift Bridges," 611, gives 32' for the roadway width; sidewalks and the trusses could easily have taken up the 13' difference.

[10] Ehernberger and Gschwind, *Smoke along the Columbia*, 14-16;MacColl, *Shaping of a City*, 133; Hardesty, "New O.-W.R.& N. Bridge," 1100.

construction crew.[11]

More intimately involved with the Steel Bridge's design was George T. Forsyth. Born in Salinas, California, Forsyth trained as an engineer at Stanford, where he was a classmate of Herbert Hoover. His Stanford years left their indelible mark in his idealistic commitment to engineering excellence and public service. He joined the engineering staff of the Southern Pacific a few years out of school, in 1900, and moved on to the O.R.& N. in 1904. He served as the railroad's bridge building specialist and remained until the completion of the Steel Bridge, his best known structure. To an enterprise that would challenge available construction techniques through the sheer weight of its components, Forsyth made crucial contributions by designing the massive, elaborate lift span falsework, traveler, and sheer-leg (gallows frame used to lift materials to the tops of the towers).[12]

The impressive talents of its engineers underscore the most important characteristic of the Union Pacific at the time the new Steel Bridge was planned and built: it had committed itself to high-quality engineering work and it had the resources to buy the best. Harriman's pattern of investment had paid off, so there was no reason to alter his strategy after his death in 1909. The new corporate entity, the Oregon-Washington Railroad & Navigation Company (O.-W.R.& N.), that emerged in 1910 when U.P. consolidated all its Washington, Oregon, and Idaho subsidiaries was prepared to create an exceptional bridge.[13]

The Politics of Bridge Building

Before any bridge construction could begin, the O.R.& N. faced a number of formidable political hurdles. Each encounter with municipal, state, and federal agencies required careful planning and benefitted from discrete mobilization of the railroad's influential allies. Several contemporary issues made the railroad's political situation especially difficult. In general, the

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[11] After Harriman's death and the break-up of the U.P.-S.P. trust, Boschke left for private practice. He returned to the S.P. in 1921 to become its chief engineer, "succeeding the famous William Hood." He went on to complete a number of difficult engineering projects, including the S.P.'s Cascade and Modoc lines in southern Oregon. "George W. Boschke Quits after 29 Years," *The Evening Telegram*, 4/10/14, p. 8; "G. B. Boschke, S.P. Engineer, Dies in S. F.," *Oregon Journal*, 3/3/32, p. 1.; "George W. Boschke, Rail Engineer, Dies," *Oregonian*, 3/4/32, p. 13; Ehernberger and Gschwind, *Smoke along the Columbia*, 14, 62. The O.R.& N. and O.-W.R.& N. Letterbooks document Boschke's ongoing involvement in the project's many diverse aspects.

[12] Thereafter, he worked for several bridge building companies before opening a private consulting practice in 1920. His other great contribution to Portland's Willamette bridges was his leading role in the investigation that resulted in bringing Gustave Lindenthal to Portland to complete the Burnside, Ross Island, and Sellwood Bridges. "Bridge Designer Dies," *Oregonian*, 9/1/25, p. 6; "George Forsyth," *The Portland Telegram*, 9/5/25, p. 8.

[13] To ensure precision, in what follows I will refer either to the O.R.& N. or the O.-W.R.& N., depending on which corporate entity took a particular action. The first began the bridge and laid much of the important political and legal groundwork; the second did most of the building and was the bridge's first official owner. Ehernberger and Gschwind, *Smoke along the Columbia*, 62; O.R.& N and O.-W.R.& N. Letterbooks, OHS.

reform movements of the era had heightened public awareness of large corporations' power and its abuse. Nationally, railroads had been subjected to regulation by the Interstate Commerce Commission. The I.C.C.'s mandate had recently been extended through the Hepburn Act (1906), whose provisions directly affected the writing of various Steel Bridge contracts. Oregon had followed the federal lead, creating its own Railroad Commission in 1907. Although not empowered to enforce much change, the Commission fed public outrage through its publication of railroad financial information.[14]

Like their contemporaries in other U.S. cities, Portland citizens had grown especially conscious that earlier officials had too readily placed public resources in private hands. For example, negotiations for the right to build the Steel Bridge took place against a backdrop of battles over public docks. Like most U.S. cities, Portland had allowed its river frontage to fall under private, mostly railroad, control. The O.R.& N. alone owned six miles of Portland waterfront. Not surprisingly, the railroads showed more concern with promoting rail than water bourne commerce; most Portland docks were operated by railroads so as to guarantee railroad profits. The issue evoked enough public concern that when Mayor Simon, a former O.R.& N. lawyer, vetoed a public dock bond sale, citizens placed an initiative charter amendment on the 1910 ballot and voters overwhelmingly supported its creation of a new, independent dock commission empowered to tax and to issue bonds.[15]

Although the railroad's overweening economic power was paramount, other issues exacerbated the difficulty of obtaining necessary permits. East siders, by 1910 making up more than half of the city's population, chafed at continued West side dominance. Knowing that rapid East side growth was a consequence of late 19th-century bridge building, the various East side real estate interests also displayed acute sensitivity to any proposed change in bridge location. These concerns came to a head because the O.R.& N. found itself seeking bridge-building rights at the same moment that the city had decided to build a new bridge downstream. That bridge, eventually the Broadway Bridge, was mired in a court challenge from aggrieved East side real estate interests just as the O.R.& N. faced its initial bridge hearings.[16]

Ordinary citizens also had reason to view O.R.& N. activities with suspicion. When the railroad closed its shops at The Dalles in 1893, it abruptly moved several hundred workers to Portland. Small, cheap workers' houses interspersed with and repeatedly displaced by railroad facilities and commercial establishments multiplied and transformed established residential areas in the company-dominated Albina section. Railroad employees living elsewhere in town also found their needs poorly served. As they noted in a 1908 petition, the railroad lines lay along the river, while the Steel Bridge's pedestrian deck delivered traffic to the bluff above. No provision had been made for access from the bridge to their work sites "except by scrambling up the bank"

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[14] MacColl, *Shaping of a City*, 350-352 and *passim*; O.R.& N. and O.-W.R.& N. Letterbooks, OHS.

[15] MacColl, 385-388 and *passim*

[16] MacColl, *Shaping of a City*, 18, 387-388 and *passim*; O.R.& N. and O.-W.R.& N. Letterbooks, OHS.

or by a circuitous route "which is both dark and unsafe." Their request that the City build a flight of steps down the bank evoked further evidence of O.R.& N. disdain. The City Engineer reported: "The Railroad Company, owners of the property, are not willing to give their consent to building steps on their land, I presume for the reason that if an accident happened the Company might be held responsible."[17]

Directly or indirectly, these various issues surfaced in the political battles over the Steel Bridge. The Port of Portland Commission provided the first stage. A self-perpetuating organization of Portland elite, the Commission had been created by the State Legislature in 1891; it assumed full state power over the Willamette and Columbia Rivers from the City to the sea, including power to authorize bridge building. In general, the Commission showed considerable friendship for the railroads and for bridges; many railroad directors served on it and, in the decade from 1901 to 1911 when conflict of interest remained a vestigial concept, its perennial leader was Charles F. Swigert, first holder of the Steel Bridge electric railway franchise and builder of Portland's other 19th-century Willamette River bridges. However friendly the agency, though, every hearing provided an opportunity for local opponents to voice their objections.[18]

In several respects the 1912 Steel Bridge took shape through the dialogue between the O.R.& N. and the Port of Portland. The project received its first public airing before the Commission in April, 1909, at which time the railroad expected to replace the old swing span with a new bridge of the same type. River pilots and streetcar users showed up to object, because even small craft would require full and time-consuming draw openings. Opponents wanted the Railroad to build a high bridge which would need to open only occasionally, when large vessels needed to pass. This solution had considerable public visibility at the moment. The City's Consulting Engineer, Ralph Modjeski, had recommended it in 1908 as best way for the city to build a new bridge north of the Steel Bridge. Eventually, the Broadway Bridge embodied his recommendation.[19]

For the O.R.& N., which needed to locate its bridge with existing track and stations in mind, a high bridge was not a viable alternative. Tracks and right-of-way both north and south lay along a low, narrow slice of river front land up against a higher embankment on Portland's

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[17] MacColl, *Shaping of a City,* 133; Undated copy of petition by F. O. Blazier and others to Mayor and Council and D. W. Fowler, City Engineer, to Committee on Streets of the Council, 6/29/1908, City Council Documents, Improvements - Bridges, 1908, City Archives, Portland.

[18] MacColl, *Shaping of a City,* 95, 153, 283-287, 421-422; E. Kimbark MacColl with Harry H. Stein, Merchants, Money and Power: *The Portland Establishment, 1843-1913* (Portland: The Georgian Press, 1988), 292-293; O.R.& N. Letterbooks, OHS.

[19] *Oregonian,* 8/11/1909, p. 11; 8/12/1909, p. 10. According to the newspaper, the plans submitted to the Port were drawn up by O.R.& N. Chief Engineer Boschke. Although it is always risky to trust press reports of technological activity, contracts with Waddell & Harrington, the consulting engineers for the bridge, were not signed until October, so Boschke or his staff probably did prepare the preliminary sketch presented to the Port Commission. O.R.& N. Letterbooks, OHS, 10/11/1909.

East side. After the April Port of Portland hearing, the Railroad sought out other solutions. By the time O.R.& N. officials returned for a second Port Committee hearing four months later, they had found an alternative that worked at their preferred site. They presented plans for a vertical lift bridge, a type whose chief advantage lay in its ability to accommodate small craft through brief, partial openings. Moreover, the upper, highway deck would not have to lift when the lower, railway deck did. Like the high bridge opponents had favored, it would only need to open occasionally.[20]

J. B. C. Lockwood, engineer for the Port of Portland, whose role in the April hearings had included suggesting compromise solutions to meet other objections, may well have played a crucial role in this development. He had visited Chicago as part of a Port delegation that accompanied Modjeski; the group's bridge tour had included Waddell's pioneering South Halsted Street bridge, the first large-scale, high-clearance vertical lift bridge. Through his former company, Puget Sound Bridge and Dredge, Lockwood almost certainly knew of the second vertical lift bridge, Waddell & Harrington's first, just proposed for Sandpoint, Idaho. Port Commissioners might also have suggested the type because they had recently reviewed proposals for the Hawthorne Bridge, the fourth vertical lift bridge to be built nationally.[21]

But the O.R.& N. may also have identified its technological choice through sources in the industry. The other two early vertical lift bridges were both railroad structures: the Keithsburg Bridge, under construction for the Iowa Central Railroad, and the North Kansas City A.S.B. Bridge, whose telescoping lower lifting deck, designed to serve the Burlington Railroad, provided a partial model for the Steel Bridge. In particular, Frederick W. Fratt, President of the North Kansas City Bridge and Railroad Company, had come to his current position from the engineering department of the Northern Pacific; he most probably had developed acquaintance with O.R.& N. engineers.[22]

In addition to prompting the O.R.& N. search that led to a vertical lift bridge, the Port hearings assured that the span would have two different decks. The rapidly growing city clearly needed highway bridges. At a time when the city was struggling to accommodate the demand for trans-Willamette passage, the Port was unwilling to permit the Railroad to build a new bridge that eliminated the first Steel Bridge's provision for vehicular traffic. The bridge's location in the

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[20] *Oregonian*, 4/23/1909, p. 14. On Lockwood, see Historic American Engineering Record, (HAER), National Park Service, U.S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20.

[21] Kathi Ann Brown, *Diversity by Design: Celebrating 75 Years of Howard Needles Tammen & Bergendoff, 1914-1989* (Kansas City, MO: The Lowell Press, 1989); Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Armour, Swift, Burlington Bridge (A.S.B.)," HAER No. MO-2. 4-5, 8. See also Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Hawthorne Bridge" HAER No. OR-20.

[22] W. W. Cotton to J. P. O'Brien, General Manager, O.R.& N. Letterbooks, OHS, 5/9/1910.

heart of the city made the Port Commission especially adamant on this point.[23]

The Port hearings also helped determine the division of space on the upper, highway deck, a perennial bone of contention on the city's bridges. Two Commissioners, Swigert, the president, and John C. Ainsworth, Jr., both men who had figured prominently in street railway development, pressed for wider sidewalks. Finding the street railways and other fast moving vehicles well provided for on the 28' roadway between the trusses, the Commissioners argued that pedestrians needed a larger share of the area outside the trusses. Forsythe, more sensitive to the demands of vehicular traffic, had developed a configuration that divided space outside each truss into a 12' roadway and 5' sidewalk, thus assuring ample space for the passage of horse-drawn and other slow moving vehicles. Although the Port authorized a Steel Bridge permit on 17 August, 1909 without insisting on the change, the Railroad's legal department recognized the value of the Port Commissioners' continuing support as the Railroad encountered other political hurdles. At its behest, over the next few months engineers Forsythe and Boschke and General Manager J. P. O'Brien each engaged in ongoing negotiations with the Port; the final bridge included 6' sidewalks alongside 11' outer roadways.[24]

The issue that received most attention at the Port hearings, however, was that of location. To permit trains to enter and leave the new east portal and turn both north and south while still keeping the bridge near Union Station, the Railroad proposed moving the bridge 600' upstream. Businessmen and residents along Holladay Avenue, the East Side street to which the old Steel Bridge connected, showed up in force. Naturally, they objected to a plan that would transfer traffic to Oregon and Adams Streets, reducing the value of their real estate. Although they continued to voice their objections at every subsequent hearing, the Railroad's obvious need for the new location proved persuasive, especially as the Holladay Improvement Association's lawyer offered a host of transparent and specious arguments. Among other things, the group attempted to blame a recent collision between a steamer and the Burnside Bridge, just upstream, on the current proximity of the Burnside and Steel Bridges and to argue that moving the Steel closer to the Burnside would cause more accidents.[25]

Although the Railroad needed the Port's approval before presenting its case to the Secretary of War, once the Port issued its license, which carried a two-year limitation, the Railroad needed subsequent hearings to proceed expeditiously. Under those circumstances, its

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[23] A. C. Spencer to J. P. O'Brien, 11/18/1909 and A. C. Spencer to J. P. O'Brien with cc. to G. W. Boschke, 12/18/1909; MacColl, *Shaping of a City*, 254; Hardesty, "New O.-W.R.& N. Bridge," 1101. Judging from contemporary newspaper accounts, Port negotiations may also have resulted in a wider deck, providing a larger "pie" to divide. On the other hand, these accounts include somewhat contradictory figures, raising questions about their credibility.

[24] *Oregonian*, 4/23/1909, p. 14; Hardesty, "New O.-W.R.& N. Bridge," 1100.

[25] A. C. Spencer to Geo. W. Boschke, 7/31/1909, O.R.& N. Letterbooks, OHS; W. W. Cotton to General Manager, 8/11/1911, O.-W.R.& N. Letterbooks, OHS; W. W. Cotton to J. P. O'Brien, 1/29/1908, O.R.& N. Letterbooks, OHS; W. W. Cotton to J. P. O'Brien, 6/4/1909, O.R.& N. Letterbooks, OHS.

interaction with the Corps of Engineers proved frustrating. In the late 19th century, Congress had vested in the Secretary of War its power to approve the location and character of bridges such as those on the Willamette that were entirely within the limits of a single state. The Corps of Engineers acted as the Secretary's agent to review proposals. As the Railroad's legal department had learned through repeated experience, the Secretary's potential power was enormous. Railroad attorney W. W. Cotton explained to J. P. O' Brien, General Manager of the O.R.& N.: "The Secretary of War at any time has authority to modify or change its specifications, or the nature of any bridge, and even if the bridge as at present constructed is in accordance with the permit which he has granted, he would have authority to change this[.]"[26]

Such a powerful authority needed to be approached with care. In particular the O.R.& N. had learned the wisdom of honoring bureaucratic procedure. Although the U. P. was well represented in Washington, O.R.& N. attorney Arthur C. Spencer cautioned General Manager O'Brien, "In our opinion it is losing time to send the application with the accompanying papers to our representative at Washington, because the War Department would immediately send them back to Major McIndoe and he would feel slighted because of our failure to present them through him. We made this mistake upon one occasions...and I therefore proceeded through the local office in this matter."[27]

Going through channels required both patience and perseverance. After assembling all application materials and personally carrying them to the Corps' Office in late August, Spencer learned that the Major would be away until the next week. He had to content himself with urging Chief Clerk Upton "to see that the Major acted upon the matter as soon as he returned." More than a month later, no action had yet been taken because of the Major's serious illness. Hearings finally took place in late September under his temporary replacement.[28]

Surviving correspondence reveals the Railroad working hard to assure a successful outcome. Knowing that many of the bridge's earlier opponents would turn out for the hearing, the O.R.& N. mobilized supporters such as the Columbia River Pilots, notifying them of the hearing and reminding them that "you were consulted in the matter by the Port of Portland, and certain recommendations made by you . . . were acted upon by the railroad," a reference to the development of vertical lift bridge plans. After opponents had delayed matters by persuading many river users to sign a protest, early October found the Railroad's legal department contacting the proprietors of various Willamette River navigation enterprises and pleading the case for the bridge. To J. Poulson, whose firm towed logs on the river and who had signed the protest without seeing bridge plans, the Railroad pointed out the advantages the proposed bridge offered

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[26] Arthur C. Spencer to J. P. O'Brien.

[27] Arthur C. Spencer to J. P. O'Brien.

[28] A. C. Spencer to Columbia River Pilots, 9/21/1909, O.R.& N. Letterbooks, OHS; A. C. Spencer to J. Poulsen, 10/4/1909, O.R.& N. Letterbooks, OHS (see also similar correspondence of the same date to W. E. Jones; W. W.

his towboats. It provided wider horizontal clearance (205' versus 140' for the earlier swing span); located its draw more centrally, placing it both in the current and in line with the draw of the Burnside Bridge just upstream; and disturbed the current less by placing relatively small piers flanking the new draw "whereas the draw-rest of the present bridge splits the current, thereby throwing the vessel or the raft . . . out of line." Railroad efforts paid off in at least one important conversion; Captain J. W. Shaver of the Shaver Transportation Co., heavily involved in towing logs, ships, and barges on the Willamette and upper Columbia. Shaver not only withdrew his objections but put himself on record favoring the new bridge.[29]

Once the local Corps officials forwarded the application to Washington in mid-October, the Railroad called its national resources into play. Local lawyers had kept A. A. Hoehling, the Railroad's Washington attorney, posted since August so as to expedite matters. As the application moved to the desk of the Secretary of War, O.R.& N. management also got in touch with Oregon's Senators Bourne and Chamberlin and with Congressman Ellis either to ask for help in getting prompt, favorable action or to neutralize appeals the legislators were receiving from the still-disgruntled East side property owners. Thanks to these and other efforts, the necessary permit emerged from the Secretary's office in early November.[30]

But both Port hearings and War Department negotiations paled by comparison with the Railroad's last major hurdle: the City of Portland. A number of factors made these proceedings especially challenging. Perhaps most important, there were a large number of individual permits at issue, mostly street vacations to make way for permanent construction, but also temporary permits for construction traffic. As had been the case with previous hearings, each and every City Council hearing provided a potential forum for those with objections. Already aggrieved at City Council decisions to build the Broadway Bridge, East side property holders were especially vocal. At the same time, the City sought a number of concessions from the Railroad, opening up the possibility of trades, but in Portland's volatile Progressive Era climate also engendering calls for condemnation of Railroad land. Indeed, energized by the long history of City-Railroad interaction, surviving correspondence from both parties displays overtones of hostility and contempt that could only have aggravated an already difficult situation. Unlike its dealings with the Port and the Corps, Railroad discussions with the City repeatedly bogged down in debates over historic privileges and abuses. Local newspapers mostly fanned the flames of these passions with the Journal castigating the O.R.& N. while the Oregonian almost as ardently

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[29] Cotton to J. P. O'Brien, 11/4/1909, O.R.& N. Letterbooks, OHS; A. C. Spencer to G. W. Boschke, 2/10/1910, O.R.& N. Letterbooks, OHS; "History of the Shaver Transportation Co., 1893-1959," Ms. #2021, OHS.

[30] W. W. Cotton to J. P. O'Brien, 10/18/1909, 11/4/1909, O.R.& N. Letterbooks, OHS; W. W. Cotton to A. A. Hoehling, Jr., 8/31/1909, 9/20/1909, 10/18/1909, O.R.& N. Letterbooks, OHS; A. C. Spencer to W. R. Ellis, 11/1/1909 (copy of telegram), 11/2/1909, O.R.& N. Letterbooks, OHS; W. W. Cotton to Hon. Jonathan Bourne, 11/1/1909 (copy of telegram), O.R.& N. Letterbooks, OHS; W. W. Cotton to R. Blaisdell, Auditor, 2/24/1911, O.-W.R.& N. Letterbooks, OHS.

defended it.[31]

The charged political climate and complex array of items under discussion combined to generate a lengthy series of skirmishes. By the time the Port and the Secretary of War had granted their approval, former O.R.& N. lawyer Joe Simon had succeeded Portland's reform Mayor Lane. He readily negotiated an agreement granting the Railroad the street vacations it needed for the new bridge approaches and tracks leading north from the bridge's east end. In exchange, the City got the land it needed for the Broadway Bridge east approaches and stood to gain land for a South Portland park, passage through Railroad land for a new Albina boulevard, and permission to construct a sewer along the Sullivan's Gulch railway right-of-way.[32]

Simon's support, announced at the same May, 1910, City Council meeting where he vetoed the popular public dock proposal, proved a curse rather than a blessing. Urged on by public reaction, City Council jumped into the fray, reopening negotiations and seeking better terms. At various moments between May, 1910 and May, 1911, when the issue was effectively resolved, the Council seemed headed toward breaking open the package agreement and addressing each of the various issues individually or, alternatively, toward pursuing condemnation while simultaneously insisting on high fees in exchange for street vacations. At one point an exchange package had all but passed City Council when effective lobbying by East side interests persuaded the Chamber of Commerce to weigh in against East side street vacation. Several Councilmen had second thoughts and withdrew promised support.[33]

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[31] For example, whereas Railroad correspondence concerning the Port and the Corps focused on taking care to follow the procedures specified by these agencies, letters concerning the City often developed alternative strategies, some of them at variance with the a strict construction of the City Charter whose provisions the Railroad's legal department characterized as "quite burdensome, and to some extent absurd." The Railroad also readily anticipated conflict and prepared in advance to use the weapons at its disposal. For example, when condemnation proceedings loomed it prepared to transfer ownership of its land to a non-resident, "thereby compelling the city to publish summons for six weeks and enabling us then to remove the case to the Federal Count and secure non-residents of the city as jurors." Some portions of surviving letters from the Railroad's legal department are also encoded, suggesting the possibility of flagrant disregard of the law. On the City's side, councilmen repeatedly espoused dramatic actions such as condemnation of Railroad land when the city's need for prompt action made such a course undesirable because legal battles would predictably be lengthy. W. W. Cotton to J. P. O'Brien, 7/11/1910, 1/1/1911, and passim and A. C. Spencer to W. W. Cotton, 11/25/1910, O.R.& N. and O.-W.R.& N. Letterbooks, OHS. Characterizations of the City and newspaper's behavior also depend on a reading of contemporary stories in the *Journal* and *Oregonian* and on MacColl, *Shaping of a City, passim*. Spencer to Cotton 11/25/1910 offers the Railroad's perspective on local newspaper coverage and one of many examples of the O.R.& N. or O.-W.R.& N.'s attempts to influence press coverage.

[32] MacColl, *Shaping of a City*, 385-388 and *passim*; W. W. Cotton to Zera Snow, 1/3/1910, O.R.& N. Letterbooks, OHS and *passim*.

[33] MacColl, *Shaping of a City*, 385-388; O.R.& N. and O.-W.R.& N. Letterbooks, OHS, passim, especially W. W. Cotton to R. S. Lovett, 10/4/1910, 4/10/1911; A. C. Spencer to W. W. Cotton, 11/25/1910, 12/12/1910; W. W. Cotton to J. P. O'Brien, 2/24/1911; W. W. Cotton to J. W. Morrow, 5/15/1911; W. W. Cotton to H. W. Clark, 5/18/1911; A. C. Spencer to Geo. H. Baker, 11/25/1911. The East siders evidently turned to the Chamber of

Although the exchange of Railroad property for City franchises finally earned Council approval, Steel Bridge construction proceeded against a backdrop of an initiative charter amendment campaign that ultimately prohibited any future street vacations near either waterfront or railroad terminals. Combined with the year-long Council battle, the amendment's resounding victory made Railroad officials leery of any occasion potentially requiring Council action. When slow deliveries from Eastern steel suppliers necessitated extending the 1911 permit for spur tracks used to move steel to the Bridge, the Railroad made the request as innocuous as possible, asking only four months time and making even that period subject to Council revocation. As Railroad lawyer Spencer cautioned engineer Boschke, however modest, any O.-W.R.& N. proposal would "furnish matter for considerable unpleasant discussion." This legacy of ill will haunted post-construction rental negotiations as well.[34]

Creating a Novel Bridge: Waddell, Harrington, and Howard

While the O.R.& N. General Manager and legal department slowly negotiated Portland's political currents, the Railroad's engineering department moved rapidly ahead on plans for an innovative new structure. By early August 1909 Boschke and his colleagues had enough familiarity with Waddell & Harrington's vertical lift bridge technology to sketch the basic shape of the new Steel Bridge: two independently movable decks with telescoping vertical members, two independent sets of counterweights suspended within its towers, and a machinery house placed at mid-span between the lift deck's top chords. Although innumerable mechanical designs and decisions would be needed to translate this sketch into a workable structure, the overall goals were clearly articulated. The sketch shows that O.R.& N. engineers and the Harriman System's consulting bridge engineer, John D. Isaacs, had grasped the potential advantages of the new vertical lift bridge technology. More remarkable, they had readily committed themselves to creating an unprecedented new variety of the type. Appreciating just how venturesome they were requires that we survey the state of the art in vertical lift bridges.[35]

In 1909, the whole history of the modern vertical lift bridge came down essentially to the projects of one firm: Waddell & Harrington. Its senior partner was John Alexander Low

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Commerce after the issuance of Kiernan v. City of Portland, the court decision that scuttled their hopes to defeat the Broadway Bridge in the courts. See Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Broadway Bridge," HAER No. OR-22.

[34] MacColl, *Shaping of a City*, 387-388; A. C. Spencer to G. W. Boschke, 11/9/1911 and passim, O.-W.R.& N. Letterbooks, OHS. A number of letters written during the Bridge's construction document the Railroad's care in avoiding further appearances before City Council.

[35] "Plans for Huge Span Announced," *Oregonian*, 8/11/1909, p. 11; "To Pass on Plans," *Oregonian*, 8/12/1909, pp. 10, 16. Isaacs' role was to visit, review, and approve the plans developed by regional units of the Harriman system. "Steel Bridge to Be Rebuilt Soon," *Oregonian*, 2/5/1909, p. 16; Howard, "Vertical Lift Bridges," 620; Hardesty, "New O.-W.R.& N. Bridge," 1104.

Waddell, an established figure in bridge engineering, especially prolific as a creator of railroad bridges. Waddell had published several books and many articles, including a late 19th century handbook, *De Pontibus*, often cited to establish bridge specifications. A man of abundant creativity and wide-ranging interests, his greatest legacy was to be his invention of the modern vertical lift bridge, first expressed in material form in Chicago's South Halsted Street Bridge (1893). For some years, this bridge stood as a lone example of the type. What changed the situation and made the new technology widely used, especially for railroad bridges, was Waddell's new, 1907 partnership with John Lyle Harrington.[36]

In the late 1890s, Harrington had spent two summers working for Waddell while completing his undergraduate engineering degree at the University of Kansas. Then, he took a series of jobs which provided systematic training in bridge, steel, and railroad engineering, placing special emphasis on those aspects of mechanical engineering most relevant to civil engineering. He also maintained his ties with his former employer, editing a collection of Waddell's engineering articles in 1905. He brought to the new partnership a grasp of mechanical engineering and a creativity in its deployment that made possible the translation of Waddell's prototype into a "rational machine," a "well-integrated design." While Waddell continued to travel widely to lecture and promote business, Harrington played an equally crucial role, mobilizing the impressive pool of young engineering talent Waddell had attracted. Henry C. Tammen, who came to Waddell & Harrington early in the firm's life, recalled that under Harrington, who "kept closely in touch with everything that was going on in the office," he happily worked long hours because "work was plentiful and varied, with plenty of opportunity to learn and to advance -- an ideal situation."[37]

In mid-1909, when the O.R.& N. committed itself to a Waddell & Harrington lift bridge, few of the results of this fertile partnership were yet in. Only the short, man-powered lift span on the Sandpoint, Idaho bridge, the partnership's first vertical lift span, was nearing completion. The Iowa Central Railroad Bridge at Keithsburg, Illinois, the firm's first major lift bridge and the first use of the new technology for a railroad bridge, was under construction but would not see completion until the following year. Although the City of Portland had recently contracted with Waddell & Harrington for the Hawthorne Street Bridge, the firm's third vertical lift bridge, construction would not begin until September. Moreover, all of these structures featured a single lift deck. The only earlier vertical lift bridge to include telescoping hangers and two decks, the

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[36] Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20; James K. Finch, "John Alexander Low Waddell," *Dictionary of American Biography*, Supplement 2, Robert Livingston Schuyler, ed. (New York: Charles Scribner's Sons, 1958), 685-686; Susan Schmidt Horning, "John Alexander Low Waddell," in Garraty and Carnes, XXII, 428-429; Brown, *Diversity by Design*, 4-5, 13; Waddell, Bridge Engineering, 717-723.

[37] Edwin Layton, "John Lyle Harrington," *Dictionary of American Biography*, Supplement 3, Edward T. James, ed. (New York: Charles Scribner's Sons, 1973), 331-332; Eric DeLony, "John Lyle Harrington," in Garraty and Carnes, X, 148-149; Howard, "Vertical Lift Bridges," 695; Brown, *Diversity by Design*, 7-9.

Fratt or A.S.B. Bridge in North Kansas City, remained on the drawing board.[38]

Nothing highlights the O.R.& N.'s ability to appreciate and invest in an innovative technological solution more than the contrasting history of the A.S.B. Bridge. Waddell had helped plan an earlier, one-track, single-deck high bridge at the same site, but after the 1890 completion of its piers the project languished. In 1894, the bridge's new owner hired Waddell to design a different structure using the existing piers. As was true of Portland's Steel Bridge, the new North Kansas City project required a lower deck to meet existing railroad track at river valley level and an upper vehicular and electric railway deck. Waddell responded creatively with a proposal that elaborated his South Halsted Street Bridge technology. He proposed a lower deck that lifted to permit river traffic to pass while the upper deck remained a fixed high bridge. His plan, outlined in *De Pontibus*, sketched vertical hangers that would lift by moving alongside the verticals of the truss span above. To balance the lifting deck, pairs of cast iron counterweights connected to the hangers by wire rope ran over sheaves at each panel point and hung directly below these points. Strikingly innovative, the solution was also mechanically cumbersome.[39]

Once again, economic uncertainty in Kansas City intervened. In 1907, the bridge project's new proprietors, the Union Depot, Bridge, and Terminal Railway Company, a firm created by the Armour and Swift meat packing companies and the Burlington Railroad (hence the name A.S.B.), again contacted Waddell. With his new partner, he reconfigured his 1894 plan, a project he had long hoped to see realized. Some changes simply reflected recent developments in materials and in bridge construction: concrete counterweights had become preferable to cast iron and riveting had superseded pin-connection. The most innovative changes, though, reflected Harrington's mechanical engineering genius. The lower deck hangers now telescoped into the upper deck's verticals and the wire rope connecting each hanger to its counterweight ran up through the fixed deck's truss post, over an idler sheave on the top chord, and, thence, to one of four grooved drums at the ends of top chords. The ropes descended from these drums and passed over additional idler sheaves on the upper deck's roadway to individual counterweights suspended alongside the trusses at either end of the span.[40]

Several principals of Union Bridge, Depot and Terminal remained unpersuaded that the proposed structure would work successfully. To convince these men, Waddell & Harrington

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[38] Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Hawrhorne Bridge," HAER No. OR-20. Also, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "

[39] J. A. L. Waddell, *De Pontibus: A Pocketbook for Bridge Engineers* (New York: John Wiley and Son, 1912), 114-118; Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Armour, Swift, Burlington Bridge," HAER No. MO-2, 4-5, 9-10, and photographs; Howard, "Vertical Lift Bridges," 596.

[40] Waddell, *Bridge Engineering*, 723-724, 726; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Armour, Swift, Burlington Bridge," HAER No. MO-2, 5, 9-10; Howard, "Vertical Lift Bridges," 600-601.

prepared a 1:15 scale model, constructed largely of wood. They delegated responsibility for its creation to a third engineer who would play a leading role in creating Portland's Steel Bridge, Ernest Emmanuel Howard. In 1908 when he undertook the task of working out the A.S.B. Bridge's operation in miniature, Howard served as Waddell & Harrington's principal assistant engineer. He had joined Waddell & Headrick, Waddell's earlier partnership, in 1901 after a childhood in Ontario, Canada, and rural Texas and an education in Civil Engineering at the University of Texas. His years with Waddell had brought him increasingly responsible jobs as resident engineer for various bridges. Tammen, assigned to assist him with the model, summed up why Howard was the ideal person to translate an innovative plan into a workable model: "I was always impressed by his incisive thinking in the solution of a difficult problem and above all by his calmness 'under fire.' He held to the thought that there was no problem so difficult and no mishap so serious that an acceptable solution could not be found by calm thorough investigation and analysis."[41]

Not only did the Kansas City bridge proprietors need a scale model to convince them, one that carried scale-model loads and, like the final bridge, operated by electric power, but they also required a separate demonstration of the rope drive designed to synchronize machinery located in houses at either end of the fixed span's top chord. Then, unwilling to trust either the consulting engineers or their own eyes, they insisted on a review by a four-man committee of engineers. Only after the outside professionals validated the models' success did construction proceed. Begun late in 1909, the A.S.B. Bridge saw completion at the end of 1911.[42]

The venturesomeness of the O.R.& N. contrasts sharply. At most, when they made their commitment to the dual, independently movable vertical lift deck design, they had been able to assess two actual bridges manifesting preliminary versions of vertical lift technology (South Halsted Street and Sandpoint). They almost certainly had access to early drawings for Portland's Hawthorne Bridge, a project in which many standard features of the new bridge type would be worked out. Waddell's *De Pontibus* had achieved such wide recognition in the engineering fraternity that O.R.& N. engineers would certainly have read his preliminary plans for a bridge with a separate lifting deck. During the late spring or early summer of 1909, representatives of Waddell & Harrington visited Portland, providing at least one occasion for O.R.& N. engineers to learn about the latest plans for the North Kansas City Bridge and the models demonstrating its viability.[43]

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[41] Howard, 602-605; Waddell, *Bridge Engineering*, 724-726; Brown, *Diversity by Design*, 4-6, 12.

[42] Howard, "Vertical Lift Bridges," 602-605; Brown, *Diversity by Design*, 11-12; Waddell, *Bridge Engineering*, 726. Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Armour, Swift, Burlington Bridge," HAER No. MO-2, 5, gives 28 December, 1911 as the date the bridge opened to traffic, although other sources give 1912 as the year and HAER No. MO-2 cover sheet lists 1910-1912 as the construction dates (several sources, including, text give 1909 as the starting date for construction).

[43] On the issues of timing see Historic American Engineering Record, (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20. The Hawthorne Bridge plans incorporated

E. E. Howard's retrospective account reports that he made the suggestion that combined the proposed Hawthorne Bridge technology with the proposed A.S.B. Bridge technology, creating a "double-action" lift span. Howard's intimate familiarity with the firm's current plans and models would certainly have equipped him to make the leap. If so, J. D. Isaacs, the Union Pacific's consulting bridge engineer, probably played a pivotal role by encouraging Howard to develop the suggestion. Of the engineers associated with the O.R.& N., Isaacs would have been most likely to encounter Howard, who remained in Kansas City at the time. In any event, Howard found the Railroad's response indicative that its engineers had a solid grasp of bridge technology. His report of their initial interaction presents the O.R.& N. engineers' behavior in language that contrasts sharply with his earlier depiction of the A.S.B. client's timidity: "Preliminary plans and estimates were submitted and although no such structure had ever been built, the railway officials were convinced that no problems would be involved not soluble along rational, well established practice." Howard's estimates also demonstrated that the "double-action lift" could be built for $250,000 less than a swing bridge. More important, since roughly 80% of the river traffic entering and leaving Portland's busy harbor consisted of craft capable of passing under a bridge 60 feet high, Howard could promise that vehicular and street railway traffic on the upper deck would flow almost continually, a sharp contrast with the original Steel swing bridge that had to spend at least 8 hours a day open to river traffic.[44]

Howard continued to play a central role in the Steel Bridge's creation. Promoted to associate engineer in 1910, he, Waddell, and Harrington each signed individual contracts with the O.R.& N. in addition to the Railroad's general agreement with the firm, Waddell & Harrington. The Railroad devised the individual contracts in order to comply with new I.C.C. strictures governing free passes. C. K. Allen, just finishing his stint as Waddell & Harrington's resident engineer for the Hawthorne Bridge, remained in Portland to perform the same functions for the Steel.[45]

All told, then, because the O.R.& N.'s engineers felt confident enough to endorse an innovative proposal, the Railroad tapped the resources of a highly creative engineering firm at an optimal moment. Many of the new technology's mundane features were approaching their "standard" form, but the vertical lift type remained novel enough to engage the best innovative

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features recently worked out for the Keithsburg bridge.

[44] Howard, 611-612.

[45] Brown, Diversity by Design, 14; W. W. Cotton to G. W. Boschke, 6/2/1910, 6/21/1910, O.R.& N. Letterbooks, OHS; W. W. Cotton to R. Blaisdell, 7/11/1910, O.R.& N. Letterbooks, OHS; Hardesty, "New O.-W.R.& N. Bridge," 1104; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, HAER No. OR-20. The contract with the firm, Waddell & Harrington, specified that the term "engineer" was used therein to refer to either of the partners "or their duly authorized representative," a point the legal department called specifically to the attention of Chief Engineer Boschke "in order than you may be satisfied that this power be reposed in this representative." The use of the singular, "this," suggests the general understanding that Howard would generally represent the firm.

energies of the firm's considerable reservoir of engineering talent. Both Harrington and Howard, the bridge's principal designers, were arguably in their prime creative periods. The result was a remarkable structure.

Meeting the Challenge of Erection

A formidable team of engineers shared responsibility for supervising the Bridge's erection. Ordinarily the O.-W.R.& N. relied exclusively on its own extensive engineering talent. In this case, though, Waddell & Harrington carried primary responsibility; the firm's $90,000 fee covered use of patents, design, and construction oversight. Resident engineer C. K. Allen brought the best possible preparation to the task: he had just completed serving as resident engineer on the firm's Hawthorne Bridge, its third vertical lift bridge and one in which the new technology took its more or less standard form. O.W.R.&N. correspondence concerning free passes, something federal regulators now scrutinized, strongly suggests that, in addition to Howard, each senior partner visited Portland at least once. O.W.R.&N. engineers also actively supervised erection, with George T. Forsyth, engineer of bridges, designing crucial components of the erection falsework and equipment. The railroad also took responsibility for preliminary soundings and borings.[46]

Work on the substructure began in May, 1910, about a year before conflicts with the City were resolved, a measure of the Railroad's confidence that it would ultimately prevail. Union Bridge & Construction Company of Kansas City, Missouri received the contract. H. K. Seltzer served as the firm's engineer of construction. Portland city directories document only a brief local presence for Seltzer and Union Bridge and my preliminary inquiries in Kansas City uncovered no readily accessible paper trail there, indicating a firm with a brief life and mostly local clientele. The most likely scenario is that Waddell & Harrington recommended a firm with which it was already acquainted. Robert Wakefield, who had constructed the Hawthorne Bridge's substructure must have found his resources fully occupied erecting the Steel Bridge superstructure. Also, unlike the Hawthorne Bridge, the Steel Bridge piers required dynamiting to break up the cemented gravel that formed the riverbed under all but the westernmost pier. Perhaps this demand also helped make Union Bridge a good choice.[47]

The bridge's east and west piers were located very near the riverbanks. To support the west pier, Union Bridge & Construction drove piles deep into the alluvial bottom and employed

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[46] Hardesty, "New O.-W.R.& N. Bridge," 1104; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20; O.-W.R.& N. Letterbooks, OHS, *passim.*

[47] Seltzer and Union Bridge appear only in the 1912 Portland directory, by which time their Steel Bridge work had been completed. They had been retained to complete similar work on the Broadway Bridge, just downstream. Indeed, the Railroad's lawyers spilled considerable ink trying to make sure the O.-W.R.& N.'s transportation of Union Bridge's personnel and equipment did not inadvertently subsidize the Broadway Bridge. O.-W.R.& N. Letterbooks, OHS; Hardesty, "New O.-W.R.& N. Bridge," 1100-1101, 1104; Howard, 611.

an ordinary cofferdam to complete the concrete pier. By contrast, east pier cofferdam construction immediately encountered bed-rock too hard to be penetrated by ordinary steel-shod wooden piles. Workmen drove old steel rails into the bedrock in two rows 5 feet apart, fastened timbers to the rails, and attached triple-lap wooden sheet piling driven to the cemented gravel. Then they poured a rich mortal through a pipe, binding together the river boulders that lay above the cemented gravel to form a seal with the bedrock. River mud, clay, and gravel served to reinforce the walls, allowing the cofferdam to be pumped dry and work on the pier to be completed.[48]

Constructing the two channel piers, also concrete throughout, involved blasting with 30 pound charges of dynamite placed in holes drilled every 6 feet in the underlying cemented gravel. Since the bedrock underlying both piers had a considerable slope, blasting created both sufficient depth and a uniform bottom. Blasting involved driving 4 inch pipe through the softer overlying material, inserting drills through these pipes, drilling 5 to 6 feet into the bedrock, withdrawing the drill and inserting a sheet-iron tube containing the dynamite and powder, weighting the charge, lifting the casing pipe clear, and firing the charge. Then workmen drove the casing pipe down as far as possible and repeated the entire process. Open dredging followed, using orange-peel and clam-shell buckets and a water siphon operated by large pumps. Once excavation was complete, concrete-filled, timber-walled, 36 by 72 foot cribs constructed on shore were sunk into place. Unfortunately both pier excavations proved too small; the cribs hung up on the edges, requiring additional blasting 4 feet outside the cutting edge. Thereafter, workmen successfully sunk the cribs, the cutting edge of the west crib resting 123 feet below extreme low water and the east pier's 113 feet. After pouring additional concrete under water, the cribs could be pumped dry and the remaining concrete poured in air. Near the crib tops, about 20 feet below water, workmen bolted timber cofferdams to the cribs and began pouring the neat work of the pier shafts. When complete, the piers' copings stood 22 feet above low water.[49]

Work on the superstructure commenced at the start of April 1911, somewhat before all necessary city agreements had been ratified. Robert Wakefield of Portland held the erection contract. In addition to his work on the Hawthorne Bridge, Wakefield brought a wealth of experience with the Railroad and with construction to the project. In his mid-60s, Wakefield had grown up in England, but had spent all of his working life in the United States. Before arriving in Portland in 1887, he had served several years as a Union Pacific superintendent of tracks and bridges. In the late 19th century he built Portland's first steel building (the Wells Fargo building), completed the railroads' Union Station, and erected a steel bridge over the Willamette at Albany. Early 20th century O.R.& N. correspondence is peppered with Wakefield's name as his firm completed construction projects throughout Oregon. Although these credentials might well have assured Wakefield the contract in any event, he won the job primarily because its unprecedented scale and technological features scared away other bidders. Wakefield, by

[48] Hardesty, "New O.-W.R.& N. Bridge," 1100-1101; Howard, 614.

[49] Hardesty, "New O.-W.R.& N. Bridge," 1100-1101.

contrast, appears from his record to have especially welcomed novel projects. Charles N. McDonald, who had played an important role in erecting the dome of the state capitol building and constructing Portland's 1905 Morrison Bridge, superintended the job for Wakefield.[50]

Several features of superstructure erection especially challenged Wakefield and his O.-W.R.& N. collaborators. In contrast with the Hawthorne Bridge's situation, the Steel Bridge spanned the Willamette at a narrow point near a sharp bend; its swift current precluded building the lift span near the shore and floating it into position as had been done for the Hawthorne Bridge. Because the river had to be kept open to even high-masted sailing ships, the Steel Bridge lift span had to be built while supported on columns high above the river. The great weight resulting from the two decks and the heavy individual members made this particularly difficult.[51]

The two fixed spans had to be completed first. Wakefield used falsework distinctive only in that it employed piles that were single sticks 90 to 130 feet long. A locomotive crane placed the floors and laterals, but a floating derrick lifted the trusses. Wakefield used an A-frame composed of four 112 foot fir piles. Each leg of the A-frame consisted of two piles fastened together at their ends and jacked apart to a maximum 7 foot distance at their mid-points. These double bow shaped legs were held together by double cross-bracing every 10 feet, reinforced by 1.25 inch iron tie rods. Structural components weighing up to 45 tons had to be lifted, creating longitudinal compression that would have pulled less strongly braced legs apart. The legs rested 34 feet apart in circular depressions cut in a longitudinal piece attached to the scow that held the A-frame. The depressions permitted a full range of inclinations. The distance between the legs narrowed to only a foot at the frame's apex.[52]

The far more innovative lift span required much greater innovation in erection technology. This was Forsyth's principal contribution. He designed falsework for the lift span to support 1000 tons while providing low water clearance of 115.5 feet, permitting all but one or two sailing vessels to pass without removing their topmasts. The falsework combined eight wooden cantilever brackets, sloping up and out from the piers, with four wooden Howe truss spans. At either end of the lift span, four five-legged cantilever arms footed on the piers; the legs extended at angles ranging from 90 to 30 degrees. The arms supported cribbing which, in turn, supported the Howe trusses. Two to six lines of 12 X 12 timbers comprised each leg. Ten iron tie rods of 2 to 2.5 inches anchored each leg to its adjacent fixed span. The resulting cantilever

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[50] Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20; Hardesty, "New O.-W.R.& N. Bridge," 1103-1104; "Portland Man Dies," *Oregonian,* 7/7/29, Section 1, 17.

[51] Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20; Hardesty, "New O.-W.R.& N. Bridge," 1100, 1103.

[52] Hardesty, 1103; Howard, 619.

structure narrowed the 220 foot opening between the fixed spans to 116 feet.[53]

The cantilevers supported four Howe trusses 120 feet long and 24 feet high. Cribbing elevated the trusses an extra 5.5 feet above the 110 foot elevation reached by the cantilevers. Workmen constructed the Howe trusses aboard scows, floated them to the span, and lifted them into place using the 110 foot booms of derricks set on each fixed span. Each Howe truss weighed 43 tons. Each was built up using three lines of 7 X 16 inch timbers to create its top and bottom chords, 8 X 12 inch timbers for its diagonals, and 10 X 12 inch timbers for posts. As they were constructed, the steel lift span trusses each rested on a pair of wooden Howe trusses set 9 feet 8.5 inches apart on centers. The outsides of the outermost trusses in each pair stood 44 feet apart.[54]

Erecting the lift span and parts of the towers required lifting weights up to 35 tons. Workmen first erected a 60 ton traveler atop the Howe trusses to carry out this work. A gallows frame, the traveler consisted of two timber bents 40 feet apart. 12 X 12 and 10 X 12 timbers braced by 4 X 10s extended the frame's height to 103 feet above the falsework (about 97 feet above the steel bottom chords). The traveler's extreme top width was 76 feet. To complete the tower tops required an additional 150 foot gallows frame or sheer leg set atop the Howe trusses. Workmen used the traveller to erect the sheer leg and to move it to the other end of the Howe trusses after they completed the first tower, including lifting the heavy sheaves into place. Two posts comprised the sheer leg, each consisting of two 12 X 12s bowed to 9 feet at their mid-points and crossbraced to counteract compressive forces. The sheer leg worked at a slight incline from vertical, placing its top about 290 feet above low water. Its posts, spaced 34 feet apart, rested in hollowed oak blocks resting, in turn, on longitudinal timbers that distributed the sheer leg's 40 ton weight over about 50 feet of the Howe trusses. This sheer leg managed to lift the 42 ton weight of the top main tower posts. Workers determined correct positioning of the tower tops using a plumb line of piano wire, adjusting the towers by raising and lowering their back columns. They then riveted them to the top chords.[55]

Tower erection employed a 3/4 inch fall line running over a 6-sheave block atop the sheer leg and over the top of the tower down to a 5-sheave block on a scow anchored below. A hoisting engine on the scow supplied power. The other end of the fall line attached to structural members delivered to a spot inside the tower on the lower deck of the fixed span. Railroad flatcars delivered the materials. To control the sheer leg a 5/8 inch back line ran from a 4-sheave block atop the sheer leg to a 4-sheave block on the falsework below. The other end of this back line ran to the fixed span on the opposite side of the channel, where it attached to a hoisting engine on a derrick. The operation required 2600 feet of fall line cable and 2300 feet of back line cable. Material, most of it fabricated by American Bridge Company of Pittsburgh, Pennsylvania,

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[53] Hardesty, 1103-1104; Howard, 619.

[54] Hardesty, 1103.

[55] Hardesty, 1103; Howard, 619.

arrived at the Railroad's east bank sidings. From there it was lifted over the side of the bridge and onto a specially fabricated flatcar running on a temporary trestle 25 feet above the main fixed span deck. A hoisting engine drew a 7/8 inch cable through sheaves to power the flatcar up the 7 to 8% grade, transporting chord members weighing as much as 34 tons.[56]

The massive Howe falsework was nonetheless only capable of supporting 1000 tons. The completed lift span was calculated as weighing 1750 tons, including its machinery. Therefore, once the steel truss's main members had been placed and riveted, Wakefield's men brought the main counterweights into play to balance the lift span's growing weight. Each main counterweight had been built in place on a 13 inch bed of sand, the height calculated to include 8 inches of slack in the cables and up to 5 inches of cable stretch under load. A timber platform with wooden walls contained the sand. The counterweights, built of concrete around steel frames had equalizers attached near the top of each side and cables connected to the equalizers. When the lift span reached 1000 pounds, taking nearly all of the 2.5 inch camber out of the Howe trusses, Wakefield's crew attached the main counterweight cables to the lift span and allowed the sand to flow out through holes in the wooden platform beneath the counterweights. The counterweights cleared at 11 inches, but failed to lift the span so they were built up to increase their weight. Then, steelworkers knocked out the blocking between the steel bottom chords and the Howe trusses, freeing the span and permitting the Howe trusses' removal. Partial support, comprised of falsework bearing on the cantilever arms, remained in place while McDonald supervised completion of the lift span and counterweights.[57]

Workers poured the smaller, lifting-deck counterweights on low falsework constructed on the fixed spans' upper decks. When the counterweights were ready, workmen attached their ropes, laid the ropes over the sheaves, and inserted the ropes' free ends into the lift-deck posts. Structural members of the lifting deck were then transported by barge to a location just below the lift span. Each floor beam was riveted to its two hangers and each such structure lifted into place by inserting the hangers into the lift span posts and attaching the counterweight ropes to the hangers. Then workmen completed the lower deck framework by attaching the stringers between the floor beams and adding other structural members. Because flooring would be added last, workers estimated its weight and used rails and other available materials to load the lift span and lifting deck appropriately, permitting the structure to be seated so that guides, shoes, and locks could be attached and adjusted. The lower, railway deck was then completed, permitting trains to begin using it in mid-July while work continued to complete flooring the highway deck.[58]

Although the highway portion of the bridge opened to traffic on 9 August, 1912, as late as early September the City had still done nothing to put the east side connecting streets into adequate shape to receive traffic. Finishing touches also meant that streetcar traffic waited until

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[56] Hardesty, 1103-1104.

[57] Hardesty, 1103-1104.

[58] Howard, "Vertical Lift Bridges," 619-620.

early September to begin. Against this backdrop the City and Railroad conducted one final skirmish, this one over an appropriate rental fee for the highway deck. The situation was complicated because the County had rented the earlier Steel Bridge highway deck, but Oregon legislation passed after the first Steel Bridge's enabling legislation had forbidden County operation of bridges other than those linking County roads. Thus, the Railroad once again had to reach agreement with the City. Once again, City Councilmen postured. They threatened to condemn the structure until the Mayor pointed out that the City lacked the funds to buy the structure if condemnation proceedings succeeded. Ultimately the matter was resolved by the engineers: Waddell & Harrington representing the Railroad and Ralph Modjeski, currently supervising completion of the City's Broadway Bridge, for the City. The provisions of the contract closely followed those used with the County for the first Steel Bridge. The rent was calculated based on the engineers' apportionment of $821,000 of the bridge's $1,704,000 construction costs to the upper deck and its approaches, an affirmation of the Railroad's claims. The street railway company covered $1,500 of the monthly rent, leaving $1,700 for the City to pay. The City also assumed responsibility for operating costs such as gatemen's wages, floor renewals, and repairs. The agreement, finalized in early October, brought some closure to the long conflict between the City and the Railroad. The following year everyone probably breathed a sigh of relief when the Legislature transferred operation back to the County.[59]

The 1912 Steel Bridge

The 1912 Steel Bridge was an extremely large, complex structure. Essentially unchanged nearly 90 later, its massive proportions and elegant mechanism beggar any conceivable description. What follows is an account of the Bridge's features and dimensions with particular attention to those aspects of the structure that helped define the standard "Waddell vertical lift" type and those aspects that made this particular bridge unique.[60]

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[59] O.-W.R.& N. Letterbooks, OHS, 6/5/1912, 7/24/1912, 7/29/1912[2], 9/6/1912; 10/16/1912; Hardesty, "New O.-W.R.& N. Bridge," 1104; "Critics Invited to See Plans of Bridge," The Portland Journal, 5/2/1912, 17.

The "Brief History of the Steel Bridge," attached to documents assessing the State's assumption of Steel Bridge rental in 1940 provides some more specific dates, but the fact that verifiable dates do not coincide with those documented in early records renders its precise dates suspect. This document in the ODOT History Center in combination with highly inaccurate newspaper retrospectives provided the chronology reported in Historc American Engineering Record (HAER), National Park Service, U. S. Department of the Interior "Steel Bridge," HAER No. OR-21. Given the questionable accuracy of these dates, I have used precise dates only when I could base them on contemporary sources and have stated the rest of the timetable for the Bridge's opening as precisely as primary sources permit.

[60] Although the approaches to the bridge have been reconfigured repeatedly and renewable components such as wire ropes changed periodically, the essential structure of the river spans is remarkable unchanged. The Railroad's regular program of lubrication, preserved and transmitted by an highly skilled and devoted corps of long-term oilers and operators, has proven its effectiveness in the survival of most of the mechanism's original moving parts. The only extensive replacement of original parts occurred as a result of an ill-advised economy measure on

The bridge consisted of an upper, highway deck connecting Third Street on the west side with Glisan Street on the east. Because of the high embankment on the east, the east side approach required a grade of only 2.5% whereas the west side had a grade of 5.89%. The plate-girder approaches, supported by columns save for a 250 foot concrete retaining wall on the west side, extended 738 feet on the west side and 305 on the east. The lower, railway deck required only a short (about 104 foot) west side approach to connect to track running along the river.[61]

Both decks included two 287 foot (between bearings) fixed spans with a 220 foot movable span between. Waddell & Harrington used Pratt trusses throughout. The two fixed spans were through trusses for the railway deck, carrying the highway deck on their top chords. Trains needed to make a 15 degree turn to the north on the west side toward the terminal and complete 16 degree curves north and south on the east bank to connect with track running below the high bluff. Geographic constraints on the east and real estate development on the west required these turns to begin on the bridge, so diverging trusses were used. Those on the west began 34 feet apart (on centers) at the river end and widened to 42 feet apart near the shore. Those on the east side were spaced 34 feet apart near the movable span and widened to 71.5 feet at the bank. The lift span, a through truss for the highway deck, had parallel trusses spaced 34 feet apart on centers. The trusses were 59 feet deep, center to center on the chords.[62]

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the part of the Oregon State Highway Department, which assumed rental of the bridge in 1940. With the structure's wooden pavement in dire need of replacement in 1950, the State Highway Department chose to replace only the surface layer, although the need to replace the subdeck would predictably occur a decade later. Not only was the subdeck not replaced on schedule; it remained in place for three and a half decades, by which time its decaying members had resulted in serious rust damage to structural members. In consequence, removal of the old deck revealed the need to replace numerous structural members in 1984-5. The work took place in tandem with alterations designed to accommodate Portland's new light rail line. "Complex Bridge Project at Portland for Oregon's Major Traffic Problem," *Western Construction* (June, 1951), 69; "73-year-old Steel Bridge gets new face," *Oregonian*, 1/23/1985, F10.

Ample records exist to document the Steel Bridge's repair, maintenance, and approach redesign history. These subjects are not treated here because of constraints imposed by the project's sponsor.

[61] Hardesty, 1100; Howard, 606, 615.

[62] Here and it what follows I have relied perforce on sources such as Hardesty and Howard as supplying the best available figures. The selection of engineering drawings available was limited and primarily useful in assessing individual components. I am grateful to my historian colleague Sharon Wood Wortman and to William I. James, III, P.E. of HNTB, a successor firm to Waddell & Harrington, for making available a selection of original drawings and drawings revealing details of subsequent modifications. With additional time, more Union Pacific drawings might be obtainable via HNTB.

Another obvious source of primary information about the bridge's dimensions, the Oregon Department of Transportation, proved curiously disappointing. Repeated requests during the ODOT-funded life of this project did not suffice to obtain access to plans and records of work since 1940, a potentially ample window on the original structure as Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior "Hawthorne Bridge," HAER No. OR-20 and Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Broadway Bridge," HAER No. OR-22, which relied on comparable

Although not a long structure, the Steel Bridge's massive proportions were unprecedented at the time and remain impressive. For example, the end diagonal posts were 42 inches deep and 39 inches wide. The lower chords were 42 inches deep and 36 inches wide. The tower posts were 36 inches square and the floorbeams 18 inches wide across their top flanges. The bridge was designed to conform to Harriman Lines' Common Standard Specifications 1006 and 1012 for railway and highway bridges. Waddell & Harrington assumed live loads of two Class E-55 consolidated locomotives followed by a uniform 5,000 pound load per linear foot. They calculated for a highway loading of a 24 ton truck within a 12 by 20 foot space and a pedestrian loading of 100 pounds per square foot. Streetcar loading calculations anticipated two 50 ton cars coupled to a 1,200 pound per linear foot loading per track. The piers supporting the towers and movable span were also massive. Each contained 8,650 cubic yards of concrete, conveying a total load (live, dead, and pier) of 16,000 tons to the pier foundation.[63]

The lower deck extended 26 feet above low water; 5 feet above high water. The rail's base was 6 feet higher and the upper deck 52.5 feet higher still. The lower deck lifted 46 feet, making a total 72 foot clearance over low water and permitting almost all steamboats in Portland harbor to pass under the highway deck. For high-masted sailing ships, the highway deck lifted another 93 feet, creating a total 165 foot clearance over low water.[64]

Urged on by the various regulatory hearings, planners divided the highway deck into sections to serve various constituencies. A 28 foot roadway between the lift span trusses accommodated two street railway tracks. Automobiles also used the two 14 foot lanes. Outside the lift span trusses, narrower 11 foot vehicular lanes were intended for horse-drawn traffic. Two 6 foot sidewalks ran outside the outermost traffic lanes to serve pedestrians. Because the trusses and their wooden guard rails took up roughly 5 feet of the lift span's width, the fixed spans had

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Multnomah County records, demonstrate. The potential utility of untapped records in suggested by "as constructed" drawings for the 1985 Steel Bridge reconstruction which my detective work and the timely help of Dennis Carlson, Region 1 Inspection Office, Oregon Department of Transportation, made available. For example, the "Steel Bridge Tower Measurements," drawing included in the "as constructed" drawings and initialed by resident engineer, John Howard, on 10/7/1985 supplies a chained measurement of 218.18 feet on the north side and 218.20 feet on its south side for the distance between the faces of the guides on the towers. Totals of two measurements of the spaces between the lift span and the guides were 1.34 feet on the north side and 1.39 feet on the south side. In combination, these figures give a lift span length of 216.8 (on either side) for the lift span, a more precise figure than the 220 feet given in Hardesty and in Howard. This length included the guides on the lift span. Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1025, gives a length of 211 feet for the lift span, evidently its length without the guides or with the guides compressed.

In the absence of better evidence, I have generally given preference to Hardesty, the earliest published account. Howard is not only later, but his figures appear more often to have been rounded or stated in rough terms, consistent with informal recollection. Other published accounts are both later and less complete although they have been used as a check. Hardesty, 1100; Howard, 606.

[63] Hardesty, 1100; Howard, 612, 614.

[64] Hardesty, 1101; Howard, 606.

proportionately wider (15 to 16 foot) outside roadways. The lift span also differed in that its sidewalks and outer roadways were supported by projecting floorbeams acting as cantilevers whereas only the sidewalks needed such support on the fixed spans.[65]

Its combination of lift and lifting deck made and makes the Steel Bridge unique. Steel towers resting on the piers and on the ends of the adjacent fixed spans supported the movable spans. The towers had to be substantial both to support the movable span and to accommodate two sets of counterweights within their wells. Integral parts of the fixed spans, the towers' main posts carried the weight of the lift span and its pair of large counterweights together with 75% of the combined weight of the lifting deck and its two sets of four smaller counterweights. Each of the main posts rested on a 12 by 12.5 foot cast steel base; each main post shoe carried a total load of 3,250 tons, transmitted into the shoe by a 13.5 inch diameter pin. The remaining movable span weight (25% of the lifting deck and its two sets of four counterweights) was supported by the inclined back tower legs which connected at the fixed spans' second panel points.[66]

Each pair of legs was thoroughly braced at intervals. Atop the structure, girders spanned the 20 foot space between back and main legs. Waddell & Harrington designed the towers to withstand a 15 pound per square foot wind pressure while the span was in motion and a 30 pound per square foot wind pressure with the span down. The top girders each served to carry two 6.33 foot sheaves set 16 feet apart supporting the cables linking the lower deck to its counterweights. The sheaves' centers rested 265 feet above low water. Below the top girders, 245.6 feet above low water, huge 14 foot pitch diameter main sheaves rested on each side within the tower, supported on brackets built up from the trusses that connected the main tower posts. These sheaves carried the ropes linking the lift deck with its large counterweights. Again, the massiveness of the Bridge is evident in the 24 ton weight of each main sheave. Together with their attached boxes, each weighed 35 tons when lifted into position.[67]

Recent experience with the Hawthorne Bridge's 9 foot pitch diameter sheaves, which had required repeated recasting, made Waddell & Harrington doubt that any shop could produce the Steel Bridge's much larger cast steel sheaves. To avoid flawed castings they designed built-up sheaves in which cast-steel rim sections were supposed to transfer their loads to inner steel disks to which they were connected by nuts and bolts. Unfortunately, this system required milling the steel disks' edges to a degree of precision not readily achieved in 1911. When the sheaves received their loads the pressure of the ropes forced the tiny differences between the slightly longer rims and slightly shorter inner discs to accumulate, separating the rims from the disks enough to snap the connecting bolts. Workmen below experienced the result when broken bolt ends and nuts began to fall on them. The Steel Bridge's main sheaves functioned as an immediate learning experience for Waddell & Harrington; they quickly redesigned the built-up

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[65] Hardesty, 1101; Howard, 615.

[66] Hardesty, "New O.-W.R.& N. Bridge," 1101; Howard, "Vertical Lift Bridges," 615.

[67] Hardesty, "New O.-W.R.& N. Bridge," 1101; Howard, "Vertical Lift Bridges," 615.

main sheaves on Pennsylvania Railroad bridges under construction in South Chicago to take Portland's experience into account. Meanwhile, splice plates were added to the Steel Bridge's main sheaves permitting workmen to rivet the rims more securely. Fortunately, casting technology developed apace in response to demands such as those made by the proliferation of lift bridges. By 1913, four 12 foot pitch diameter sheaves were cast without incident for the firm's Mondak, Montana bridge over the Missouri.[68]

Meanwhile, the Railroad struggled to keep the main sheaves of the Steel Bridge functioning. Larger rivets were redriven in 1916, tap and patch bolts added in 1919, and all of these repairs repeated in 1921, when reinforcing places were also found necessary. About the same time, the Railroad recognized the need for a more permanent solution, redesigning the sheaves between 1920 and 1923 when sheaves, shafts, and bearings all saw replacement. In essence, the new sheaves were built-up in the manner developed for South Chicago in response to the initial problems with the Steel Bridge sheaves.[69]

The Steel Bridge's main sheaves also included large cast steel hubs for the shaft. Because each shaft carried 1,768,000 pounds and would operate a half dozen times a day, Waddell & Harrington considered it essential to design for the replacement of the phosphor-bronze bushings. Facing tight space constraints, they devised a system of wedges. Projections on the ends of each sheave shaft allowed the shaft to rest in the steel saddle castings of the wedging device. Like other features of these transitional sheaves, this was a unique design.[70]

The Steel Bridge lift deck operated in essentially the same manner as the Hawthorne Bridge, Harrington having worked out a successful solution early in vertical lift bridge development. Trains of gear wheels transmitted power from two 200 horse power electric motors on the upstream side of the machinery house to four main drive sheaves located in the machinery house's corners. From each sheave, twin 1-1/8 inch operating cables led out along the span. One end of each pair passed under a deflecting sheaves located on the Bridge's top chord directly under the main town sheaves. From there the ropes ran to attachments high on the towers near the main sheaves. Winding in these cables lifted the span. The other ends of the cables left the opposite sides of the drive sheaves to pass over deflecting sheaves at the opposite ends of the span and from there descended to attach near the bottom of the tower posts. Winding

[68] Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1025-1027; Howard, "Vertical Lift Bridges," discussion by Van Cleve, 653; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior "Hawthorne Bridge,", HAER No. OR-20.

[69] Howard, "Vertical Lift Bridges," discussion by Van Cleve, 653. Changes in the Steel Bridge sheaves are best documented in O.-W.R.& N. plans entitled: "Repair to Center of Main Sheaves," 3/31/1919; "Proposed New Main Tower Sheaves," 1/3/1920 (2); Bearings for Proposed New Main Tower Sheaves," 4/28/1922 (2). Dates are those of the original drawings, although they bear revision dates as late as 9/7/1923. Drawings from Union Pacific courtesy of HNTB.

[70] Van Cleve, "Mechanical Features of the Vertical-Lift Bridge,"1026; Howard, "Vertical Lift Bridges," discussion by Van Cleve, 653.

in these cables lowered the span. Having experienced difficulties keeping the Hawthorne Bridge's operating ropes taut, Waddell & Harrington installed turnbuckles near these lower attachment points to permit workmen to take up the slack.[71]

As the span lifted and lowered it was supported by sixty-four 2-1/4 inch wire ropes. Sixteen of these ropes were anchored with adjustable attachments inside each end of the end, top, transverse box girders. These ropes traveled upward, passed over the grooved main sheaves, and descended to join the counterweights through equalizers comprised of a series of apex-down triangles. Each apex connected to additional triangular equalizer plates while the triangle's upper corners each connected to a counterweight rope. In the brief time between building the Hawthorne Bridge and building the Steel Bridge, then, Waddell & Harrington had developed what proved to be the "standard" equalizer and the "standard" practice of placing the main equalizer at the counterweight connection. Although much more satisfactory, especially during infrequent counterweight rope changes, these equalizers still only equalized rope stresses when all ropes were of precisely the same length. It was in the nature of steel cable technology that this state was hard to achieve and maintain.[72]

Originally the main counterweight descended to within a few feet of the bridge deck when the bridge opened fully. Movable longitudinal bars carried the portions of the street railway trolleys that ran inside the towers so as to allow them to be pushed out of the way of the descending 1,712,500 pound counterweights. Over the years, additions to the weight of the lift span and compensating additions to the counterweight mean that the bridge can no longer open fully. Its counterweights encounter the bridge deck too soon.[73]

Howard's retrospective account of the bridge featured an aspect not noted elsewhere. It was precisely the sort of simple, problem-oriented engineering solution Howard relished. His description is worth quoting:

> The bridge carries a 12-in. gas main in which continuous service at a pressure of about 60 lb. is maintained. From a section of pipe lying along the upper chords of the lift span two vertical sections of pipe are hung and telescope into vertical sections of larger pipe fastened to the towers and connecting to pipes carried out from shore on the lower decks of the fixed spans. There are stuffing boxes at the upper ends of the fixed vertical

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[71] Hardesty, "New O.-W.R.& N. Bridge," 1102; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge,", HAER No. OR-20; Hovey, *Movable Bridges*, 162-162.

[72] Hovey, *Movable Bridges*, 162; Union Pacific Railroad, "General Plan to Renew Lift Span Main Counterweight Cables," 9/15/1942, drawing courtesy of HNTB; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20.

[73] Hovey, *Movable Bridges*, 162; Hardesty, "New O.-W.R.& N. Bridge," 1101. Conversations with Rod Bates, Oiler and substitute Steel Bridge Tender, supported by the opportunity to peruse a handwritten bridge tender's book in which weight additions were recorded, clarified changes in the bridge's operation.

sections. The gas can flow uninterruptedly for any position of the lift span, and during span movement.[74]

The technology for operating the lifting deck refined the system recently devised for the North Kansas City A.S.B. Bridge and had similarities as well to Waddell's South Halsted Street Bridge wherein operating and counterbalancing ropes overlapped in function. Two separate 200 horse power motors on the machinery house's downstream side powered lower deck operation, although a common shaft assured that either set of motors might be used to move either deck should that prove necessary. Bevel gears connected the motors to a 5-3/4 inch longitudinal shaft and that shaft, in turn, to transverse shafts at either end of the top chord of the lift span. Spur pinions at the ends of the transverse shafts meshed with gears on the grooved drums which drove the operating ropes. This system ensured synchronized operation and eliminated the cumbersome rope drive coordinating separate motors housed in separate machine houses on the A.S.B. Bridge.[75]

Fourteen 1-1/4 inch wire ropes descended from each 6-1/3 foot tower-top sheave. Two of these cables continued directly down and attached to the end panel points of the lower deck. The other twelve passed under the operating drums and toward the center of the upper deck's top chord, passing over deflecting sheaves at each panel point. Four ropes descended down through each truss post at each panel point and attached to the tops of the lower deck hangers. When the lower deck was seated the ropes extended almost through the truss posts and the hangers depended from pins resting in diaphragms inside the feet of the truss posts. When the lower deck lifted, the hangers rose inside the truss posts until the point of attachment of the cables ended up just below the top chords of the span.[76]

The other ends of the panel point operating ropes passed over the tower-top sheaves and down to connect with one of four smaller counterweights located on the shore sides of the large main counterweights. When the decks were down, the lower deck counterweights hung above the main counterweights. As they descended to counterbalance the rise of the lifting deck, the lower deck counterweights ended up alongside the main counterweights, with which they descended when the upper deck lifted. The four small counterweights varied in size from 62,400 pounds for the end panel points to 145,360 pounds for the panel points closest to the center.

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[74] Howard, "Vertical Lift Bridges," 619.

[75] Hovey, *Movable Bridges*, 163; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20.; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Armour, Swift, Burlington Bridge," HAER No. MO-2.

[76] Howard, "Vertical Lift Bridges," 615-616; Hovey, *Movable Bridges*, 163; Hardesty, "New O.-W.R.& N. Bridge," 1002.

Small equalizers connected the wire ropes to these counterweights.[77]

The Railroad considered it very important to be certain that the lower deck was firmly in place once it was seated. Waddell & Harrington supplied two sets of locks for this deck. Each intermediate panel point was to be locked down by cams automatically driven by electric motors when the lower deck reached its seat. Electric lights would alert the operator whether the cams were drawn or driven. The operator could draw the cams and open the bridge by activating a small motor which caused a magnet to release the weighted levers holding the cams in place. The system was fully as clumsy as this description suggests. Locks of this type had originated in the firms' plans for its' first major vertical lift bridge at Keithsburg, they had functioned only briefly when installed on the Hawthorne Bridge, and they evidently failed to work at all on the Steel Bridge. Instead, the Railroad relied on two locks at each end of the lower deck, driven by the operator and powered by motors underneath the span. Additional end locks automatically locked down the upper deck, although the bridge operator had to release them.[78]

As was true of the locks, the Steel Bridge inherited its guides from earlier Waddell & Harrington vertical lift bridges. Jaws projected from the main counterweights' corners and engaged fixed guides on the towers. Double jaw guides on the small counterweights engaged both tower guides and tracks on the main counterweights. Spring-loaded double-roller guides keep the lift span in contact with the towers throughout its movement, while slotted jaws allow the lifting deck to move against fixed tower guides until it reached the underside of the lift span. Tapered center castings near the lower limits of span and deck movement guided the decks to their proper lateral seating. Although refurbished, these guide systems remain essentially intact.[79]

As noted repeatedly above, the bridge that the O.-W.R.& N. acquired in 1912 remains essentially intact. In addition to the major features noted above, many of which set the standard for vertical lift bridges for several decades, two additional surviving features link the existing bridge to more traditional structures. One is the bell that still hangs outside the operator's house. It was never loud enough to serve as an effective warning and the Railroad replaced it with a steam whistle early on. By contrast, the original hand lever-actuated band brakes with their oak

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[77] Hovey, Movable Bridges, 162-163; Hardesty, "New O.-W.R.& N. Bridge," 1002; Howard, "Vertical Lift Bridges," 615.

[78] As might be expected, the development of electric and electronic technology has altered the mode of the locks' operation. The lower deck end locks now have to be released via a computer operator in Omaha before the Portland bridge operator can open the bridge. Thanks to Rod Bates, Steel Bridge Oiler and replacement Operator, I was able to spend time in the operator's house and witness this and other processes.

Van Cleve, "Mechanical Features of the Vertical Lift Bridge," 1024-1025; Hardesty, "New O.-W.R.& N. Bridge," 1002-1003; Howard, "Vertical Lift Bridges," 616; Historic American Engineering Record (HAER), National Park Service, U. S. Department of the Interior, "Hawthorne Bridge," HAER No. OR-20.

[79] Hardesty, "New O.-W.R.& N. Bridge," 1101-1102; Howard, "Vertical Lift Bridges," 616. Union Pacific Drawings made available by HNTB, passim.

block wearing surfaces not only remain on the bridge, they remain in use, although skilled operators can usually cut off the motive power in time to allow the bridge to coast to a stop.[80]

CONCLUSION

In sum, the bridge Waddell & Harrington designed roughly ninety years ago was a highly successful solution to a distinctive set of geographic, economic, and political problems. It survives and operates effectively in a very different physical, economic, and political context in part because its heavy construction suits it to carry the heaviest contemporary loads. It also survives because appropriate, traditional maintenance practices have been preserved and transmitted by a series of long-term Railroad employees charged with the Steel Bridge's care and operation.

All operators begin their careers as oilers making daily rounds of the bridge, grease gun in hand. Thus, before they assume responsibility for lifting and lowering the Bridge they have acquired intimate knowledge of the structure. Once they become operators, they readily learn to adjust their timing to accommodate the changing ease with which the metal parts of this "friction bridge" move against one another as new grease is applied and temperature changes alter its viscosity. No one with whom I discussed the bridge and no one whose descriptions I read understands the bridge better or takes greater delight in the elegance of Waddell & Harrington's engineering. As a result, people visiting or living in Portland, a center for the development of the latest black-box electronic technologies, regularly encounter a classic piece of early 20th century mechanical engineering, arresting evidence that old technology has not been rendered obsolete.[81]

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[80] These observations derive both from my tour of the bridge and from time spent in the operator's house with Rod Bates. Union Pacific drawings and O.-W.R.& N. Letterbooks indicate problems with the bell and the addition of the steam whistle.

[81] Conversations with and observation of Rod Bates, replacement Operator, and Sean, a relatively new oiler, provide the background for these statements. The presence of the Steel Bridge is especially evident in Portland because the height of its towers make it one of the most widely visible structures in the city.

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APPENDIX

Figure 1:Precursor to Equalizer. J. A. L. Waddell, Lift of Bridge Patent No. 506,561

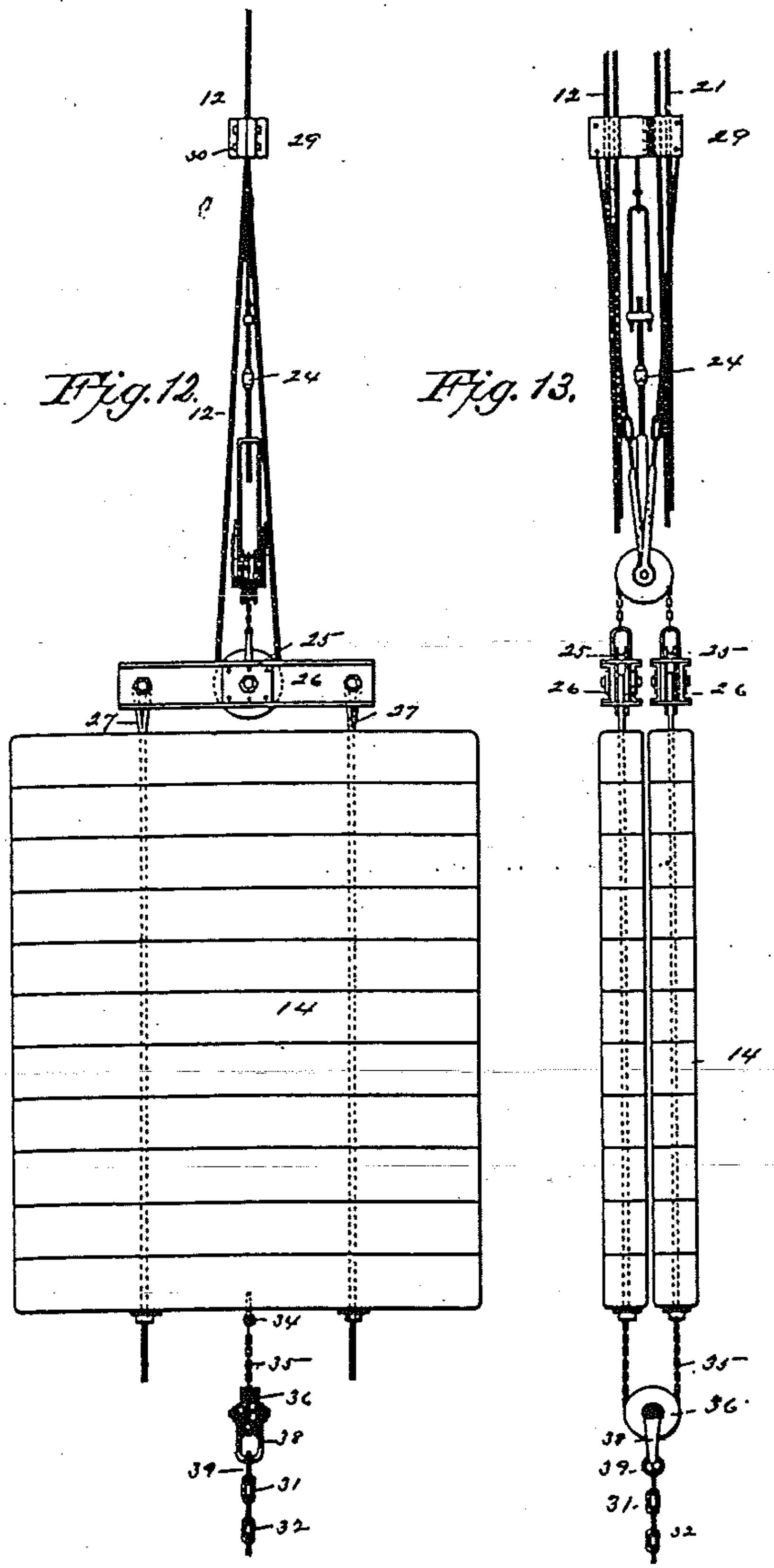

Figure 2:J. A. L. Waddell & J. L. Harrington. Lift Bridge Patent No. 953,307. Detail of Equalizer

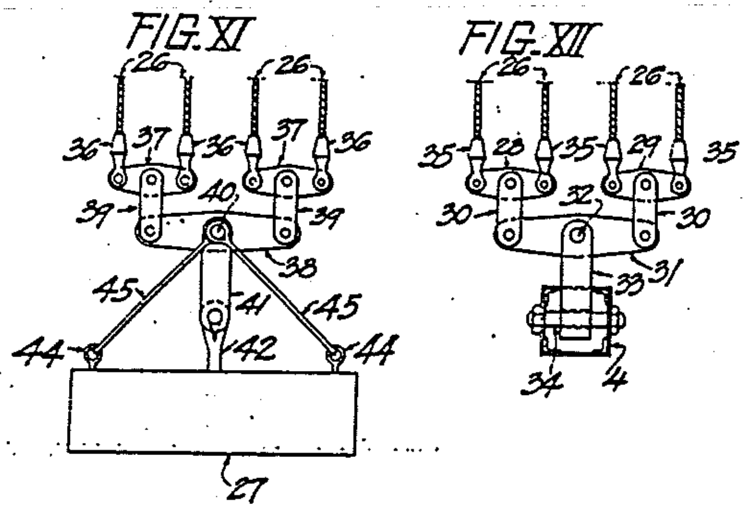

Figure 3:Hawthorne Bridge Equalizer from Drawing 55719. Counterweight Rope Replacement, August 1997.

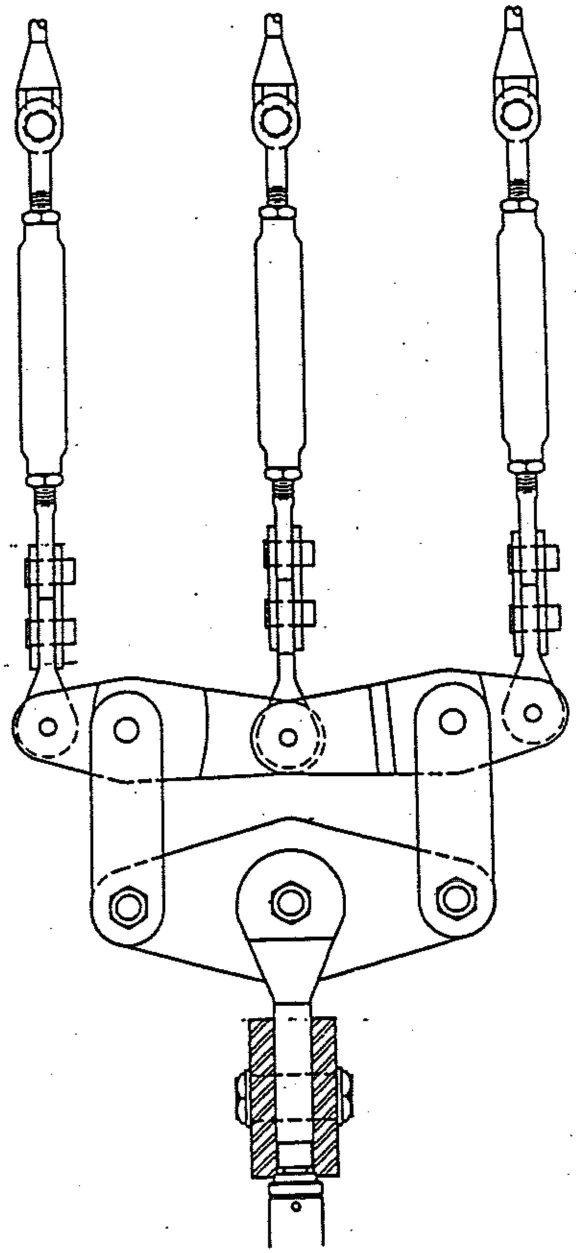

Figure 4: Steel Bridge Upper Deck Equalizer From Union Pacific Drawing Number 103261, 1985

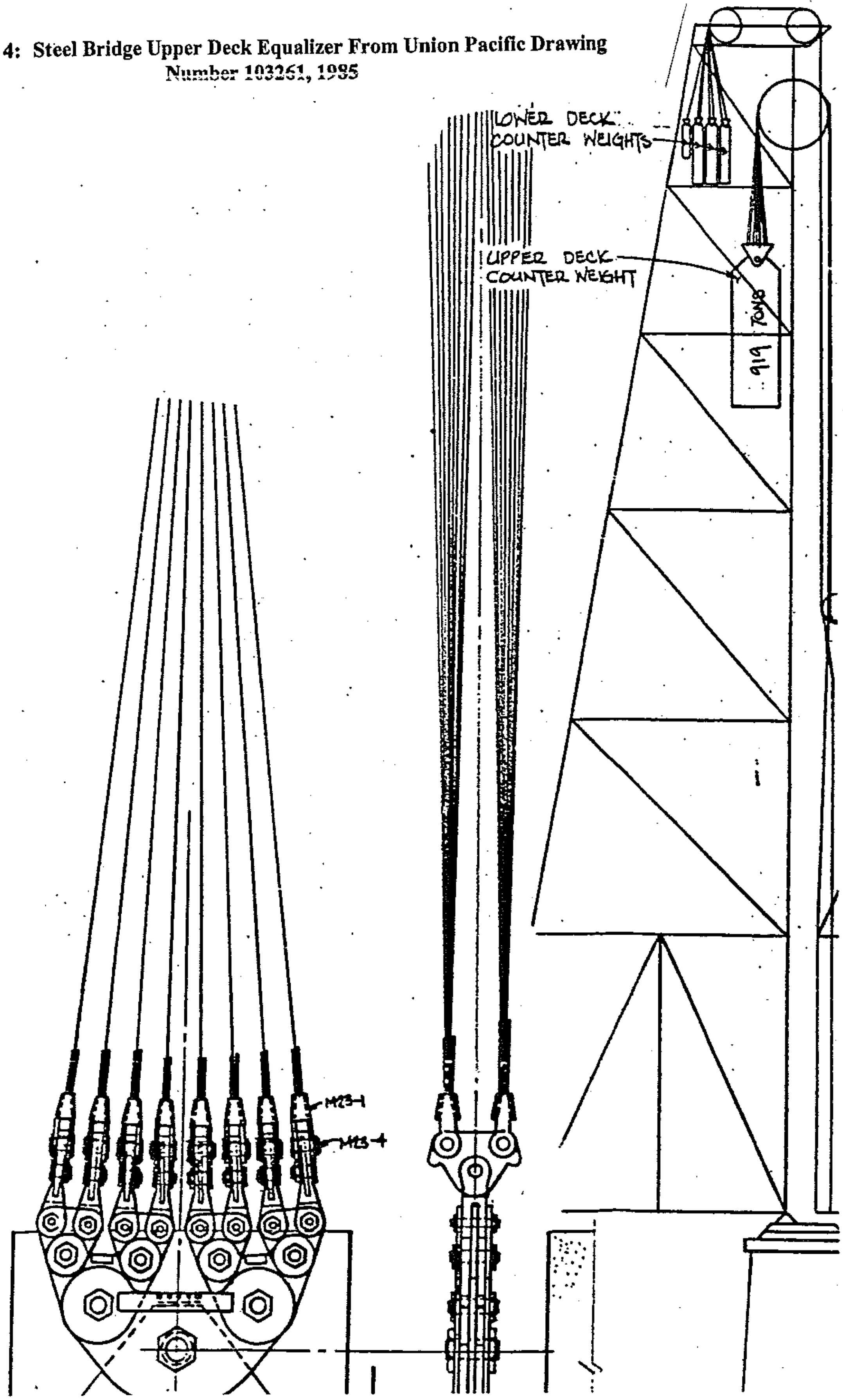

Figure 5:Steel Bridge Lower Deck Equalizer From Union Pacific Drawing Number 107108, June 1991

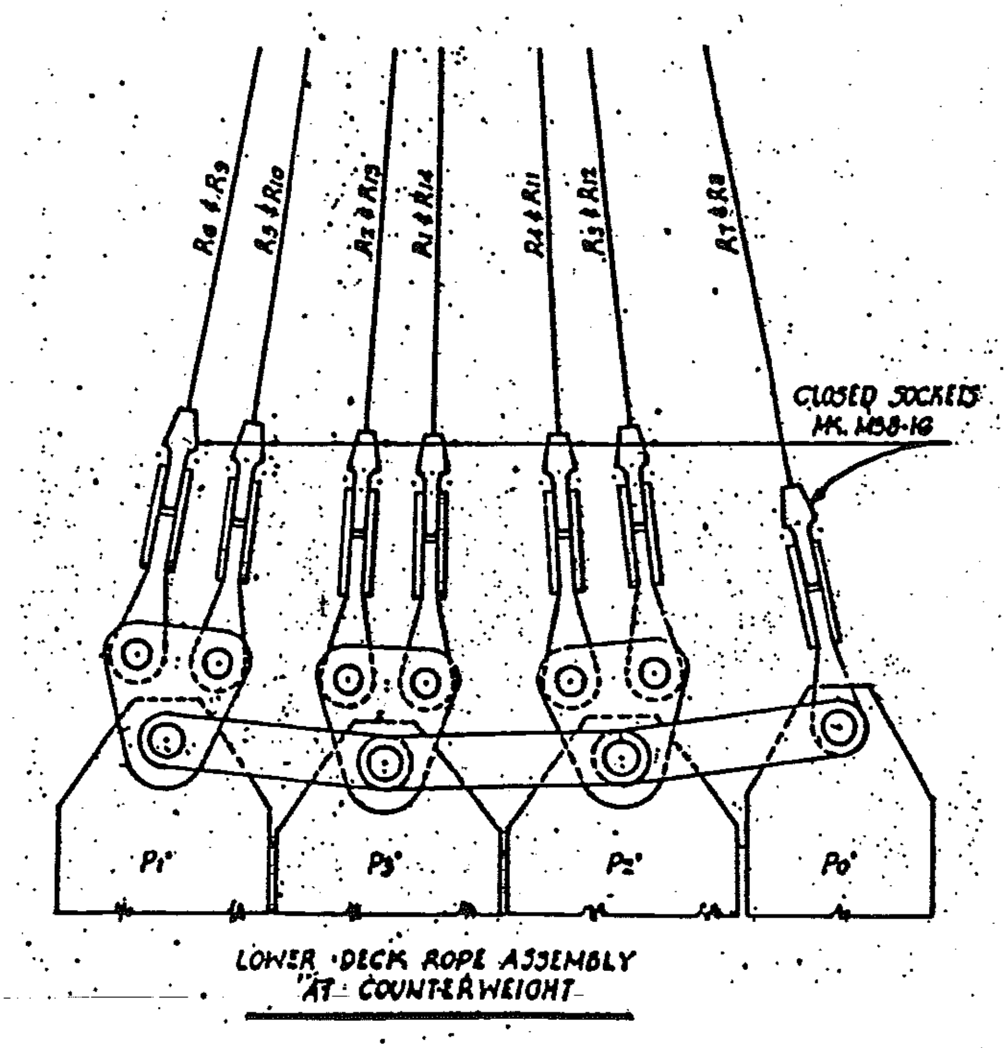

Figure 6: Standard Equalizer, E. E. Howard, "Vertical Lift Bridges," Discussion, ASCE Transactions, 1921

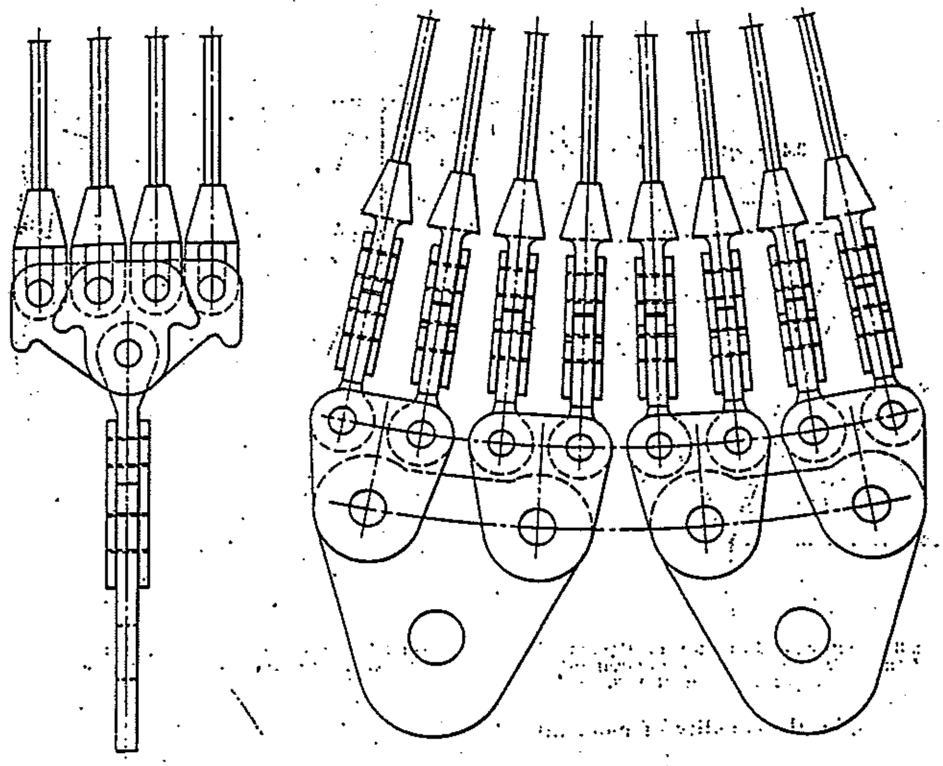

FIG. 33.—TYPICAL EQUALIZER DETAIL.