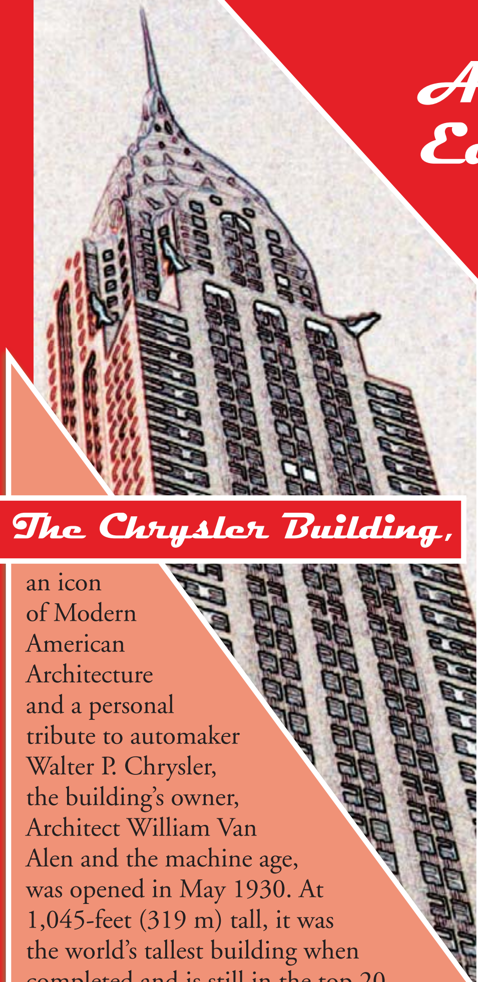
A Case Study of Early Steel Curtain Wall

By Eric Hammarberg, Assoc. AIA



The Chrysler Building,

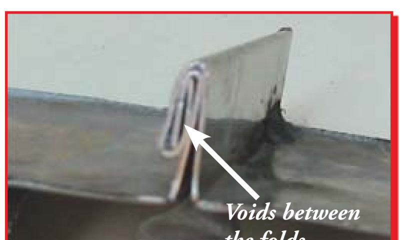
an icon of Modern American Architecture and a personal tribute to automaker Walter P. Chrysler, the building's owner, Architect William Van Alen and the machine age, was opened in May 1930. At 1,045-feet (319 m) tall, it was the world's tallest building when completed and is still in the top 20. The building was constructed similar to most large commercial structures of the time: structural steel frame encased with concrete and terra cotta fireproofing; brick facades with granite and marble decoration on the lower floors; backup brick and terra cotta block infill; cast-in-place draped mesh reinforced concrete floor and roof slabs; and steel double hung windows.

The building is capped by its famous stainless steel spire. This material is actually 22-gauge (0.080 mm) Nirosta manufactured and supplied by the company to first discover stainless steel, Krups of Germany. This material is very similar to contemporary 302 stainless. It was the first use of architectural stainless steel sheet metal in the world. In order to succeed in winning the "race" to the tallest building against another New York skyscraper being constructed at 40 Wall Street, the spire pinnacle was secretly constructed within the building and lifted into place after 40 Wall Street had been topped out. This was accomplished in little over an hour, shocking the city and the opposition!

Portions of the stainless steel cladding begin at the 60th floor, but the exclusive use of this cladding occurs in the first arch above the 68th floor and extends to the pinnacle.

There are approximately 12,500 panels of stainless steel sheet metal totaling 125,000-square feet (12,000 sm); 105,000-square feet (10,000 sm) below the 75th floor and 20,000-square feet (2,000 sm) above; with 115,000-linear feet (35,000 m) of joints and seams. The spire portion of the façade is punctuated by 120 triangular windows. Each window extends over two floors in height. These windows are composed of a mix of operable casement sashes and fixed lites. Originally, all "window" openings above the 74th floor were open with no glazing. Glazing had later been added to the window openings above the 75th floor, but 75 remains open to the elements. A flat roof exists on the 75th floor, immediately below these unglazed window openings.

Even though the building is exuberant in machine age iconography, most of the decorative work is hand crafted, including replicas of hubcaps, radiator cap hood ornaments, pineapples, eagle head gargoyles at the 60th floor and the famous spire. The stainless steel sheet metal cladding is the centuries old technology of sheet metal roofing involving flat and standing seams. This system is created by a series of folds interlocking each panel to the next. Seams and joints were typically sealed with white lead paste, most of which had deteriorated and washed out over the past seven decades. The sheet metal is anchored to the building with narrow strips of sheet metal, called cleats, folded into the seams. The cleats were nailed to wooden battens built into the masonry or simply nailed directly to the backup masonry. There is a layer of asphalt felt between the sheet metal and the masonry which acts as a slip sheet and backup waterproofing.



Original sheet metal cladding - voids between the folds were originally filled with white lead paste sealant

Behind the stainless steel cladding, the façade walls of the spire are a 12-inch (30 cm) thick mix of common brick and terra cotta block up to the 75th floor. From the 75th to the 81st floor, the exterior walls taper from 12-inches (30 cm) to 6-inches (15 cm). Above the 81st floor, approximately 900-feet (275 m) above the sidewalk, the spire consists only of stainless steel sheet metal cladding anchored directly to the exposed structural steel. There is no additional waterproofing or other protection.

The Chrysler Building is a designated New York City Landmark, is on the National Register of Historic Places and is clearly one of the favorite buildings of people around the world.

Industrial Rope Access inspection

Condition Investigation

Tishman Speyer Properties purchased the building in 1998 and asked LZA Technology Division of Thornton Tomasetti Group to survey and investigate the entire building in preparation for a planned 2-year upgrade. LZA visually surveyed the exterior masonry facades from standard suspended scaffolds. However, due to the relative delicate nature of the stainless steel cladding and difficult to reach rigging platform areas, the spire was investigated with LZA staff working alongside the firm of Vertical Access utilizing Industrial Rope Access. Vertical Access specializes in accessing and investigating difficult to reach areas. Hundreds of photographs and hours of video tape were produced. In addition, a live video feed to a television inside the building was offered to ease LZA's and Tishman Speyer's staff observations. But since members of LZA's staff are certified for rope access, we opted to join them "out on the ropes".

The spire was known to have leaks into the ceiling of the 68th floor and around the windows of the 69th and 70th floors. Our initial challenge was to determine the source(s) of the leaks. No detail drawings were available that would indicate back up construction of the spire such as weep systems or internal gutters and drains. One must also bear in mind that the work area is from 750-feet (230 m) to over 1,000-feet (300 m) above the street and near the New York Harbor and the East River – winds are ever present and can change in direction and speed in an instant. The building is also located above congested 42nd Street and Lexington Avenue across from Grand Central Terminal in midtown Manhattan, the most congested borough of New York City. In addition, the building is built out to sidewalk and there are only a few narrow roof setbacks below. The consequences would be severe if workers dropped a tool or made a more serious mistake!

Snow stop (part of the Replaced Simple Arch Cladding)

The Chrysler Building façades had not received regular maintenance over the years. However, although much of the previous repairs had done significant long-term harm to the façades, much of the building remained in good condition simply because it had not been repaired. There had been a few spire repair programs over the most recent 20-years that included: replacing most of the structure and cladding of the pinnacle; soldering discrete sheet metal seams; removing roofing tar and aluminized paint that had coated much of the east façade; and polishing all of the stainless steel.

As with the original materials in the lower façades, most of the original stainless steel remains in good condition. It has withstood the ravages of time, weather and an aggressive environment including salt laden and the once heavily polluted air of New York. The pinnacle replacement appeared to be in good condition. Soldering the sheet metal joints had locked panels of the flat and standing seams together and restricted differential expansion movement that is required in this type of system. Most of these soldered seams had either cracked or had caused the surrounding sheet metal to tear. These tears and other visible breaks were identified as highly probable leak sources. Water tests were performed to determine if these were the limit of the leak source or if the leaks came through the multiple joints and seams as well.

Our attention initially focused on the apex of the simple arch above the 68th floor, which includes a few sections of standing seam roofing where the panels are dead level. Water ponds in this area during rainfall, snow or even heavy fog. We observed several layers of sealant that had been applied over the seams in this area. All had failed and leaking clearly persisted.

Since the backup construction is mostly 12-inches (30 cm) thick and limited probes were available from the interior, the initial water tests were inconclusive. We could not determine if leaking was through discrete joints or widespread. However, through a series of visual inspections, water tests, repair mock-ups, partial repairs, probes, follow-up water tests, and finally observations of conditions during severe rainstorms over the course of more than a year, we determined that all seams and other breaks in the sheet metal are probable leak sources. In other words, "Death by 1,000 cuts."

Several repair approaches and materials were investigated, including: sealing joints and seams; coating the entire spire; even replacing the entire façade with a new state-of-the-art contemporary sheet metal system was discussed. Since the building is a New York City Landmark, all proposed work must be approved by the Landmarks Commission. The desire of all parties involved (Owner, Consultants, and Landmarks) was to retain as much of the original material in as unadulterated a state as possible. This was reasonable since the sheet metal itself was in good condition. We determined that there had been virtually no measurable loss of material thickness and the system was securely anchored.

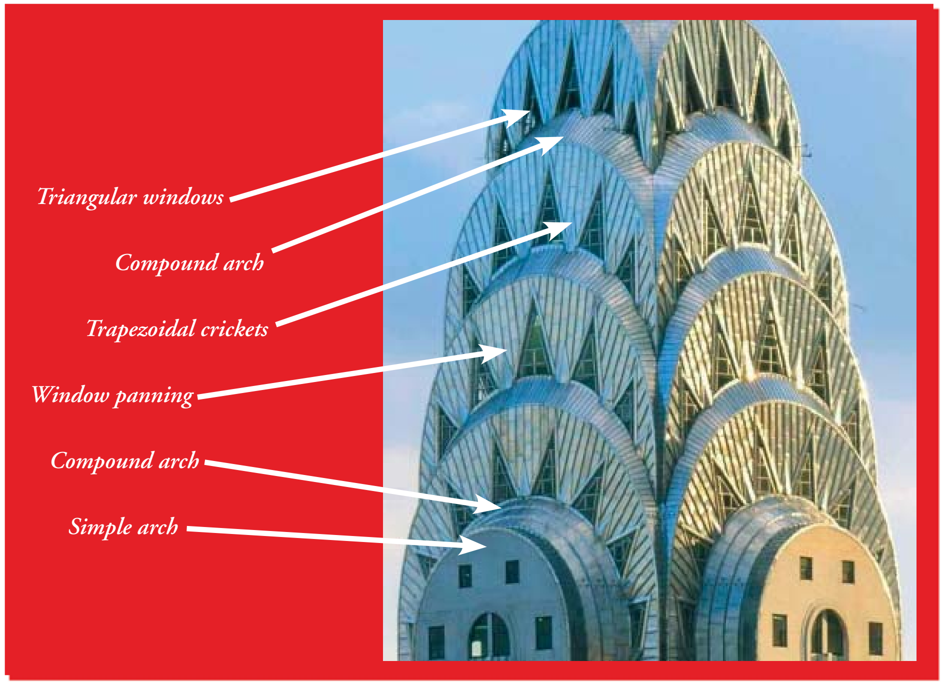
The Repair Plan

The New York City Landmarks Preservation Commission approved the following work:

Replacing the Simple Arch with New Sheet Metal

The lowest arch is a simple arch built of standing seams. This arch actually has a slight inward or back pitch toward the building. The valley formed by this back pitched portion and the stepped compound arch creates a slight trough that acts as a gutter to control rainwater and reduce the amount of runoff over the outboard brick façade.

The supplier of the original Nirosta remains one of the world's largest suppliers of stainless steel sheet metal. They also support state-of-the-art "seam welding" technology, including a fully detailed system of cleats and expansion. This system is often used for water storage tanks. The system requires special very low temper 26-gauge (0.50 mm) stainless steel sheet metal which is fusion welded together using a hand-held welder about the size of a wood working router. The seam welder includes self propelled pinch-rollers that deliver controlled high heat and produce a uniform weld (continuous spot weld) without burning through the metal. The result is an air tight seam. All necessary expansion is detailed into the system. Thirty-five linear feet (11 m) of arch, four-feet (1.2 m) wide, was replaced at each of the four elevations.



Cracked solder

Sealant and Liquid Applied Membrane Repairs at Failed Joints, Tears and Missing End Caps

Cracked solder typically occurred at complex intersections, where two panels of sheet metal were not parallel. Cracked solder and pinholes in the metal were repaired with either sealant or liquid applied membrane.

All sealants were Dow Corning Silicone, either 795 or 995 depending on desired modulus of elasticity. These were chosen for superior adhesion to the stainless and long life expectancy. Liquid applied membrane was Mathys Noxide. This was the only acceptably performing membrane available, at the time of this project, which included a color coating that matched the polished stainless steel… an aesthetic requirement.

The original window panning that joins the windows to the field of standing seams was poorly detailed in the original construction. It consisted of a simple stainless steel bar bolted through two panels of sheet metal bent upward at 90-degrees and butted together. The joint was originally packed with white lead paste. The lead had deteriorated and is mostly gone, so these joints leaked badly. The repair consisted of removing the bolts and bar, installing an inverted "U" shaped strip of 20-gauge (1.00 mm) stainless filled with sealant over this joint and pop-riveting it into place. All pop rivets are self sealing closed ended stainless steel rivets.

Window Repairs

The windows consist of fixed glazed lites and operable hinged casement sashes. All frame sections closely resemble traditional steel casement window sections, except these were fabricated in stainless steel. The windows consist of "Z" shape frame members with operable sash frames that nestle into these members when closed. The operable casement window sashes typically functioned well, but do not tightly seal when closed. Originally, these units did not have weather stripping or gaskets and leaks occurred under normal wind and rain conditions. Installation of gaskets and adjusting locks and hinges in all operable casement windows would greatly improve the window performance. In order to improve the waterproofing, prefabricated rubber and sprung bronze weather stripping was considered for retrofitting the operable sash openings. However, after brief design review and testing, these were rejected due to large and inconsistent gap dimensions between the sash and frames throughout the spire.

Sealant repairs

The selected approach included installation of sealant (same used on sheet metal) on the operable sash — along the sash/frame meeting surfaces. A bond break was applied to the frame so the sealant would not "glue" the window shut. The window was closed and latched, the sealant allowed to cure for one-week, and then the window was opened. This created a cast-in-place gasket seal that closely aligns between the two mating surfaces. The sealant is expected to have at least a 20-year lifespan. In addition, the sashes are generally not operated in order to maintain the "balance" of the building heating, ventilation and air conditioning system so very little wear and tear is anticipated. When the "gaskets" do wear out, repair/replacement would follow the same simple technique. In addition, all window lites were reglazed and cracked glass lites were replaced.

The scope of the work described above was completed by Arrow Restoration on floors 68 through 74 from scaffold platforms, suspended on cables, supported by counter-weighted beams, which were cantilevered out of the 75th floor windows.

75th Floor Through-Wall Flashing

As the project proceeded, it became evident that all seams, regardless of the floor, were probably leak sources and the owners required a 100% leak free spire.

Since there is a roof at the 75th floor level and windows punctuate the majority of the wall area, LZA suggested installing through-wall flashing in case any leak occurs in the spire and pinnacle above. A few courses of brick were removed around the window sill level of the 75th floor and a layer of membrane through-wall flashing installed. The membrane was terminated onto the backside of the stainless steel sheet metal skin and on all the steel framing within the walls. Then all masonry was replaced. Therefore, if water infiltrates behind the stainless steel skin, it may run down in the narrow space between the skin and the backup masonry and asphalt felt, become captured by the through-wall flashing and be dumped out on to the 75th floor roof and drain.

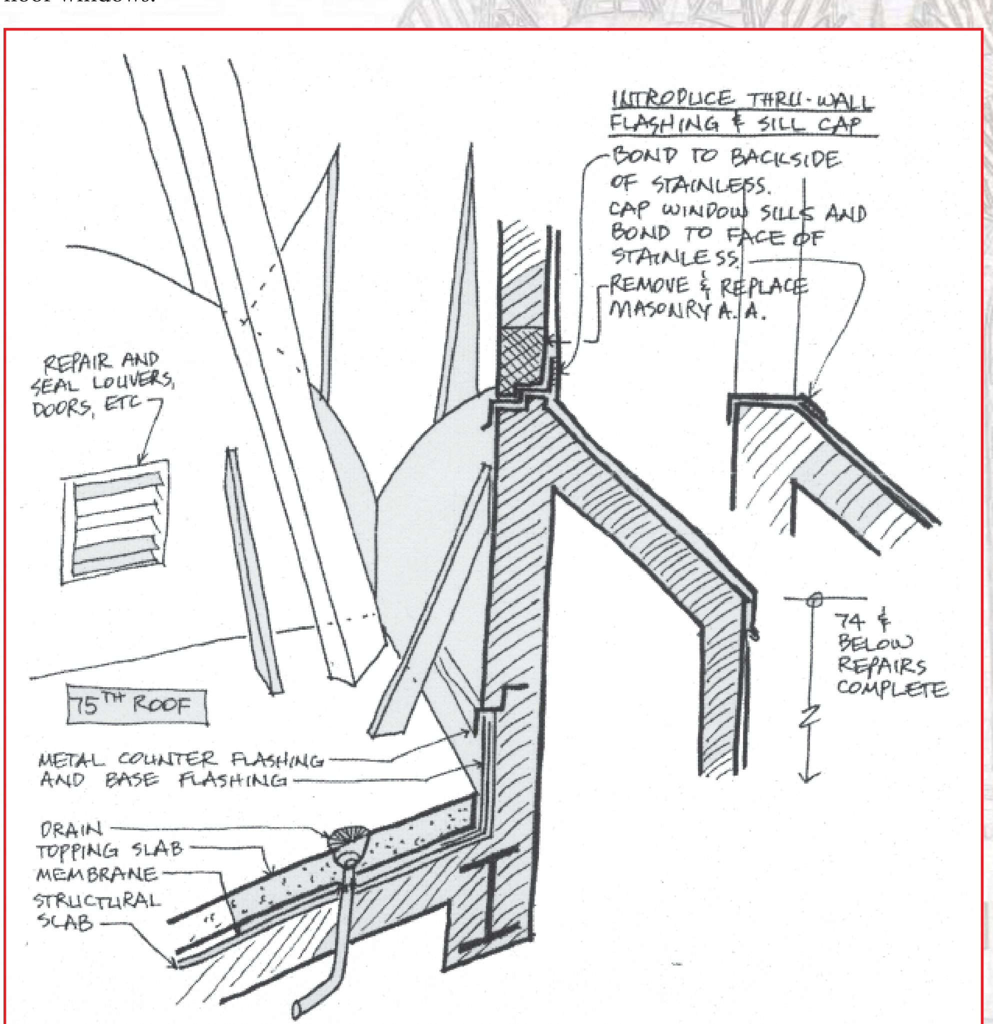
Final inspection

Pinnacle Repairs

Tishman Speyer wanted even more leak protection; they wanted to seal the entire spire all the way up to the tip of the pinnacle. Since there was no reasonable way to rig above the 75th floor with suspended scaffolding, and pipe scaffolding was cost prohibitive, Industrial Rope Access was again utilized. Through the course of the repairs on the lower areas of the spire, LZA had fine tuned the work and were able to detail all necessary repairs utilizing sealant. Universal Steeple Jacks (USJ), a firm that specializes in building repairs utilizing rope access, was engaged to perform these sealant repairs. USJ also performed inspections of the work on floors 68 through 75 so everyone would be doubly sure that the work was complete and thorough. Again, LZA's staff "got on the ropes" to observe the work and respond to particular conditions as they arose. USJ again offered a live video feed, and Tishman Speyer took advantage to verify that all the work was acceptable to them as well.

Results

There have been no leaks reported since the work was completed in 2003. A few years longer than originally planned, but successful. The future of the Chrysler Building looks bright for the 21st century!▪



75th Floor through-wall flashing

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