- SECTION SEVEN -

Conclusions and Recommendations

This ultrasonic testing and analysis report should be viewed as a first step in determining the general condition of the condenser water piping system at this Center Port Mall facility. Although it is based upon accepted engineering calculations, ASME pipe specifications, and the latest ultrasonic technology, it is not, in every case, intended to serve as an absolute and conclusive determination of pipe condition.

Following the results presented here, we generally recommend further non-destructive and/or metallurgical testing of all problem areas before giving consideration to pipe replacement. Further testing may not be necessary, however, in cases where the data from which our conclusions are based is clear and conclusive. As with most testing methods, is often necessary to review this report in relation to other knowledge about the piping systems in question.

In order to gain the most benefit from this investigation, it is useful to hold some understanding of the property itself, and of the information which was used in the preparation of this report. While we can very accurately measure existing wall thickness, we must rely upon the building or engineering personnel for supplemental information such as installation dates, material type, and pipe schedule, etc. Obviously, the more accurate and reliable the information used in the calculations, the more accurate and reliable our final report. Where no original pipe schedule or installation dates exists, and where assumptions based upon other criteria have been used in the determination of such details, that resulting evaluation will have a degree of less certainty than one where the required information was available through original documents.

In developing this pipe analysis report, CorrView International, LLC has made the arbitrary decision to raise concern for the potential replacement of any section of pipe showing a minimum wall thickness based retirement date within 10 years of our testing on 7/19/2003. We believe a 10 year lead provides sufficient warning that a problem may exist, as well as the time necessary to further investigate and correct the cause or causes of the problem. This, however, is a general guideline, and will vary depending upon the pipe location tested and its service.

Many operating engineers and property managers would regard a 30 year retirement date as unacceptable; others might postpone corrective action at 5 years. For a system in service three years, for instance, a 10 year retirement date would signal a very advanced rate of pipe corrosion.

Our ultrasonic investigation into this condenser water system revealed some very surprising conclusions which both confirmed and discounted some previously held assumptions. Unlike other properties which have a more straightforward and vertically oriented piping layout, the widely dispersed layout of condenser water pipe at this mall location seems to have produced a wider variation in test result. This is likely due to the long horizontal runs and the various differences in flow rates which exist. As shown in this report, the effect of winter drain down against the roof level pipe is dramatic.

Beginning our testing at the roof level, we found a very high loss of wall thickness from pipe which is believed to be originally standard grade ASTM A 53 having a factory specified wall thickness of 0.375 inches. Our testing identified generally low wall thickness values of under 0.200 inches, with some locations showing a wall loss resulting in a remaining wall thickness of under 0.100 inches. This higher wall loss was identified in the immediate area of the pumps, which would have the highest turbulence, the highest erosion due to particulates, and the highest migration of fresh air in the winter months.

We quickly found that the pipe wall thickness improved slightly as we tested along the length of the pipe to the entrance into the building. This is likely due to its distance from the open points at the tower pans and the fact that less moisture and oxygen would have the ability to travel into this area. We found the piping at the roof level to be deteriorated generally beyond the point of repair, and in need of replacement. We would recommend replacing all existing roof level piping back to the vertical connections at the roof leading into the building.

While it now seems a secondary point given knowledge of the poor roof pipe condition, there is also a heavy localized corrosion condition existing at the roof supports of both supply and return lines. This is an area which has produced leaks in the past, and which currently presents the greatest threat to the operation of the roof level piping. During our testing, we were able to measure exterior pitting on an average of 0.050 inches deep, and with extremes of 0.100 inches. Viewing this external wall loss with the knowledge that the pipe itself has been reduced to wall thicknesses in the range of 0.120 inches and below makes it easy to understand that multiple points along this exposure pipe are subject of failure at any time.

Moving our testing into the mall area provided dramatically different results. Here we identified substantially higher wall thickness values at virtually all main riser piping, and in all areas of the mall. Testing revealed a generally low corrosion rate of between 0.5 mils per year and 1.5 mils per year, with an average of about 1 MPY. We also identified a moderate degree of pitting throughout most areas tested. Considering the worst-case scenario for each test point, which is based upon that highest degree of corrosion caused by pitting, we could still show generally good result throughout the areas tested at the main riser. We were quite pleased by the uniformity of test result, which helps to substantiate the assumption that areas of larger diameter pipe not tested will be very similar in condition to those which are addressed in this report.

This low corrosion rate produces outstanding results in some locations tested, such as location No. 11. Here we found average wall thickness values approaching that of new schedule 40 pipe, and therefore almost unlimited service life. At location No. 14, we found the pipe currently near the specification of new factory steel, and again having almost unlimited service life. Other sections of main riser were found having less favorable results, but with still high remaining wall thickness and service life.

We found a few areas of pipe showing dramatically different results. Located in the DEMO store, testing generally identified double the corrosion activity as well as much higher pitting activity. Shown in location No. 15, for example, we measured a wide variation in wall thickness generally along the bottom of the pipe and at its lower sides. This produced very low wall thickness values down around 0.127 inches, and in the range approaching minimum acceptable standards. Testing at the adjacent supply line produced a lower corrosion rate and less pitting, but it is quite obvious that some localized problem exists in this area.

This higher corrosion and pitting activity is also shown at other areas of pipe tested in this Demo store space. At location No. 21, for example, we found a high degree of pitting, with lowest wall thickness values approaching minimum standards. It is important to remember that our testing procedure is only a random spot check method, and can never conclusively identify the lowest areas of the pipe, or that area of pipe likely to fail.

Where corrosion is generally uniform, it can reasonably be assumed that other areas in the general vicinity will show a similar wall thickness profile. However, where a high degree of pitting exists, that ability to assume similar wall thickness integrity does not hold true. In fact, as the degree of pitting increases, so does the probability that lower wall thickness values exist beyond what has been reported. For each test location, we calculate out that lowest theoretical wall thickness based upon the standard deviation of the wall 12 measured test points. While we do not incorporate this theoretical low thickness value into a service life prediction, it is very worthwhile to consider its existence wherever pitting activity is high.

We measured consistently high corrosion rates and pitting activity at different areas within the DEMO store space, and identified location No. 32 as providing the greatest threat identified in this report. Here we showed a high degree of pitting, with low wall thickness values at 0.090 inches. Unlike the larger diameter welded pipe, however, the factor of threads in this area becomes important since approximately 50 percent of the original wall thickness is removed during the threading process. This is discussed in detail in our addendum section further in this report, and is recommended reading. At location No. 32, multiple low wall thickness values of under 0.100 in., less the thread cut of 0.085 in., leaves at most 15 thousands worth of material at some areas of the threads. We can suggest that only due to the very low pressures under which the system operates, has this pipe not already failed. We can easily show that this area of pipe should be replaced as soon as possible. Due to the high pitting and corrosion condition throughout this immediate area, consideration to replace some of the larger distribution lines would also be warranted.

Our testing at other small diameter threaded piping showed similar results, primarily due to the fact that schedule 40 pipe does not carry sufficient wall thickness, even when new, to satisfy minimum acceptable wall thickness requirements for condenser water service. This is not to say that schedule 40 cannot be used in open condenser water systems, but that it should not be used due to the loss of approximately 50 percent of the pipe wall during the process of threading, in combination with the inherently high corrosion activity in open systems. While our ultrasonic testing identified the threaded pipe as generally requiring replacement, a close review of the results showed that varying degrees of the need for replacement exist, with the more critical areas to replace having the higher pitting and wider variation in wall thickness.

Test location No. 35, for example, is a good representation of this concern. Here we can show the same low corrosion rate as found throughout most areas of this small condenser water piping. However, given the fact that this pipe is threaded and of inherently low wall thickness, we can easily show that approximately only 20 thousands of material remains in the areas of the threads. This is a very minor amount of material remaining, and we provide a graduated scale of wall thickness dimensions in the addendum of this report for comparison.

We also identified a much higher degree of pitting and corrosion in the Cohen Optical store area. Here, testing showed little to no life remaining at the main three inch distribution lines, and at the take-off lines serving the air conditioning equipment. Shown at location No. 36, we can estimate approximately 15 mills or 0.015 inches remaining at the threads at both sides of this isolation valve. Multiple leaks currently exist in this area as well.

Throughout our testing, we noticed a generally higher degree of corrosion and wall thickness loss at the bottom and lower sides of most pipe locations. While there were some test points which did not show this characteristic at all, most locations did. This strongly suggests the presence of dirt, iron oxide and particulates at the horizontal lines which have initiated an under deposit corrosion condition. Much of the corrosion product from the roof level pipe would likely have settled in the lower horizontal piping.

A generally subjective feeling from this report was that we seemed to find generally higher corrosion rates and pitting at its furthermost extremes. This would be expected as water flow reduced, giving particulates the opportunity to settle out. In reviewing the data, however there is no very clear indication of this suspicion since the variation in results is so small, and the number of test points not sufficient. The tremendous difference in pipe quality between the roof level and the mall area is not shown at points taken within the mall itself.

One area which showed a higher degree of corrosion and pitting activity was Northwest of the main riser from the roof - including the previously referenced DEMO store. We can suggest that the piping layout itself may be a strong contributing factor to the higher corrosion and pitting activity in the Northwest area by channeling a higher degree of dirt and particulates in one direction. Particulates travel in a generally straight lines due to inertia, and therefore would tend to bypass the inlet of a side entry tee in order to travel straight through. While we were not able to visually inspect this concealed area of piping at its split to North and South, we understand that it is not a simple tee arrangement, but rather some unusual piping configuration. We suspect that some form of similar arrangement or uneven distribution exists in this separation of North and South condenser supply water flow exists to allow a greater proportion of a rust and particulates to enter the Northwest area and create this higher degree of corrosion and pitting activity.

A review of the graphs produced in Section Five of this report show the very clear relationship which exists in this piping system. We can see the dramatically higher loss of wall thickness at the first five locations taken at the roof level. We can also show a slightly better uniformity of the wall thickness presented for the smallest diameter piping. At the larger diameter main lines, however, we see a variation of result whereby some areas show a much higher degree of pitting activity than others.

Except at the roof level piping, our testing does show a generally even degree of mild corrosion activity throughout all mall area locations - which is suggestive that similar conditions exist elsewhere in areas not tested. While a moderate variation in wall loss can be easily handled by the larger diameter pipe due to its inherently greater wall thickness, that same variation can bring smaller sections of pipe having less wall thickness to the point of failure. This is the threat always existing at smaller diameter piping.

Overall, we are pleased by this report in that we have clearly identified three specific areas of piping in need of replacement. We have also provided solid evidence that the majority of the piping, which was of concern previously, is in very good condition and suitable for many more decades of service given continued good water treatment service.

We recommend replacing all roof level piping back to the elbows at the entrance to the building, and considering the condition of the tower itself, would suggest this work be incorporated into a full tower replacement. We recommend replacing the piping at Cohen Optical area as well as the DEMO store area - especially the small diameter threaded piping.

Some action must be taken to remove the deposits within the system in order to slow down the pitting activity which clearly exists. Various filtration options exist, which require extensive thought and planning due to the almost exclusively horizontal piping layout and different “zones” of this mall. Without some form of filtration to remove the particulates which exist, the pitting rates shown in this report are guaranteed to increase to the point of threatening the larger diameter main piping as well. It might also be worthwhile to consider a water flow survey before any major renovation of the tower in order to determine if sufficient flow exists at the extremes of the piping layout. Also, a review of the split in piping between North and South zones would be appropriate.

Any filtration effort would need to be coordinated with the water treatment company and the addition of dispersing agents to break up and remove the existing debris. We would consider the addition of filtration as mandatory in extending the life of this piping.

Specific Recommendations Related to the Findings of this Report

1. **Review this report with your water treatment contractor for opportunities to improve the current treatment program. Add a mild dispersant agent to remove any existing interior deposits.**
2. **Review this report with your consulting engineer for their comment and recommendations.**
3. **Replace all roof level main supply and return lines back to the elbows entering the building.**
4. **Replace the small diameter threaded piping at Cohen Optical and DEMO stores with new Schedule 80 heavy wall stock.**
5. **Install galvanic insulators at any black pipe to copper connections.**
6. **Perform a visual inspection of the condenser water system to identify any visual examples of leakage at the threaded areas and address their replacement first.**

7. **Consider the replacement of other threaded piping with new schedule 80 stock.**
8. **Consider adding one or more water filtration units to the condenser water system in order to remove existing deposits and prevent new deposits from settling.**
9. **Perform a water flow study on the piping in order to determine if sufficient flow exists at the extremes of the piping layout.**
10. **Review the layout of the supply side split between North and South zones**
11. **Consider raising the flow rate of the system to help minimize settling of deposits.**

General Recommendations

In order to prevent the damaging effects of corrosion you may wish to incorporate the following general recommendations into your building operation:

A) Maintain a strict water treatment program from a reliable vendor. Automate all chemical feeds and blowdown. Review all test reports carefully. Consider an outside consultant to review the water treatment program on a regular basis.

B) Chemically clean and sterilize all open water systems twice per operating season. Chemically clean and sterilize all closed systems every three to five years.

C) Clean and flush tower basins regularly.

D) Incorporate a supplemental chemical dispersing agent into your water treatment program.

E) Perform regular corrosion coupon testing or ultrasonic template testing.

F) Include monthly testing for biological cell counts in your water treatment program. Biological contamination can develop within a few days period of time under favorable conditions. Currently used non-toxic inhibitors place an added emphasis on the effectiveness of biocides.

G) If possible, prevent the buildup of dirt and debris by eliminating low flow areas. This is especially common in secondary water lines having long horizontal runs. Some studies have shown low flow conditions to reduce the effectiveness of water treatment inhibitors as well as allowing dirt to deposit. Booster pumps are one option to increase flow rates in smaller size pipe lines.

H) Install a side stream filtering system to reduce overall particulates. Filtering even 10% of the flow rate will greatly help in reducing the buildup of dirt and debris. A wide variety of manual and automatic filters are available.