

WATERJET CLEANING OF TRUCK-MOUNTED CONCRETE MIXING TANKS

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ABSTRACT

Manually removing hardened concrete from inside concrete mixing tanks using tools such as pneumatic chipping hammers has been identified by the National Institute for Occupational Safety and Health (NIOSH) as being a hazardous occupation. Engineers at NIOSH's Spokane Research Laboratory (SRL) teamed up with students from Gonzaga University to design an automated cleaning method for such tanks. The team built a prototype consisting of a remotely controlled lance with two opposing waterjet nozzles mounted on one end. The lance and its drive assembly are mounted on a control pedestal, which allows the lance to be adjusted for optimizing tank entry. The pedestal is supported and elevated by a scaffold-type frame. The system was tested using a 1,000-psi pump supplying up to 215 gal/min of water to the nozzles. It was shown that semi-cured concrete could be removed effectively from the tank walls. In cooperation with an industry partner, Central Pre-Mix Concrete Co. of Spokane, WA, the system will be demonstrated at a concrete mixing plant as a daily or weekly cleaner, and the results will be compared to current rinsing and cleaning methods. The goal is to reduce the build-up of concrete over time, thereby reducing or eliminating the need to chip concrete manually from inside the tanks.

1. INTRODUCTION

The Spokane Research Laboratory (SRL) of the National Institute for Occupational Safety and Health (NIOSH) focuses on providing engineering solutions to occupational health and safety hazards in the mining and construction industries. This paper summarizes a project that addresses the hazards associated with cleaning hardened concrete from inside truck-mounted mixing tanks.

The project was born out of a hazard recognized by both NIOSH and the Occupational Safety and Health Administration (OSHA). It addresses the exposure of construction workers to a multiple-hazard situation while cleaning concrete mixing trucks. The workers are exposed to extremely high noise levels, high concentrations of respirable dust that may contain silica, hand and arm vibrations from the use of pneumatic tools, the possibility of traumatic injuries from falling debris, and musculoskeletal disorders from lifting chunks of concrete and heavy tools inside confined work spaces. The goal of this project is to design an automated cleaning process that will remove a worker from this hostile environment.

In 1997, the Wisconsin OSHA consultation program, in conjunction with the Sentinel Event Notification System for Occupational Risks (SENSOR) program, did a preliminary investigation of this problem and cited silica exposure as a “serious hazard” (i.e., can cause a health hazard exposure resulting in death or serious physical harm). Searches of Bureau of Labor Statistics data by NIOSH researchers indicated that 570,417 workers at 60,222 establishments could be involved. It appeared that the hazards of cleaning out concrete tanks were a serious health hazard that had been overlooked for a variety of reasons. Therefore, assessing the problem and providing methods for reducing worker exposure to these hazards lay directly within NIOSH’s mission.

2. BACKGROUND

The ready-mixed-concrete industry is a vital part of modern life and many other industries depend on it. Every day, millions of tons of ready-mixed concrete are transported from concrete plants to job sites via mixing tanks mounted on trucks. The tanks have a helical screw system of baffles to mix the concrete or to force it out the back of the drum when pouring, depending on the rotational direction of the drum (Figure 1). After months of use, concrete builds up on the baffles, causing a loss in efficiency of the baffles and a decrease in the volume the trucks are able to transport. As much as 1-1/2 yd³ of concrete per load, depending on drum size, can be lost because of build-up.

Two cleaning processes are commonly used to clean concrete haulage tanks. The first involves flushing out the tank daily with a large volume of water. The specifics of this process vary somewhat, but typically the tank is flushed for 5 to 10 min following every load of concrete and for approximately 15 min at the end of each work shift. In some cases, operators will add coarse aggregate to the tank to improve scouring of semi-hardened concrete. Despite this treatment, concrete hardens and builds up on tank surfaces over time.

The second process is to chip the built-up, hardened concrete manually from the inside of the tank. This is done on an as-needed basis, typically about one to three times per year, and entails sending

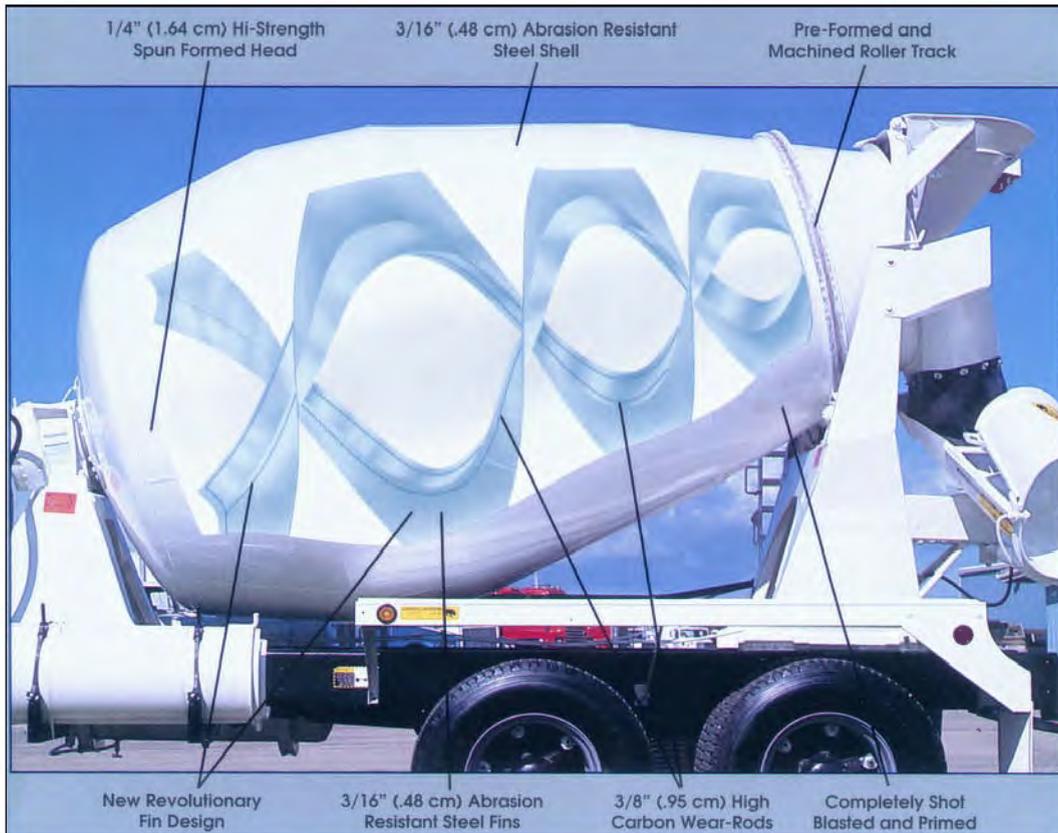


Figure 1. Tank geometry. This cutaway illustrates the complexity of the twin helical mixing baffles.

an employee into the tank with pneumatic tools such as hand-held chippers and jackhammers. The procedure takes between 1 and 8 hr and places the employee in an enclosed, hazardous environment that may even require a confined-space permit. According to a recent study, this task could cause negative health effects, such as hearing loss and silicosis (Williams and Sam 2000a, 2000b; Sam and Williams 2000). The number of times this chipping must be done varies, depending on the type of concrete mixed and how effective the flushing process has been. The criteria used to decide when it is time to chip out a tank are—

1. When the discharge from the tank becomes inefficient because the mixing baffles are heavily coated with concrete,
2. When the weight of the empty truck is excessive because of the accumulation of hardened concrete (up to 10,000 lb of concrete can build up inside the tank), and
3. When the capacity (i.e., delivery volume) of the tank is reduced significantly because of the accumulation of hardened concrete.

Both cleaning processes are somewhat complicated by the interior geometry of the tanks (Figures 1 and 2). In the case of the tank rinsing technique, the agitated water easily scours the rear sides of

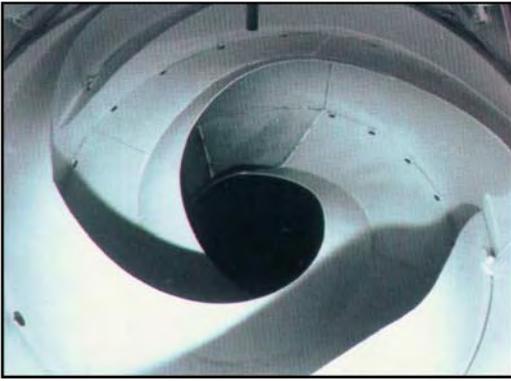


Figure 2. Mixing baffles. This view from inside an unused tank shows the surfaces that will become coated with concrete.

the baffles as it is propelled out of the tank by the rotating baffles. However, because the front sides are protected, concrete tends to build up preferentially on the front side of the baffles. During the chipping process, the baffles make maneuvering inside the tank difficult. The odd geometries of the baffles create hard-to-reach spots and also present more surface area for concrete to adhere to. The complex geometry and concrete build-up on the front sides of the baffles were a major consideration in developing design concepts for automated cleaning systems.

In addition to hazards associated with cleaning, there are economic disadvantages to continuing these work practices. A preliminary economic feasibility study¹ was conducted that indicated haulage productivity could be reduced by as much as 15% because of reduced delivery volumes resulting from concrete build-up inside the tanks and reduced fuel economy. Such reductions would translate into a significant loss of income for concrete mixing companies and might easily justify the cost of an automated cleaning system.

The goal of this research project is thus to build and field test an automated tank cleaner so that the industry will have hard data on which to make decisions about whether to incorporate such technology into their work practices.

3. RESEARCH APPROACH

NIOSH researchers called on the talent of engineering students at Gonzaga University, Spokane, WA, to help tackle this problem. Through the Gonzaga Center for Engineering Design, a group of fourth-year mechanical engineering students was assigned the problem as a senior design project. The design team consisted of students, an adjunct professor who served as project advisor, and two liaison engineers from SRL. The team's mission was to design, build, and test a prototype automated tank cleaning system.

The team assessed the problem in brainstorming sessions, via phone conversations with industry representatives, and by field trips to a local concrete mixing plant. This preliminary assessment led to the selection of hydroblasting as the technology of choice for solving the problem, and further design work therefore focused on hydroblasting techniques. The team generated a list of design requirements and then developed five unique preliminary design concepts using these requirements as a guide (Lazenga et al. 2000). The concepts were evaluated using a weighted decision matrix.

¹Lazenga, Nathan J. Economic Analysis of the Installation and Application of an Automated Concrete Removal System for the Ready-Mixed Industry. Proposal prepared for Engineering Economics course, School of Engineering, Gonzaga University, Spokane, WA, Nov. 2000, 14 pp. Available from authors of this paper.

The “winner” became the concept that was developed further for testing. Below is a list of the requirements and a brief overview of the various preliminary concepts.

3.1 Design Requirements

3.1.1 Functional Requirements

- Cleaning should prevent the accumulation of hardened concrete in the tank.
- Cleaning must remove uncured and semi-cured concrete from 90% of the tank interior.
- Cleaning system must not damage the tank or truck.
- System must accommodate standard truck geometries. Design should focus on the McNeilus Bridgmaster truck, which is a truck commonly used in the industry.
- Cleaning time must not exceed the current cleaning cycle time of 15 min.
- Prototype must be rugged and dependable to withstand impacts of falling debris within the tank.
- All components must be capable of operating in a wet environment.
- Jet(s) must be capable of being guided through the rear entry and baffles.
- Use of an external water supply must be easy.

3.1.2 Operational Safety Requirements

- System must be semiautomatic, i.e., operable by one semiskilled technician.
- Failsafe system must ensure that the jets operate only inside the tank.
- Jets must shut off if any part of the apparatus gets tangled or obstructed.

3.2 Additional Parameters

In addition to the design requirements listed, several other issues were taken into account.

- In discussions with workers who regularly clean tanks, it was noted that most of the build-up is deposited on the front sides of the baffles, i.e., the side that faces the front of the truck. During the rinsing process, the back side of the baffles (where the water discharges from the tank) acts as a trough in which water collects. Agitation of this water prevents the semi-hardened concrete from being deposited on tank surfaces. Conversely, water on the front sides of the baffles is not agitated, and therefore concrete builds up rapidly. This location is where cleaning efforts must be focused.
- Environmental regulations restrict the methods used for draining and disposing of wastewater and materials. Wastewater will likely need to be captured in a settling pond and cleaned before disposal or re-use.
- Every mixing tank has a side access panel through which a person enters the tank to chip the concrete free. Although it is feasible that this panel could be used as an access for an automated system, this is not desirable because it can take over an hour to remove and replace the panel.
- Concrete can build up in the tank to a thickness of nearly 18 in.



Figure 3. View showing limited access to tank interior.

- Access to the tank interior is quite restricted due to the limited clearance at the rear of the tank (Figure 3).
- Differences in initial truck heights and the amount of height reduction caused by the increasing weight of accumulated water in the tank during the cleaning process (“truck squat”) may require that an automated system be vertically adjustable.

4. PRELIMINARY DESIGN CONCEPTS

Using the list of design requirements and additional parameters as a guide, the following preliminary design concepts were generated (Lazenga et al. 2000).

4.1 Locking Chain Waterjet Deployment

This design incorporates a specially designed chain link that can be curled up in one direction, but when unrolled in the other direction, locks to form a rigid wand. This mechanism would allow the waterjet to be deployed from above the truck through the limited-access hopper and into the drum. While the tank spins, the jet sprays and cleans the interior of the tank.

4.2 Locking Chain System, Deployment from Side of Tank

In this design, the existing side access panel is used to gain entry to the tank interior. A hose deployment apparatus, perhaps the locking chain, would enter the hole and spray the baffles.

4.3 Baffle-Guided Crawler

This design entails a simple frame with wheels or rollers on the bottom and side. The apparatus rests in the trough of the baffle and rolls down the inside of the tank as it slowly rotates. An arm with a waterjet(s) on it is attached to the top of the frame and drapes over the top of the baffle. As the crawler moves, the waterjet sprays the backside of the baffle the crawler is resting on. The crawler is tethered to the pump by means of a high-pressure water hose.

4.4 Chaos Waterjet Ball

This concept incorporates a ball tethered to the pump by means of a shielded high-pressure hose. As the tank spins, the ball moves down the tank baffles in the same manner as the crawler. The water is shot out of an asymmetrically positioned nozzle in the ball. Due to the force of the water, the ball twists and spins so the stream is randomly directed throughout the inside of the tank.

4.5 Helix-Mounted Waterjets

This design would require a permanently mounted track of waterjets welded on top of the baffles. The waterjets point at the back of the previous baffle. A pipe along the top of the baffle connects all the waterjets and provides pressurized water that cleans the baffles. A pump is connected to the pipe from outside the drum, providing pressure to the waterjet's baffles.

4.6 Lance-Mounted Waterjet

A waterjet is mounted on a lance that moves in and out of the spinning tank. The waterjet sprays the tank interior, removing built-up concrete. The set-up and alignment of the apparatus is the most difficult part of the cleaning cycle. Access to the tank is limited (figure 3), and misalignment could be disastrous to the entire system. However, with the right control system, this design could be made practical.

4.7 Concept Evaluation

The design concepts were assessed using an evaluation based on a weighted decision matrix. This technique, known as Pugh's method, allowed all proposed concepts to be compared directly. The first step in Pugh's method is to choose the criteria to be compared. These criteria were derived from the design requirements and from discussions among team members. A weighting factor was assigned to each relative to its overall importance. One concept was then selected as a datum. The design team chose to use the locking chain waterjet deployment as the datum. The datum was assigned values of zero on the decision matrix, while the other concepts were given a score ranging from -3 to +3.

A score of +3 indicated that the given concept met the evaluation criteria much better than the datum, while -3 indicated that the datum was far superior to the concept. Each of these values was then multiplied by the weighting factor. The weighted values were then summed for each concept to give a weighted total. The concept that best met the list of evaluation criteria was that concept that had the highest weighted total on the decision matrix. The decision matrix is shown in Table 1.

Table 1. Weighted decision matrix

Criterion number	Criterion	Weighting factor	Side, tank	Baffle-guided crawler	Chaos waterjet ball	Helix-mounted jet	Lance-mounted waterjet
1	Easily inserted	8	-2	-1	-1	3	1
2	Accurately inserted	10	0	1	1	3	1
3	Setup time	8	-3	-1	-1	3	-1
4	Position nozzle effectively to clean 90% of tank	10	-2	0	-3	-1	0
5	Mechanical reliability	8	0	1	2	-2	2
6	Resistance to entanglement	10	1	-2	-3	3	1
7	Cannot damage tank interior	10	-1	-1	-3	0	1
8	Resistance to debris impact	8	-1	-1	2	-3	1
9	Quick cycling time for cleaning	7	-2	-2	-3	-3	0
10	Easy to remove from tank in case of failure	4	-2	-1	1	-3	1
11	Sensitivity to varying internal geometry	8	0	-2	2	3	0
12	Sensitivity of varying truck heights	8	1	2	2	3	-1
13	Dependence on support structure	5	0	1	1	3	0
14	Cost to build	4	-1	2	3	-3	2
15	Cost to operate	8	-2	-1	-1	1	0
16	Ease of maintenance	7	-1	1	2	-3	1
17	Cost to maintain	7	0	1	1	-3	1
18	Resistance to water and rust	8	0	0	1	-2	1
19	Ease of operation	9	0	-2	-1	2	0
20	Ease of fabrication	5	0	1	2	-3	1
21	Mechanical simplicity (number of moving parts)	7	0	1	3	2	2
22	Breakdown time	8	-3	-2	-1	2	-1
23	Ease of storage	2	0	2	3	3	-1
24	Compactness	3	0	1	2	2	-2
25	Safe	10	-1	-2	-2	3	0
26	Weather-resistant	8	0	2	2	2	0
27	Easily transported and redeployed	3	0	2	3	-3	-1
28	Simplicity of control system for insertion	8	0	1	2	3	1
29	Simplicity of control system for cleaning cycle	8	-1	-1	1	-3	0
30	Ease of nozzle replacement	4	0	2	2	-3	0
31	Avoidance of obstacles	9	0	-2	-2	-3	0
32	Navigation of obstacles	9	0	1	2	-3	-1
33	Aesthetically pleasing	4	0	2	-1	-2	-1
34	Aesthetically robust	4	0	0	2	-3	1
35	Does not require tank modification	10	0	0	0	-3	0
36	Does not require access panel removal	8	-3	0	0	0	0
Weighted totals			-175	-41	56	40	88

NOTE: Weighted totals at the bottom of each column are calculated by multiplying rating number (either -3 or +3) for each criterion by the corresponding weighting factor, then summing all products. The locking chain option was used as the datum (0) and therefore had a weighted total of 0.

Based on this evaluation, the design team chose to continue development of the lance-mounted waterjet. This concept ranked highest because it was safe, simple, and inexpensive to build. Other advantages were that it allowed reliable surface coverage in a single pass and required the least amount of operator intervention. It would also clean the tank quickly by allowing the tank to rotate.

5. FINAL DESIGN: LANCE-MOUNTED WATERJET SYSTEM

5.1 Support and Controls

The prototype cleaning system includes a 24-ft-long jetting lance with two opposing nozzles mounted at the tip of the lance. The lance and drive system are mounted on a control pedestal (Figure 4). The pedestal allows both vertical and horizontal adjustment. The drive system propels the lance 15 ft along its axis by means of specially contoured urethane wheels driven by a 1/2-hp dc permanent magnet motor. Since the tilt angle of the tank is fairly constant on different trucks, the lance tilt was made adjustable using a simple manual system, i.e., a pinned support rod. The lance must enter the tank along the centerline, as shown in Figure 5, and therefore care must be taken to align the system properly during field use. Left-right lateral movement is controlled remotely from an operator's station that communicates with an electric motor, and a manual hydraulic foot pump controls vertical adjustment of the pedestal. The system is supported and elevated by a 6-ft-high scaffold (Figure 6).

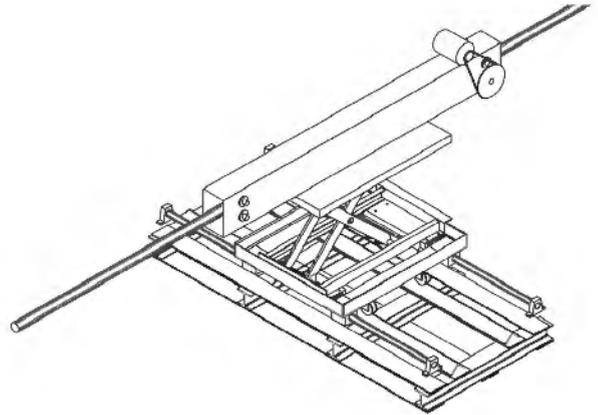


Figure 4. Control pedestal.

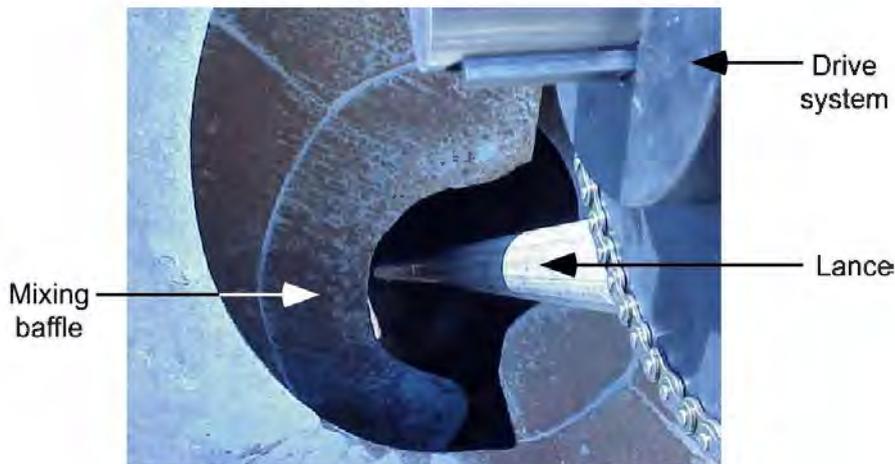


Figure 5. View of rear of tank as lance is inserted.

5.2 Hydroblasting Subsystem

A key decision for this subsystem was whether to address removing hardened concrete or to focus on preventing build-up on tank surfaces via regular daily or weekly cleanings. Preliminary tests conducted with a 5,000-psi, 15-gal/min hydroblasting pump indicated that standoff distances were

excessive and curtailed removal of hardened concrete. A second test conducted with an extension wand alleviated the standoff problem, but introduced another problem—the interaction between the extension wand and the mixing baffles. After these preliminary tests, the team concluded that the



Figure 6. Scaffold-mounted system.

more practical approach would be to use a streamlined lance for ease of insertion and couple it with a higher-volume, lower-pressure hydroblasting source. With less horsepower, this combination would deliver a more stable (albeit lower pressure) jet stream to the tank surface. It was hypothesized that such a system could be used as a daily or weekly cleaning device to prevent concrete build-up. Also, it would be simpler and cheaper to build and operate. In the worst case, such a system would slow the build-up of concrete, which would still offer a great advantage in terms of increased delivery volumes for the trucks and therefore in economics. In the best case, it would obviate the need for the manual chipping process.

5.3 Sizing the Waterjet

The system required a waterjet that would deliver enough pressure to remove semi-hardened concrete at a standoff distance of about 3-1/2 ft. The hardness of the concrete as it sets up on the mixing baffles is unknown. According to ASTM standards, portland cement must have an initial set in 1 hr, final set in 10 hr, and achieve a strength of 1,200 psi in 3 days. The initial set of cement is checked by resting upon it a 1/12-in-diameter, blunt cylinder supporting a 1/4-lb weight. When the flat end of the cylinder no longer dents the cement, initial set has occurred. The final set is checked in a similar manner using a 1/24-in-diameter needle and a 1-lb weight.

The system required a waterjet that would deliver enough pressure to remove semi-

Based on this information and extrapolations of the data (dotted line) presented in Figure 7, strength of 1-day-old concrete was estimated to be around 400 psi. Assuming that effectively removing the concrete would require at least half again this amount of impact pressure, it was decided the target stagnation pressure at the tank surface would be 600 psi. Using a graph of the Tollmein equation for jet degradation (Figure 8) adapted from Miller et al. (1997), we estimated the jetting parameters necessary to achieve this pressure.

With a known standoff distance of 42 in, a likely nozzle size (for example, 1/4 in) was assumed, which gave the result that $x/d = 168$. The graph gives a value of $P_s/P_n = 0.8$ at that point (see dotted lines on Figure 8), which is the ratio between stagnation pressure (P_s) at a given distance and original nozzle pressure (P_n). Using a desired stagnation pressure of 600 psi, the resulting nozzle pressure is $P_n = 600/0.8 = 750$ psi. Using the Bernoulli equation, the exit velocity was calculated at 328 ft/sec, which results in a flow rate of 100 gal/min for two nozzles.

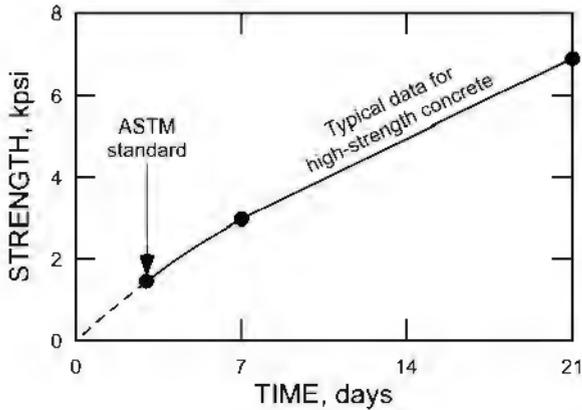


Figure 7. Data for determining compressive strength of concrete.

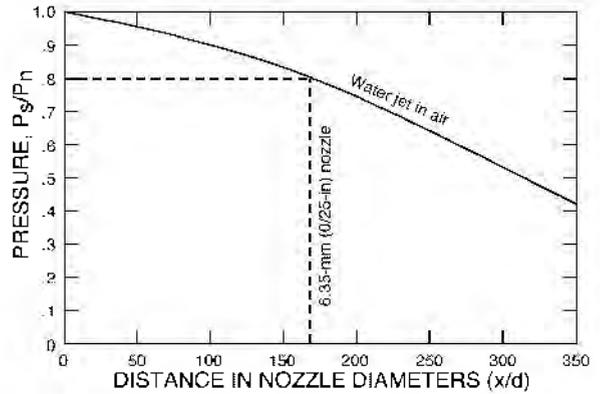


Figure 8. Variation in stagnation pressure with standoff distance for a waterjet in air.

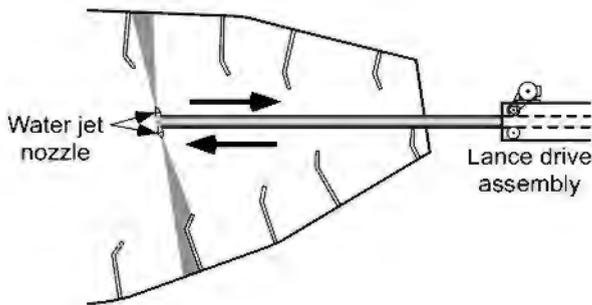


Figure 9. Sketch of lance inside mixing tank showing jetting angles.

Similar calculations using nozzle sizes between 1/8 and 3/8 in led to the conclusion that the system would function well with a pump that could generate somewhere between 680 psi at 215 gal/min and 1,200 psi at 35 gal/min. The pump chosen for the first tests was a seven-stage, axial flow, centrifugal pump capable of generating 1,000 psi at up to 235 gal/min.

To balance the forces at the tip of the lance, the opposing nozzles were similar in diameter, with the downward nozzle slightly enlarged to offset the force of gravity on the extended lance. To optimize the cleaning action of the jets, the nozzle angle and/or the lance insertion angle can be varied to achieve the result shown in Figure 9. This allows best coverage of the mixing baffle surfaces, i.e., the slightly larger jet would blast the front of the mixing baffles where concrete build-up is more pronounced.

5.3 Water Management

For field tests, a system for water management similar to that used at a local cement mixing company was selected. This entailed drawing gray water from the still end of a settling pond and returning it to the opposite end (Figure 10). A hydroblasting pump was placed near the still end to draw water directly from the pond, taking care to suspend the suction hose off the bottom and to use a screen to filter out debris. The water was pumped through a hose to fill and pressurize the 2-in (inside diameter) lance, supplying flow to the nozzles. After the water left the concrete mixing tank (along with a considerable amount of concrete debris), it was captured in a catch tank. From the catch tank, it was pumped back to the head of the settling pond using an 8-hp trash pump.

5.4 System Operation

The final field-ready system will be designed for use by specially trained truck drivers. When a fully functional system is installed at a mixing plant site (Figure 10), the following steps show how the system will be operated, presumably by a trained driver, at the end of each shift.

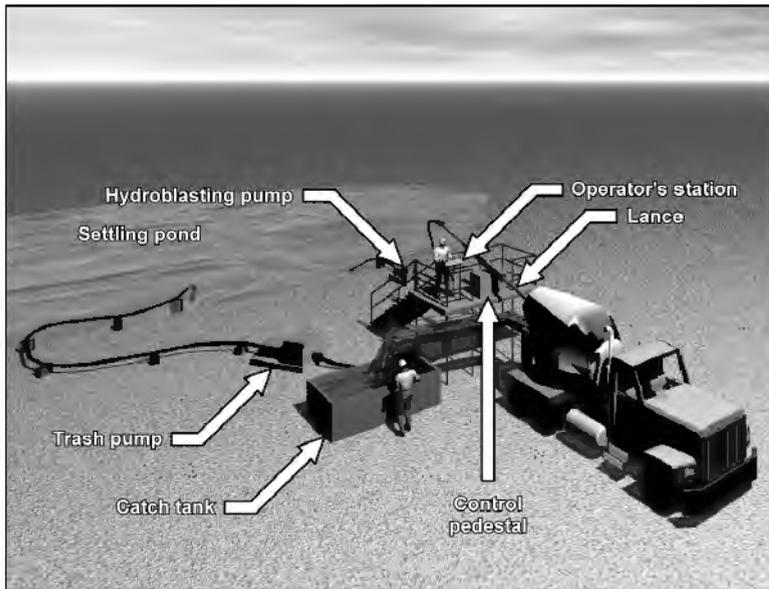


Figure 10. Artist's sketch of cleaning system at field site.

- Shuts down pump.
- Retracts lance to neutral position.
- Turns system "OFF."
- Continues spinning tank to discharge waste.
- Stops tank rotation.
- Drives away.

- System is in the neutral position.
- Truck is backed into place using guides or stops and lowers outrigger wheels. The driver then—

- Sets brakes.
- Starts tank rotation.
- Climbs onto scaffold and goes to control station.
- Turns system "ON."
- Manipulates positioning controls to align lance with tank entry.
- Operates lance drive until lance enters tank.
- Powers up pump.
- Advances/retracts lance for one or more cycles.

6. TESTING

Initial tests of the cleaning system were completed at SRL on April 20 (Figure 11). The truck was provided by Central Pre-Mix Concrete Co. Because a proper wastewater disposal system was not available, the initial tests were performed on a relatively clean truck. The objectives were to ensure that the lance could be properly positioned using the lateral and vertical motion systems and to determine the optimum height and angle of insertion for the lance. Testing was also necessary to ensure that the fully inserted lance would not come into contact with the tank interior during rotation.

Several cleaning cycles were completed. The angle of insertion of the lance was adjusted to optimize ease of insertion while ensuring that the lance would not contact the tank interior during rotation. The platform was also raised about 12 in, which improved ease of insertion. As expected, the limited clearance to the tank interior required careful positioning of the waterjet delivery system, but the lateral and vertical motion devices accomplished insertion and retraction of the lance smoothly and at a controllable rate. Thus, the results of the initial tests were considered positive.

Field tests of the cleaning system were done at Central Pre-Mix on April 27 (Figure 12). For these tests, trucks were cleaned when they returned from job sites in Spokane and the interiors of the tanks were coated with a layer of uncured and semi-cured concrete.



Figure 11.—Preliminary tests at SRL.

The team found that not all trucks could be cleaned. Because truck design tends to vary somewhat from year to year and the trucks are not designed to allow straight-line access to the tank interior via the rear orifice, some trucks possess features that block access to the tank interior. The cleaning system could not be used on these trucks. However, many newer truck models have

features that are compatible with the cleaning system, such as an upper loading hopper that can be raised out of the way and a lower hopper with a geometry that does not block the tank orifice. Another difficulty was that some trucks are not capable of driving in reverse with the rear set of wheels in the “down” position, which is necessary to permit the cleaning system to be operated. The driver must lower the wheels—because the axle blocks the tank entrance when in the up position—and then back the truck to the cleaning station.

Successful tests were performed on several newer trucks with an upper hopper capable of being raised and capable of being driven in reverse with the rear wheels in the down position.

Parameters monitored during the tests included total cleaning-cycle time, total volume of water used, and effectiveness of cleaning. Positive results were obtained in all three areas. The test team and Central Pre-Mix employees present determined that only one cleaning pass—from one end of the tank to the other and back—was required. The time required for this pass was 1 to 2 min, which was a fraction of the team’s initial goal of 10 min. Roughly 200 gal of water were used for each cleaning cycle versus the 500 to 1,000 gal required for the current flushing method, and the wastewater leaving the tank was visibly dirty at the beginning of the cleaning cycle and clear at the end of the cycle.

Central Pre-Mix employees had positive responses to the cleaning system. They stated that the system was more effective in removing uncured and semi-cured concrete from the tank than the flushing method currently used. The employees were also enthusiastic regarding the small volume of water required for the cleaning cycle; smaller volumes of water processed through the settling pond place less stress on the settling pond system



Figure 12. Field testing the cleaning system at Central Pre-Mix Concrete Co.

than larger volumes. The short cycling time was also a great improvement on the current time of 10 to 15 min.

7. CONCLUSIONS

Cleaning hardened concrete from mixing tanks has been identified as a hazardous occupation. NIOSH researchers and Gonzaga University students teamed up to develop an alternate solution. They hypothesized that a daily or weekly tank cleaning using a remotely controlled hydroblasting system could prevent build-up of concrete on tank surfaces. They built a prototype automated tank cleaning system and demonstrated its effectiveness in cleaning semi-hardened concrete from concrete mixing tanks. A prototype was demonstrated that could offer companies an economical alternative to current cleaning methods while providing workers with a higher level of safety while on the job. Results from this project could conceivably prevent numerous job-related injuries every year and save the concrete mixing industry considerably in terms of medical expenses, injury leave time, and legal settlements. It is recommended that this work be taken to the next level, which would include improving the of the system and conducting long-term field tests.

8. RECOMMENDATIONS

- Because the lance tends to rotate while being inserted and retracted from the tank, the next lance should employ an anti-rotation device, such as a keyed system.
- The linear bearings used in the lateral motion system are sensitive to misalignment, so other methods of preventing tipping of the system should be explored.
- Interchangeable nozzles should be employed to allow for differences in cleaning tasks.
- The scaffolding or platform should be mobile, which would allow the operator to move the entire system to the truck to be cleaned. One possibility would be to mount the scaffolding on rails.
- Use of alternative hydroblasting pumps should be explored. The pump used for the experimental cleaning system is rather unique and not commercially available at a price that would make it conducive to wide-scale use. It is also possible that if the tanks are cleaned regularly, a lower-pressure pump might suffice.
- A control system should be developed that includes safety mechanisms such as limit switches and emergency stops. Controls for vertical motion, lateral motion, and the waterjet delivery system should be located on a single control panel.

9. ACKNOWLEDGMENTS

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Members included Nathan Lazenga, Jeremiah Pappé, Vincent Petersen, Ryan Wade, Adam Baron, Vanedee Moua, and Dave Quadracci. We would also like to thank Gonzaga University's faculty project advisor, Thomas Zysk, for his excellent technical and motivational leadership of these student teams.

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Artwork cut in marble using abrasive-waterjet

Courtesy of Hydrodesign S.r.l. of Italy

The design of the cover is made by M. Hashish, assisted by Judith Fulmer

Preface

More than twenty years ago, the first US Waterjet Symposium was held in Golden Colorado. This marked the beginning of what we know today as the WJTA Conferences. Twenty-five papers, presented in five sessions, were published in the *Proceedings* of that Conference. Then, there were no papers addressing such topics as precision, abrasive–waterjets, suspension jets, micro jets, 3-D sculpting, or many of the topics contained in this *Proceedings*.

The papers in this *Proceedings* are contained in two volumes. As in previous conferences, the first volume is related to research, while the second is related to applications although this distinction is sometimes a bit blurry. This distinction, however, helps divide the volume of papers into two manageable book sizes. A CD-ROM is provided to electronically access papers and make searching for topics more effective. I am predicting that soon, there will be no paper proceedings, not even a CD-ROM because all the proceedings will be easily accessible on the Web.

The papers are further grouped into sessions addressing similar subjects. This *Proceedings* contains 15 sessions. An additional session on Safety in Job Shops and Factories was held during the Conference. An outline of a potential recommended safety practices is given in an appendix.

The success of this Conference is mainly attributed to the authors who submitted their work for publication, presented their work, and responded to questions. Equally critical to the success of the Conference are the exhibitors and the technical tour hosts. Without them, the Conference would not be the same. The efforts of the Conference Chairman, Dr. George Savanick, in hosting the conference - in his, the beautiful city of Minneapolis, Minnesota - and facilitating the tours has been most critical to the success of this Conference. The paper review committee: Dr. Thomas Kim, Dr. Lydia Frenzel, and Dr. Andy Conn provided scholarly and timely reviews of the papers. Birenbaum and Associates continue to provide excellent administrative support to WJTA. They are especially recognized for organizing the Conference and managing the publication of this *Proceedings*. Many thanks to Dr. Mark Birenbaum, Ken Carroll, LeAnn Hampton and Lois Schwoebel. Special thanks to Jan Tubbs for her editorial work, logging abstracts and papers, sending review requests, notifying authors, and communicating with numerous national and international authors in a most pleasant and professional way.

Finally, I would like to thank my mother, who is always praying for me and my father, who is rooting for me in the heavens. Thanks to Nadia - my beautiful wife - for her continued understanding, help, and support; and to my two sons - Ameer and Rami - for their help, discussions, continued patience, and their ever fascination with waterjets.

I hope that this *Proceedings* will be a valuable contribution to waterjet technology and will significantly enhance our knowledge.

— Mohamed Hashish, Ph.D.
Editor

Foreword

The WaterJet Technology Association (WJTA) exists to disseminate information concerning waterjet technology. WJTA is very successful in this mission because it has found a way for waterjet practitioners from the many diverse branches of waterjet technology to share insights and information so that the members of the entire waterjet community can learn from each other.

Membership in WJTA is open to all interested parties so that the state-of-the-art of waterjet technology is aided by the combined efforts of workers with widely differing perspectives on the applications of waterjets to technical problems. Job shops, cleaning contractors, medical researchers, miners, equipment manufacturers and academics, among many others, share their ideas on the useful applications of waterjets.

Many examples of this idea-sharing occurred during the 2001 WJTA Conference. Pre-conference courses taught by experts in the field presented students with a view of the present state-of-the-art of waterjet technology. During the conference 61 papers ranging from micro-abrasive machining to underground mining were presented and discussed. Copies of these papers are included in this book.

The WJTA Safety Committee met in open session to gather advice from the membership regarding the content of the prospective safety publication, *“Recommended Practices for the Factory Use of High Pressure Waterjetting Equipment.”* A video version of the widely used safety publication, *“Recommended Practices for the Use of Manually Operated High Pressure Waterjetting Equipment,”* was released. The conference ended with a live demonstration of waterjet equipment presented by nine companies at the facilities of Jet Edge, Inc. in St. Michael, Minnesota.

Widespread interaction among workers from the many parts of the waterjet industry has lead to a successful 2001 WJTA Conference.

— George A. Savanick, Ph.D.
President

To work at pushing back the limits of knowledge is a noble human endeavor. To share this new knowledge is also honorable and rewarding. The WJTA Conferences are an efficient and effective means of assisting in the transfer of knowledge regarding fluid jet technology. These written proceedings further amplify and preserve the new discoveries being made in our industry. They will have long lasting benefits for each of us, our profession, and humankind in general.

My sincere thanks goes out to all the authors represented in these proceedings. They have willingly devoted time and energy to documenting their work and sharing it with the rest of us. Their endeavors provide the very foundation for our association.

— John Wolgamott
Chairman of the Board,
WaterJet Technology Association

WaterJet Technology Association

The WaterJet Technology Association (WJTA) was created in 1983 at the 2nd U.S. Water Jet Conference, held on the campus of the University of Missouri-Rolla, by members of the waterjet industry acting in concert with university and government officials. The major impetus to the creation of the Association was to provide a means of service and communication within the industry, as epitomized by the biennial waterjet conferences.

Formal objectives of the Association have been adopted as follows:

- To provide a means of cooperation between government, industry, university, and research institutions on all matters of fluid jets, including waterjets and abrasive jets for jet cutting, industrial cleaning, and other uses in the manufacturing, mining, construction, and process industries.
- To foster domestic and international trade in jet cutting and jet cleaning, products and services.
- To promote in general the interests of the jet application industry in all branches, including establishment of recommended practices.
- To promote the mutual improvement of its members, and the study and advancement of the arts and sciences connected with jet cutting and industrial cleaning.

In regard to the third objective, it should be noted that at the 3rd U.S. Water Jet Conference held on the campus of the University of Pittsburgh in May of 1985, the Association adopted the first **Recommended Practices for the Use of Manually Operated High Pressure Water Jetting Equipment**.

The *Recommended Practices* are revised and updated periodically, the most recent revision being published in April 1999.

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