Putting a chill in your concrete

By William A. Orth, Jr.

(Reprinted from the August 3, 1987 issue of Construction Digest.)

Liquid nitrogen, sprayed into the filled agitators on readymix concrete trucks, has been effectively utilized to cool concrete just prior to placement in new Missouri River treatment plant structures near the St. Louis suburb of Creve Coeur.

Injected directly into the mix instead of the usual ice cooling at the ready-mix plant, the liquid nitrogen, which has a temperature of minus 320 degrees, cooled the warm concrete to spec'ed requirements of 70 degrees for the placement in a matter of minutes.

The concrete placement was part of Tarlton Corp's $13.2 million contract to build primary clarifiers and digester foundations during Phase I work at the treatment plant. Tarlton has also been awarded the $12.3 million Phase II contract to build a secondary treatment facility. When completed, the 28-million-gallon-per-day (mgd) primary treatment facility will serve the entire Lower Missouri River Basin area.

"The specification is 70 degrees," said Ed Lee, marketing director for Coldcrete, Inc., Colorado Springs, Colo. "Our objective is to meet the specs and not waste the cooling. The tendency with concrete producers in general is that when they use ice, they will over-cool the concrete."

Coldcrete had a pair of cooling towers set up at the rear entrance to the jobsite where ready-mix trucks from a pair of suppliers entered the site. There, the mix in the trucks was checked for temperature, and as required, were given injections of liquid nitrogen to cool the load of concrete. No ice was used at the readymix plants to pre-cool the concrete.

"We're using two units here for productivity," Lee said. "There is a 150-yard-per-hour requirement and the work is being done during the hottest period of the year." Ideally concrete would be delivered from one source, and "the mix would even out and perhaps we would only check every third or fourth truck. But coming from two different plants at different time periods, we are trying to check every one as long as we don't slow them up."

Larry Mrazek, an engineer with Sverdrup Corp., St. Louis, engineers for the St. Louis Metropolitan Sewer District (MSD), told of the reasons for cooling the concrete on this particular project.

"In the first place we are working with sanitary-type structures, of which a key function of ours is basically to insure a crack-free, watertight structure with a concrete mix that will minimize corrosion of the reinforcing steel and deterioration of the concrete."
Continuing, Mrazek noted: "Basic concrete technology in mass concreting and related American Concrete Institute (ACI) and Portland Cement Association (PCA) information over the years has dictated that the temperature, along with water content, is important to maintain a relatively crack-free, functional-type of concrete under this kind of condition (warm weather concrete placement).

"So with that in mind, for certain thickness pours, we did two things. We ultimately specified a maximum concrete placement temperature, and we substituted cement with a Type F flyash," he said.

Mrazek, and other Sverdrup engineers, studied various sections of walls and mats, and using data that has been developed by the Bureau of Reclamation and an ACI committee, determined what temperature the concrete itself would reach from the heat of hydration for certain types of cement and certain cement factors.

"With those factors," Mrazek continued,"we had a pretty good idea what we were going to specify. From there, we worked our way backwards and developed a maximum temperature for concrete placement.

"Furthermore, we substituted the flyash, no greater than 20%, which did two things. One, it lowered the heat of hydration, and, two, it gave us higher sulfate resistance in the concrete."

The Sverdrup engineer, after initial use of the chilled concrete in a pumping station, said he felt the formulas for the concrete had "really paid off."

"We've minimized any major cracking, and our concrete strengths reached 5,000 psi in 90 days. We'd specified 4,000 psi. The resident engineer and I agree that by holding the temperature down, and using a water reducer, we were able to better control the concrete.

"The laborers liked it because it was 95-degrees in the sun and they were working next to a 70-degree concrete which held that temperature through the major placement and into the finishing and initial set," Mrazek concluded.

Concrete pours at the MSD treatment plant ranged from as small as 350 cubic yards to as large as 1,200 cubic yards.

Although the use of the Coldcrete system for final cooling was somewhat more expensive, Tarlton was offered a fixed price per cubic yard for the complete project, no matter how much cooling would be required to meet the maximum 70-degree placement temperature. Personnel from Coldcrete were on hand at all times to operate the cooling equipment to eliminate waste of coolant and time.

In another circumstance, concrete mix chilled at the batch plant is being required for St. Louis' Metropolitan Square project.
In this instance, water, chilled to approximately 45 degrees, is injected as the concrete is mixed. Concrete placement can be at no more than 90 degrees, according to specification.

Ahal Contracting Co., Bridgeton, Mo., has the subcontract for all flatwork concrete placement in the 45 story structure. Dennis Ahal, president, said there is an on-site inspector who checks every load, and if the concrete is 91 degrees or above, that load will be rejected.

"The general contractor had a bigger problem with concrete temperatures, because he had to pour a lot of walls later in the day than when we poured. He was able to keep the mix at 90 degrees, however.

"We have a chiller system set up that pre-cools the water and then the water is stored in a large tank. We're injecting the cold water directly into the mix," Ahal said. "The fact that we are using lightweight concrete helps keep the aggregate a little cooler since the aggregate is being soaked constantly.

"That cools it down as opposed to regular-weight aggregate that sits in the sun and no water or air reaches it, and it just sits there and builds up tremendous heat."

There is a pre-soaking requirement for the aggregate to enable us to pump it properly. This inadvertently helps to cool it," Ahal said, "although it wasn't planned that way."

The concrete has been running in the mid-80s. It leaves the plant at about 80 degrees, and it's temperature rises to about 84 or 85 degrees by the time it is placed. Depending on traffic, the ready-mix trucks have a 15-minute drive to the jobsite, which is just less than eight miles from the batch plant.

Winter Brothers Concrete Co. owns and operates the batch plant, which is located near I-55 on St. Louis' southeast side. Ahal is purchasing the concrete from Winter Brothers, but Ahal was required to get the chiller installed.

The refrigeration equipment, which is leased from Coldercrete, Inc., cools the water by 35 to 45 degrees. That water is pumped into a tank and stored and then run right into their system and used as the entire water supply for the mixing process. "So we had to have a large enough chiller to have a recovery period so that in 12 hours we get enough water recovered," the concrete contractor said, "and a large-enough tank system in which to store the water."

One disadvantage with the project set-up, Ahal said, is trying to figure costs. "On this particular job we have an arrangement where we pay a certain amount, total. If we cool two yards or 10,000 yards, the cost is the same, except for the electricity to run it. So we don't know what our cost is going to be. It could be astronomically high per yard, or relatively inexpensive."
Ahal said his company thought this process would be a little better than the ice system that other companies use. "If we use enough quantity of water, it will be." That cooling system has to run continuously in order to supply sufficient cooled water. It has a temperature sensor, such as an air conditioning thermostat, and as soon as the water gets above a certain temperature, it recycles and chills the water.

A part of the system is holding enough chilled water so that it is not taking the water from 80 degrees to 40 degrees. As temperatures rise, the system starts cooling, and as that is used, fresh water is pumped through the chiller. "We've had an unusually warm spring and summer," Ahal commented.

Once the concrete is delivered to Metropolitan Square, Ahal Contracting uses a Thomsen pumping system to deliver the mix to the pour area. Superintendent Jerry Elmore says that pumper will be able to push concrete to the top of the 42-story building.

Concrete placement generally starts at 7:30 a.m., and is usually completed by 10:30. The average pour is approximately 120 cubic yards on the decks.

Ahal has used concrete cooling processes before, but primarily on Corps of Engineers projects. "On this particular job the engineer has been very stringent on tolerances. Concrete slump and temperatures are very carefully checked." Ahal said.

At the jobsite, Elmore checked temperature charts for loads delivered that morning. "They range between 81 and 85 degrees, so we're in good shape," he said. "Once the air is able to get to the concrete, there's no problem with temperatures at all."

Metropolitan Square will require a total of about 16,000 cubic yards of concrete, the majority of that lightweight. There is some normal weight concrete on the floors where the mechanical rooms are located, Elmore noted. Maximum slump allowed is five-inches without plasticizer, and eight inches with plasticizer.

"This system serves our purpose to keep the concrete under 90 degrees," Elmore said, "and it is about one fourth of the cost of using the liquid nitrogen cooling process."