INTERNATIONAL GREEN SAND MOLDING CONFERENCE PRESENTATION ON

"The trials, tribulations and successes of a foundry under attack by nitrogen"

As a way of introduction and to set the stage for this presentation I will briefly describe my employer's foundry, the Dotson Company of Mankato, Minnesota.

This is a modern, well-equipped and well manned privately owned gray and ductile iron foundry employing 75 people. The foundry uses Hunter molding machines, electric melting and modern core making methods to produce castings for a very demanding clientele.

My own employment history includes experience at four foundries in England, four in Canada and five in the U.S. Other than the Dotson Foundry, only one other foundry had severe nitrogen contamination problems. This foundry was making 20 ton ingot molds using hot blast water cooled cupolas to produce the metal and chemically bonded air-set sands to produce the main cores for molds.

Both the melting and core making processes resulted in serious problems that were ultimately shown to be related to nitrogen and which took substantial time and effort to resolve.

Until this recent outbreak of nitrogen porosity, The Dotson Foundry, which has extensive well-documented records, had no known record of scrap due to nitrogen.

From here I would make the point that this presentation is not intended to show that:

- Fissure like defects in heavy section gray iron castings are produced when nitrogen precipitates from solution during solidification.
- Or that the nitrogen must be nascent atomic nitrogen released from a compound of ammonia.
- Or that tensile properties are improved by dissolved nitrogen.
♦ Or that hydrogen and nitrogen may act in a synergistic fashion to compound the problem.

♦ Or that higher carbon equivalent irons are less susceptible than low carbon equivalent irons.

♦ Or that the main sources of nitrogen are:
  1. Resin bonded sands
  2. Shell core sands
  3. Binders in exothermic sleeves
  4. Petroleum coke carbon raisers
  5. Seacoal in molding sand
  6. Core pastes
  7. Steel scrap
  8. Contaminated returns

♦ Or even that bentonite readily adsorbs nitrogen and releases it to the metal during mold filling.

No, I'm not going to talk about these because all of these are true. They have been researched by others better able and more qualified for the task than me.

What this presentation is about is how a modern well-equipped foundry got into the problem. The trauma, the disbelief, and the uncertainty during the period that the problem remained unresolved. The initial difficulties and unsuccessful attempts to resolve the problem. The successful steps taken to resolve the problem. And, the steps taken to avoid the re-occurrence in the future.
THE TRAUMA, THE DISBELIEF, THE UNCERTAINTY

First, the big question — How could it happen to us?

Primarily, it happened because we had no program for analyzing nitrogen and therefore we did not know the levels in our sand or metal. We were taken by surprise when our sand and metal became contaminated enough to cause problems. The real question is why didn’t we have a nitrogen testing program. The main reasons for no testing program were:

♦ Because our long and short term history said there is no need. There is no problem.

♦ Because only one known instance on one particular casting ever showed nitrogen porosity.

♦ Because there was no record of nitrogen pinholing from contaminated sand or metal.

♦ Because there is a well-documented record of scrap incorrectly diagnosed as nitrogen and later proven via scanning electron microscopes, etc. to be carbon monoxide.

♦ Because we had very little faith in the reliability of nitrogen analysis. Even some recent test results showed dangerously high levels in the new washed and dried sand delivered to the foundry.

♦ Because testing adds cost and why add costs?

How could we operate for so many years without a testing program and without any major problems from nitrogen contamination?

♦ Because by chance the nitrogen bearing materials in our foundry sand system were continually being diluted to levels below that which any problems of porosity would occur.

♦ Because with this dilution, in effect for other reasons, the need for nitrogen testing was not apparent.

This situation is not too dissimilar to our environmental problems of increased population over burdening natural treatment of effluents and thus contaminating the air and water.

What caused the so far unidentified changes?

- Increased pressure to survive in a world demanding more and more for less and less.
- The addition of a new molding line to our present sand system.
- The addition of a second U-180 Isocure core making machine.
- A 250% increase in shell core usage.
- A significant increase in the use of exothermic riser sleeves.
- The addition of a vertical fluidized bed sand cooler causing the attrition of unoxidized resin bonded cores.
- The location of our core butt removal screen in relation to our sand cooler and shakeout. It was located after the cooler rather than in front of the cooler.
- Bond additions were automated.
- Increased occurrence of segregation in the sand storage system.

Our first notification that we have a problem is from one of our customers asking what has gone wrong. The last batches of castings are full of holes. The second, third and fourth notifications of a problem are also from customers asking what has gone wrong and when will the replacements arrive.

Now, the disbelief. It cannot be happening. But it is.

What is our next step?

- Stop production or make castings?
- Make some castings, but what to change?
- Issue the next credit and answer the next phone call?
- Watch our good name for quality disappear?
-- INITIAL DIFFICULTIES AND UNSUCCESSFUL ATTEMPTS --

The first problem was positive identification. In fact, because of our history, the defect was first thought to be carbon monoxide. Thus application of corrective action for carbon monoxide such as higher temperatures, etc. made matters worse.

At this stage, there was no thought that the molding sand or the metal per se could be severely contaminated. Something must be wrong with one or more of our incoming supplies, but which one.

◆ Those related to the metal:
  - Steel Scrap
  - Foundry Returns (gates and risers)
  - Pig Iron
  - Carbon Raisers
  - Ferro Alloys
  - Fluxes
  - Slag Remover

◆ Those related to the sand and its components:
  - Return Sand
  - New Sand
  - Clays
  - Seacoal
  - Cellulose
  - Cereal

◆ Those related to core sands and their components:
  - Isocure Resin Binders
  - The Hexa in Shell Sand

◆ Those related to other purchased components:
  - The Binders in Riser Sleeves
  - Petroleum Coke Carbon Raiser
  - The New Source of Steel Scrap
  - Etc., Etc., Etc.

What has changed and which of the above items is the culprit. The quick answer is that one of our suppliers has a process out of control and has delivered faulty nitrogen rich material.

If only that were the case. How much more readily it could be tracked down and explained away. How much the burden could be eased, anything but our own house practices. Then the light dawns, our suppliers have continued to deliver the same high quality of materials that they always have. Alas, the problem is ours.

Our customers are anxious for replacements, for an answer, for renewal of confidence in us. The phone is ringing.

Some of the many suggestions put forward by associates need to be checked. These all take time.

- Melting temperatures too high
- Pouring temperatures too high
- The new source of steel
- Etc., Etc., Etc.

When the early quick test and quick fixes do not solve the problem, it becomes apparent that some very sound rational thinking is required. We need a plan to systematically eliminate each possible cause or source of nitrogen.

- First, identify all possible sources of ammoniacal nitrogen:
  - Isocure Process Resins
  - Shell Sand Binder Catalyst
  - Riser Sleeves
  - Petroleum Coke
  - Steel Scrap
  - In House Returns
  - Etc., Etc., Etc.

- Send samples out for nitrogen analysis and check with material suppliers for the results of their nitrogen analyses on the batches in question.

- Set up furnace charges to eliminate sources of nitrogen and in addition add nitrogen neutralizing elements such as titanium. Minimize melting and pouring temperatures consistent with good practice. Use clean ladles and good furnace slagging practice.

As this proceeds, things start to look right and confidence builds that the problem will soon be under control. Because, even though we are not sure as yet where the problem begins, we believe we are taking steps that will at least neutralize the offending element. We go ahead and pour molds and obtain samples for machining as soon as possible. The results are discouraging. The castings are just as bad if not worse!
What went wrong? It should have worked. So now let's go through it again. It seems OK. The only things we didn't do were add enough titanium. After all some of it could have been oxidized and some of it was carry over from the charge materials. Also, let use a "no core" job as the test casting. This will eliminate the danger that the core materials are a major factor.

Now let's do it all over again. The results are just as bad!

Now in week five there is doubt that perhaps it is not nitrogen after all. Perhaps it could be hydrogen or carbon monoxide or a combination.

Let's hurry up the results of the samples sent to experts for positive identification. Two of the three are out of town and the third is pretty sure of the analysis but wants a second opinion. Considering the magnitude of the problem, this seems prudent. But time is passing and customers are pressing. To the customer the problem is gas porosity of the very ordinary kind.

Our own analysis still points to nitrogen. But, now our attention moved from the metal to the molding. We set up sand mixes that include substantial infusions of new sand to dilute the ammoniacal nitrogen down to safe levels. Then, because we now believe our problem to be in the molding sand and because we want to prove this conclusively, we return to the same metal charge make-up that was used before the nitrogen problem arose. Again, test castings were obtained as soon as possible and machined. Again, the results were devastating. The castings were almost as bad as ever.

What is the cause of this porosity and why have our tests and corrective actions failed?

This problem must be resolved, the foundry and our customers cannot stand any further delays. Once again, completely review and analyze every detail from the very beginning.

♦ Was the defect correctly identified?
♦ Have we applied the correct action?

Even though we do not have conclusive identification of this defect from experts, there is strong evidence to support the belief that the defect is related to nitrogen. The fissure or pear shape of the cavities, the discoloration of the cavity, the brightness of the cavity, the structure of the matrix around the cavity, etc. Everything points to nitrogen as the culprit.

So then, if this is true, why have our efforts to eliminate the problem failed?

The answer, of course, is that we have taken a systematic approach to the problem. We used a process of elimination which demands that we make one change at a time. Thus we missed the point that by the time we realized that we had a problem, both our metal and sand systems were contaminated with nitrogen to such a degree that steps taken to correct one or the other did not eliminate the defect from our test castings. To be successful, concurrent action must be applied to both the metal and sand.
— SUCCESSFUL ATTEMPTS —

At some time just prior to obtaining some successful results, our progress to date was yet again under review. Out of this latest session came the conclusion that we should abandon an old foundry tradition of changing only one thing at a time and attack both the sand and the metal concurrently. Since we felt that individually those changes that were made were correct.

Then, just about at this stage, one of our suppliers who had been extremely helpful suggested that we make a phone call to Ezra Kotsin at the American Foundrymen's Society and as he put it "run everything by him." This very fine suggestion resulted in instant clarification.

♦ Yes, the defect is nitrogen pinholing.
♦ Yes, your problem is extensive.
♦ Yes, it originates from the various materials used in your casting production.
♦ Yes, both metal and sand are contaminated.

The doubts and uncertainties were instantly removed and it then only remained to institute decisive effective corrective action to both the metal and the molding sand.

Thus, the following steps were taking with the metal:

1. Find, spray paint and remove from the foundry all and any gates, risers, scrap castings, or cast metal with even a suggestion of nitrogen contamination.

2. Set up new charges using:
   - Ductile Returns
   - Pig Iron
   - Steel Scrap
   - Ferro Alloys
   - Crushed Graphite Electrodes as Carbon Raiser

3. Melt and tap at temperature not to exceed 2,750 °F. (1510 °C)

4. Make sure that melting and ladle practices with respect to cleanliness, dryness, and temperature are strictly adhered to.

5. Pour at start temperature of 2,550 °F. to 2,575 °F.
   \[ (1400 °C - 1413 °C) \]

6. Include a titanium bearing inoculant as part of inoculating practice to give levels of 0.020% to 0.030% titanium in the final chemistry.

And, the following steps taken with the molding sand:

1. Aim to dilute the molding sand by 50% based on the reported levels of nitrogen ascertain by chemical analysis.

2. Discard about 50% of stored sand.

3. Then remove the remaining sand from storage in a systematic way, through the sand muller and distribution belts to a hopper. On an area of concrete floor prepared for this purpose, spread out and layer with equal amounts of new sand.

4. Return sand back to the system through the shakeout.

5. Circulate the sand through the system adding premixed additives so that binder levels can be made adequate.

Now that the metal and the molding sand have been modified, use the "no core" job as the test piece. Results are SUCCESS! SUCCESS! SUCCESS! Not a suggestion of a pinhole to be found anywhere.

In addition, customers anxiously awaiting replacement castings were able to feed back to us confirming reports very quickly.

Next, begin the process of returning our sand and metal compositions to a more affordable blend of components. At the same time it should be made clear to everyone that only castings which were subsequently fully annealed and/or used for non-engineering purposes were produced during our testing periods.
— NITROGEN DEFECT PREVENTION PROGRAM —

- Confirm safe levels of nitrogen in metal and molding sand
- Evaluate levels of ammoniacal nitrogen in all materials.
- Evaluate benefits of substituting low or nitrogen free materials for those presently in use.
- Ascertain schedule of when problems occurred during operation.
- Purchase and put into service ammoniacal nitrogen testers.
- Locate and develop rapport with analytical laboratory for nitrogen analysis of metal.
- Determine optimum levels of scacoal and loss on ignition levels that can be added to sand.
- Work with suppliers on levels of nitrogen in scacoal.
- Seek out and test inoculants with respect to aluminum and titanium levels and to their effectiveness.
- Investigate the effectiveness of slag coagulants and fluxes.
- Resolve to be less hesitant in using specialized professional help in order to speed up the identification and elimination of costly scrap problems.