Information Management in the Ferroalloy Business

M. S. Rennie, W. D. Carew, R. Terblanche, A. L. Moolman, N. Anthony

Mintek, P/Bag X3015, Randburg, 2125, South Africa

ABSTRACT

As the 20th century drew to a close, ferroalloy producers had to deliver a cheaper product to tighter specification for a more demanding customer in a very competitive market. How has this been possible? Besides the very necessary advantages of scale, cheap raw materials and energy, the producer has had to manage his production process more efficiently. This has been possible because of the exponential growth in computer power and capability. Twenty years ago there were a few mini-computers around with 16 to 32kbytes of memory to monitor the process and a few mainframes to manage the finances.

Today there are intelligent instruments in the field talking to PLC/DCS* systems, which control the process, monitor themselves and communicate with SCADA* systems. Information is passed along a local area network to metallurgists, maintenance engineers and managers, who are locked into the greater Enterprise Resources Planning systems, which know who the customers are and what they want and on to executives who may be on the other side of the world. Simply put, this business is about control, communication, information and decision making. Thus, there are systems in place, which ensure that the right people get the right information to make the correct decisions. This is logical, straightforward and easy to implement and maintain – yes?

There are excellent PLC/DCS/SCADA* systems, there are industry standard operating systems and communication protocols, there are databases linked to the web and there are software systems to tie all this together. The only problem is that none of these systems were specifically designed for the ferroalloy business. The petrochemical industry, the manufacturing industry, banking and insurance all get systems very much customised for their needs as they make the big bucks. The ferroalloy industry gets what salesman can shoehorn into an attractive, desirable contract that will solve all known problems, but which may create a few problems along the way.

Realising that there was a need to provide a more integrated, maintainable solution for managing ferroalloy furnaces, Mintek will discuss some of the problems encountered and solutions that have been developed.

* A glossary of all the abbreviations used is presented at the end of the paper.

1. INTRODUCTION

As the 21st century has begun, more information is passed and more business is done over the Internet than one would ever have believed a few years ago. Even for the ferroalloy producer, managing information and communication is an integral part of the business. With the power of the present day computers and the software available, the producer should have little problem in getting what he wants to run his business. Finding an integrated, maintainable solution may be less easy than one would expect. Keeping pace with new developments is a mission in itself as Mintek has found out. Some of their experiences in the process control field will be discussed.

2. COMPUTERS – HARDWARE AND SOFTWARE

About thirty years ago the first mini-computers started appearing on the scene. They had 16 to 32 Kbytes of memory and some enormous large disk drives with 1 to 2 Mbytes. On the whole they were difficult to program, not very reliable and very expensive, but they offered university departments and research institutes freedom from the mainframe tyranny. Some of these even found their way into chemical plants and calcium carbide furnaces for monitoring and control purposes[1]. But it was the microcomputer chip that found its way to the desktop and everywhere else to change the way we think, work and play.

Having one thousand times the power of an old mainframe may sound wonderful, but this is less of an advantage if it is one thousand times more complex to do anything – and it is. Those of you who have gone through several generations of the "Hullo world" exercise will understand that layers of complexity are progressively hidden from the end user in the interests of speed, efficiency and product marketing. So having been released from the mainframe tyranny, we are now vassals of the greater and lesser software gods and creeds. All you have to do is believe that that the software package you have purchased will solve:

- all your needs
- some of your needs
- or next release will
- or next release won't.

The first SCADA systems were wonderful. They took care of reading, scaling, timing, logging, plotting and sometimes reporting of data – provided one was talking to a PLC, or a device that looked like a PLC. But SCADA systems usually could not talk to DCS systems, because DCS systems were very careful whom they spoke to. DCS systems usually had their own proprietary network and most PLC's had preferred networks. But that was in the bad old days, these days one has open systems with agreed on standard protocols to interconnect different pieces of hardware and software. But the real standards are set by the latest hardware or software offering that provides the biggest bang for the buck. This is great for progress, but less good for compatibility – usually claimed, but less often achieved. But if it performs its job reliably and well – what is the problem? The problem is times have changed and continue to change at a great rate.

3. THE GROWTH OF COMPUTERS IN THE FERROALLOY INDUSTRY

Twenty to thirty years ago there were no process computers on most ferroalloy plants. Manual or semi-automatic regulation systems worked for most plants as the raw materials were of good quality, the operators were experienced and the profit margins were adequate. But energy costs increased and everything else with it, except the price of the end product. Now as it became important to reduce energy and raw material costs and maintain product grades, the time was right for the process computer, the business computer, the spreadsheet and the accountant. PLC's were more powerful and flexible than dedicated controllers and could control weighing systems, gas plants and maximum demand systems, while spreadsheets could be used to store analyses, calculate totals and recoveries, generate daily and monthly reports, and minimise costs.

A problem with using a spreadsheet is that all the data must be entered manually and extracting and collating that data could be a very time consuming process. Spreadsheets do not easily allow for the selective grouping or interrogation of data. This is the job of databases. Databases have historically been stored on mainframe computers, need to be structured, require data-processing specialists to manage and were very expensive. Currently databases are stored on servers that are little different to the average desktop computer. As before, they still need to be structured and still require specialists to manage.

The sort of sub-systems ferroalloy producers need to manage their business look something like this:

- *raw materials*
- *energy*
- *process*
- *electrodes*

- *product handling*
- *product quality*
- *maintenance*
- *orders*
- *financial*

One could simply reduce this list to two headings:

- *process management*
- *business management*

where traditionally the process was controlled by dedicated controllers, PLC's and PC's, while a mainframe or equivalent managed the business side. Now, for efficient running and decision making, all aspects of the production/business process need to communicate with each other so that the plant people have the right information available when they need it. Not long ago, PLC's had very low-level programming and communication capabilities, the latest models have several processors, one of which will be dedicated to communication. If the processing capabilities are more powerful, how is all this information going to be integrated into the business system? How does one store, access and process divergent data from different sources. The answer is with great difficulty. This answer you will not hear from anyone under 30 years of age, any system software provider or any salesman who sees a good commission coming his way – their answer will be "cinch", "no problem", "simple". Finding out how easy this is may cost a great deal of time and money.

What is the solution? That depends on simple questions like:

- how much extra income will the system generate?
- how much will we lose if we don't upgrade now?
- how much time and money can we afford?
- what is the existing infrastructure?
- what is the hardware/software competence level?
- what level of integration do you what to achieve?
- what is the company/group policy?
- what support can you get from local companies?

4. DEVELOPMENT OF CONTROL SYSTEMS

The Measurement and Control Division of Mintek[2] has supplied control systems for submerged arc furnaces, milling and flotation circuits for the past twenty years. The emphasis has always been on effective control, but over the years it became apparent that other issues were important for the sustainability and marketability of these systems. Some of these issues were:

- *security*
- *reconfiguration/maintenance*
- *software platforms*
- *hardware platforms*
- *logging and trending*
- *communication.*

As this is a ferroalloy conference, most of the discussion will focus on our experiences in that market, but the experiences were similar in the other fields. Initially, the Minstral was a stand-alone resistance and power controller for submerged arc furnaces. It looked like a control desk and providing similar functionality. Trending of the electrical data was performed on a separate PC running a SCADA package. Subsequently, the SCADA system was incorporated into the Minstral controller once colour LCD screens became affordable.

Although a very important aspect, controlling electrode penetration and power input is just one part of furnace control and management. At INFACON 7 Mintek introduced FurnStar[3] to address some of the problems of managing the submerged-arc furnace operation. The function of FurnStar was to incorporate electrical, metallurgical, electrode and weighing system data in a single database and to provide tools to process and analyse the data. Microsoft Access/SQL was used for the database, interfaces were written in Visual Basic, Neural Network and Statistical Analyses packages were incorporated and an Expert advisory system based on the plant procedures was available to the operators. The philosophy was to use as much commercial software as possible to limit the amount of in-house development required and to update the packages as new releases became available.

While the initial objectives were achieved thanks to a dedicated and hardworking team, what happened subsequently was:

- the Expert System supplier went out of business
- the Statistical Analysis Package company was taken over and the product went off the market
- upgrading from the original 16 bit software to 32 bit software was an expensive and time consuming exercise especially as insufficient care had been put into securing the database.

5. MANAGING DATA

The lesson we learned was that while the tools were available, getting data from a variety of sources, checking this data, securely storing the data and retrieving the data for further processing was no simple matter. This is why data processing companies employ many people and charge much money for creating and managing such systems. But these days, all relevant data needs to be captured, processed and distributed around the network or over the Internet. If you are in the process control business, you need to be able to communicate with your customer on his hardware and software platforms. This used to mean getting or writing drivers for a number of different PLC systems. Rather than having to learn how to function in a variety of environments, a large number of process control companies have adopted OPC as the standard interface between clients and servers.

OPC (OLE for Process Control)[4] is a set of Database and Client/Server tools designed to allow applications access to process data in a consistent manner. As a growing number of custom programs are developed in different software environments, OPC needs to communicate with these programs. Microsoft understands and supports this trend and designed OLE/COM/DCOM to allow components written in C to be utilised by custom programs usually written in VB. Thus all the developer needs to know are the interfaces to the OPC objects. An example of the FurnStar application is shown in figure 1.

In addition, we needed a database platform that was stable, reliable and easy to configure and maintain. To achieve this functionality we are using a flexible object model of the database structure (NeuralFrameWork). Neuratech[4] has developed a model, which facilitates

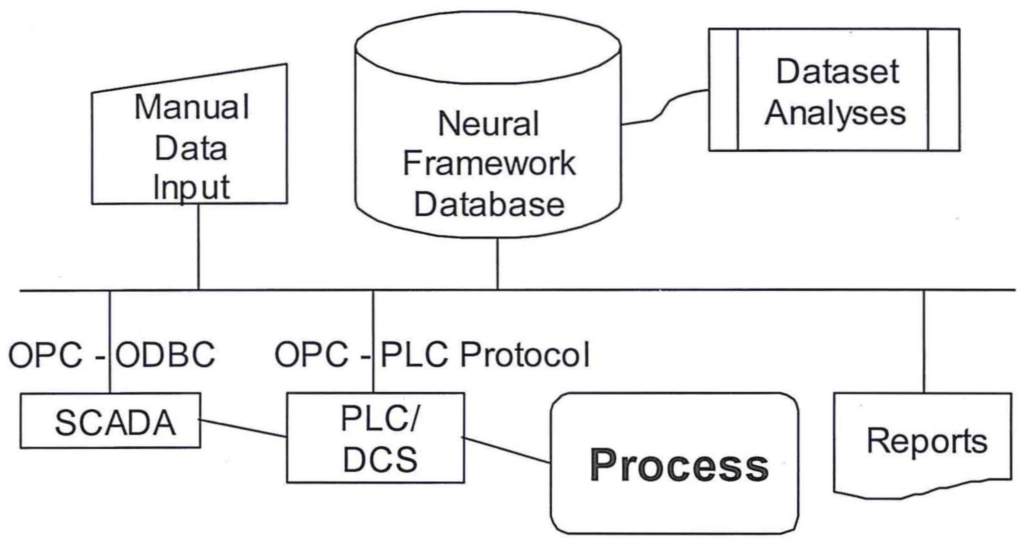

Figure 1. FurnStar structure

configuring, maintaining and upgrading of both the server database and client workstations. Objects are connected through relationships and this association provides powerful navigation capabilities enabling a logical approach to information recall. Access to the information, stored in a conventional SQL database, is both secured and facilitated by a management buffer.

The advantage of both these approaches is that other companies/organisations are going to ensure compatibility with current software versions and provide updated tools for use. This comes at a price, but we believe that this is the most viable/sustainable option for an enterprise like ourselves. The implication for the end user is that he either sticks with what he has and then buys a new system or he takes a maintenance/upgrade contract. Either way costs more money than one would have believed necessary ten years ago, but there appears to be no option if one wishes to function in the present rapidly changing business environment.

6. INFORMATION MANAGEMENT

Assuming that one has secured the data in a database, what does one do with it? The main function, which has not changed for hundreds of years, is to collate and summarise business information. The financial manager wants to know income and expenditure, the process manager needs to know what went in, what came out and the efficiency. This information, normally grouped according to the topics listed in Section 3 is summarised in daily and monthly reports. Some of the data is obtained from process computers, but much is from sheets of paper or copies of sheets of paper. Working on paper is a time consuming process, but is good for checking, auditing, filing and storage. Now, as there is so much data and there are fewer people to process the data and the reports are required sooner, there is little option but to use electronic media for storage. This is both efficient and cheap, but may have a limited life span. We have process data going back twenty years stored on a variety of media. One cannot tell whether the data is still there as we have little hardware left to access most of it. Perhaps this is what Data Warehousing is meant to solve.

To generate a report from a SQL database one sends a large number of simple queries that look something like this:

```
SELECT DISTINCTROW [Raw Material Consumption].[Raw Material],[Raw Material Consumption].Date, [Raw Material Consumption].Classification,( [Raw Material Consumption] ![Mass]*[Reductant Analysis]![%C])/100 AS CarbonMass, [Raw Material Consumption].Mass INTO [Carbon Units] FROM [Raw Material Consumption].Mass INNER JOIN [Reductant Analysis] ON [Raw Material Consumption].[Raw Material]=[Reductant Analysis].[Common Name];
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Writing queries is not something that metallurgists or managers want to do. They will decide what reports are required and the programming will be done by someone skilled in the art. But what happens if they want to change the raw materials or process the data differently for a trial. There needs to be a higher level of data processing tools for the end user and for on-going maintenance. This is one advantage of the object model of the NeuralFrameWork structure.

The object model of the database defines key information in the business as objects, which have a defined relationship with each other. Hence, associated with each furnace, there will be a metal and a slag. Associated with the metal there will be a mass and an analysis and associated with each analysis are the different components. The user can navigate, view and manipulate the information. New objects will inherit all the properties and relationships of similar objects. The object model is intuitive to use and the metallurgist can select a number of different objects over a time period, export the data to Excel and subsequently graph or analyse this data using the range of tools available in Excel (Figure 2).

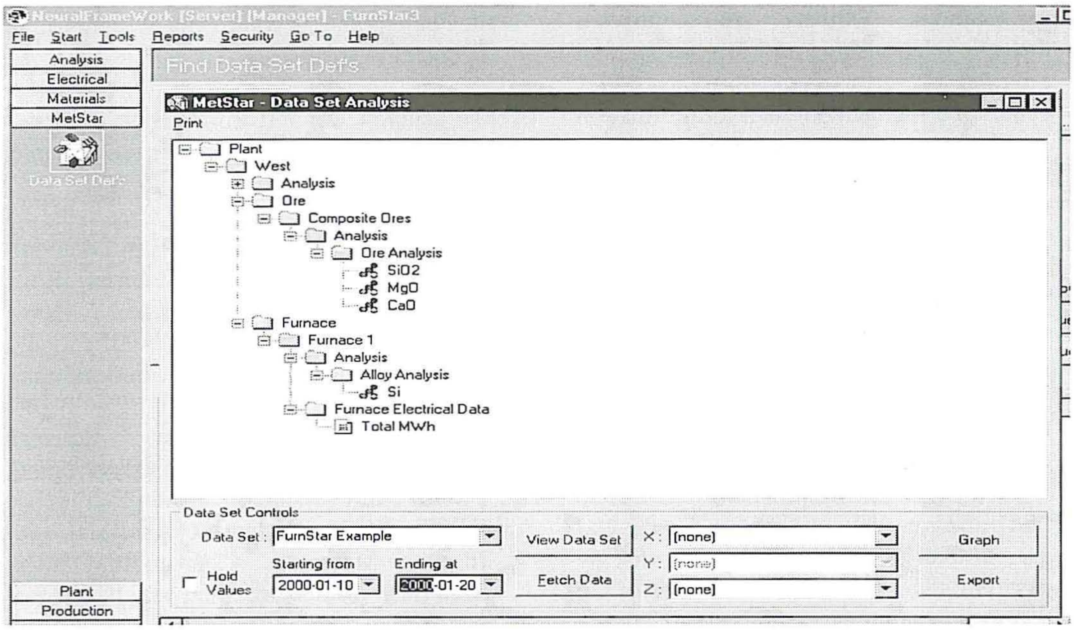

Figure 2. Example of the Object Model of the database

7. FURNSTAR PHILOSOPHY

The philosophy of FurnStar is to provide a secure, maintainable, robust database to receive data from a variety of sources, to process the data for management reports and make that data available over the net (Intranet/Internet). Microsoft products and components are used extensively as they dominate the desktop market and offer compatibility across a range of desktop products for further processing and analysis. Hence all of the data selected can be exported to Excel or other SQL databases

Except for neural net processing, data processing will be mainly well defined metallurgical and business type reporting. There are many commercial statistical analysis packages available, which can access spreadsheet data. Although they have their place, there are no standards for expert system control. The problem, particularly for ferroalloy processes, is that conditions change with the raw materials, the process and the market. Hence until there is a well-developed self-adaptive process model to link to the expert system, expert systems will offer limited general control potential.

The Measurement and Control Division has developed two generic software structures – PlantStar for control and InfoStar for information management. These have well defined interfaces and procedures for control and data processing and can be configured for furnaces, mills and flotation banks. The advantage of this approach is to make available the latest hardware and software tools to all our products as and when they are required, with the least amount of effort. The advantage to the client is that the process information is accessible by all the latest applications that he may wish to use. This is but one approach to the problem of creating and maintaining a software product in the changing world of process control and information management.

8. REFERENCES

1. Casciani RA, Franson PD, Wilburn WL. *Computer Control of Submerged-Arc Ferroalloy Furnace Operations,* Electric Furnace Conference Procedings, (1967).
2. www.mintek.co.za/mac/
3. Reuter MA et al. *Intelligent Control of Submerged-Arc Furnaces,* INFACON 7, (1995), 505-510.

4. www.opcfoundation.org
5. www.neuratech.com

9. GLOSSARY

component object model (COM)
The model upon which SQL distributed management objects is based.

distributed control system (DCS)
A collection of modules, tightly interconnected, to carry out integrated data acquisition and control applications.

object linking and embedding (OLE)
Microsoft component object technology and extensible service architecture.

programmable logic controller (PLC)
Employs the hardware architecture of a computer with a relay ladder diagram language to perform sequential control functions.

structured query language (SQL)
A database query and programming language originally developed by IBM® for mainframe computers. It is widely used for accessing data in, querying, updating, and managing relational database systems. There is now an ANSI-standard SQL definition for all computer systems.

supervisory control and data acquisition (SCADA)
A system of software programs designed to send and receive data and commands from PLC's and similar devices.

- Reactivity number (ratio carbon reacting in the outer zone versus total carbon),

- Gas temperature before burning out of the furnace,

- Ratio water/carbon of the raw materials.

To make the study more complete, we have added two cases :

- The SiC recovering in the crucible.

- The case when a segregation occurs in the mix.

CALCULATION

In the outer part of the furnace, we calculate the rate of the two reactions : condensation and reaction SiO-C , knowing the gas available from the inner zone.

For the reaction SiO - C, we need the ratio carbon/silica in the mix and the reactivity number.

For the condensation, we need the elements of the heat balance in the outer part of the furnace.

The gas available is the result of the previous iteration.

This calculation gives the amount of SiO2, C, SiC, and Si that enters the inner zone.

In the inner zone, we only consider the amount of elements Si, O and C that are contained in the products from the outer zone and we calculate with that what SiO2, C, SiC, Si, SiO and CO mix gives the minimum value for Gibbs free energy.

This gives new values for SiO and CO that are used for a new iteration in the calculation of the outer zone, and a temporary value of the condensed phases.

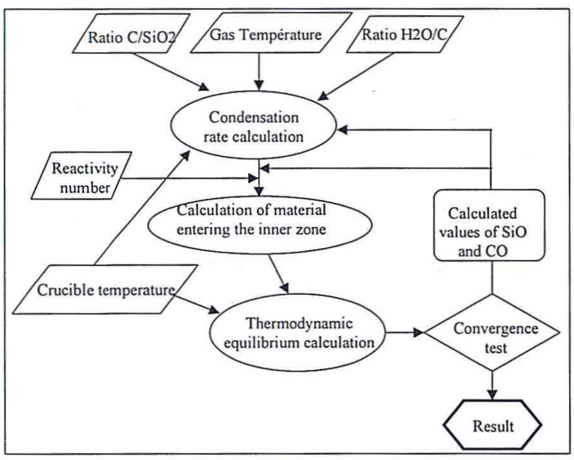

Figure 2 : calculation diagram

The results of two following iterations are compared, and the calculation is stopped when the difference is lower than a fixed value.

The calculation is made in a simple Excel sheet.

RESULTS

We have done a run with the following parameters :

- Crucible temperature : 2000°C,

- Gas temperature : 600°C,

- Water content of raw materials : H2O/C : 80% (weight ratio between the amount of water and the amount of carbon in the mix),

- Reactivity number : 75%.

We have varied the C/SiO_2 ratio from 0,14 to 0,46, and plotted the amount of Si, SiO and SiC produced by the furnace versus Carbon/silica ratio. We have also plotted the gas composition inside the crucible.

Crucible temprature(°C)	2000	Reactivity number	75.0%
Gas temperature (°C)	600	SiC consumed in crucible	0.10
H_2O/C	0.80	**Si recovery max**	**84.5%**

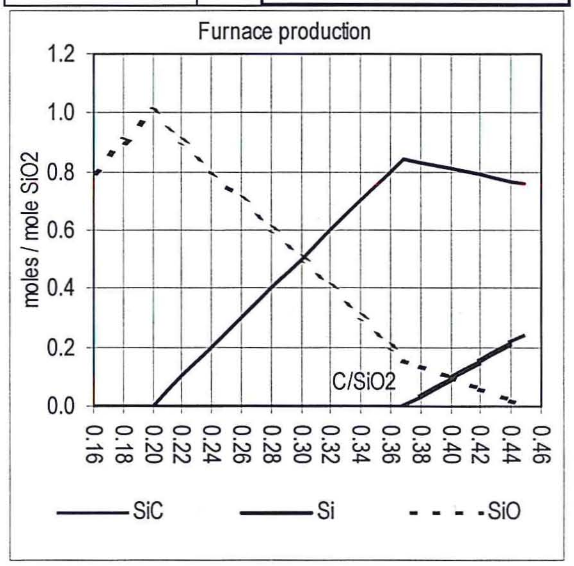

Figure 3 : Results with reference parameters

We can see in figure 3 that as the carbon increases, first the silicon yield increases (undercoking conditions), then decreases with a smaller slope while SiC is formed (overcoking conditions). So, we can find the optimum silicon recovery possible with these parameters.

Another result is interesting : the SiO/CO ratio in the crucible gas is constant with overcoked conditions (near unity), but increases dramatically with undercoking conditions when the C/SiO2 ratio decreases (see fig.4).

With the chosen parameters, the maximum silicon recovery is 84.5% with a ratio C/SiO2 = 0.369. We