TECHNOLOGICAL CHANGE YIELDS BENEFICIAL PROCESS IMPROVEMENT FOR LOW CARBON FERROCHROME AT ZIMBABWE ALLOYS

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ABSTRACT

Zimbabwe Alloys has been producing Low Carbon Ferrochrome since 1953. A number of operational and technical advances have been made since then. Some of these advances improved production significantly. Process control, however, remained a challenge not only in the production process itself but also in the handling of finished product. In addition the handling of the slag created an environmental problem.

Process control issues were addressed by Zimbabwe Alloys Limited and Japan Metal & Chemicals (JMC) entering into a Technical Transfer Agreement. The aim of the technical transfer was to improve production, alloy quality and, thereby, the financial performance of Zimbabwe Alloys. In addition, the Low Carbon Ferrochrome production process was made environmentally friendlier by modifying the final slag handling methodology.

The aspects that are covered and discussed in this paper are, ladle refractory lining changes, improved *control of the process, changes in the alloy casting methodology and granulation of the final slag.*

The improved control of the process was enhanced by the conversion from ladle duplexing to argon purging, introduction of on-line sampling and introduction of second stage process.

The combined effect of the above was a significant improvement on on-grade material production, production efficiencies, unit cost of production and a cleaner working environment.

1. INTRODUCTION

The production of Low Carbon Ferrochrome (LCFeCr) at Zimbabwe Alloys started in June 1953 using the Perrin Process.

Continuous modification of the Perrin Process resulted in a number of milestones being achieved since then in terms of volumes of production, quality of alloy and process control. In spite of these achievements it was clear that the existing process had limitations that inhibited further improvements leading to lost opportunity for Zimbabwe Alloys. An opportunity arose when Japan Metals and Chemicals Corporation (JMC), a long-standing customer of Zimbabwe Alloys, decided to cease the production of LCFeCr. JMC had developed a process that ensured pristine process control resulting in consistent and predictable alloy output, improved alloy grade with significantly lower off-specification alloy, reduced fines generation and significantly higher chromium recoveries than those obtaining at Zimbabwe Alloys.

Technical discussions were embarked upon and an agreement was reached for a Zimbabwe Alloys/Japan Metals and Chemicals Corporation (ZAL/JMC) technical transfer to the benefit of both Companies.

The achievements of the technical transfer are discussed in detail in this paper.

2. LCFeCr PROCESS

The process flow starts with the blending of the chrome ore concentrates and lime. The feed blend is fed into the kiln for preheating and then discharged into the furnace for melting.

A single duplexing process stage was in place prior to the process re-engineering in preparation for the ZAL/JMC agreement.

LCFeCr production in the new process takes place in the process ladle. This process is termed the primary process. Argon gas purging is used for mixing the reactants. The alloy from the primary process is cast into moulds and then quenched before being broken and sized for export. A secondary process is for further chromium recovery for the residual chrome units in the slag from the primary process. The slag from the secondary process is granulated. The alloy from this process is used as a feed-stock to the primary process.

3. ZAL-JMC AGREEMENT

Zimbabwe Alloys Limited and Japan Metals & Chemicals Corporation having signed the technical agreement, targets of the agreement were drawn up in terms of product quantity, quality and feed quality.

3.1 Agreement Targets

From the onset, the following product targets and raw materials specifications were agreed upon and are shown in Tables 1 and 2.

Table 1. Agreed Product Specification.

Product		
Production Output	t/day	104
Alloys Grade	Cr (% min)	≥65.0
	Si (% max)	≤1.2
	C (% max)	<0.06
On-grade Alloy Production*	(% min)	≥98.0
Chromium Recovery	(% min)	≥93.8

*On-grade alloy production meant the on-specification for %Cr, %Si and %C in alloy as set in the targets.

The 104 tonnes per day was derived from a 25% improvement in production from the pre-agreement levels.

Table 2. Furnace and Process Chrome Ore Feed Specification.

Cr_2O_3 (% min)	47.0
SiO_2 (% max)	6.9
Cr/Fe	2.5

The control of silica (SiO_2) in chrome ore was necessary, as an abundance of silica would result in a polymeric silica structure adversely affecting the slag viscosity and hence inhibiting the ladle metallurgical process.

3.2 Process Reductant

The slag from the primary process was further reacted with a reductant to recover the residual chromium units in the secondary process. The intermediate alloy from the secondary process was a feedstock to the primary process.

The reductant for the LCFeCr process is Ferrosilicon Chrome (FeSiCr). The quality required for the agreement is shown in Table 3 for both the primary and the secondary processes.

Table 3. Primary and Secondary Process Reductant Specification.

	Primary Process	Secondary Process
Cr (%)	35.5	34.5
Si (% min)	42.5	44.0
C (% max)	0.050	0.050

The reductant FeSiCr had to be in liquid form to achieve required temperatures for sufficient chromium recovery.

3.3 Lime

Lime specifications were not considered in the agreement, but extensive discussions were conducted on the variation of lime analysis.

The variation of CaO and SiO_2 in the lime used by ZAL was an initial concern raised by the JMC team. It was later agreed that it could be used for the technical transfer without an effect on the process.

4. TECHNICALTRANSFER PREPARATIONS

To enable the fulfilment of the agreed targets, plant modifications and process re-engineering had to be carried out. This was complemented with the purchase of requisite capital equipment.

The whole process was re-engineered over a period of 4 months in preparation for technical transfer. A simplified process flow for LCFeCr after re-engineering, is shown in Figure 1. The primary process occurs at stage ‘A’ and the secondary process occurs at stage ‘B’.

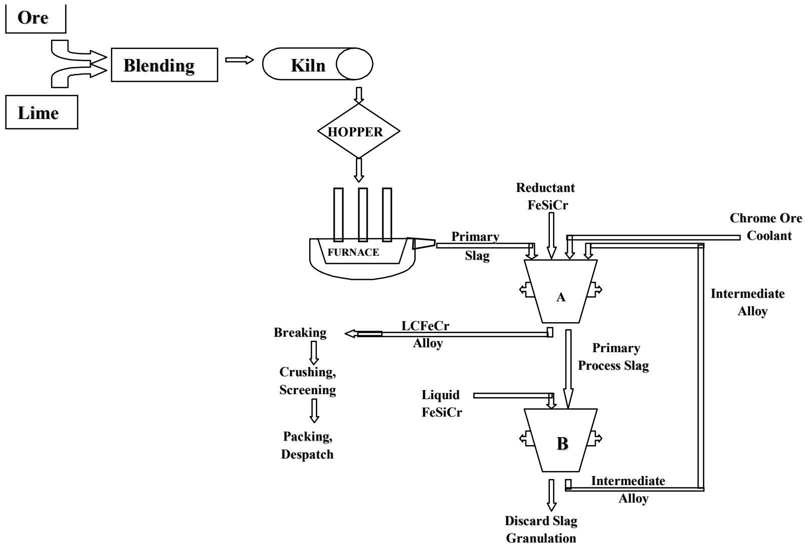

Figure 1. LCFeCr Flowsheet.

The following were carried out in preparation of the technical transfer:

- A new remote controlled crane was acquired and installed.
- Installation of an argon bulk supply tank and flowmeters.
- Process pit modifications.
- Chrome ore and FeSiCr hopper installations at the process pit.
- Alloy casting moulds modification.
- Alloy Quench Plant construction.
- Slag Granulation Plant construction.

4.1 Installation of a New Remote Controlled Crane

The process flow was fundamentally important for control, production quality and quantity. It was envisaged that a remote controlled crane allowed smooth process and movement control. The crane also offered high safety on the operators and other workmates.

4.2 Argon Bulk Supply Tank and Flowmeters Installations

The tank was to consistently supply argon for agitating process reactants to facilitate maximum contact for reactants. Flowmeters were for argon flow control to safeguard refractory wear and ensure adequate agitation.

4.3 Process Pit Modifications

Process pit modifications was part of the process re-engineering. It enabled safe in-process sampling for both slag and alloy, the addition of reductant FeSiCr, coolant addition, visual process control and containment of ladle reactants in case of a ladle breakout.

4.4 Chrome Ore and FeSiCr Hoppers Installation at the Process Pit

Chrome ore addition was mainly to control temperatures since the ladle reaction is exothermic. Furthermore, the chrome ore addition to the primary process enhanced productivity by utilizing in-process heat resulting in significant saving on electricity utilisation. FeSiCr addition was initially added to ensure under siliconising the process with subsequent small addition to ensure a tight control of the process.

The FeSiCr and chrome ore hoppers were installed with load cells to accurately weigh process inputs for precise quality control.

The in-process sampling approach was used for both the primary and secondary processes with slag chromium content being also a major quality control issue, apart from the alloy.

4.5 Alloy Casting Moulds Modification

The modification of the casting moulds resulted in each process being cast into four small moulds instead of one big mould as previously practiced. This resulted in small ingots easier to handle and break. This in turn reduced the generation of the fines.

4.6 Alloy Quench Plant Construction

Ingots quenching enabled the separation of the residual slag from the surface of the alloy carried over from the casting process.

The quenching process improved handling and subsequent breaking of ingots, to keep the rhythm of the entire process.

4.7 Slag Granulation Plant Construction

Prior to the granulation technology the final slag decrepitated into ultra-fine lime material which was easily wind blown causing an environmental problem. The granulated slag remains competent, resulting in an environmentally friendlier process. The slag could be sold to cement manufacturers or to agricultural concerns as there was very little remnant chromium.

5. TRAINING

The initial fundamentals of technical transfer agreement were signed which saw an operative team from ZAL sent to Japan for 50 days for technical training.

This was followed by training at Zimbabwe Alloys Limited when five Japan Metals and Chemicals Corporation trainers arrived. Having been satisfied with the technical transfer preparations, training started and was confirmed adequate after seven months.

The training emphasized on in-process sampling which played a major role on control of product quality and chromium recoveries.

6. VERIFICATION

Having completed the requisite preparations, both technical teams mutually agreed to the start of the verification. The 30-day period was successfully completed without interruption.

7. RESULTS

The results achieved during the 30-day verification period were compared to the agreement targets.

The results are shown in Table 4 below.

Table 4. Product Attainment Compared to Agreed Targets.

	Attainment	**Target**	**% Var**
Production (t/d)	115.7	104.0	+11.3
Alloy Grade (%Cr)	100	98.0	+2.0
(%Si)	99.5	98.0	+1.5
(%C)	96.9	98.0	-1.1
On grade Production (%)	99.1	98.0	+1.1
Chromium Recovery (%)	96.9	93.8	+3.3

The actual ore feed analysis during the countdown period was as follows:

Table 5. Actual Ore Feed Analysis Compared to Agreed Targets.

	Actual	**Target**	**% Var**
Cr_2O_3 (%)	45.8	47.0	-2.6
SiO_2 (%)	8.5	6.9	-23.2
Cr/Fe	2.8	2.5	+12.0

The Cr_2O_3 content variation during the countdown period is shown in Figure 2.

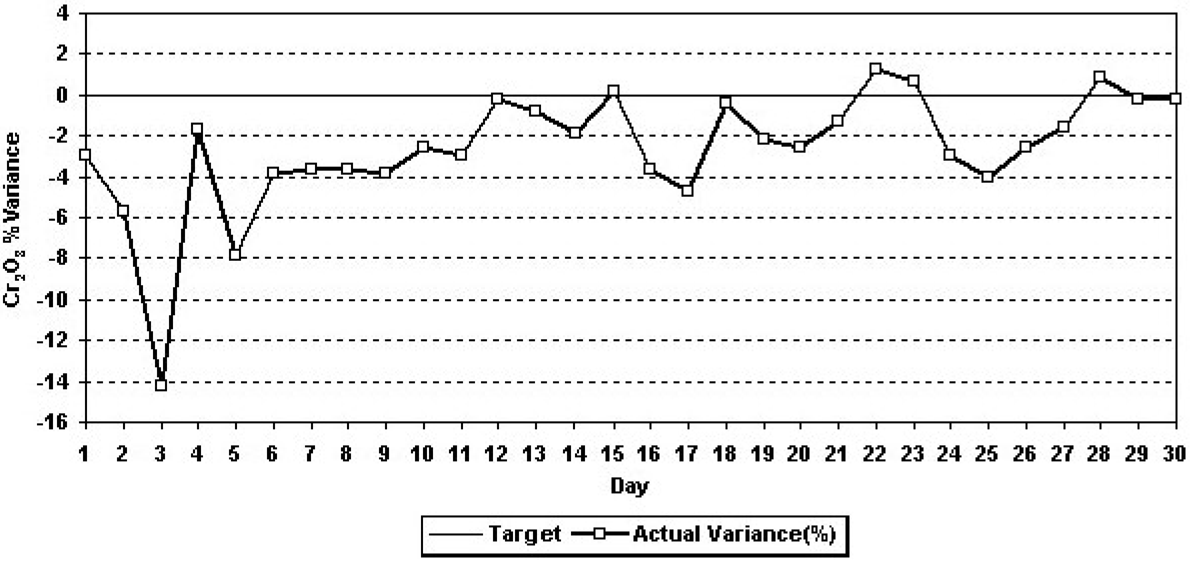

Figure 2. Furnace Ore Blend: Cr_2O_3.

Table 6. FeSiCr Reductant for the Primary Process.

	Actual	**Target**	**% Var**
Cr (%)	36.0	35.5	+1.4
Si (%)	41.9	42.5	-1.4
C (%)	0.055	0.050	-10.0

Table 7. FeSiCr Reductant for the Secondary Process.

	Actual	**Target**	**% Var**
Cr (%)	35.4	34.0	+4.1
Si (%)	43.1	44.0	-2.0
C (%)	0.043	0.050	+14.0

Table 8. Conformance of the Process Feed During the Verification Period.

7.1.1.1.1.1.1 Analysis	**% Conformance**
Cr_2O_3 in Ore (%)	16.7
SiO_2 in Ore (%)	0.0
Cr/Fe	100
Si in FeSiCr for Primary Process (%)	46.7
C in FeSiCr for Primary Process (%)	40.0
Cr in FeSiCr for Primary Process (%)	70.0
Si in FeSiCr for Secondary Process (%)	6.7
C in FeSiCr for Secondary Process (%)	36.7

The table below shows a comparison on production rate, recoveries, unit cost, ongrade alloy, offgrade alloy and fines generated on alloy crushing prior to ZAL/JMC agreement and post ZAL/JMC agreement:

Table 9. The Comparison of the Performance before and After ZAL/JMC.

	Prior ZAL/JMC	**Post ZAL/JMC**	**% Variance**
Production Rate (t/d)	83.2	116.9	+40.5
Process Recovery (%)	84.7	96.8	+14.3
Overall Recovery (%)	80.0	93.1	+16.4
Unit Cost of Production (US$/t)	257.0	187.3	+27.1
Onspec Production (%)	77.0	98.9	+28.4
Offspec Production (%)	23.0	1.1	+95.2
Fines Generation (%)	11.1	8.7	+21.6

The success of the verification period was largely determined by the on-line process sampling method which the ZAL team mastered well, the ability of the ZAL team to take ownership of the entire process with a lot of drive and the overall management of the verification period.

This enabled the excellent attainment of agreed targets although feed components failed to conform.

8. LATER DEVELOPMENTS

Operational experience and logistics post the technical transfer period dictated a re-look at:

- Ladle refractory lining.
- Reductant for the secondary process and
- Tapping launder arrangement.

8.1 Ladle Refractory Lining

The success of the technical transfer was accompanied by an accelerated refractory wear in the process ladle at the primary process stage. The refractory cost increased ten-fold.

Extensive refractory testwork programme was initiated in order to reduce refractory costs to acceptable levels.

Various trials were carried out over a period of six months with ramming mass materials from different suppliers which were used as substitutes for conventional refractory bricks.

An evaluation was carried out on the best suitable refractory with emphasis on the following:

- Refractory Unit Cost
- Availability of the Material
- Operational Performance

A suitable castable refractory emerged from the trials. This resulted in an improvement of the performance of lining from an average of 6 heats per lining to an average of 18 heats per lining. A significant reduction in refractory cost was achieved (Figure 3).

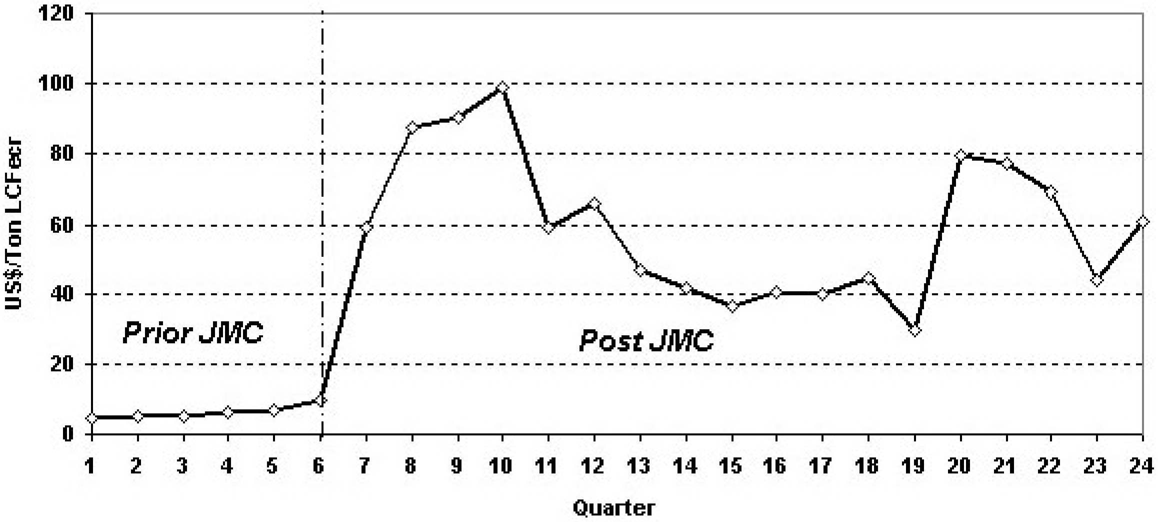

Figure 3. Refractory Cost.

8.2 Reductant for the Secondary Process

The cost effectiveness of the secondary process was affected by the increasing production cost of FeSiCr. A successful replacement of FeSiCr with FeSi75 was carried out with a significant improvement in cost of the secondary process. The change did not compromise the chromium recovery of the secondary process.

8.3 Tapping Launder Modifications

The major bottleneck during the verification period was the transfer of liquid slag from the furnace into the primary process ladle. The slag transfer was by means of a cast steel runner, which was consistently breaking out and blocking.

A new graphite runner was successfully installed without compromising alloy quality, much to the surprise of the JMC personnel who had expected Carbon pick up to occur. This change eliminated the loss of production due to runner related problems.

8. SUSTAINABILITY

The technology has since been sustained and the levels of production, quality and recovery maintained and in some instances bettered. Figures 4 to 6 show the production, quality and recovery after the technical transfer compared to the pre-technical transfer period.

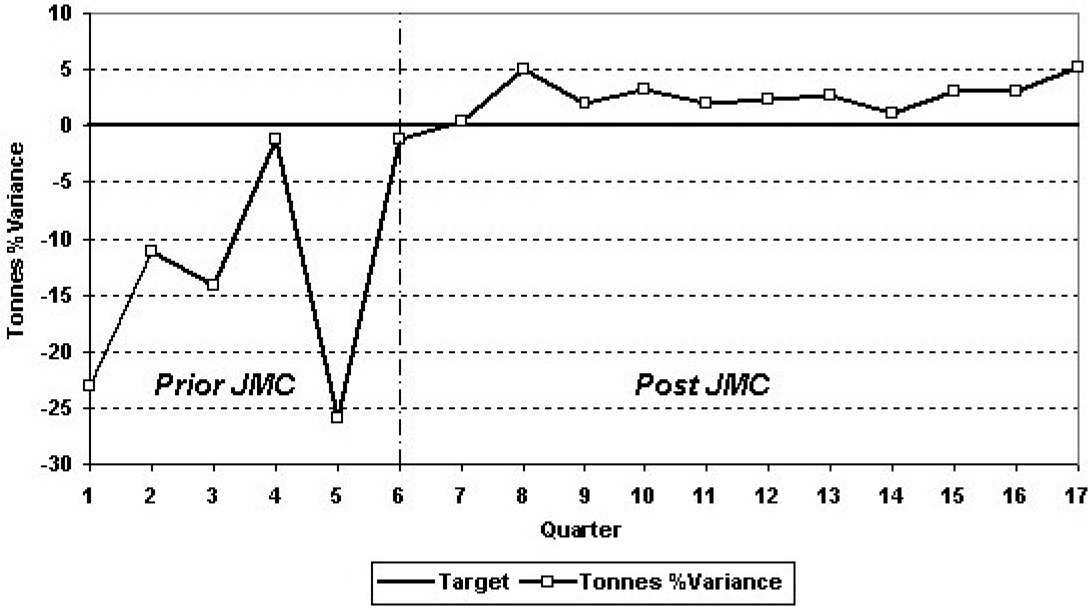

Figure 4. LCFeCr Production.

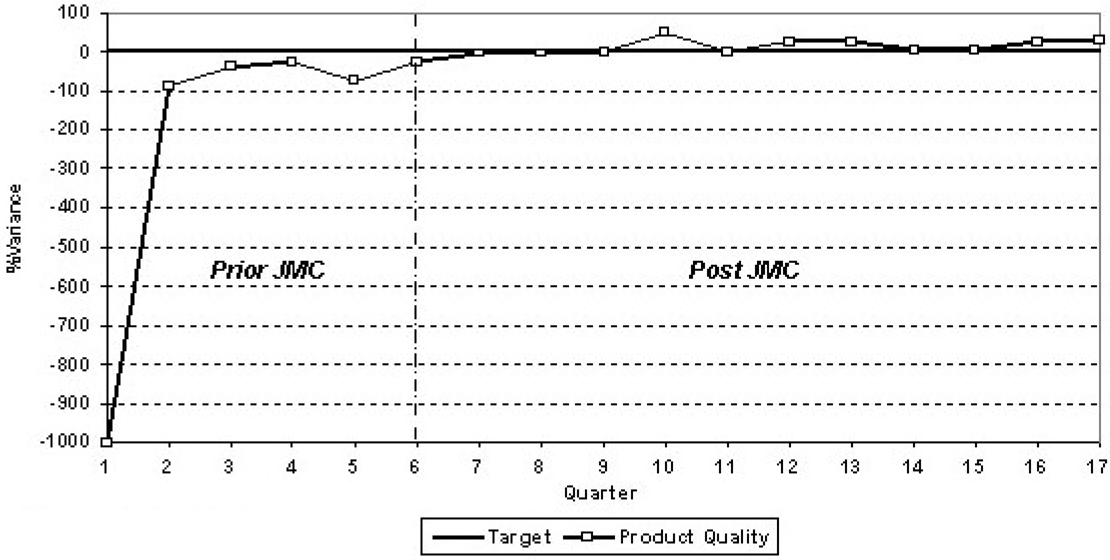

Figure 5. Product Quality.

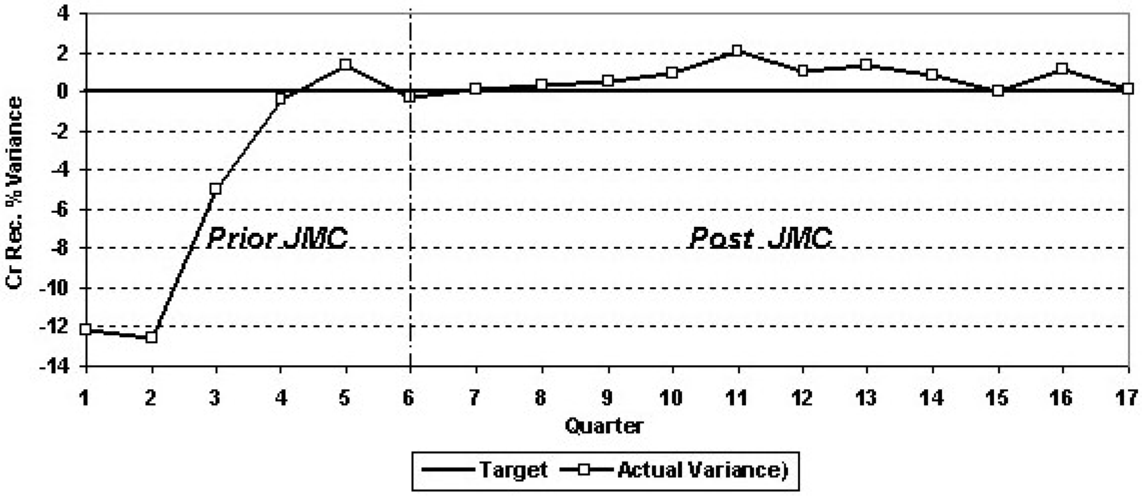

Figure 6. Chromium Recovery.

The implementation of the ZAL/JMC technical transfer resulted in consistent production, quality of low carbon ferrochrome and helped contain the unit cost of the product impacting on the bottom line.

Figure 7 shows the cost benefit derived from the technical transfer in terms of unit cost of production brought about by improved efficiencies and production.

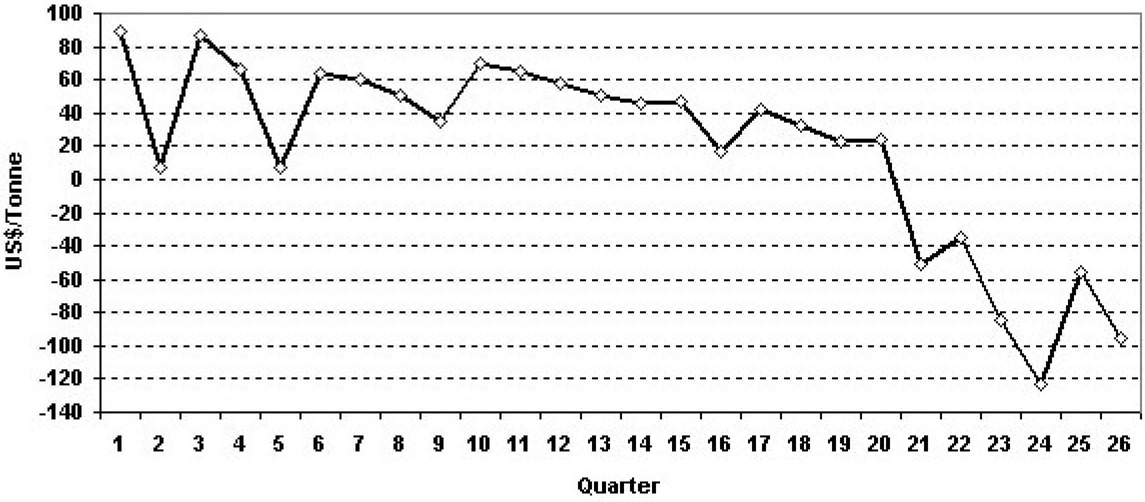

Figure 7. Savings on Production Unit Cost.

The technical transfer savings benefit in US$/tonne of LCFeCr alloy was realized for five years. Diminishing of the savings to the point of negative realizable savings was due to increasing costs for ores, cost of the reductant ferrosilicon chrome, increase in refractory cost, other local production costs and the local inflation.

9. CONCLUSION

The technological transfer was a remarkable success. This technological transfer improved process control, production, quality of product, efficiencies and therefore unit cost of production. All these had a marked improvement on the profitability of Zimbabwe Alloys.

In addition to the above the technological transfer had a positive impact on the environment as it related to slag handling.

The remarkable aspect of this transfer is that it demonstrated that a lot can be achieved without a huge capital outlay.