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Research Article

Observation of Anomalous Production of Si and Fe in an Arc Furnace Driven Ferro Silicon Smelting Plant at levels of Tons per day

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Abstract

In the period 1978–2002, The Silcal Metallurgic Ltd., a Coimbatore (India) based company, was engaged in the production of ferro silicon alloy deploying a 12 MVA "Submerged Carbon Arc" powered smelter. During a 11-week long non-stop round the clock operation of the plant in 1995, daily feed of raw materials was: Quartz (33.4 ton), charcoal (with fixed carbon content of 13.2 ton) and scrap steel (5.1 ton) while the daily output production of Fe–Si alloy (73.5% Si) was 24.75 ton. From the total weights of Si and Fe in the input feed and assuming 100% recovery of the metals, the daily output alloy production could at best have been only 20.5 ton. However to our surprise throughout the 11-week period the total daily Fe–Si alloy (with 73.5% Si) output was consistently 24.75 ton, corresponding to a daily "anomalous" excess metal production of 4.25 ton of Fe–Si alloy. The only source of Si entering the smelter furnace was the quartz raw material and that of Fe was the scrap steel (except for minor additional amounts of Fe originating from the steel casing of the consumable Söderberg carbon electrodes). Very careful vigil of the weights of daily input feed of raw materials and output alloy drained out as also the electrical energy consumption was maintained. It was evident that roughly 20% more metal than could be accounted for from the input feed was being produced and consequently we have been obliged to come to the conclusion that anomalous quantities of Si (2.8 ton/day) and Fe (1.45 ton/day) were being synthesized during the smelting process. Discussions with researchers involved in the Cold Fusion/LENR field have suggested that a likely explanation for the anomalous metal production could be the occurrence of transmutation reactions between nuclei of C and the O stripped from the SiO_2 during the chemical reduction process. It is speculated that the intense varying magnetic fields generated by the kilo-amp levels of alternating current (AC) driving the arcing between the three gigantic carbon electrodes and the carbonic hearth of the furnace, in the 2000°C temperature environment, could have somehow catalyzed transmutation reactions to occur, very similar to the transmutations reported in laboratory scale "Carbon-Arc experiments" first revealed by George Oshawa in 1964. But the more puzzling aspect of our observations is that there was no evidence of release of the expected massive amounts of nuclear energy that should have accompanied the postulated transmutation reactions based on the atomic masses of the nuclei involved.

Keywords: Carbon Arc, Energy balance, Fe–Si alloy, Transmutation

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1. Introduction

Silcal Metallurgic Ltd. was incorporated as a private limited company in the southern Indian industrial town of Coimbatore in 1978 and attained commercial production in 1980. It deployed the well-known ferro silicon smelting technology involving high current "Submerged Electric Arc furnaces". This electro-thermic manufacturing process for ferro-silicon alloy is known to be highly power intensive since the temperature in the reaction zone has to be maintained at around 2000°C. References [1–3] give comprehensive overviews of this technology. The Silcal furnaces had ratings of 5 and 12 MVA and were operated on a round-clock basis. They deployed the traditional Söderberg self-baking carbon electrodes in steel casing, which have been successfully used for over a century [4]. The 5 MVA furnace was used for the production of low carbon silico manganese while the 12 MVA furnace was dedicated to the production of Fe–Si alloy of 70–75% Si grade.

2. Brief Remarks on the Plant and Operation

Raw materials used for the production of Fe–Si alloy are low alumina content quartz (SiO_2) of 98–98.8% purity, steel scrap and wood charcoal with low ash content which served as the reducing agent. Quartz was sourced directly from selected mines in the state of Tamil Nadu, which are known to have low alumina content. On receipt of the consignment at the plant site, dust and fines were screened out and the stock stored outdoors. Wood charcoal on arrival was tested for moisture and fixed carbon and screened to separate fine dust and placed in indoor/outdoor storage. Steel scrap was stored in an outdoor yard. All received raw materials were analyzed for purity at the in-house testing lab and the data carefully archived.

The screened raw materials were taken using a conveyer system to the third floor of the furnace and stored in separate over head bunkers. Each of the three raw materials were weighed according to a computerized batching system and transferred into charging buckets running on monorails in the second floor. Charging buckets then discharged the premixed raw materials into the furnace every 10–15 min through chutes. Shift-wise consumption of all raw materials was totalized to obtain daily (24 h) consumption data.

The molten alloy product was drained through one of the three tap holes at the bottom of the furnace every 2–2.5 h into tiltable "teeming ladles" mounted on rail tracks. The teeming ladles were then emptied into large stationary heat resistant cast iron trays to a thickness of approximately 50 mm. Next day, during the day shift the solidified Fe–Si slabs were manually broken into small pieces, weighed and packed into 40 kg bags for domestic consumers or in 1 ton jumbo bags for export. Each batch of Fe–Si was individually analyzed adopting standard procedures prevalent in this industry.

The voltage applied to the three electrodes was 3-phase alternating current, typically in the 100–200 V region, using step down transformers to convert from 110 kV/11 kV/ to furnace voltage from grid supplied power. Arc currents were in the 30–60 kA region. The arc is struck between the 1 m diameter vertically mounted steel encased consumable Söderberg electrodes and the floor of the carbon hearth. Both the carbon of the self-baking electrodes and its steel casing are consumed in the smelting process, the consumption being 50–60 kg/ton of Fe–Si. Details of the procedure adopted to replenish the electrodes online without interrupting furnace operation is discussed in [1–4]. The whole process is slagless and the only product is molten Fe–Si alloy drained from the bottom and carbon monoxide (CO) effluent gas which burns at the top of the furnace, combining with the atmospheric oxygen to become CO_2 which is released through a stack after scrubbing as per applicable environment regulations.

The 12 MVA furnace was operated round the clock at variable ratings from 7 to 12 MVA, depending on the availability of power. Various charge mix ratios and operating electrical parameters were experimented with in order to arrive at the optimum conditions required for achieving 73–74% silicon content alloy. Systematic records of the total weight of the raw material feed consumed every day, as also the total weight of the product alloy tapped out daily was maintained. Cumulative daily consumption of electrical power was also recorded. A maximum daily production of 27.5 ton of product alloy was achieved when the furnace was operated under full load conditions. The company was very successful and made good profits, supplying high quality products to both local and export markets.

3. Energy Requirement for Chemical Reduction of SiO_2

Plant records show that to produce 1 kg of Silicon content in the product alloy, about 10.92 kWh of electrical energy is consumed, on 100% recovery basis. This observation also tallies with the expected energy consumption estimate based on theoretical considerations of the chemistry of the reduction reaction which is endothermic. In our plant the product alloy contained 73–74% silicon content. Taking an average value of 73.5%, 735 kg of Si would be present in each ton of product alloy (balance being iron). Power consumption for producing 1 ton of alloy thus works out to $10.92 \times 735 = 8027$ kWh. However, dissolving iron into molten silicon is exothermic; rough estimate of this energy release for 265 kg of Iron dissolving into 735 kg of silicon is around 75 kWh of heat energy. Thus production of 1 ton of ferro silicon alloy of 73.5% Si content would require a net energy input of $8027–75 = 7952$ kWh. (Ref. [3] also quotes a similar figure.) The relevance of discussing chemical reaction energy consumption considerations will become apparent later in the paper.

4. Remarks On Inconsistencies Observed between Weights of Input Feeds and Output Products During a 11-week Run in 1995

During early 1995, the furnace was operated continuously on a round the clock basis at a rating of between 8.5 and 8.75 MVA with a daily power consumption of 1,68,000 kWh/day. The feed mixture composition of the raw materials which was not changed throughout the 11-week period was: (a) Quartz – 33.4 ton; accounting for its purity of 98.7% the actual weight of SiO_2 in the feed stock works out to 33 ton. The weight component of Si in this therefore works out to 15.4 ton. (b) Daily iron feed was 5.1 ton. Minor additional contributions from the quartz and electrode casing have been included in this. (c) Fixed carbon input from charcoal was set as 13.2 ton based on chemistry considerations for reduction of 33 ton of SiO_2. The actual weight of charcoal fed on any given day was however higher depending on the moisture content of the particular feedstock of charcoal. Thus the total weight of the main raw materials, namely SiO_2, Fe and C consumed daily was 51.3 ton.

Based on the above raw materials consumption, the maximum possible daily production of Fe–Si alloy at 100% recovery of Si for an alloy of 73.5% silicon should have been not more than 20.5 ton. However, in comparison with the actual daily production of Fe–Si alloy was consistently 24.75 ton with a 73.5% content silicon. This implies a total "anomalous" excess metal (silicon plus iron) production of 4.25 ton/day. Net silicon content in product alloy works out to 24.75×0.735 ton $= 18.2$ ton compared to 15.4 ton in the input feed. Excess silicon was thus 2.8 ton corresponding to18% increase. Likewise net weight of Fe in product alloy works out to $24.75 \times 0.265 = 6.55$ ton compared to 5.1 ton that was input, implying excess iron of 1.45 ton or 28.4% weight gain.

5. Discussion and Remarks

Although we had been observing anomalous excess production of Si and Fe ranging from 200 to 400 kg/day right from 1985 onwards, we were not sure whether these were due to errors in weighing or could be attributed to anomalous generation of Si and Fe. However, following the consistent and repeated observation of about 4.25 ton of daily excess metal production over the 11-week round the clock run in 1995, we were convinced beyond doubt that anomalous transmutation processes are indeed occurring, pointing to the existence of new science. It was only after this that we went public and released our findings in a press briefing in 1999.

We are fully aware that our claims of ton level transmutations will be met with intense skepticism. The first most obvious possible source of doubt leading to incorrect conclusion is errors in weighing of input feedstock and output alloy produced. All raw materials on arrival are weighed in an electronic weigh bridge and stored indoor/outdoor after screening out the fines and dust. In each shift, quartz, charcoal and steel scrap are shifted from ground level bunkers, to storage bins in the top of the furnace floor through conveyors, after a final fines screening. The discharges from the bins are weighed in a computerized batching and weighing system and recorded before feeding into the furnace through chutes. The finished product in the packing floor are weighed in precision weighing balances after size reduction and loaded in bags for shipments to customers. These weighing machines are made by reputed manufacturers such as Avery, whose technicians visit the factory periodically to calibrate and check their accuracy as per industrial regulations. It should be remembered that as operators of a commercial production plant we are most conscious of maintaining proper records of material balance from an accountancy point of view. Payments are involved for raw materials received and products dispatched to customers. Shift wise consumption of raw materials, power used and total daily production and also logs of operational plant parameters were monitored and recorded accurately. There were thus no chances for any errors to occur in the measurement of quantities of input raw materials or output finished product.

The other doubt often voiced is that somehow additional amounts of Si and Fe could have entered the furnace without the knowledge of the plant management. One critic for example suggested that may be the quartz used was not 100% SiO_2 but may have been partly in the form of SiO in which case the weight fraction of silicon in the quartz would be more than 46.7% (28/60) as assumed by us. Critics argued that this could explain the anomalous appearance of "additional" Si. The main argument against this criticism is that SiO is actually a gas and there is no question of its being a contamination in the quartz raw material. References [1–4] clearly point out that quartz as mined is primarily in the form of SiO_2

During the 11-week continuous nonstop run of the furnace, when excess production of 4.25 ton/day was attained, the daily power consumption and load was maintained at a constant level of 1,68,000 kWh/day. In the presently adopted technology it is impossible to produce 1 ton of 73.5% grade Fe–Si alloy at less than 7952 kWh power consumption, as discussed earlier. But in our case in the presence of transmutation also the total power used remained the same in spite of the weight of product alloy having increased, resulting in the "specific power consumption" dropping to (1,68,000/24.75) = 6788 kWh /ton of product alloy, during the entire period of 11 weeks. This observation can be taken to be indicative of the fact that the additional Si production did not come through chemical reduction processes, but must have arisen as a result of some other cause (see Appendix A).

Some amount of SiO gas does get formed during the smelting process if operating conditions are not optimized and this escapes along with CO. One can clearly observe the presence of SiO in the effluent gas stream from the blue tinge in the flame caused by CO burning to CO_2. In our material balance considerations we have not accounted for any loss of Si through the effluent gas and have assumed 100% recovery of Si. If SiO escape is taken into account, the quantum of transmuted Si would actually work out to be even more.

A significant additional qualitative observation we made was that whenever nuclear transmutation processes appeared to be taking place, the heat radiated in the furnace top floor where CO burns to form CO_2, was noticeably less implying that the quantum of CO reaching the top of the furnace was lesser.

6. Possible Relevance of the Carbon Arc Experiment

In quest of an explanation of these anomalous observations, the author was advised (in 1999) to meet the then Director of the Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam, Tamil Nadu, who himself was a distinguished Metallurgist. This Director, however, cautioned us that mainstream Science has no ready explanation for these results and suggested that I meet one Dr. Mahadeva Srinivasan, formerly of the Bhabha Atomic Research Centre (BARC) Mumbai, India, who had been closely following the progress of a new field of research called Cold Fusion/LENR. It is only after discussions with Dr. Srinivasan in the year 2000 that we became aware of the existence of LENR. It was Dr. Srinivasan who first introduced us to the so-called Carbon Arc experiments [5–8] in which anomalous generation of Si and Fe had earlier been reported by many researchers. Indeed, the carbon arc experiment itself was pioneered by a Japanese researcher by the name of George Oshawa in 1964 and the iron reportedly generated in such experiments has come to be known as George Oshawa steel in [9].

At ICCF 20 conference where our paper was presented, coincidentally there was also a paper presented by George Egely [10,11] of Hungary which described a variation of the Carbon Arc experiment in which also anomalous quantities of iron appears to have been generated. Instead of arcing between carbon electrodes Egely has however used carbon powder carried in a silica crucible and subjected it to microwave heating. Presence of iron could be observed readily by using a magnet placed above the post reaction powder mixture.

Our attention was also recently drawn to a patent titled "Silicon Extraction Method" that has been awarded in Ukraine in January 2007 to Bolotov [12] for what appears to be a somewhat analogous method of producing Si from the fusion of the nuclei of the neighboring elements of copper and phosphorous. The method involves application of electric currents with density more than 10^{11} A/m^2 under temperatures below 1050° C. However, there does not appear to be any arcing involved in this process but rather high pressure is employed. Details are available in the patent disclosure [12].

7. Puzzle of the Missing Nuclear Energy

A worth noting feature of the Silcal observations was that there was no dramatic change whatsoever in the energy dissipation. Using the estimated energy release values of 17.13 MeV/atom of Si or 49.58 MeV per atom of Fe given in Appendix B, for the postulated nuclear transmutation reactions, it can be shown that corresponding to 4.25 ton of metal transmutation, the power generated should have been the equivalent of the total thermal power generated by hundreds of 1000 MWe nuclear power stations. However, in our plant there was no evidence of such massive amounts of nuclear energy being released throughout the 11-week period, giving a handle to the skeptics to question our claims of ton level elemental transmutations. In this context it is worth noting that nobody in published LENR literature (to the best of our knowledge) has established a clear correlation between the quantum of transmutation products generated in carbon arc and the expected nuclear heat release based on atomic mass considerations. On the other hand neither has any publication claimed that the Carbon Arc experiment violates Einstein's $E = mc^2$ dictum. Thus if indeed the Silcal transmutation claims are confirmed it would clearly point to the operation of new Science wherein transmutation could be occurring without the accompaniment of the expected nuclear energy release.

In the context of these remarks the arguments of Daniel Szumski elaborated in his "Least Action Nuclear Process" (LANP) Theory appear relevant. We learnt about Szumski's work through his paper presented at ICCF 20 conference [13]. Szumski who has taken great pains to analyze in detail the transmutation observations of George Miley (see www.LeastActionNuclearProcess.com) argues that both endothermic and exothermic nuclear reactions can and do occur concurrently in LENR experiments, partly or wholly cancelling out net energy release. In fact he has referred to some experimental observations of Mizuno wherein transmutations have reportedly been observed by him not accompanied by energy release. Szumski is thus not at all surprised by our observation of "energy neutral" transmutation reactions.

8. Remarks on Possible Future Studies

Unfortunately Silcal operations were severely crippled by power cuts ranging from 30 to 100% and frequent power interruptions from 1996 onwards till 1999. Following a dispute regarding violation of Power Tariff agreement with the state government and withdrawal of exemptions from power cut for our industry, the Silcal plant had to be shut down in 2002 and the company wound up in 2010. This was an inevitable consequence of the fact that cost of electrical power consumed forms a substantial component of the net cost of production of Fe–Si alloy by the smelting process.

What has been has been observed by us in our plant may be considered to be only partial transmutation of the C and O present in the reaction zone into Si and Fe. As such we were making attempts to attain 100% transmutation of all the carbon and oxygen nuclei present in the input feed, from 1995 to 2002. For the last 15 years, we have been contemplating various ways of improving the technology, hoping to move towards achieving 100% transmutations. We do believe that we now have the design and operational parameters for such an improved plant design. If we had carried out isotopic analysis of the produced Fe–Si alloy it would have given us very valuable clues. We deeply regret not having thought of doing this those days. We are meanwhile continuing efforts to try and set up a new plant where these transmutation results could be replicated once again.

The objective of this paper is to share our findings with the LENR community, with the hope that operators of similar plants elsewhere in the world, especially in Norway, could be encouraged to look for the occurrence of anomalous production of Si and Fe in similar submerged arc furnace smelting plants. On our part we shall be most happy to share our results and experience in a true scientific spirit with anyone interested.

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Appendix A: Ferro–silicon 73.5% (Balance Iron) Production Parameters: Recovery Percentages and Electrical Power Consumption Per Ton of Products

Electrical power consumption per kg of silicon produced is 10.92 kWh at 100% recovery for 735 kg of silicon in 1 ton of alloy produced, power consumption is 735 × 10.92 is 8027 kWh 8027 – 75 = 7952 kWh in regular operation. If the recovery of Si is lesser than 100% the corresponding power consumption values will be higher as given below:

100%	99%	98%	97%	96%	95%
7952	8032	8114	8198	8283	8371

Typical energy demand in kWh and recovery percentages of various grades of Fe–Si per ton of alloy in European plants [3]

	Fe–Si 45	Fe–Si 65	Fe–Si 75
Electrical energy	4800	7400	8800
Recovery %	98–99	92–94	91–93

Appendix B: Atomic mass data and computation of expected nuclear energy release in transmutations reactions

Amu data used for computations:

2 Helium	3He 3.016029	0.000137
	4He 4.002603	99.999863
6 Carbon	12C 12.000000	98.93
	13C 13.003355	1.0
8 Oxygen	16O 15.994915	99.757
	17O 16.999132	0.038
	18O 17.999160	0.205
14 Silicon	28Si 27.976927	92.2297
	29Si 28.976495	4.6832
	30Si 29.973770	3.0872
26 Iron	54Fe 53.939615	5.845
	56Fe 55.934942	91.754
	57Fe 56.935399	2.119
	58Fe 57.933280	0.282

Suggested nuclear reaction leading to production of Si				
$_6C^{12}$	+	$_8O^{16}$	=>	$_{14}Si^{28}$
12.000		15.9949		27.9765 (amu)
Total amu of LHS = 27.9949				
Total amu of RHS = 27.9765				
Therefore mass lost = 0.0184 amu (means energy released)				
Multiply by 931 Mev to convert to Mev units				
Energy release is 17.13 MeV per nuclear reaction (exothermic)				

Suggested nuclear reaction path for generation of iron (Fe^{56})				
2 $_6C^{12}$	+ 2 $_8O^{18}$	$\Rightarrow$ $_{26}Fe^{56}$	+	$_2He^4$
2 × 12.00	2 × 17.999160	55.9349		4.002603 (amu)
Total amu of LHS = 59.99076				
Mass lost is 0.05326 amu				
Total of RHS = 59.9375 amu				
In MeV units = 49.58 MeV (exothermic)				

2 Helium	3He 3.016029	0.000137
	4He 4.002603	99.999863
6 Carbon	12C 12.000000	98.93
	13C 13.003355	1.07
8 Oxygen	16O 15.994915	99.757
	17O 16.999132	0.038
	18O 17.999160	0.205
14 Silicon	28Si 27.976927	92.2297
	29Si 28.976495	4.6832
	30Si 29.973770	3.0872
26 Iron	54Fe 53.939615	5.845
	56Fe 55.934942	91.754
	57Fe 56.935399	2.119
	58Fe 57.933280	0.282