Case Study

# Re-engineering of a Reheating Furnace in Secondary Steel Sector - A Case Study

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## Abstract

The popular parable *energy makes the mare go* is set to be extinguished as the energy resources get depleted. There is thus a need to bring austerity in its consumption. The holistic solution is in using proper design of say a reheating furnace – as exemplified in the present case study.

The process attributes of reengineering of furnace and the outcomes of case study have been reported in this work. The results show advantage in terms of both productivity and quality of product and the infrastructure.

Quantitatively the endeavour helped the entrepreneur to save at least Rs.50.00 lac per annum on his oil bill on an average production of 80 tons/day single-shift basis and taking 300 working days per year. Also it saved at least Rs. 120 lac on account of improved material yield due to reduced scale losses. The consequent increase in profitability displays holistic benefits of the reengineering initiative.

**Keywords:** Energy conservation, Furnace design, Productivity, Sustainability, SHEQ

## The Ground Level Sustainability in Secondary Steel Sector

Energy being one of the major inputs for the economic development of any country is considered as an important indicator of societal progress *1+. Consequently, "the need of the hour and duty of society is both energy development and on the other hand its effective utilization. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. The other option is in the increased effective utilization both by prioritizing and largely by reduction of specific consumption – or say lowering the avenues of energy wastage. However, one well-understood products of energy is the cause of global warming[1] and thus threatens the paradigm of sustainability. It calls for a reduction in its consumption, by the dint of increased productivity and not by lowering of production.[2] The other metric which needs be optimized is the flow.[3] The energy availability must match with the rate of energy consumption, especially until energy becomes store-able. However, because of unnecessary affluence and poor conscientiousness of the industry, the energy scenario remains critical.[4] Till any endeavour of development and/or storage succeeds one can never guarantee its uninterrupted availability." The solace thus resides in its productivity and loss prevention.[5]

The global primary energy consumption is increasing at a very fast rate and was more than 13 billion tons of oil equivalent (Mtoe) at the end of 2013. Figure 1 shows the global energy consumption trends.

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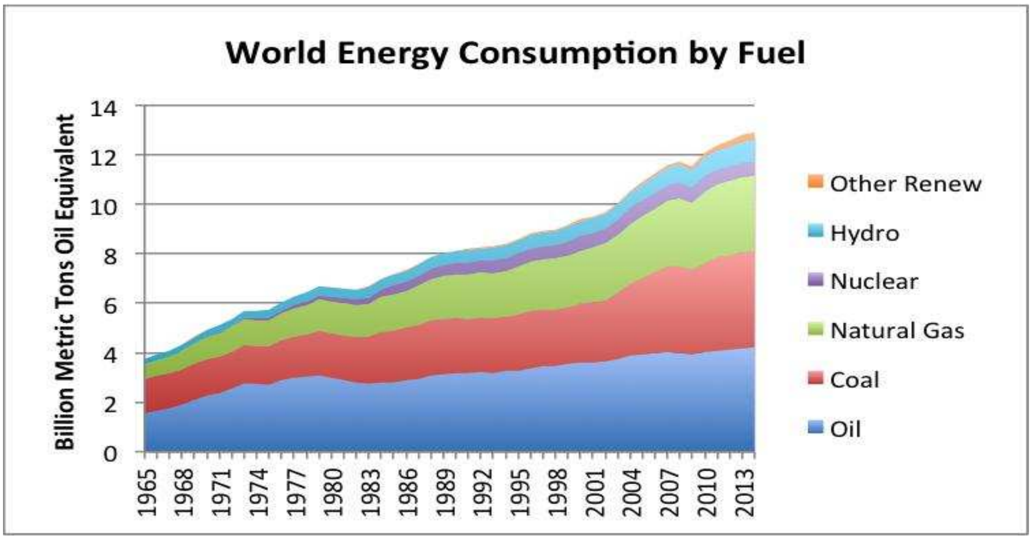


Figure 1.The Global Energy Consumption Trends[6]

It is, therefore, recommended to engineer a systematic methodology to improve energy efficiency while improving product quality synchronously.[7] Another work of the principal author discovered a hidden factory in the metallurgical industry reviewing the steel industry. Though the wastage is essentially higher being an energy-intensive industry, many instances would solicit a change in technology. Others can be helped by incorporating superior management practices, viz., the reheating operations in integrated steel plants (say when steel ingots are transported for subsequent rolling) a better layout or energy conservative transportation obviates major energy wastage. On the contrary, in secondary steel sector retrofitting of furnaces to improve energy efficiency is seen to be the major initiative that must be prescribed.

For re-rolling industry in secondary steel sector in particular, the cost analysis of re-rolling operation shows that energy cost has a share of 55–60% of which the fuel cost itself has the major share of 35–40%. Thus energy efficiency is a key to survival, and therefore the sustainability issue becomes important at the mere ground level, rather than the global or ecological level. The need for energy conservation spells a do-or-die situation, as is evident from the cost analysis given in Fig. 2.

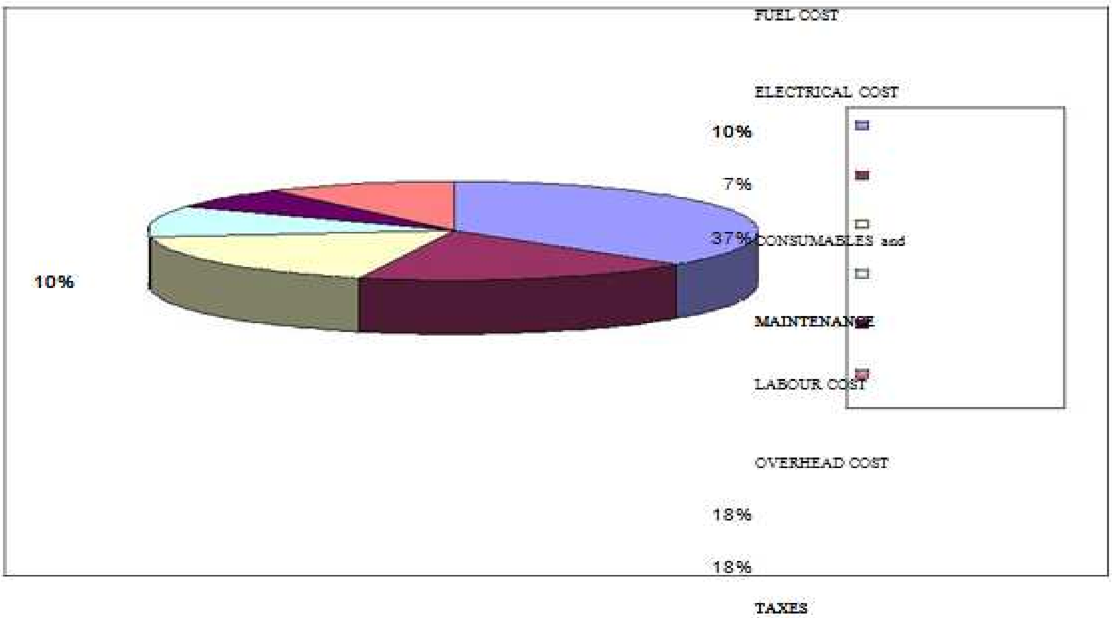


Figure 2.The Cost of Rolling of a Bar and Round in a Re-rolling Mill in Secondary Steel Sector

## Cost of Re-Rolling in a Bar and Round Mill

The performance analysis of reheating furnaces employed in re-rolling mills in secondary steel sector show that there is a lot of potential in improving the furnace efficiency and in reducing the specific fuel consumption levels. Such information comes from both the state of high emission of pollutants, temperature profile of furnace or of raw material stock and the quality of the latter.

As there is a big gap between the theoretical energy required and practical energy input levels, there is another case to understand the reasons of discrepancy. The theoretical energy required to heat the steel to rolling temperatures is around 180 Kcal/kg only. Status-wise, as per bench marking of the best oil fire furnaces in India have showed an energy consumption level of 300 Kcal/kg. Some properly designed furnaces duly bench-marked showed that compliance with required operational parameters and practices may lead to savings in fuel consumption to the tune of 10 to 15% without necessitating any major investment. However studies reveal that many a time the improvement in operational parameters alone does not suffice and that there is a need to re-design the furnace.

The competitiveness requirements also entail the bigger furnaces display better specific energy productivity than smaller furnaces. However, any increase in capacity requirements reiterates a need to redesign the furnace. This work reports the results of endeavors or reengineering a reheating furnace to improve productivity, sustainability measured through energy consumption.

## Ground Analysis of a Reheating Furnace

Any equipment which does not operate to its optimal performance poses multiple threats to the society, many of which get attributed to the paradigm SHEQ (Safety, Health, Environment and Quality).[8] The analysis of problems, encountered in the reheating furnaces duly surveyed, also reciprocate in the same way. The operators' responses generally revolve along the evils, which are reported in Table 1..

Table 1.Evils of the Reheating Furnaces

| The situation analysis discloses the reheating furnaces in general face the following problems: |
|---|
| Quality and Productivity High Scale Losses |
| Bad Surface Qualities Improper Heating and Soaking Lower Productivity |
| **Cost and Economics** |
| High Energy Consumption Levels |
| Higher furnace and infrastructural maintenance Excessive inventory and fuel storage costs Product loss due to scrapping and scaling |
| **Operational comfort** |
| Bad Environmental quality due to soot / CO causing suffocation |
| Noisy operations |
| Dusty environment |

Their causes were analyzed and categorically grouped into three reasons, viz., quality and productivity, cost and economics and operational comforts. The analysis seems to disclose more of design issues, and hence it suggests a need for retrofitting existing furnaces. In addition, there are issues which ignored options to reduce wastage and losses the valued resource.

The following reasons duly identified as the problems faced by these furnaces are detailed. These are also categorized into three classes: design related; equipment related; and related to control parameters.

### Design issues

- Improper Furnace Design.
- Design related Improper Combustion Equipments
- High Heat Losses From Furnace

### Control parameters

- Inadequate Combustion Parameters
- Improper Temperature Profiles Of Furnace Stock
- Inadequate Furnace Draught
- Atmospheres Inadequate Hearth Loadings.

### Inadequate equipment/initiatives related

- Low Waste Heat Recovery from Flue Gases.
- provision related Improper Combustion Equipments

## Re-Engineering of a Reheating Furnace

To improve upon the design of furnace two options are available, either to rebuild an aboriginal well designed furnace, the other is to modify the existing furnace design to suit newer/ or changed requirements. To make an entirely new furnace not only huge investments are required but also shut down of the unit is required for longer period. However by applying concepts of reengineering the existing furnace can be modified for desired results in relatively small costs. It may be between 1/3rd or 1/4th of the above. In view of this, the best course of action is to reengineer; to affect a holistic solution to steel rolling mills macro and micro environment as well as its economy.

"Re-Engineering of a Reheating Furnace" involves the study and analysis of the operational/design parameters of a particular reheating furnace and to formulate the line of action to improve upon these parameters as per required levels so as to improve the energy efficiency and productivity of the furnace. In general following points are deemed to be important while redesigning a new furnace. These are divided into capacity + competence, tools and techniques, and operational characteristics.[8] These are schematically illustrated in Fig. 3:

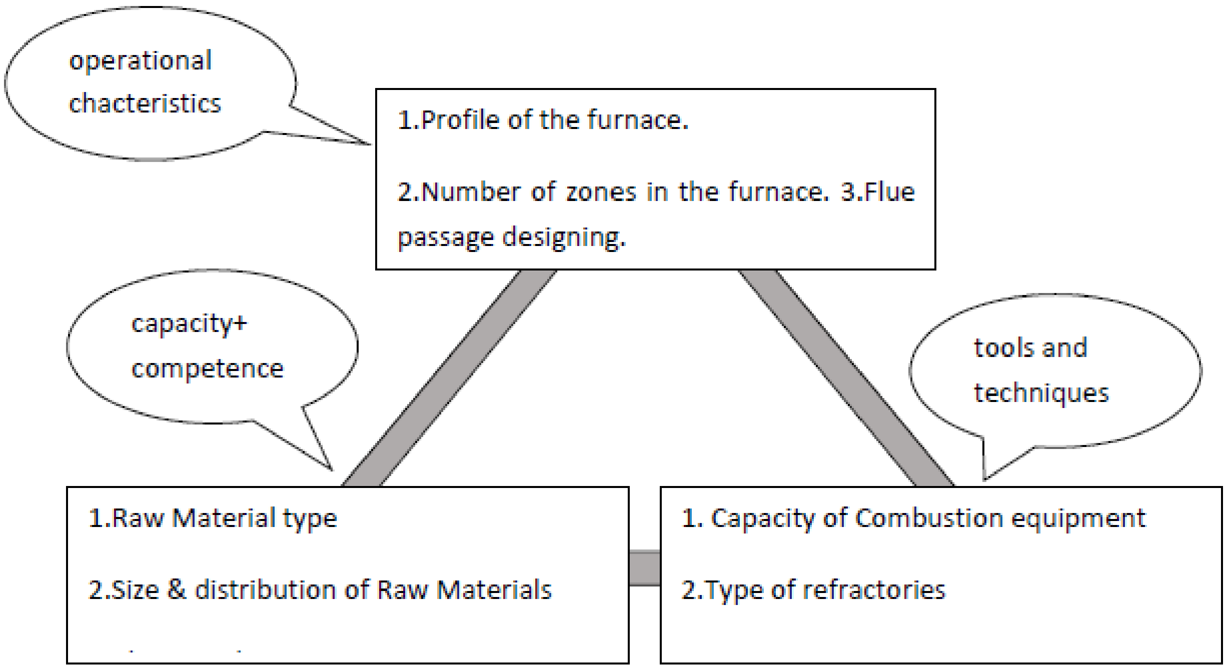


**Figure 3.The Guide Map for Designing of a Reheating Furnace**

There is a need to list the principles of reengineering here. The theoretical tenets of reengineering [10] duly employed in the exercise are namely:

(i) Capture information once and at the source. (ii) Organize around Outcomes, not the task. (iii) Identify all processes and prioritize them in order of redesign. (iv) Put the decision point where the work is performed, and build the control into the process. (v) Treat geographically dispersed resources (vi) Link Parallel activities to integrate the results. (vii) Integrate information processing work into real work that produces the information.

## The Design Contemplations of Case Unit

In the present case a detailed analysis of one Reheating Furnace (case unit) of a Re-rolling mill was carried out with regard to all it's operational parameters. The specific heat energy consumption in the furnace was average 405000 Kcal/T (45 Litre/ton of furnace oil (FO)) of steel produced before modification. The furnace gave a scale loss of approx 3%. Recuperator was duly installed to recover waste heat of flue gas pre-heating the air to a temperature of approx 175 0C.

The studies showed that major areas desiring improvement were: (i) zoning of furnace (ii) heat loss through furnace structure (iii) combustion parameters, (iv) proper designing of combustion equipments (v) flue gas loss etc.

A detailed energy balance of the furnace was attempted to find out the areas of heat losses. Detailed calculations were made (in lieu of these typical thumb rules were deployed) at times using simultaneous equations to optimize on the desired profile/design of furnace. The objective was to enhance both the size (at least for a 9 ton/hr capacity) and energy productivity of the modified furnace. The required combustion equipments, furnace accessories and refractories etc. were carefully selected taking into account the short comings in the equipments as evidenced from heat balance of previous furnace. The modified furnace was then operated with all its modified/ corrected operational parameters and design features. The detailed study of its operation and temperature profiles etc. was undertaken to record the improvements in the results and resultant changes in heat balance.

## Methodology

Using the principles of reengineering, as enumerated above, a tactical methodology was charted to understand current situation, identify the improvement options, and apply the reengineering impetus as and when applicable.

The aforementioned listed steps were adopted to reengineer the present furnace for best results. These are reported in accordance with applicability but adapted to the present situation. Hence the listed order may not be seen in following discussion. However as the reengineering process, by very design, is iterative thus there is a scope to chose and optimize various steps according to best effect case.

### (i) Capture information once and at the source

In this step the analysis of Initial performance was carried out duly studying the exquisite design parameters of furnace. The operational parameters were recorded for two weeks. The oil consumption levels vis-à-vis production levels were recorded for five days.

### (ii) Organize around Outcomes, not the task

The changes in the existing furnace were proposed and the improvements expected from the re-engineered furnace were enlisted as given below.

## Type A goals (complimentary)

- Productivity improvement. (6 Ton/Hr. to 8-9 Ton/Hrs).
- Reduction in fuel consumption. (45 Ltrs/Ton to approx. 40 Ltr/Ton).
- Reduction in Scale losses (to be reduced by at least 1%)

## Type B goals (complimentary)

- Proper heating and soaking to avoid formation of cobbles.
- Improvement of general work environment and ambience.
- Treat geographically dispersed resources
- Link Parallel activities to integrate the results. Consideration of requirements and the attributes of existing furnace were duly considered in accordance with salient considered above.
- Identify all Processes and prioritize them in order of redesign.
- Put the decision point where the work is performed, and build the control into the process.

The two areas which needed to be worked upon were chosen as (a) Structural Parameters and (b) Operational Parameters. The Improvement envisaged in new design was enlisted in sync with above mentioned goals.

## Calculation of New Structure

The detailed energy balance of the furnace was calculated to find out the areas of heat losses. Detailed calculations were made or thumb rules may be used (in lieu of the typical simultaneous equations) to reach the desired profile/design of the modified furnace for a 9 ton/hr capacity. Reevaluation of number of zones in the furnace to be reengineered was done.

The length and breadth of the furnace i.e. the hearth area of the furnace were ascertained. The required combustion equipments, furnace accessories and refractories etc. were carefully selected taking into account the short comings in the equipments and or heat balance of previous furnace.

A rough Profile of the furnace in newer circumstances was prepared. Furnace volume from the above steps was calculated and it was matched with the combustion volume required. Redesigning of flue passage and chimney was undertaken in modified conditions. Furnace reconstruction with regard to refractory lining was done. Based on the above, the modified design was calculated for production of 9 ton/hr. the design parameters of the two furnaces were as give in Table 2.

It may be noticed that the furnace length was seen to be reduced, though not in terms of the total span of plant equipment.

Further with reduction in burners in new design and the consequent reduction in c.f.m the benefit of energy conservation should be obvious.

Table 2.The Modified Structural Design Parameters and Erstwhile Status

| Furnace | New | Old |
|---|---|---|
| Furnace length (Feet) | 70 | 53 |
| Internal width (Feet) | 5.5 | 5.5 |
| No. of zones | 2 | 1 |
| Burners | 4 | 2 |
| Burner size | 2 of 4 no. and 2 of 4a no. | 2 of 4a no. |
| Blowers | 2 | 1 |
| Total c.f.m. | 3100 | 1450 |
| Pressure | 44”, 48” | 44” |
| Flue passage size | 3’ x 2’ | 3’3” x 2’ |
| Chimney dia | 2.5’ | 2.5’ |
| Chimney distance from | 35’ | 75’ |
| Back end | | |

## Study of Operational Parameters of Modified Furnace

Applying the principle: (vii) Integrate information processing work into real work that produces the information, the operational parameters were adjusted to newly envisaged levels as listed in table 3. The new operational parameters of the two furnaces are compared below.

Table 3.The New Operational Parameters of Reengineered Furnace (With Original Ones)

| Furnace | New | Old |
|---|---|---|
| Oil characteristics | | |
| Preheat temp. | 105 0c | 80 0c |
| Oil pressure | 1.5 kg/cm2 | 0.9 kg/cm2 |
| Air characteristics | | |
| Preheat temp. | 2000c | 1500c |
| Air pressure | 35” wg | 32” wg |
| Stock temp. at discharging door | 11500c | 11750c |
| Furnace wall temp. | | |
| Soaking zone | 800c | 90-1000c |
| Heating and preheating zone | 600c | 700c |
| Furnace temp. | | |
| Soaking zone | 13000c | 12750c |
| Heating | 10500c | 9750c |
| Preheating zone | 7000c | 6000c |
| Combustion analysis | | |
| Oxygen | 3% | 8.5% |
| Carbon dioxide | 12% | 9.0% |
| Excess air | 10% | 70% |
| Carbon monoxide | 150 ppm | 50 ppm |
| Back end temp. | 6000c | 500c0 |
| Temp. at chimney | 1800c | 2000c |

## Study of Reengineered Furnace

The modified furnace was then operated with all its modified/corrected operational parameters and design features. The detailed study of its operation and temperature profiles etc. was undertaken to record the improvements in the results and resultant changes in heat balance. The heat balances of pre and post reengineered furnace have been given in the Table 4 below.

Table 4.The Heat Balances of Reengineered Furnace with Pre and Post

| | Old | New | Relative Saving |
|---|---|---|---|
| Heat input | % | % | % |
| Heat due to combustion of fuel | 94 | 88.78 | 5.5% |
| Heat due to oxidation of stock | 0.3 | .07 | 0.23% |
| Sensible heat of input air | 5.68 | 11.13 | |
| Total | 100 | 100 | |
| Heat output | | | |
| Heat imparted to stock | 37.6 | 41.7 | |
| Heat loss due to flue gas | 29.55 | 29.16 | |
| Heat lost through furnace structure | 6.48 | 1.3 | |
| Heat lost due to radiation through openings | 5.00 | 3.4 | |
| Heat lost due to incomplete combustion | 4.99 | 0.11 | |
| Heat loss due to hydrogen and moisture in fuel | 8.27 | 10.19 | |
| Heat loss due to escape of furnace gases from doors | ---- | 6.53 | |
| Unaccounted losses (including heat lost through openings by gas | 8.11 | 7.61 | |
| Flow, operational delays). | | | |
| Total | 100 | 100 | |

## Results of Reengineered Furnace

The various benefits achieved after reengineering (redesigning) of furnace resulted in following:

- Furnace production was increased from 6 Ton/Hr. to 8-9 Ton/Hrs.
- Specific energy consumption was reduced from 405000 to 333000 Kcal/T (45 Ltrs/Ton to approx. 37 Ltr/Ton).
- Scale losses were reduced from avg. 3% to less than 1%.
- Reduction in cobbles due to improper soaking.
- Improvement in surface quality of rolled product.

The benefits are schematically shown in the following graph as in Fig. 4.

The present case study enabled the entrepreneur to save at least Rs.50.00 Lacs per annum on his oil bill on average production of 80 tons/day single shift basis and taking 300 working days per year. Also it saved at least Rs. 120 Lacs (At cost of product of Rs 25000/Ton) on account of the higher material yield due to reduced scale formation in the furnaces. Not only the operations became cleaner, the surface quality also improved. Consequently, the profits of the organization increased due to higher turnover resulting from higher production.[10]

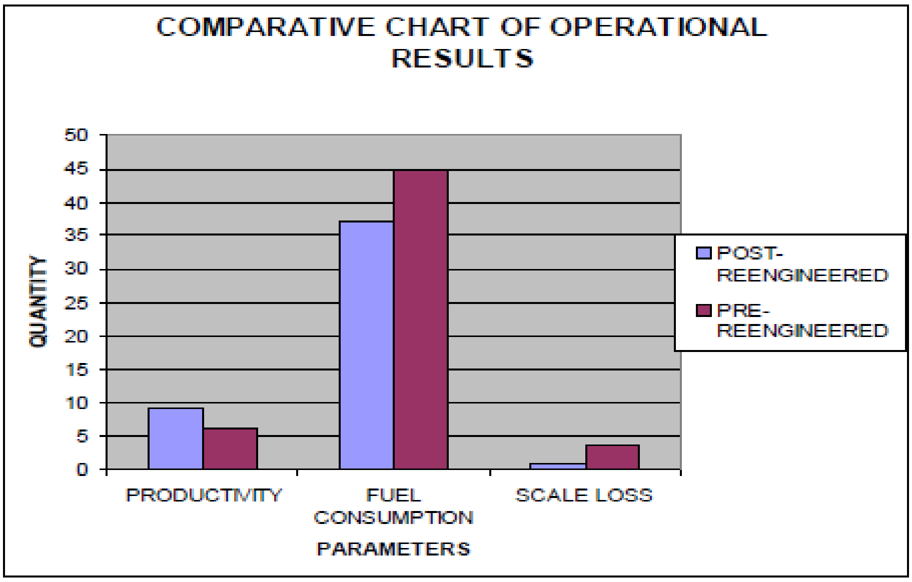


Figure 4.The Benefits Post Reengineering

## Conclusions

That the reengineering initiative of the reheating furnace in present case study paid rich dividends is implicit from the two previous tables, namely, Tables 2 and 3, viz., the temperatures encountered or energy required. No wonder the quality of both products and the operations are set for improvement.

The industrial practice has it that the components of any business process are enabling conforming products and services to the highest satisfaction of all interested parties. Any mismatch therefrom in meeting the 'Total' requirements for these customers may only entail increased entropy of the system.

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