ANNEX II

Technical Specification of the Project

Monitoring and Automation Control in Two Hoffman Kilns

“Sofal Diana Brick” Company

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1- Introduction

“Sofal Diana Brick” Company has been established in 1382 (2003) within the area of 79,000 m^2. The production capacity of the Company is 50 Ton per hour and the main products are face brick, ceiling block, perforated bricks. The production line is equipped with one dryer with 18 chambers and two Hoffman kilns. Two Hoffman kilns contain 100 chambers (Ghamirs) totally and natural gas is used as the main fuel. The amount of natural gas consumption is about 30,000 m^3 per day, in winter.

Considering the Hoffman kiln is the main energy user of the plant, the implementation of energy saving action on the kiln will result on a considerable reduction in the energy consumption as well as energy cost. Moreover, it will bring non-energy benefit such as increasing the competitiveness of the company.

2- Hoffman kiln

Hoffman Kiln is popular in brick production in Iran. The main reasons for popularity are:

- Low initial investment;
- Easier operation;
- Low cost materials.

The energy efficiency of the kiln is about 40%. The average thermal Specific Energy Consumption (SEC) is 100 m^3 of natural gas per ton of product.

2-1- Hoffman kiln Issues

The technology of Hoffman kiln has not been improved since 1858, therefore it is very inefficient compared to more recent technologies, e.g. tunnel kiln. The major efficiency gaps are as follows:

1- **Firing Time**: the actual firing time is longer compared to standard firing curve due to the manual control and lack of knowledge of the plant managers. As a result, it leads to more fuel consumption and yield reduction.

2- **Product waste**: One of the disadvantages of Hoffman kiln is the product waste, e.g. over-burnt bricks due to exposure of bricks to higher temperatures.

3- **Higher Fuel Consumption**: In principle, the human intervention in the firing process tends to prolong the firing curve and increasing the gas consumption. This situation is very frequent during the night shift.

4- **Non-uniform Product**: Since the firing performance is completely dependent on human actions, the quality of bricks varies from one batch resulting on a wide range of qualities.

3- Monitoring and Automatic Control System

3-1- Benefits of the System

The aim of using monitoring and automation control system (MACS) is to improve the performance of Hoffman kiln particularly the firing process, to be assimilated to more modern technologies such as the Tunnel kiln.
In absence of any MACS, Hoffman kiln performance is dependent on human management, and errors. By applying a MACS, the variability due to the manual management will be eliminated.

In this specific proposal, MACS will provide an on-line and systematic control for two Hoffman kilns within the company. The system consists of hardware and software components. Hardware includes 110 thermocouples, 110 transmitters, 15 electric control valves for regulating flow of fuel, 15 inverters for air adjustment and other auxiliary equipment illustrated in the following table, with regard to software, this consists of a PLC system.

Studies on kiln performance shows that the following parameters are affected by the operator (kiln-man) management:

- Kiln performance;
- Firing time;
- Firing temperature;
- Number of chambers (ghamirs) in the firing zone.

The study on firing curves and its condition, shows that the firing pattern differs for different ghamirs and there is no a stable pattern. In addition, the number of ghamirs in the firing, preheating and/or cooling is not properly balanced and it is dependent on skills of the operator (kiln-man). Applying MACS facilitates operation of the kiln through a permanent monitoring and management of the main parameters of the kiln. Thus, adhering to the firing curve will result in the optimized energy consumption, thus:

- Avoid over-burnt bricks (reduced wastes);
- Reduce energy consumption by reducing firing time as well as lower operating temperature.

3-2- Detail description of the system

1- On-line and accurate measuring of the temperature of each chamber:

In existing kilns, the temperature is being controlled visually, while in MACS, 110 thermo-couples will be installed in order to monitor and control the temperature of firing and preheating zones of the kiln. The system minimizes human errors and consequently, improves cooking process and performance of the kiln.

2- Steady temperature rising in line with cooking curve

In the current operation, kiln temperature is controlled manually if kiln-man changes flow of fuel by adjusting manual valves of the burners. While, in automation system, the number of 15 electric control valves will be installed on the burner sets and the flow of fuel will be adjusted by kiln-man from control room. It should be noted that the error of electric valves is less than 1%. So, it is clear that MACS will cause reduction of cooking time which leads to fuel saving as well as production of uniform bricks due to more steady performance of the kiln.

3- Avoid over-burnt brick formation

Having over-burnt bricks is usual in traditional Hoffman kilns. Whereas, automation system will eliminate this problem which causes reduction of product waste, significantly. When the temperature rises upper than the allowance temperature, the program (software) will alarm and command to the control valves for changing or even switching off (if required) the fuel flow. Thus, increased temperature does not occur, as a result production of over-burnt brick will be eliminated.

4- Automatic Firing Process

The system is programmed to alarm and switch off the fuel flow when the cooking is completed. Switching fuel flow off is provided by electric control valves which are installed on the burner sets. Time and percentage of opening of the valves are the main parameters which are defined in the program (software). In addition, three standby burner sets are considered in preheating zone. Once the firing time is completed, the burner sets of firing zone will be turned off and the standby burner sets will be turned on automatically which prevents human error, especially in the night shift.

5- Air Adjustment

The amount of inlet air to the kiln is one of the main parameters which determine the oxidation or reduction condition of the kiln. Hence, controlling the amount of air will have considerable effect on kiln performance.

In the current condition, each set of burner is equipped with a fan that its duty is to supply combustion air into the burners. In MACS, the air flow can be adjusted based on the amount of fuel whether manually or automatically by inverters. It should be noted that automatic control of air flow is applicable after implementing MACS, once correlation of air flow versus fuel consumption can be formulated based on enough recorded data.

3-3- Level of access

Since the data extracted from MACS is beyond the need of operator, the system will deliver three levels of accessibility as follows.

1- Top Manager

2- Technical manager

3- Operator

Level of Access	Description	Remarks
Operator	Ability of manual cooking; Ability to adjust automated cooking; Alarming system in weak function of kiln-man; Alarm system for equipment failures.	Access to operational conditions of the kilns and cooking process without any capability to change in software adjustment
Technical Manager	On-line access to cooking curves (Analyzing cooking curves will provide this possibility for technical manager to detect the malfunction of operator/kiln-man e.g. kiln temperature, way of moving burner sets, reducing gas flow during the night shift, etc. Supervising the arrangements of bricks within ghamirs and place of burner sets, at the same time, resulting in make a balance between them.	Enable to change and modify temperature level and reporting
Top Manager	The following information will be provided: Number of opened ghamirs daily and monthly, Number of produced brick monthly in each type, Estimation of number of products for next month and delivery time of new orders as if previous orders do not have any delay.	

Abilities of the monitoring and control software have been represented below. As stated previously, Software will be designed in three levels of accessibility.

As stated above, this system is expected to provide the following services and gains.

- Reducing cooking time and increase production yeild of the plant
- Reducing gas consumption
- Decreasing waste amount
- Providing uniform product in terms of quality
- Providing different levels of monitoring access
- User friendliness of the system (Ease of working for operators)
- Low pay-back period
- Low commissioning period
- One-year warranty
- Flexible to use specialized and customized program
- Five-year after-sales services

3-4- Equipment Specifications

3-4-1- Thermocouples:

The thermocouples are k-type which functions to the temperature of 1300 ^{o}C. The materials of thermocouples are two inconsistent metals -Nickle and Chrome-. The metals' diameter is different from type to type. In this project, the diameter of 3 mm which is almost the common largest size has been applied. The higher diameter will guarantee the longer lifetime of the thermocouple. Two different metals will be welded to each other and the quality of welding will affect the accuracy of thermocouple. The thermocouple will embedded by a metal pod that 80% of it is made of steel 310 and on the head of thermocouples, fireproof ceramic is used which can tolerate the temperature of 1300 ^{o}C. All materials of thermocouple will be imported from Europe, and only assembling is performed in IRAN. Assembled thermocouples have been tested in the accredited calibration lab and their accuracy has been approved. The similar type of thermocouple is installed in "ZarNAMA" brick Company since three years ago and it is working properly so far.

3-4-2- Electric Control Valve

The control valves are made in USA and the type is on-off. Since the on-off valve will not meet the requirement of the project, the Local contractor has designed a control board and converted the On-Off valve to the proportional valve. Terminal box of IP67 has been used in the valves, so they are dust proof and water proof (except for immersion state). The valve comprises three main parts including:

1. **Valve**: Globe valve stainless steel from "Flowtech" Company, USA.
2. **Positioner**: It is reducer of motor rpm with the ratio of 1 to 120.
3. **Control Board**: It is added by local contractor in addition to and supports the protocol of MODBUS. This part is added further to American control board.

3-4-3- PLC

For each kiln, one CPU and MODBUS cards are applied which connect thermocouples and valves to the kiln. Application of MODBUS protocol will increase the security of the work; however more cabling would be required rather than typical protocols.

4- Training Services

The training will be held in two steps and three levels. In the first step, the installation of thermocouples, proportional valves, etc. will be trained to the operators and technical experts during the project implementation. Second step of training will be held after implementation of the project for three levels; operators, technical experts and top manager of the company.

5- System Security

Regarding that the operating temperature in Hoffman kilns is around 1000 to 1100 ^{o}C, the security is prominent. Furthermore, kiln is the last step of production line and any failure in the final product will impose extra cost to the company. The system will alarm if the thermocouples are disconnected.

- Fuel supplying (here is natural gas) will be turned off and system will alarm, when the temperature of the kiln goes higher than 1300 ^{o}C (critical temperature).
- In each electric control valve, a maximum range of temperature has been set. If the temperature reaches to the maximum level, the valve will run automatically and reduce the gas flow in. So that the temperature maintains in the acceptance range.
- If the electric control valves are disconnected for any reasons like power failure, disconnection to the data cable, etc., the alarm system will work and warn the operator.
- The system is programmed in the way that the command of PLC to the valve will be compared with the feedback to that command from the Valve. If there is 1% difference between the amount

which is commanded by PLC and the amount reported by valve, it means that there is no error in valve system.

- The system contains uninterruptible power supplies (UPS). When the power is turned off, the central fan will be off as well, therefore it is essential to automatically turn off the gas supply in order to avoid occurrence of any risk, due to existing fire inside the firing zone.

6- Guarantees and Calibration

All parts and equipment have one year guarantee. In addition, the whole system has also one year guarantee of good performance. The thermocouples and transmitters will be calibrated by the local contractor yearly and the certification will be submitted.

7- Project Cost

Description	No.	UNIT Price (IRR)	Total Price (IRR)
Thermocouple	110	3,300,000	363,000,000
Transmitter	110	4,000,000	440,000,000
Proportional Electric Valve	15	55,000,000	825,000,000
Computer	2	30,000,000	60,000,000
PLC & etc.	2	90,000,000	180,000,000
Wireless	3	5,000,000	15,000,000
Electrical panel	2	10,000,000	20,000,000
Inverter	15	10,000,000	150,000,000
UPS	2	20,000,000	40,000,000
Wires, cables, fire resistant hose pipe, flexible hose pipe	2	100,000,000	200,000,000
Personnel Costs	6	15,000,000	90,000,000
Transportation Costs	120	850,000	102,000,000
Overhead Costs , spare parts etc.	_	100,000,000	200,000,000
Total Cost			**2,685,000,000**

8- Time Scheduling

The project will be implemented in five phases in the duration of 6 months.

8-1- Phases and duration

#	Phase	Estimated Time (Month)
1	Study the lay out of the plant and plant survey, measuring the required dimensions (e.g. thickness of kilns' roof, distance of each ghamir to monitoring room (Kiln man room) and determine the best location for server/control room etc.).	**3**
2	Procurement, purchasing and manufacturing required equipment, conducting initial and on-site testing and quality control of the product	**3**
3	Start with installation of equipment like drilling of the roof, mounting thermocouples, cabling and sending data to the control/server room, installing required electrical circuits, start monitoring of the kilns and storing the data in database, setting up of monitoring phase and primary training of kiln man and managers.	**3**
4	Analyzing the data stored on database and determining appropriate control method in Hoffman kiln based on real data obtained from cooking, and setting up primary cooking system on the kiln.	**3**
5	Specific training of personnel (kiln man, technical manager, plant manager to work with system based on three defined levels of access.	**4**

8-2- Time Table

Phase	Time (Month)					
	1	2	3	4	5	6
1						
2						
3						
4						
5						

9- Economic Assessment of the Project

Principally, Hoffman kiln itself accounts for 80 percent of natural gas consumption in brick factories. The cost of fuel in the Company is over 800,000,000 IRR per month. Considering that 80% of total fuel consumption is contributed to Hoffman kiln, the fuel cost of the kiln will be around 640,000,000 IRR per month.

Based on the last experiences of monitoring and control system and performed testing and calculations, the minimal of 15% energy saving is expected to be achieved. By obtaining 15% energy saving, the cost reduction of the energy bills would be around 96,000,000 IRR per month. Therefore, having the investment cost of 3,685,000,000 IRR, the simple pay-back time is calculated around 27 months (2.3 years) which is reasonable and economically acceptable.

It is noticeable that above assessment has been performed based on minimal possible energy saving and it is very likely to gain more saving in practice.