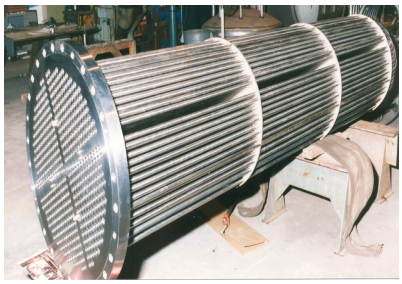
DETAILED PROJECT REPORT
ON
WASTE HEAT RECOVERY IN ROLLER KILN
(MORBI CERAMIC CLUSTER)











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WASTE HEAT RECOVERY IN ROLLER KILN

MORBI CERAMIC CLUSTER

BEE, 2010
Detailed Project Report on Waste Heat Recovery in Roller Kiln
Ceramic SME Cluster, Morbi, Gujarat (India)
New Delhi: Bureau of Energy Efficiency;
Detail Project Report No.: **MRV/CRM/WHR/13**

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Acknowledgement

We sincerely appreciate the efforts of industry, energy auditors, equipment manufacturers, technology providers, consultants and other experts in the area of energy conservation for joining hands with Bureau of Energy Efficiency (BEE), Ministry of Power, and Government of India for preparing the Detailed Project Report (DPR) under BEE SME Program in SMEs clusters. We appreciate the support of suppliers/vendors for providing the adoptable energy efficient equipments/technical details to the SMEs.

We have received very encouraging feedback for the BEE SME Program in various SME Clusters. Therefore, it was decided to bring out the DPR for the benefits of SMEs. We sincerely thank the officials of BEE, Executing Agencies and ISTSL for all the support and cooperation extended for preparation of the DPR. We gracefully acknowledge the diligent efforts and commitments of all those who have contributed in preparation of the DPR.

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List of Abbreviation

BEE	Bureau of Energy Efficiency
WHR	Waste Heat Recovery
SME	Small and Medium Enterprises
DPR	Detailed Project Report
GHG	Green House Gases
CDM	Clean Development Mechanism
DSCR	Debt Service Coverage Ratio
NPV	Net Present Value
IRR	Internal Rate of Return
ROI	Return on Investment
SCM	Standard Cubic Meter
MWh	Mega Watt hour
SIDBI	Small Industrial Development Bank of India
FD	Force Draft

EXECUTIVE SUMMARY

SEE-Tech Solution Pvt. Ltd. is executing BEE-SME program in Morbi Ceramic Cluster, supported by Bureau of Energy Efficiency (BEE) with an overall objective of improving the energy efficiency in cluster units.

Morbi cluster is one of the largest ceramic clusters in India; accordingly this cluster was chosen for energy efficiency improvements by implementing energy efficient measures/technologies, so as to facilitate maximum replication in other ceramic clusters in India. The main energy forms used in the cluster units are grid electricity, Natural gas, charcoal, lignite and small quantity of diesel oil.

There are two sources of exhaust heat from the roller kiln. One is flue gas from the preheating zone of the roller kiln at a temperature of about 249 ^{o}C. The other exhaust is hot air from the final cooling zone at a temperature of about 250 to 300 ^{o}C which is already been utilized in almost all the ceramic unit for drying or heating purpose. But the waste heat from flue gas is not utilized in any of the ceramic unit due to presence of sulphur in flue gas. Utilization of flue gas for preheating of combustion air leads to saving in fuel consumption in roller kiln.

Installation of waste heat recovery system i.e. recuperator on roller kiln exchanges the heat from the waste flue gas to the combustion air. It preheats the combustion air upto a temperature of about 180 ^{o}C.

Total investment required and financial indicators calculated such as debt equity ratio, monetary saving, IRR, NPV, DSCR and ROI etc for proposed technology is furnished in Table below:

S.No	*Particular*	*Unit*	*Value*
1	Project cost	₹(in lakh)	8.46
2	Natural gas saving	kWh/year	69,620
3	Monetary benefit	₹(in lakh)	10.44
4	Debit equity ratio	ratio	3:1
5	Simple payback period	years	0.80
6	NPV	₹(in lakh)	19.25
7	IRR	%age	89.28
8	ROI	%age	20.76
9	DSCR	ratio	4.51
10	Process down time	days	12

ABOUT BEE'S SME PROGRAM

Bureau of Energy Efficiency (BEE) is implementing a BEE-SME Programme to improve the energy performance in 25 selected SMEs clusters. Morbi Ceramic Cluster is one of them. The BEE's SME Programme intends to enhance the energy efficiency awareness by funding/subsidizing need based studies in SME clusters and giving energy conservation recommendations. For addressing the specific problems of these SMEs and enhancing energy efficiency in the clusters, BEE will be focusing on energy efficiency, energy conservation and technology up-gradation through studies and pilot projects in these SMEs clusters.

***Major activities in the BEE -SME program are furnished below*:**

Energy use and technology audit

The energy use technology studies would provide information on technology status, best operating practices, gaps in skills and knowledge on energy conservation opportunities, energy saving potential and new energy efficient technologies, etc for each of the sub sector in SMEs.

Capacity building of stake holders in cluster on energy efficiency

In most of the cases SME entrepreneurs are dependent on the locally available technologies, service providers for various reasons. To address this issue BEE has also undertaken capacity building of local service providers and entrepreneurs/ Managers of SMEs on energy efficiency improvement in their units as well as clusters. The local service providers will be trained in order to be able to provide the local services in setting up of energy efficiency projects in the clusters

Implementation of energy efficiency measures

To implement the technology up-gradation project in the clusters, BEE has proposed to prepare the technology based detailed project reports (DPRs) for a minimum of five technologies in three capacities for each technology.

Facilitation of innovative financing mechanisms for implementation of energy efficiency projects

The objective of this activity is to facilitate the uptake of energy efficiency measures through innovative financing mechanisms without creating market distortion

1 INTRODUCTION

1.1 Brief Introduction about cluster

Morbi SME Cluster is one of the largest ceramic clusters in India and mainly famous for manufacturing of ceramic tiles. Over 70% of total ceramic tiles product comes from Morbi cluster. This cluster is spread over a stretch of about 10km on the Morbi–Dhuva Highway.

There are approximately 479 ceramic units in this cluster which are engaged in manufacturing of wall tiles, vitrified tiles, floor tiles, sanitary wares, roofing tiles and others product. There are around 50 more ceramic units coming up in Morbi cluster.

Primary raw materials required for manufacturing of tiles are various types of clay, quartz, calcite/wool astonite, frits & Glazes. Most of the raw materials are easily available in Gujarat and in the neighboring state of Rajasthan. Some of the units use raw material produced at another plant. The main reason for growth of ceramic cluster in Morbi is easy availability of raw material viz; clay suitable for ceramic tiles.

The main form of energy used by the cluster units are grid electricity, Natural Gas, charcoal, lignite, and diesel oil. Major consumptions of energy are in the form of Natural Gas and lignite. Details of total energy consumption at Morbi ceramic cluster are furnished in Table 1.1 below:

Table 1.1 Details of annual energy consumption

S. No	*Type of Fuel*	*Unit*	*Value*	*% contribution*
1	Electricity	GWh/year	1,200	8.23
2	Natural Gas	SCM/year	660,000,000	46.32
3	Charcoal	tonne/year	165,000	8.55
4	Lignite	tonne/year	1,320,000	36.84
5	Diesel	litre/year	800,000	0.06

Classification of Units

The ceramic units can be broadly categorized into four types based on product manufactured

- Floor tiles unit
- Sanitary ware unit
- Vitrified tiles unit
- Wall tiles unit

Further the ceramic cluster is classified into three type based on capacity of unit viz small scale, medium scale and large scale unit.

Products Manufactured

There are many types of ceramic product manufactured from four different types of units. Details of product manufactured and number of units engaged in manufacturing of such products are given in Table 1.2 below:

Table 1.2 Details of types of product manufactured

S. No	Type of Product	No. of unit	%age share
1	Wall Tiles	178	37
2	Vitrified Tiles	36	8
3	Floor Tiles	52	11
4	Sanitary Wares	43	9
5	Spray dryer Mud manufacturing	40	8
6	Roofing Tiles (seasonal operation)	120	25
7	Third firing manufacturing (Producing pictures on tiles)	10	2
8	Total	479	

Capacity wise production

Capacity wise production breakup is furnished in Table 1.3 below:

Table 1.3 Production wise unit breakups

Type of product	No. of Units.				Production (m^2/day or MT[a]/day)			
Scale of Unit	Small	Medium	Large	Total	Small	Medium	Large	Total
Wall Tiles	43	100	35	178	2,500	3,500	7,500	13,500
Floor Tiles	8	38	6	52	3,000	4,000	7,000	14,000
Vitrified Tiles	NA	22	4	26[b]	NA	5,760	11,520	17,280
Sanitary Wares	10	24	9	43	4	8	14	26

[a]- In case of sanitary wares, production is measured in MT.
[b]- During audit no SSI vitrified tiles units were covered, therefore production data are not available for these units.

Energy usages pattern

Average monthly electricity consumption in ceramic unit ranges from 1 lakh to 2 lakh kWh depending on the size of the unit. In thermal energy, solid fuel such as lignite, charcoal, Indonesian coal, briquette, etc are used in spray dryer and natural Gas is used in kiln in all almost all units. Solid fuel consumption in spray dryer ranges from 80 to 160 kg per MT and. natural Gas consumption in kiln varies from 1.01 to 1.4 SCM per m^2 of tiles produced.

General production process for ceramic cluster

The units of Morbi ceramic cluster are involved in the manufacturing of four different types of products such as floor tiles, wall tiles, vitrified tiles and sanitary wares. Production process for manufacture of wall, floor and vitrified tiles is nearly the same except some differences in process parameters while the manufacturing process of sanitary wares inter alia involves manual moulding whereas in case of tiles, press is used to form the biscuits. General production processes for manufacturing of ceramic products is are following:

Wet Grinding

The raw material such as clay, feldspar, quartz, calcite etc. are mixed with water in a proper proportion and grind in a ball mill to make homogeneous mixture. Ball Mill is a batch type of process. After completion of one batch of ball mill, slurry is sent to the underground tanks containing the agitator motor in each tank to maintain the uniformity of mixture. Mainly blungers are used for mixing and grinding in case of wall and floor tiles, while ball mills are used for grinding in case of vitrified tiles.

Spray Drying

After preparation of slurry of required density it is stored in the underground tanks in which it is agitated to maintain uniformity of slurry. The slurry is then pumped through a hydraulic pump into the spray dryer where it is sprayed through nozzles. The material is dried in spray dryer to remove the moisture added during the grinding process in a ball mill. The moisture in the raw material is brought down to about 5–6 % from 35-40%. The product from spray dryer is stored in silos. Hot flue gases at a temperature of about 550 – 600 °C is used as the heating source which is generated by combustion of lignite, Indonesian coal, saw dust, briquette, natural gas etc.

Pressing/Moulding

The product from spray dryer is then sent to the press section which is pneumatically operated where the required sizes of biscuit tiles are formed. In case of sanitary ware manual moulding is carried out by hand held hose.

Drying

After pressing/moulding products containing about 5–6% moisture is dried to about 2–3% moisture in a dryer. In some units, hot air from kiln cooling zone exhaust is used in dryers and additional fuel firing is provided if required whereas in case of wall and floor tiles, fuel firing is done continuously.

Glazing

After drying, biscuit tiles are send for glazing on a glaze line. Glaze is prepared in ball mills. Glazing is required for designing on tiles. In case of sanitary ware the dried wares are glazed in several spray glazing booths, where compressed air is used.

Firing and Baking

After glazing product are then sent for final firing in kiln where temperature of 1100-1150 ^{o}C is maintained in the kiln. Natural gas is used for combustion in kiln. In some units hot air from gasifier is utilized for combustion.

Sizing

Tiles coming out of kiln are sent for sizing and calibration in case of wall and floor tiles. The tiles are cut in proper sizes so that all tiles have similar dimensions. After sizing the finished product is ready for dispatch.

Polishing

Polishing is required for vitrified tiles. It utilizes 40-45% of total electricity consumption of plant. After kiln the vitrified tiles are passed through polishing line. Polishing line consist of sizing, calibration and polishing machines.

General production process flow diagram for manufacturing of ceramic product is shown in Figure 1.1.

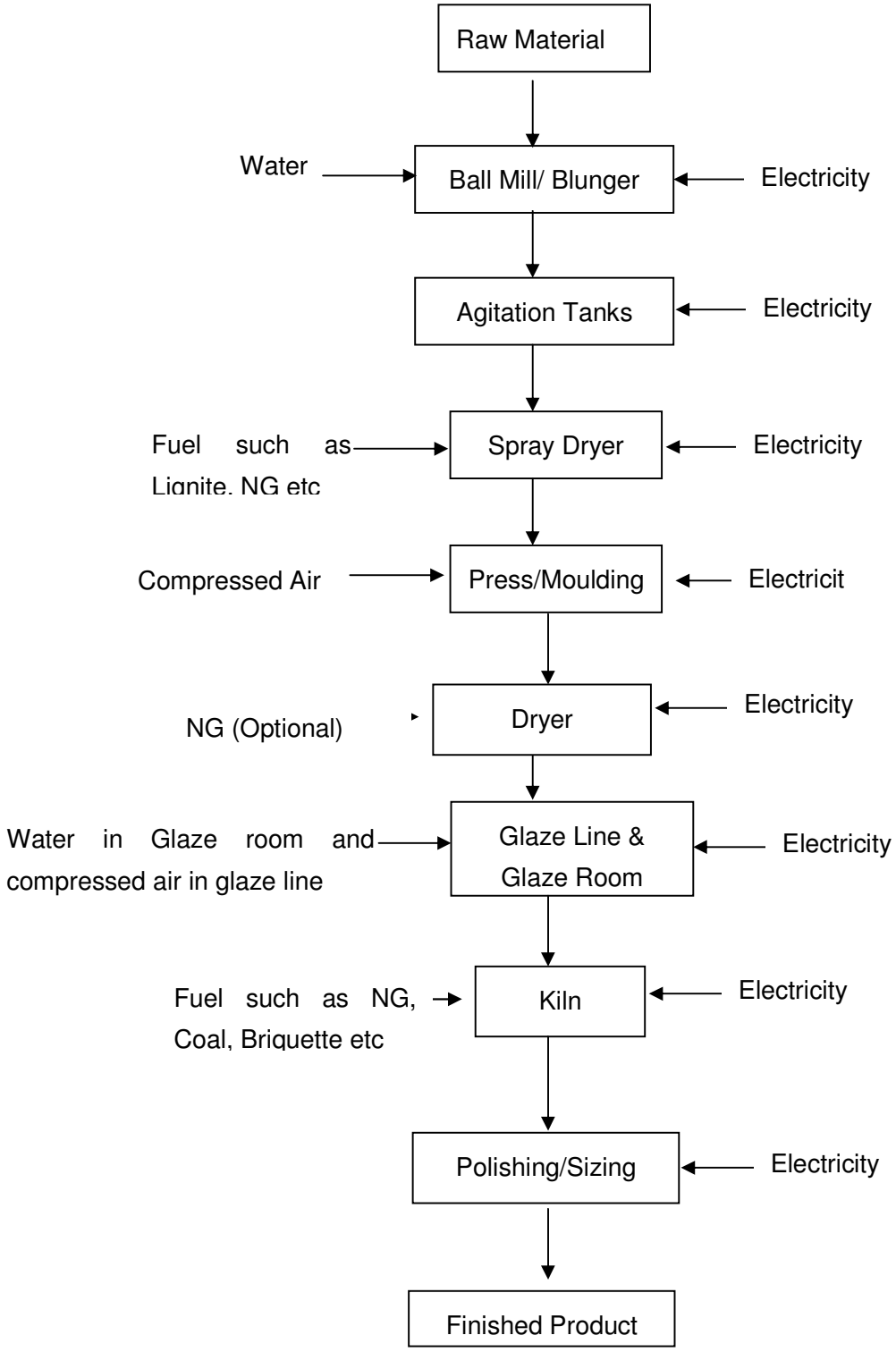


Figure 1.1Process flow diagram

1.2 Energy performance in existing system

1.2.1 Fuel consumption

Average fuel and electricity consumption in a typical ceramic unit is given in Table 1.4 below:

Table 1.4 Average fuel and electricity consumption

Energy	*Electricity (MWh per year)*			*Natural gas (SCM per year)*			*Solid Fuel [lignite] (Tonne per year)*		
Scale of Unit	*Small*	*Medium*	*Large*	*Small*	*Medium*	*Large*	*Small*	*Medium*	*Large*
Wall Tiles	900	1500	2400	750,000	1,050,000	2,250,000	2,400	2,880	3,600
Floor Tiles	900	1500	2400	900,000	1,200,000	2,100,000	3,600	4,200	4,800
Vitrified Tiles	NA	6000	12000	NA	2,700,000	6,000,000	NA	6,000	9,000
Sanitary Wares	2400	450	900	120,000	240,000	420,000	NA	NA	NA

1.2.2 Average annual production

Annual production in terms of m^2/year is taken in case of tiles and in terms of MT/year in case of sanitary wares is given in the following Table 1.5 below:

Table 1.5 Average annual production

S. No.	*Type of Industry*	*Production (m^2/year) or MT/year*		
		Small scale	*Medium scale*	*Large scale*
1	Vitrified Tiles	750,000	1,050,000	2,250,000
2	Wall Tiles	900,000	1,200,000	2,100,000
3	Floor Tiles	NA	1,728,000	3,456,000
4	Sanitary Wares	1200	2400	4200

1.2.3 Specific energy consumption

Specific energy consumption both electrical and thermal energy per m^2 or MT of production for different type of ceramic products are furnished in Table 1.6below:

Table 1.6 Specific energy consumption

S. No.	Type of Industry	kWh/m^2 or kWh/piece[c]	SCM/m^2 or SCM/ piece[c]
1	Vitrified Tiles	3.71 - 5.01	1.51 - 3.11
2	Wall Tiles	0.61 - 2.47	0.68 - 1.65
3	Floor Tiles	1.51 - 1.92	1.28 - 1.8
4	Sanitary Wares	0.78 - 1.73	1.10 - 1.49

Equipment wise specific energy consumption

The specific energy consumption of the equipments used in the ceramic industry is given in Table 1.7 below wherever possible.

Table 1.7 Equipment wise specific energy consumption

S.No	Equipment	Electrical energy		Thermal energy	
		Unit	Vale	Unit	value
1	Ball Mill/Blunger	kWh/MT	4 -12		-
2	Agitation process	kWh/m^3/hr	0.2 - 0.8		-
3	Spray Dryer	-	-	kg/MT	80 - 160
4	Press	kWh/m^2	0.22- 0.4		-
5	Dryer	kWh/m^2	0.011	SCM/m^2	0 - 0.63
6	Glaze line + Glaze ball mill	kWh/MT	2 - 9		-
7	Kiln	kWh/m^2	0.36 - 1.26	SCM/m^2	1.01 -1.4
8	Polishing line/sizing	kWh/m^2	1.74 - 2.35		-

[c] *In sanitary ware production is measured in term of pieces only.*

1.3 Existing technology/equipment

1.3.1 Description of existing technology

Roller kiln is used for final firing of tiles to get the finished product. Natural gas is used as a fuel in roller kiln. Tiles are fired upto a temperature of about 1200 ^{o}C. There are two sources of exhaust from the roller kiln. One is flue gas from the preheating zone of the roller kiln which is at a temperature of about 249 ^{o}C. The other exhaust is the hot air from the final cooling zone which is at a temperature of about 250 to 300 ^{o}C. This hot air is already utilized in almost by all the ceramic unit owners for drying or heating purpose. But the waste heat of flue gas is not utilized in any of the ceramic unit due to presence of sulphur in flue gas. Utilization of flue gas for preheating of combustion air leads to saving in fuel consumption in roller kiln.

1.3.2 Role in process

Roller kiln is used for final firing of the tiles to get the finish product. Natural gas is used as a fuel in roller kiln. Ceramic tiles are fired upto a temperature of about 1200 oC in the roller kiln. It removes the moisture present in the product and also improves the strength of the products by firing at higher temperature

1.4 Baseline establishment for existing technology

1.4.1 Design and operating parameters

In roller kiln, one of the requirements is that the product should be heated upto a temperature of about 1200 ^{o}C. Electrical and thermal energy consumptions in roller kiln for different ceramic products are given in Table 1.8 below:

Table 1.8 Electricity and thermal energy consumption in roller kiln

S. No.	*Product type*	*Electricity consumption kWh/year*	*Natural gas consumption SCM/year*
1	Vitrified Tiles	54,58,560	24,57,213
2	Wall Tiles	9,41,700	6,30,382
3	Floor Tiles	36,62,510	43,77,434

1.4.2 Operating efficiency analysis

Operating efficiency of roller kilns is found to be in the range of 30 % to 40 % varies from unit to unit. Detailed parameters and calculations used for operating efficiency evaluation of roller kiln efficiency are given in the Annexure 1.

1.4.3 Specific electricity consumption

In roller kiln, electrical energy is utilized for running blowers. Specific energy consumption for both electrical energy and thermal energy for different ceramic products of roller kiln are given in Table 1.9 below:

Table 1.9 Specific electricity consumption in roller kiln

S. No.	*Product type*	*Production m^2/day*	*Electricity consumption kWh/m^2*	*Natural gas consumption SCM/m^2*
1	Vitrified Tiles	5929	5.01	2.26
2	Wall Tiles	2118	2.47	1.65
3	Floor Tiles	3344	1.92	1.8

1.5 Barriers in adoption of proposed equipment

1.5.1 Technological barrier

This technology is known to everyone but unit owners don't want to take initiative to implement this project because of the fear of corrosion due to presence of sulphur in flue gas. Corrosion will occur due to improper selection of material of construction of recuperator. Technology providers of this project available at Morbi have least interest in taking up this type of projects.

1.5.2 Financial barrier

Availing finance is not the major issue. Among the SMEs, the larger units, if convinced, are capable of either financing it themselves or get the finance from their banks. The smaller units will require competitive loan and other support to raise the loan. SIDBI loan will play a catalytic role in implementation of this project.

1.5.3 Skilled manpower

At Morbi ceramic cluster, the availability of skilled manpower is one of the limitations due to more number of ceramic units. One local technical persons available at Morbi takes care of about 5 - 10 ceramic units. For major equipments of ceramic units like kiln, Polishing Machine etc maintenance or the repair work of these equipments will be taken by the equipment suppliers itself even the suppliers like Sacmi, KEDA, Modena etc depute one of their representative staying at Morbi for the maintenance work. Local technical persons of Morbi takes care As not many experts/skilled persons are available in the cluster, one expert takes care of all maintenance & operational problems of about 5 - 10 industries.

1.5.4 Other barrier (If any)

After discussion with the plant person during our audit, many of them agreed with the possible saving measures but they demand demonstration of same energy saving technologies in some other plant thereafter they have readiness to follow.

2. PROPOSED EQUIPMENT FOR ENERGY EFFICENCY IMPROVEMENT

2.1 Description of proposed equipment

2.1.1 Detailed of proposed equipment

For utilizing exhaust heat of flue gas a waste heat recovery system i.e. recuperator has been installed on roller kiln. Recuperator takes heat from the waste flue gas and transfer to the combustion air through heat exchanger. It preheats the combustion air upto a temperature of about 150 to 200 ^{o}C before supply to the roller kiln. For implementation of this measure, require the following:

- Design of recuperator
- Piping arrangement
- Instrumentation system for proper monitoring

2.1.2 Equipment/technology specification

For implementation of the waste heat recovery system on roller kiln of vitrified tiles manufacturing plant having production capacity of about 5929 m^2/day, equipment specification and operating parameters are also shown in Table 2.1 below and further details of technical and equipment specification are given in Annexure 8.

Table 2.1 Equipment specification and operating parameter

S. No.	Particulars	Unit	Existing Technology	Proposed equipment
1	Flue gas flow rate	m^3/hr	3365	3365
2	Combustion air flow rate	m^3/hr	2968	2968
3	Inlet combustion air temperature	^{0}C	40	180
4	Outlet flue gas temperature	^{0}C	249	125
5	Heat transfer area of recuperator	m^2	32	
6	Overall heat transfer coefficient	KCal/m^2-hr-^{0}C	52	

2.1.3 Integration with existing equipment

Implementation of this technology on a roller kiln will require the design of recuperator based on the operating parameters and the arrangement for retrofitting of recuperator at the exhaust of roller kiln from preheating zone. Presently, flue gas at a temperature of about 249 oC is released to atmosphere.

This technology has been selected for the following reasons:

- In ceramic tiles unit, around 50 % of the thermal energy is consumed in kiln.
- It reduces the fuel consumption in roller kiln.
- It significantly increases efficiency of the Kiln.
- Resulting in reduction in GHG emissions.
- Technology is easily available.

2.1.4 Superiority over existing system

In this technology we are utilizing waste heat of flue gas. This leads to reduction in natural gas consumption in roller kiln.

2.1.5 Source of equipment

This technology is already in use in furnaces in which the operating temperature is same like in kilns. They also got the results of reduction in fuel consumption and the technology is running successfully.

2.1.6 Availability of technology/equipment

This is one of the well known technologies in market. Many of the persons already know about this technology but had not implemented it. The main reason is that lack of initiative and fear of corrosion of equipment after utilizing the flue gas of roller kiln. Many of the suppliers of this technology are available at Gujarat.

2.1.7 Service providers

Details of technology service providers are shown in Annexure 7.

2.1.8 Terms and conditions in sales of equipment

The Heat Exchanger shall be guaranteed to give the desired thermal performance as indicated. Also guarantee the Heat Exchanger against defective material or faulty workmanship for a period of twelve months from date of commissioning or eighteen months from date of supply, whichever is earlier. However we do not take Guarantee for Corrosion Related Issues

2.1.9 Process down time

Technology supplier will completely prepare the recuperator based on the measured and collected parameters on their site. For retrofitting work, process down time require will be of 12 days. Details of process down time are given in Annexure 6.

2.2 Life cycle assessment and risks analysis

Life cycle of provided heat exchanger is about 5 years but it needs cleaning at regular intervals to achieve the better performance.

The factors which effects the implementation of this technology are as follows

- Lack of initiative of the unit owner
- Always have attitude that we implement only after seeing the same installation in same unit
- Delay in implementation due to requirement of breakdown of plant

2.3 Suitable unit for Implementation of proposed technology

Suitable unit for implementation of this technology has been considered which engaged in manufacturing of vitrified tiles having production capacity of about 5929 m^2 per day (15980 tiles per day of size 2 ft x 2 ft) is considered.

3. ECONOMIC BENEFITS FROM PROPOSED TECHNOLOGY

3.1 Technical benefit

3.1.1 Fuel saving

Preheating of combustion air by the flue gas leads to savings of about 3% of total fuel consumption in roller kiln. Total Natural gas saving is about 69,620 SCM per year.

3.1.2 Electricity saving

This project does not reducing the electricity consumption in tunnel kiln however this will increase the electricity consumption which is negligible.

Effects of recuperator on the existing FD Fan load

Power consumption of FD fan will increase due to resistance develop to travel through recuperator. But this is very small. In this case, new blower shall be required. But it is not necessary at all sites. In some cases, we can use the existing blower also which depends on the present operating load. The cost of new blower is already considered in the project cost.

3.1.3 Improvement in product quality

Product quality achieved would be same as in the present quality. It does not have any impact on the improvement in the quality of the product.

3.1.4 Increase in production

Implementation of this project will not lead to any increase in production.

3.1.5 Reduction in raw material

Raw material consumption is same even after the implementation of proposed technology.

3.1.6 Reduction in other losses

There is no other reduction losses

3.2 Monetary benefits

Implementation of proposed project saves about 69,620 SCM Natural gas per year hence, total monetary benefit is ₹ 10.44 per year. Detail of monetary saving is furnished in table 3.1 below:

Table 3.1 Energy and monetary benefit

S.No	*Parameter*	*Unit*	*Value*
1	Present Natural gas consumption	SCM/day	9540

S.No	Parameter	Unit	Value
2	Natural gas consumption after project implementation	SCM/day	9236
3	Total working days	days/year	236
3	Total Natural gas saving	SCM/day	295
5	Cost of Natural gas	₹ /SCM	15
6	Total monetary benefit	₹ in lakh/year	10.44

Further details of total monetary benefit are given in Annexure 3.

3.3 Social benefits

3.3.1 Improvement in working environment

No improvement on the working environment in the plant.

3.3.2 Improvement in workers skill

Technical skills of persons will definitely be improved. As the training will be provided by equipment suppliers which improve the technical skills of manpower required for operating of the equipment and also the technology implementation will create awareness among the workforce about energy efficiency and energy saving.

3.4 Environmental benefits

3.4.1 Reduction in effluent generation

There is no significant impact in effluent generation due to implementation of the project.

3.4.2 Reduction in GHG emission

Implementation of this project will result in saving of Natural gas consumption of about 69,620 SCM per year. This will leads to about 142 tCO_2 emission reduction per year from one ceramic unit. Project can get additional benefit from carbon credit.

3.4.3 Reduction in other emissions like SO_X

Sulphur is not present in Natural gas hence not impact on SO_X emission.

4 INSTALLATION OF PROPOSED EQUIPMENT

4.1 Cost of project

4.1.1 Equipment cost

Total cost of project is about ₹ 6.90 lakh which includes design and fabrication of the recuperator.

4.1.2 Erection, commissioning and other misc. cost

Other cost includes cost of commissioning, implementation during implementation and man power cost. Details of total project cost requires for implementation of proposed technology are furnished in Table 4.1 below:

Table 4.1 Details of proposed technology project cost

S.No	Particular	Unit	Value
1	Cost of recuperator	₹ (in lakh)	6.90
2	Erection & Commissioning cost	₹ (in lakh)	0.35
3	Interest during implementation	₹ (in lakh)	0.18
4	Taxes(VAT)	₹ (in lakh)	0.35
5	Other misc. cost	₹ (in lakh)	0.69
5	Total cost	₹ (in lakh)	8.46

4.2 Arrangements of funds

4.2.1 Entrepreneur's contribution

The total cost of the proposed technology is estimated at ₹ 8.46 lakh. The entrepreneur's contribution is 25% of total project cost, which is ₹ 2.12 lakh.

4.2.2 Loan amount.

The term loan is 75% of the total project cost, which is ₹ 6.35 lakh.

4.2.3 Subsidy by Government

As the overall energy efficiency in the project is more than 15% it qualifies for subsidy of 25 % of the project cost as per the NMCP scheme of Ministry of MSME, GoI. 25 % of the project cost in this case works out to ₹ 2.12 lakh. As the subsidy is normally available after implementation of the project the same has not been taken in the project cost and means of finance. On receipt of subsidy from Ministry of MSME, GoI through the nodal agency the amount of subsidy is generally set off [reduced] from the loan outstanding by the lender bank. Availability of this subsidy will make the project economically more attractive.

4.2.4 Terms & conditions of loan

The interest rate is considered at 10% which is SIDBI's rate of interest for energy efficient projects. The loan tenure is 4 years excluding initial moratorium period is 6 months from the date of first disbursement of loan.

4.3 Financial indicators

4.3.1 Cash flow analysis

Profitability and cash flow statements have been worked out for a period of 5 years. The financials have been worked out on the basis of certain reasonable assumptions, which are outlined below.

The project is expected to achieve monetary savings of 10.44 lakh per year.

- The Operation and Maintenance cost is estimated at 5% of cost of total project with 3% increase in every year as escalations.
- Interest on term loan is estimated at 10%.
- Depreciation is provided as per the rates provided in the companies act.

Considering the above mentioned assumptions, net cash accruals starting with ₹ 7.60 lakh in the first year operation and gradually increases to ₹ 28.07 lakh at the end of fifth year.

4.3.2 Simple payback period

The total project cost of the proposed technology is ₹ 8.46 lakh and monetary savings is ₹ 10.44 lakh hence the simple payback period works out to be 0.80 years.

4.3.3 Net Present Value (NPV)

The Net present value of the investment at 10% works out to be ₹ 19.25 lakh.

4.3.4 Internal rate of return (IRR)

The after tax internal rate of return of the project works out to be 89.28%. Thus the project is financially viable.

4.3.5 Return on investment (ROI)

The average return on investment of the project activity works out at 20.76%.

Details of financial indicator are shown in Table 4.2 below:

Table 4.2 Financial indicators of proposed technology/equipment

S.No	Particulars	Unit	Value
1	Simple Pay Back period	Month	10
2	IRR	%age	89.28
3	NPV	lakh	19.25
4	ROI	%age	41.62
5	DSCR	Ratio	4.51

4.4 Sensitivity analysis

A sensitivity analysis has been carried out to ascertain how the project financials would behave in different situations like when there is an increase in fuel savings or decrease in fuel savings. For the purpose of sensitive analysis, two following scenarios has been considered

- Optimistic scenario (Increase in fuel savings by 5%)
- Pessimistic scenario (Decrease in fuel savings by 5%)

In each scenario, other inputs are assumed as a constant. The financial indicators in each of the above situation are indicated along with standard indicators.

Details of sensitivity analysis at different scenarios are shown in Table 4.3 below:

Table 4.3 Sensitivity analysis at different scenarios

Particulars	DSCR	IRR	ROI	NPV
Normal	4.51	89.28%	41.62%	19.25
5% increase in fuel savings	4.29	84.62%	41.19%	17.95
5% decrease in fuel savings	4.72	93.89%	42.02%	20.56

4.5 Procurement and implementation schedule

Total procurement and implementation period required for implementation of this technology is 14 weeks and process down time requires 12 days their details are shown in Annexure 6.

Annexure

Annexure -1: Energy audit data used for baseline establishment

Efficiency calculation and heat balance of roller kiln in ceramic are as given below.

Input Data

S. No.	Parameter	Unit	Value
1	Natural Gas Consumption	SCM/day	9540
2	Hydrogen in fuel	%age	25
3	Carbon in fuel	%age	74
4	Weight of one tile going to kiln	kg	8.94
5	Weight of one tile coming out from kiln	kg	8.5
6	CO_2 in flue gas	%age	15.4
7	Production from kiln	tiles/day	15980
8	Production from kiln	m^2/day	5929
9	Production from kiln	MT/day	136
10	kiln Cycle time	min	49
11	Highest heating temperature in firing zone	^oC	1223
12	Smoke air (flue gas) temperature	^oC	249
13	Hot air temperature from indirect cooling zone	^oC	324
14	Hot air temperature from final cooling zone	^oC	108
15	Density of air	kg/m^3	1.129
16	Specific heat capacity of air	kCal/kg ^oC	0.24
17	Specific heat capacity of flue gas	kCal/kg ^oC	0.23
18	Inlet temperature of product	^oC	60
19	Outlet temperature of product	^oC	200
20	Initial temperature of flue gas	^oC	249
21	Final temperature of flue gas	^oC	125
22	Temperature of ambient air	^oC	40

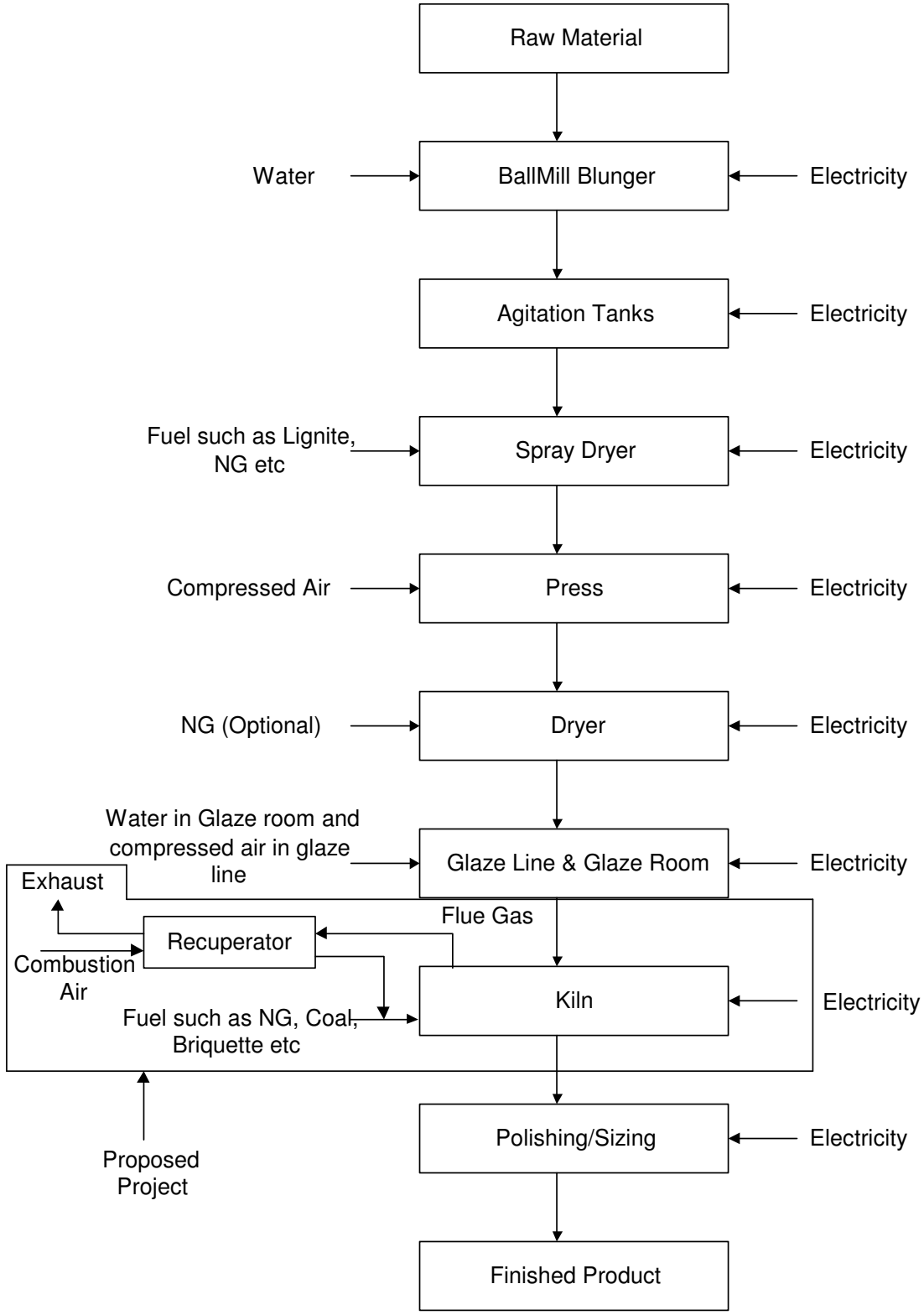
Calculation Data

S. No.	Parameter	Unit	Value
1	Moisture removed from tiles	MT/day	7.03
2	Flue gas Flow rate	kg/day	81274
3	Hot air from indirect cooling zone	m^3/day	269934
4	Hot air from final cooling zone	m^3/day	506998
5	Heat input by fuel	kCal/day	839520000

Heat Distribution in Kiln

S. No.	Heat taken source	Unit	Value	%age
1	Product	kCal/day	3613078	4.30
2	Flue gas (Pre heating Zone Exhaust)	kCal/day	4411490	5.25
3	Radiation loss	kCal/day	6249564	7.44
4	Hot Air from heat exchange cooling zone or rapid cooling zone	kCal/day	20775292	24.75
5	Hot air from final cooling zone/suction cooling	kCal/day	28853401	34.37
6	Loss due to hydrogen present in fuel	kCal/day	8732606	10.40
7	Loss due to moisture present in tile	kCal/day	4690162	5.59
8	Unaccounted loss	kCal/day	6626408.2	7.89
9	Total heat input	kCal/day	83952000	100.00
10	Heat required to heat the product	kCal/day	30051920	
11	Efficiency of roller kiln	%age	35.79	

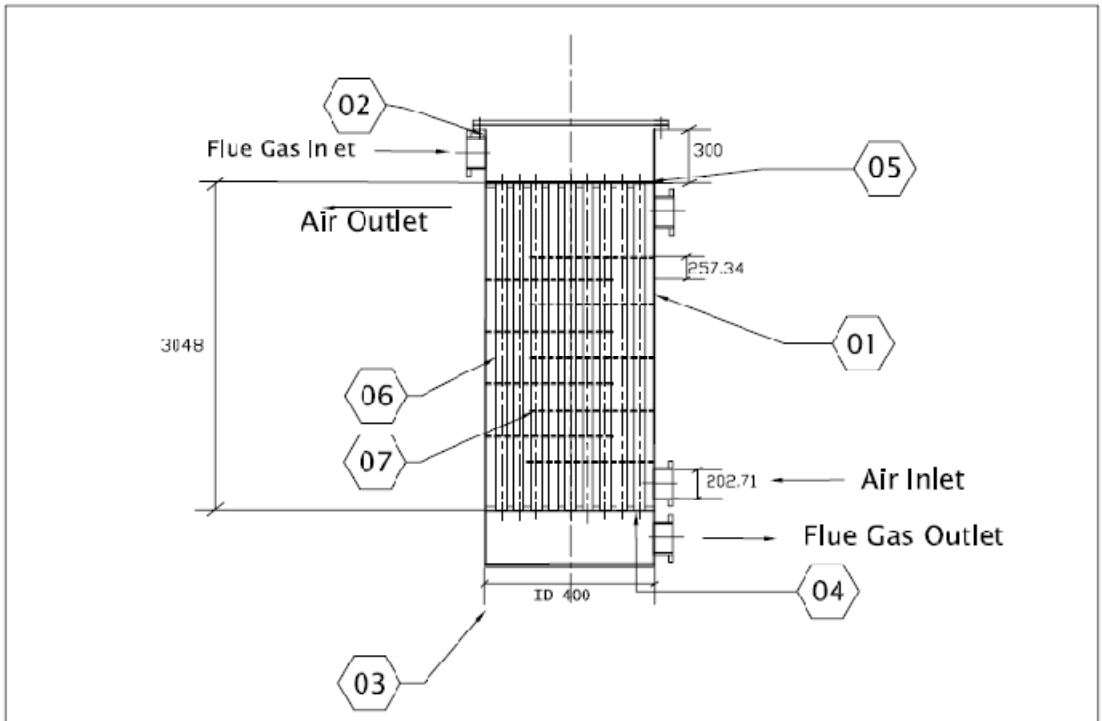
Annexure -2: Process flow diagram after project implementation

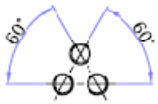


Annexure -3: Detailed technology assessment report

Sr. No.	Particulars	Unit	Existing Technology	Proposed equipment
1	Flue gas flow rate	m^3/hr	3365	3365
2	Combustion air flow rate	m^3/hr	2968	2968
3	Inlet combustion air temperature	^0C	40	180
4	Outlet flue gas temperature	^0C	249	125
5	Heat transfer area of recuperator	m^2		32
6	Overall heat transfer coefficient	$KCal/m^2\text{-}hr\text{-}^0C$		52
7	Flue gas flow rate	m^3/hr		3365
8	Natural gas consumption	SCM/day		9540
9	Combustion air flow rate	m^3/hr		2968
10	Flue gas temperature	^oC		249
11	Combustion air temperature	^oC		40
12	Final temperature of flue gas	^oC		125
13	Heat available in exhaust flue gas	Kcal/hr		108350
14	Heat gain by combustion air	Kcal/hr		108350
15	Final temperature of combustion air achieved	^oC		175
16	Equivalent Natural gas saving	SCM/day		295
17	Calorific value of Natural gas	kCal/SCM		
18	Total operating days	days		236
19	Monetary benefit	₹ in lakh/year		10.44

Annexure -4 Drawings for proposed electrical & civil works





PITCH DETAIL

184 NOS. OD 19.05 ø HOLES ON
25.33 mm TRIANGULAR PITCH

Drawing is not to scale
All Dimensions are in mm.

SR. NO.	DESCRIPTION	SIZE	MATERIAL
01	SHELL	400 ID x 3048 HT X 6 MM Thk.	Carbon Steel
02	TOP SHELL	400 ID x 300 HT X 6 MM Thk.	Carbon Steel
03	BOTTOM SHELL	400 ID x 300 HT X 6 MM Thk.	Carbon Steel
04	BOTTOM TUBE SHEET	25 Thk. x 400 O.D	SS - 316
05	TOP TUBE SHEET	25 Thk. x 400 O.D	SS - 316
06	TUBES	19.05 MM.OD x 3.048 M HT	SS - 316
07	BAFFEL	ID 400 X 10 Thk.	Carbon Steel
08	NO. OF TUBES	184 Nos	
09	CLADDING		ALLIUMINIUM , 22 g.
10	INSULATION		GLASSWOOL , 75 MM THK.
11	GASKET		CAF
12	BOLTS & NUTS		STD

Annexure -5: Detailed financial analysis

Assumption

Name of the Technology	*Recuperator on Roller Kiln*		
Rated Capacity			
Details	***Unit***	***Value***	***Basis***
Installed Capacity	MW		Feasibility Study
No of working days	Days	236	Feasibility Study
No of Shifts per day	Shifts	3	Feasibility Study
Capacity Utilization Factor	%		Feasibility Study
Proposed Investment			
Plant & Machinery	₹ (in lakh)	6.90	Feasibility Study
Erection & Commissioning	₹ (in lakh)	0.35	Feasibility Study
Investment without IDC	₹ (in lakh)	7.25	Feasibility Study
Interest During Implementation	₹ (in lakh)	0.18	Feasibility Study
Taxes(VAT)	₹ (in lakh)	0.35	Feasibility Study
Other charges(Contingency)	₹ (in lakh)	0.69	Feasibility Study
Total Investment	₹ (in lakh)	8.46	Feasibility Study
Financing pattern			
Own Funds (Equity)	₹ (in lakh)	2.12	Feasibility Study
Loan Funds (Term Loan)	₹ (in lakh)	6.35	Feasibility Study
Loan Tenure	years	4	Assumed
Moratorium Period	Months	6	Assumed
Repayment Period	Months	54	Assumed
Interest Rate	%	10.00	SIDBI Lending rate
Estimation of Costs			
O & M Costs	% on Plant & Equip	5.00	Feasibility Study
Annual Escalation	%	3.00	Feasibility Study
Estimation of Revenue			
Natural Gas saving	SCM	69620	
Cost of Natural gas	Rs. / SCM	15	
St. line Depn.	%age	5.28	Indian Companies Act
IT Depreciation	%age	80.00	Income Tax Rules
Income Tax	%age	33.99	Income Tax

Estimation of Interest on Term Loan *(₹ in lakh)*

Years	*Opening Balance*	*Repayment*	*Closing Balance*	*Interest*
1	6.35	0.66	5.69	0.57
2	5.69	1.44	4.25	0.50
3	4.25	1.56	2.69	0.35
4	2.69	1.68	1.01	0.19
5	1.01	1.01	0.00	0.03
		6.35		

WDV Depreciation

Particulars / years	***1***	***2***	***3***	***4***
Plant and Machinery				
Cost	7.43	1.49	0.30	0.06
Depreciation	5.94	1.19	0.24	0.05
WDV	1.49	0.30	0.06	0.01

Projected Profitability

Particulars / Years	***1***	***2***	***3***	***4***	***5***
Revenue through Savings					
Fuel savings	10.44	10.44	10.44	10.44	10.44
Total Revenue (A)	10.44	10.44	10.44	10.44	10.44
Expenses					
O & M Expenses	0.42	0.44	0.45	0.46	0.48
Total Expenses (B)	0.42	0.44	0.45	0.46	0.48
PBDIT (A)-(B)	10.02	10.01	9.99	9.98	9.97
Interest	0.57	0.50	0.35	0.19	0.03
PBDT	9.45	9.50	9.64	9.79	9.94
Depreciation	0.45	0.45	0.45	0.45	0.45
PBT	9.00	9.06	9.19	9.34	9.49
Income tax	1.19	2.83	3.20	3.31	3.38
Profit after tax (PAT)	7.81	6.23	6.00	6.03	6.11

Computation of Tax ***₹(in lakh)***

Particulars / Years	***1***	***2***	***3***	***4***	***5***
Profit before tax	9.00	9.06	9.19	9.34	9.49
Add: Book depreciation	0.45	0.45	0.45	0.45	0.45
Less: WDV depreciation	5.94	1.19	0.24	0.05	-
Taxable profit	3.51	8.32	9.40	9.74	9.94
Income Tax	1.19	2.83	3.20	3.31	3.38

Projected Balance Sheet ***₹(in lakh)***

Particulars / Years	***1***	***2***	***3***	***4***	***5***
Liabilities					
Share Capital (D)	2.12	2.12	2.12	2.12	2.12
Reserves & Surplus (E)	7.81	14.04	20.04	26.07	32.18
Term Loans (F)	5.69	4.25	2.69	1.01	0.00
Total Liabilities D)+(E)+(F)	15.61	20.40	24.84	29.19	34.29
Assets					
Gross Fixed Assets	8.46	8.46	8.46	8.46	8.46
Less: Accm. Depreciation	0.45	0.89	1.34	1.79	2.23
Net Fixed Assets	8.01	7.57	7.12	6.67	6.23
Cash & Bank Balance	7.60	12.84	17.72	22.52	28.07
TOTAL ASSETS	15.61	20.40	24.84	29.19	34.29
Net Worth	9.93	16.16	22.16	28.19	34.30
Dept equity ratio	0.57	0.26	0.12	0.04	0.00

Projected Cash Flow: ***₹ (in lakh)***

Particulars / Years	*0*	*1*	*2*	*3*	*4*	*5*
Sources						
Share Capital	2.12	-	-	-	-	-
Term Loan	6.35					
Profit After tax		7.81	6.23	6.00	6.03	6.11
Depreciation		0.45	0.45	0.45	0.45	0.45
Total Sources	8.46	8.26	6.68	6.44	6.48	6.56
Application						
Capital Expenditure	8.46					
Repayment of Loan	-	0.66	1.44	1.56	1.68	1.01
Total Application	8.46	0.66	1.44	1.56	1.68	1.01
Net Surplus	-	7.60	5.24	4.88	4.80	5.55
Add: Opening Balance	-	-	7.60	12.84	17.72	22.52
Closing Balance	-	7.60	12.84	17.72	22.52	28.07

Calculation of Internal Rate of Return ***₹ (in lakh)***

Particulars / months	*0*	*1*	*2*	*3*	*4*	*5*
Profit after Tax		7.81	6.23	6.00	6.03	6.11
Depreciation		0.45	0.45	0.45	0.45	0.45
Interest on Term Loan		0.57	0.50	0.35	0.19	0.03
Salvage/Realizable value	-	-	-	-	-	-
Cash outflow	(8.46)	-	-	-	-	-
Net Cash flow	(8.46)	8.83	7.18	6.80	6.67	6.59
IRR	89.28%					

NPV	19.25

Break Even Point ***₹ (in lakh)***

Particulars / Years	*1*	*2*	*3*	*4*	*5*
Variable Expenses					
Oper. & Maintenance Exp (75%)	0.32	0.33	0.34	0.35	0.36
Sub Total (G)	0.32	0.33	0.34	0.35	0.36
Fixed Expenses					
Oper. & Maintenance Exp (25%)	0.11	0.11	0.11	0.12	0.12
Interest on Term Loan	0.57	0.50	0.35	0.19	0.03
Depreciation *(H)*	0.45	0.45	0.45	0.45	0.45
Sub Total (I)	1.12	1.06	0.91	0.75	0.60
Sales (J)	10.44	10.44	10.44	10.44	10.44
Contribution (K)	10.13	10.12	10.11	10.10	10.09
Break Even Point (L= G/I)	11.07%	10.47%	9.03%	7.47%	5.91%
Cash Break Even {(I)-(H)}	6.66%	6.05%	4.61%	3.05%	1.48%
BREAK EVEN SALES (J)*(L)	1.16	1.09	0.94	0.78	0.62

Return on Investment ***₹ (in lakh)***

Particulars / Years	*1*	*2*	*3*	*4*	*5*	*Total*
Net Profit Before Taxes	9.00	9.06	9.19	9.34	9.49	46.09
Net Worth	9.93	16.16	22.16	28.19	34.30	110.72
						41.62%

Debt Service Coverage Ratio ***₹ (in lakh)***

Particulars / Years	*1*	*2*	*3*	*4*	*5*	*Total*
Cash Inflow						
Profit after Tax	7.81	6.23	6.00	6.03	6.11	32.18
Depreciation	0.45	0.45	0.45	0.45	0.45	2.23
Interest on Term Loan	0.57	0.50	0.35	0.19	0.03	1.65
TOTAL (M)	8.83	7.18	6.80	6.67	6.59	36.06

Debt

Interest on Term Loan	0.57	0.50	0.35	0.19	0.03	1.65
Repayment of Term Loan	0.66	1.44	1.56	1.68	1.01	6.35
TOTAL (N)	1.23	1.94	1.91	1.87	1.04	8.00
Average DSCR (M/N)	4.51					

Annexure:-6 Procurement and implementation schedule

S. No.	Activities	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Design of recuperator														
2	Preparation of recuperator as per design.														
3	Procurement of equipment														
4	Installation of the pipeline system & heat exchanger system														
5	Commissioning of all the components														

Breakdown period of 12 days will be required for implementation of this technology.

S. No.	Activity	No. of Days											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Time period required for cooling down of tunnel kiln												
2	Dismantling												
3	Installation												
4	Piping System along with instrumentation												
5	Insulation												
6	Commissioning												
7	Trial												

Annexure -7: Details of technology service providers

S.No.	*Name of Service Provider and address*	*Contact Person mobile no. and email ID*
1.	Chemequip Industries 451/2 GIDC Makarpura Industrial Estate Vadodara -390 010	Mr. Parthiv Adeshra 09824209898 info@chemiquip.in

Annexure–8: Quotations or Techno-commercial bids for new technology/equipment

Chemiquip Industries
451/2, G.I.D.C Estate, Makarpura Road, Baroda – 390 010
Tele/Fax : 00912652643318, E-mail: info@chemiquip.in

Tuesday, March 30, 2010

REF: CQP/STLP/Q/54/2009-2010

Monika Chaudhari
Manager – Projects
SEE-Tech Solutions Pvt. Ltd.
11/5, Lets Conserve, MIDC InfoTech Park,
Near VRCE Telephone Exchange,
South Ambazari Road,
Nagpur-440 022 (India)

Ref: Your Enquiry for Recurperator.

Sub: Quotation for Design, Manufacture, Supply, of Shell & Tube Type Heat Exchanger (Recurperator) for Heating Combustion of Air.

Dear Sir,

We are pleased to offer quotation for Design, Manufacture, Supply, of Shell & Tube Type Heat Exchanger (Recurperator) for Heating Combustion of Air as per attached specifications.

The details regarding Scope of work, Technical & Commercial Terms & Conditions are as under:

1. OUR SCOPE OF WORK & SUPPLY

Our scope of work & supply will be Design, Manufacture, Supply, of Shell & Tube Type Heat Exchanger (Recurperator) for Heating Combustion of Air as per attached specifications.

2. TECHNICAL DETAILS

2.0 Thermal Design Parameters

As per the enquiry and understanding your requirements, we have considered the following parameters and have worked out the Model, which is most suitable to your needs.

Flue Gases available	3365 SM3/HR (Minimum)
Air Pressure at Inlet	1.00 Kg/cm2 (G)
Combustion Air Temperature Available (At Heat Exchanger Inlet)	40 C (Minimum)

Chemiquip Industries
451/2, G.I.D.C Estate, Makarpura Road, Baroda – 390 010
Tele/Fax : 00912652643318, E-mail: info@chemiquip.in

Combustion Air Pressure Available (At Heat Exchanger Inlet)	1.0 Kg/cm2
Combustion Air Flow Rate (At Heat Exchanger Inlet)	2968 SM3/Hr (Minimum)
Flue Gases Inlet Temperature (Before Heat Exchanger)	249 C (Minimum)
Flue Gases Outlet Temperature (After Heat Exchanger)	125.0 C
Combustion Gas Outlet Temperature (After Heat Exchanger)	160.0 C

2.1 Material of Construction & Schematic Drawing

All the material of the Heat Exchanger shall be of Carbon Steel, which is in contact with Combustion Air.

All the material of the Heat Exchanger shall be of Stainless Steel 304/316 Quality, which is in contact with Flue Gases.

We have assumed BEM Type Heat Exchanger i.e. Straight Tube, Fixed Tube Bundle.

2.2 Guarantee

The Heat Exchanger shall be guaranteed to give the desired thermal performance as indicated above. We shall also guarantee the Heat Exchanger against defective material or faulty workmanship for a period of twelve months from date of commissioning or eighteen months from date of supply, whichever is earlier. However we do not take Guarantee for Corrosion Related Issues.

2.3 Painting

The Heat Exchanger shall be painted with two Coats of Zinc Chromate Primer after Hydro-test on Carbon Steel Parts & Acid Cleaned on SS Parts.

Chemiquip Industries
451/2, G.I.D.C Estate, Makarpura Road, Baroda – 390 010
Tele/Fax : 00912652643318, E-mail: info@chemiquip.in

3 Commercial Terms & Conditions

3.0. Schedule of Rates:

Sr No	Description	Quantity	Rates Rs
1.0	Design, Manufacture, Supply, of Shell & Tube Type Heat Exchanger (Recurperator) for Heating Combustion of Air	1 Nos	6,90,000/- Per Nos

3.1 Vat

Extra, as applicable (presently it is 5.0 %)

3.2 Excise Duty

Not Applicable.

3.3 Payment Terms

50% Advance with order, Balance against Proforma Invoice before delivery.

3.4 Price Validity

Our offer is valid for a period of 30 days, after which the same has to be obtained from us. Our price shall remain firm during the entire execution of the contract

3.6 Delivery Period

We shall effect delivery, ex-works, within 10-12 weeks after receipt of order & advance. We shall however endeavor to effect the delivery at the earliest.

Thanking you,

Yours faithfully,

For Chemiquip Industries

Parthiv Adeshra

Output Summary

Page 1

Released to the following HTRI Member Company:

Xist E Ver. 5.00 30/03/10 18:35 SN: Friendsl **MKH Units**

Design - Vertical Countercurrent Flow TEMA BEM Shell With Single-Segmental Baffles

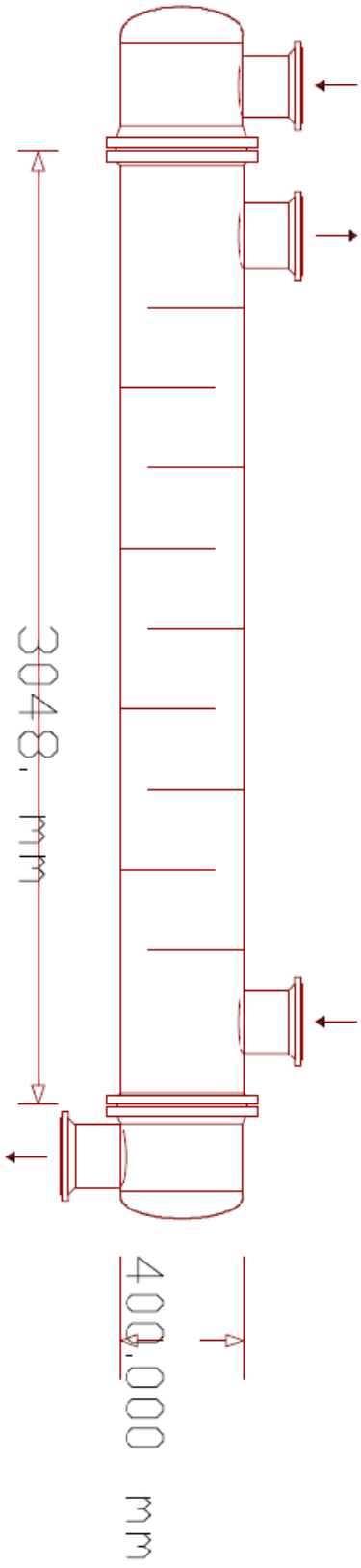
Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		COMBUSTION AIR		FLUE GASES	
Flow rate	(1000-kg/hr)	3.7510			4.2070
Inlet/Outlet Y	(Wt. frac vap.)	1.000	1.000	1.000	1.000
Inlet/Outlet T	(Deg C)	40.00	180.43	249.00	125.00
Inlet P/Avg	(kgf/cm2A)	1.500	1.321	1.500	1.477
dP/Allow.	(kgf/cm2)	0.359	0.500	0.045	0.500
Fouling	(m2-hr-C/kcal)		0.000500		0.000200

Exchanger Performance					
Shell h	(kcal/m2-hr-C)	206.75	Actual U	(kcal/m2-hr-C)	59.99
Tube h	(kcal/m2-hr-C)	110.19	Required U	(kcal/m2-hr-C)	52.13
Hot regime	(--)	Sens. Gas	Duty	(MM kcal/hr)	0.1283
Cold regime	(--)	Sens. Gas	Area	(m2)	32.682
EMTD	(Deg C)	75.3	Overdesign	(%)	15.07

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type	(--)	Single-Seg.
Shell ID	(mm)	400.000	Baffle cut	(Pct Dia.)	23.77
Series	(--)	1	Baffle orientation	(--)	Perpend.
Parallel	(--)	1	Central spacing	(mm)	257.348
Orientation	(deg)	90.00	Crosspasses	(--)	10

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	202.718
Tube OD	(mm)	19.050	Shell outlet	(mm)	202.718
Length	(mm)	3048.	Inlet height	(mm)	22.647
Pitch ratio	(--)	1.3333	Outlet height	(mm)	22.647
Layout	(deg)	30	Tube inlet	(mm)	202.710
Tubecount	(--)	184	Tube outlet	(mm)	202.718
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s		Flow Fractions	
Shell	29.00	Shellside	22.29	A	0.198
Tube	65.87	Tubeside	29.94	B	0.613
Fouling	4.45	Crossflow	29.76	C	0.073
Metal	0.680	Window	54.37	E	0.115
				F	0.000


3048.0 mm
400.000 mm

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