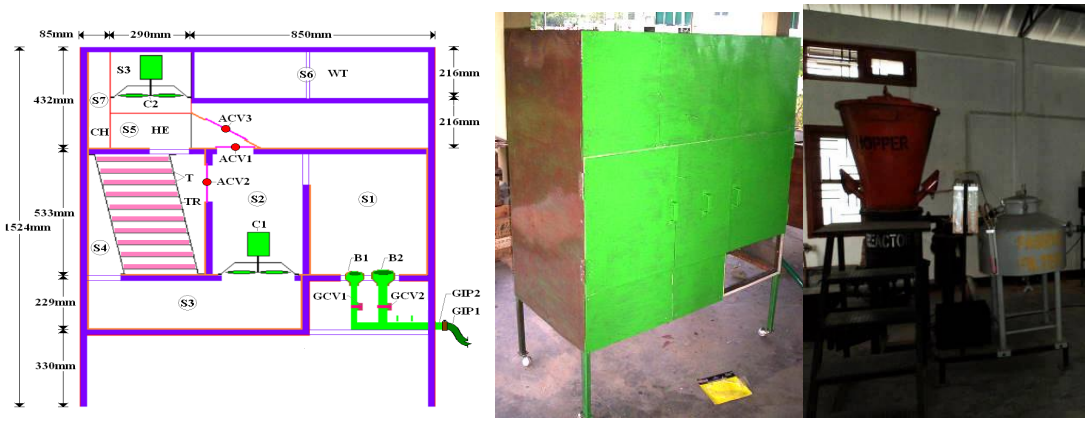
**PROJECT REPORT FOR RPS PROGRAMMES**

File No.: 8023/BOR/RID/RPS-25/2007-08

Subject Area: Renewable Energy Application

Project Title:

# Design and Development of Renewable Energy Hybrid Tea Dryer for Fossil Fuel Substitution in Tea Industry





Project conducted at & Report submitted by:

D C Baruah & PP Dutta

Department of Energy, Tezpur University, Tezpur Assam 784028


Submitted to:

All India Council for Technical Education

NBCC Palace, East Tower, 4th Floor

Bhisham Pitamaha Marg, Pragati Vihar

New Delhi 110003, India

## PROJECT REPORT FOR RPS PROGRAMMES

File No. *(As mentioned in sanction letter)*: 8023/BOR/RID/RPS-25/2007-08

Date of Sanction: March 5, 2008

Subject Area: Renewable Energy Application

1. (a) Principal Investigator (Name & address): D C Baruah, Professor,
   Department of Energy,
   Tezpur University, Tezpur
   Assam 784028

   (b) Co-Investigator: P P Dutta, Assistant Professor
   Dept. of Mechanical Engineering
   Tezpur University, Tezpur
   Assam 784028

2. Project Title: Design and Development of Renewable Energy Hybrid Tea Dryer for Fossil Fuel Substitution in Tea Industry

3. Total Cost of the Project: Rs. 12.5 Lakh

4. Date of Commencement of the Project: April, 30, 2008

5. Duration of the Project: Two Years

6. Date of Completion: March 31, 2011

7. Objectives of the Project:
   - (a) To assess the need of thermal energy for tea drying on temporal basis in representative tea estates in Assam.
   - (b) To assess the temporal availability of "biomass" and "solar radiation" for thermal application in tea drying
   - (c) To design, develop and test of a tea dryer for operation on "biomass" and "solar" hybrid modes and to study the techno-economic viability of the system over conventional system

8. **Salient Research Achievements (Till now)**:

8.1 **New Findings/Achievements/IPR Potential**:

*Findings of the project*

**Characterization of thermal energy demand is assessed through survey and personal visit. Some indicative statistics concerning energy demand in tea processing are noted below:**

There exists temporal variation of thermal energy requirements of drying tea in tea gardens. This is mainly due to production pattern and resulting processing schedule. The thermal energy demands during November to May are lower compared to the demands of remaining months.

The tea garden, where survey was conducted, producing about 2 million kg of made tea per annum, processes about 75% of annual production in five months viz., June (12%), July (15%), August (15%), September (16.6%) and October (17%). A proportionate demand of thermal energy is generated in tea processing (Fig. 1).

Tea gardens located in North bank of Brahmaputra depend on coal as source of thermal energy for drying process. On the other hand, tea gardens located in upper Assam and middle Assam (South bank of Brahmaputra) use natural gas as source of thermal energy due to proximity to gas grid. Occasionally TD oil (tea drying oil) is also used, though higher cost has reduced its use.

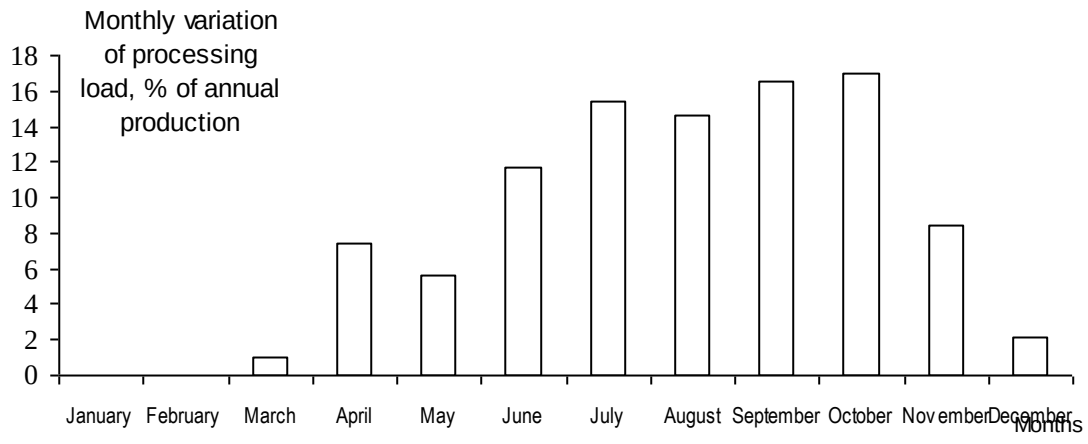



Fig.1 Monthly variation of processing load in a tea processing units with two million kg of annual production

On an average 0.68 kg of coal (with GCV 25 MJ/kg) is required per kg of made tea for drying. The specific energy requirement for coal based drying is more (17.0 MJ/kg) than natural gas based drying (13.5 MJ/kg).

Tea processing units are operated throughout day and night.

**Availability of (i) biomass and (ii) solar radiation for supplementing/substituting fossil fuel are assessed for Sonitpur District. Salient outcomes concerning this assessment are noted below:**

***Biomass resources***

To make woody biomass available for thermal energy demand in tea processing, plantation is to be planned. Promotion of biomass (woody) gasification technology would necessitate additional generation of woody biomass. Woody biomass available in tea gardens (pruning litter and uprooted tea plants) is totally consumed as domestic fuel by workers on an average at the rate of 10-15 kg/day/family. Traditional cook-stove is used which are reported as inefficient. Introduction of improved cook stove could lead to saving of woody biomass for process heat.

Paddy straw biomass is adequately available around tea gardens (Fig. 2). At present straw biomass (left-over portion) is not commercial commodity in this region. Economic analysis of straw biomass utilization through combustion route favours its utilization for process heat generation.

Fig. 2 A paddy field with left-over straw in Sonitpur district

Calorific values of up-rooted tea plant and paddy straw are determined and found as 20 MJ/kg and 14.5 MJ/kg, respectively.

About 93 thousand tonnes of paddy straw biomass is available within 15 km distance of 25 tea gardens (out of 65 tea gardens in Sonitput District) to fulfil more than 100% of their estimated thermal energy demand (28 thousand tonne).

Paddy straw biomass can economically compete with coal as a source of thermal energy in tea processing and contribute to the farmers earning from otherwise waste straw, if coal equivalent price is fixed for straw.

***Solar energy resources***

Temporal variations of the availability of solar radiation as recorded by Automatic Weather Station at Tezpur are noticed. Average daily solar energy availability ($kWh/m^2$) in the months of August (3.47), September (4.25), October (4.04) and November (3.11) are better compared to remaining months (Fig. 3). Thus, peak production/processing of tea are matching with better solar energy availability.

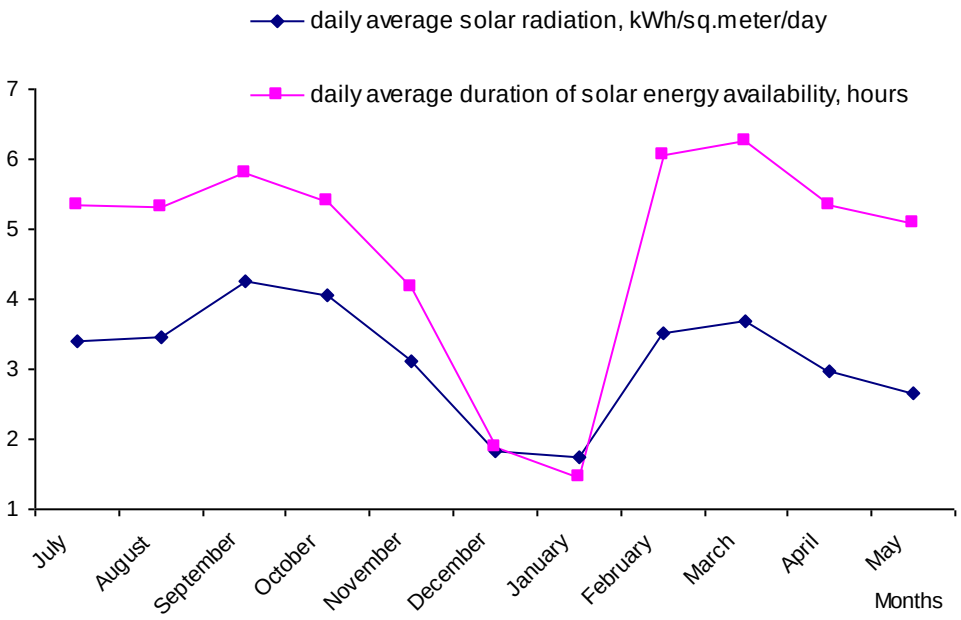



Fig.3 Monthly variation of available solar energy in Tezpur

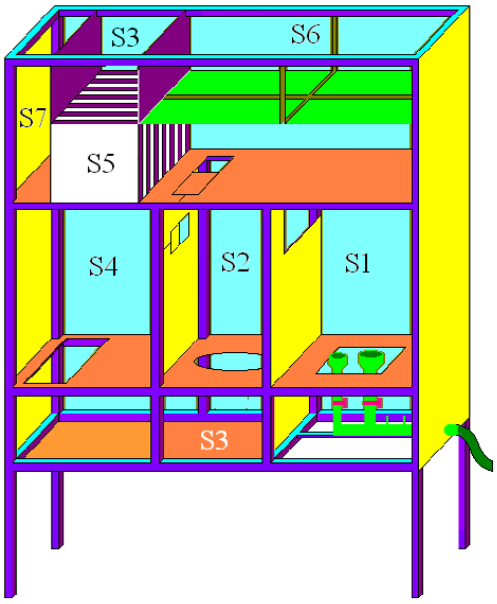
### 8.2 Product Developed:

#### *i) Batch type tea dryer*

A batch type tray dryer (Figs. 4a, 4b & 4c) is designed and developed with a provision of using thermal energy either any one or combination of (a) producer gas (Fig. 5), (b) straw fired hot air (Fig. 6a) and (c) solar generated hot air (Fig 6b).

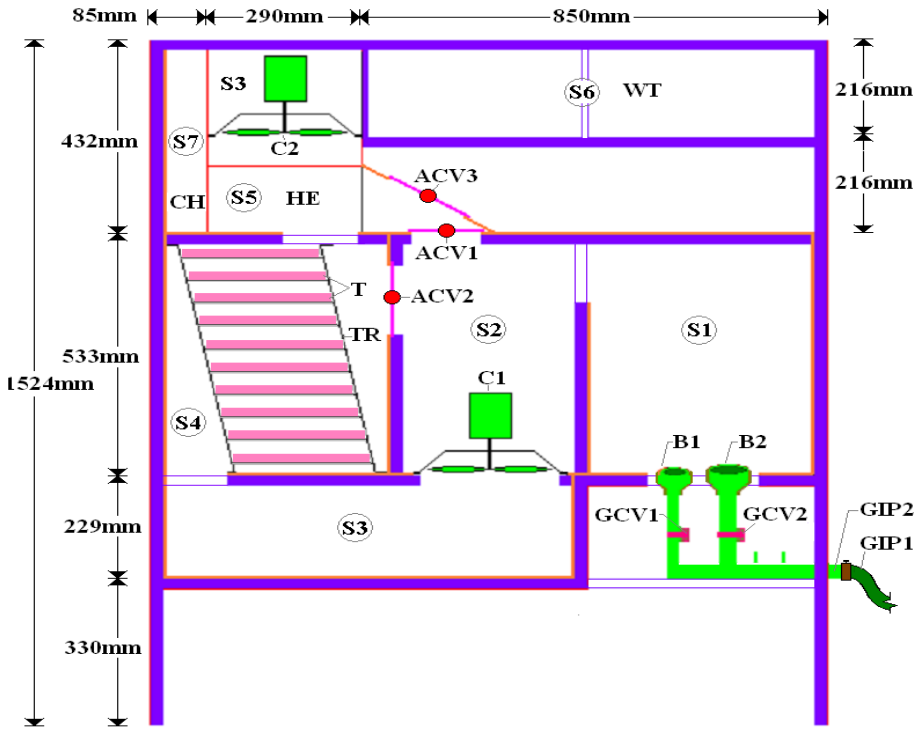
| |
|---|
| Different sections of the batch dryer:<br>S1: Combustion Section, S2: Mixing Section, S3: Compressor Section; S4: Drying Section;<br>S5: Heat exchanger Section; S6: Withering section; S7: Exhaust<br>Gas inlet pipes:<br>GIP1: Gas inlet flexible hose pipe; GIP2: Gas inlet GI inlet pipe<br>Gas Control valves:<br>GCV1: Main burner on-off/control valve; GCV2: Additional burner on-off/control valve<br>Air control valves:<br>ACV 1: Fresh air control valve; ACV 2: Recirculation air control valve; ACV 3: Withering air control valve<br>Burners:<br>B1: Main burner (25 mm diameter); B2: Additional burner (12.5 mm diameter)<br>Compressors:<br>C1: Hot air Compressor; C2: Fresh air Compressor<br>Other components:<br>TR: Tray rack T: Trays; HE: Heat exchanger; WT: Withering trough; CH: Chimney |

Different sections and components of the batch type dryer (Ref Fig. 4a & 4 c)




(a)

(b)




(c)

Fig. 4 (a) Graphical view and (b) external view of the proto-type and (c) view showing different components of the batch type tea dryer

A gasification based drying system for drying of hygroscopic material including tea is developed using a commercial biomass gasification unit (10 kWth) (Fig 5). While drying tea using producer gas, specific energy consumption is found as 9.80 MJ/kg of made tea. The average calorific value of producer gas (measured using Junker Gas Calorimeter) is found as 1150 kCal/$Nm^3$ with tea bush as fuel.

The straw-fired furnace cum heat exchanger is designed and developed for generation of hot air (Fig 6a). The performance of the system was found satisfactory that can supply hot air for tea drying. Flue gas obtained by burning straw is used in a air heat exchanger. Provision is kept for straw feeding through a feeding inlet, 0.33 m × 0.33 m in size in one side of the combustion chamber. The bottom of the surface (made of mild steel) is made inclined for convenience of ash collection and removal. The grate is made of mild steel bar of thickness 3mm. The grate area of the furnace is 0.3 m × 0.4 m with

a loading capacity of 4.5-5 kg. Hot air (at 77$^{o}$C) could be generated with straw consumption 3 to 4.5 kg/h.

Fig. 5 Commercial biomass gasification unit for generation of producer gas

(a) (b)

Fig. 6 (a) A laboratory model of straw fired hot air generator for drying tea (biomass component of hybrid) and (b) Solar hot air generator (solar component of hybrid)

A solar hot air generator is developed for solar component of hybrid (Fig 6b). The maximum air temperature available from the solar air heater, while conducting test in the month of September, is 70°C. The solar air heater can reduce the moisture content of fermented tea up to 15% (w.b.) in a full sunny day. This is estimated as 50%

substitution of thermal energy requirement in thin layer tea drying process. Preheating of drying air, and use for withering process are two prospective uses identified for the solar air heater.

***ii) Fluidized bed tea dryer***

A laboratory model of two-stage fluidized bed dryer is also designed (Fig. 7a) for investigating the prospect of hybrid mode of renewable energy application. Preliminary results suggest quicker drying using fluidized bed dryer compared to tray dryer. Further investigation is going on to prove its efficacy.

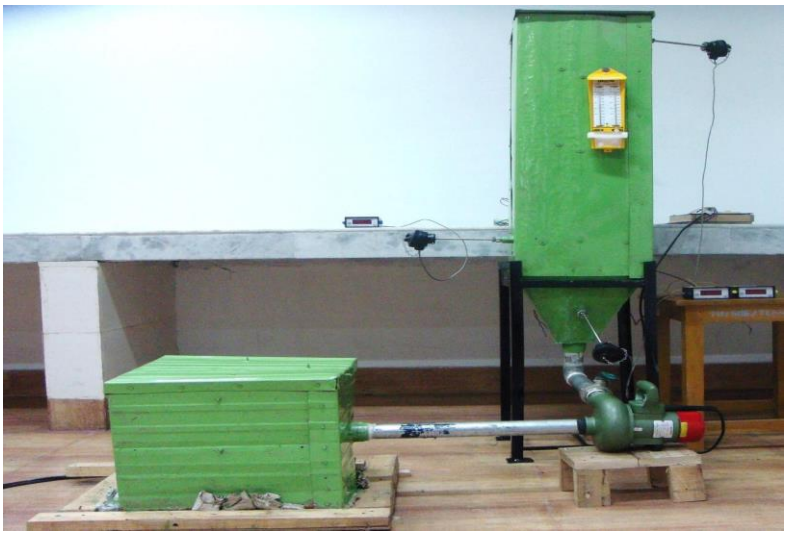
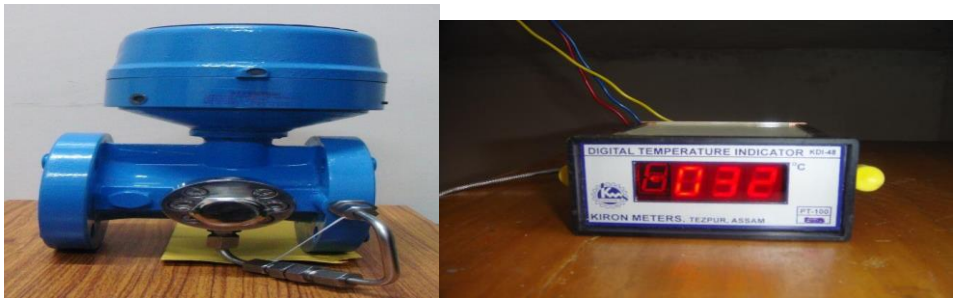


Fig. 7 laboratory setup of two stage fluidized bed dryer.




(a) (b)

Fig.8 (a) Gas turbine flow-meter and
(b) PT100 type thermocouple display unit used for experiments

**8.3 Patent(s) Applied for/Taken, if any:**

The possibility of patenting two-stage fluidized drying with renewable hybrid fuel will be explored.

**8.4 B. Tech. Project / M. Tech Thesis /:Ph.D., if any**

B. Tech thesis: Eight students have done B. Tech final year projects.
M. Tech thesis: Five M. Tech theses completed.
Ph.D.: One Ph.D. programme is going on.

**8.5 Consultancy:** Not taken yet.

**9. Conclusions Summarizing the Achievements Indicating the Scope for Future Work:**

On the basis of characteristics of resources, *straw biomass* and *solar energy* have been identified as the potential components of the hybrid dryer. Technologically, producer gas obtained from woody biomass can also be utilized for tea drying. However, availability of woody biomass for tea processing for 100% replacement in a tea estate is not certain under the present circumstance. In this regard, a viable figure with partial substitution of thermal energy requirement by biomass gasification (in the order of 10%) may be recommended. By techno-economic analysis it can be shown that a 150 $kW_{thermal}$ woody gasifier can supplement 10% of thermal energy requirement for an average size tea estate (3 million tonne/year). The required woody biomass may be procured from nearby market or can be generated from own plantation, uprooted tea branches, litters etc. in the tea estate itself. The payback period for the additional plant and machinery is less than one year. It can be estimated that total 26877 tonne/year $CO_2$ emission can be reduced by substituting 10% thermal energy requirement by biomass gasifier in all tea estates of Sonitpur district of Assam assuming biomass combustion is carbon neutral.

Both *straw fired hot air generator* and *solar hot air generator* are found as prospective technologies of thermal energy conversion for tea drying. The tray-type batch dryer fueled by producer gas is found working perfectly. Multistage fluidized bed tea dryer was found more energy efficient, taking lesser time to dry per batch. It is expected that the multistage fluidized bed tea dryer based on producer gas and solar generated hot air in hybrid mode would be better option for renewable energy application.

The future work of this project is technology refinement, demonstration, popularization among the prospective tea industries to substitute conventional energy by solar and biomass renewable energy. Comprehensive work concerning tea quality and economy need to be continued.

**10. List of Publications arising from the Project (**please give Author (s), Title, Journal, and Year**):**


1. Baruah D, Mahilary H, Baruah DC. Experimental investigation of fossil fuel substitution by straw biomass. In: National conference on renewable energy for development of under-developed areas with particular reference to North-East India held at Tezpur University, 23-25 March, 2010.
2. Baruah D, Mahilary H, Baruah DC. Climate change mitigation opportunities through industrial utilization of straw biomass. In: National seminar on climate change and sustainable development with reference to India held at Tezpur University, 1-3 April, 2010.
3. Baruah DC, Dutta P P and Hiloidhari M. Fossil fuel substitution in tea processing through biomass energy: A study in Sonitpur district of Assam. In: All India seminar on bio-energy and biodiversity initiative held at Assam State Centre of the Institution of Engineers (India), Guwahati, Assam, 28-29 August, 2009.
4. Baruah DC, Dwivedi J, Baruah D. Design and development of producer gas fired tea dryer. In: 96$^{th}$ Indian Science Congress held at NEHU, Shillong, 3-7 January, 2009.
5. Dutta P. P., Baruah D., Experimental study on performance evaluation of totally producer gas based drying of turmeric (*Curcuma longa L*) at cottage level. (Communicating) Energy Conversion and Management.2011.
6. Dutta P.P., Baruah D.C. Gasification of tea (*Camellia Sinensis var. assamica*) tea shrubs for process heat generation in tea manufacturing. (Communicating) Bio-system Engineering.2011.
7. Dutta P.P., Baruah D.C., Das S., Pathak B, Baruah, P. Performance testing of renewable energy based hybrid tea dryer. (to appear) In: National Conference on Water Energy and Biodiversity with special reference to North East India. August 20-22, 2011 at Institution of Engineers, Tripura Centre.



Acknowledgement: AICTE, New Delhi

FORMAT FOR UTILIZATION CERTIFICAT for RPS Project: Design and Development of Renewable Energy Hybrid Tea Dryer for Fossil Fuel Substitution in Tea Industry

Sanction Letter No. F. No.: 8023/BOR/RID/RPS-25/2007-08 Date: March 5, 2008

A. Non-Recurring

| Financial Year | Name of the equipment procured | Amount sanctioned, Rs. | Amount utilized (Item wise) | Unspent Balance, Rs. |
|---|---|---|---|---|
| 2008-09 | Biomass Gasifier | 10,50,000.00 | 4,24,125.00 | Additional expenditure of Rs. 713.00 |
| | Junker Gas Calorimeter | | 95,650.00 | |
| 2010-11 | Thermocouple based Multi-channel Temperature Indicator | | 2,05,313.00 | |
| 2010-11 | Digital Hygrometer cum Thermometer | | 1,78,875.00 | |
| 2010-11 | Gas Turbine Flow Meter | | 1,20,750.00 | |
| | Wet Sieve Shaker | | 26,000.00 | |
| Total, Rs. | | 10,50,000.00 | 10,50,713.00 | |

B. Recurring

| Financial Year | Amount sanctioned, Rs. | Amount utilized | Unspent Balance, Rs. | Remarks |
|---|---|---|---|---|
| 2008-09 | 2,00,000.00 | 33,469.00 | Rs. 713.00 | Unspent balance of Rs. 713.00 is adjusted towards the non-recurring head of the project |
| 2009-10 | | 70,683.00 | | |
| 2010-11 | | 95,135.00 | | |
| Total, Rs | 2,00,000.00 | 1,99,287.00 | | |

Certified that the grant has been utilized for the purpose for which it was sanctioned in accordance with the "Terms and Conditions" attached to the grant. If, as a result of check or audit objection some irregularity in noticed at a later stage, action will be taken to refund, adjust or regularize the amount objected to.

24/8/11

Finance Officer
Finance Officer
TEZPUR UNIVERSITY
(Signature & Seal)

Dated:

24/8/11

Registrar/ Principal/ Director
Registrar
Tezpur University
(Signature & Seal)

Dated:

Note: The Utilization Certificate (UC) will be signed by the Registrar/ Finance Officer in the case of Universities, Principals in the case Colleges and Executive Heads of other Institutions. The Provisional UC may be countersigned by the internal auditors wherever the system of the internal audit exists. In case of the Self Financing/ Private Institutions, UC has to be signed by a Chartered Accountant.