CLIMATE CHANGE 2
TORONTO, OCTOBER 3-5, 2001

THE TER CONTRIBUTION TO POLLUTION REDUCTION

E. Hay, A.K.Azad

Thermal Retrieval Systems Ltd.
Montreal, Canada

Abstract

Large quantities of waste heat that can be converted to useable energy are available in the transportation and the power generation sectors. The related emissions corresponding to such energy are surveyed and quantified in this paper. The application of the TER system to diesel engines and power generating stations is then presented and the related gain in fuel consumption efficiencies for the cycles (2% to 8%) explained. The potential for emissions reduction world wide, using TER, is then quantified. The capital and operating cost for a recuperation system using ammonia in a coal-fired station are also presented. The reduction in cost of the specialized equipment needed has greatly contributed to making this fuel-free power generation scheme more affordable. The downward trend in capital cost is towards 1500 dollars per KW installed.

1. Introduction

Large quantities of waste heat that can be converted to usable energy are available in the transportation and the power generation sectors. The related reduction in emissions corresponding to such energy savings can be very substantial and would greatly contribute to the Kyoto protocol requirements.

A system called TER was developed in the mid-nineties for recuperating waste energy from low-grade waste heat. It has been applied to both the energy and the transportation sector.

1a. TER System in Thermal Stations: Ammonia Cycle

Any plant or process that rejects heat at a temperature above normal conditions could be used for deriving work energy. Fossil fuel-fired thermal power stations usually discharge major quantities of hot water through their condensers. Hot water from the conventional condenser is used in an ammonia bottoming cycle as may be seen in Fig. 1a. Hot wastewater is used to evaporate ammonia which is fed through a turbine / expander to produce recuperated power. The expanded ammonia gas is then condensed by circulating cold water and pumped back to repeat the closed cycle. The circulating cold water also passes through the steam condenser, which condenses the steam coming out from the station boiler. Typically, a 300 MW power station could offer a recuperation of 10 to 28 MW [Ref.1].

1b. TER55 System in Transportation

Alternatively, the TER system could recuperate the waste heat from hot coolants and hot exhaust gases in internal combustion engines and many other heat/power generating sources and would transform it into additional motive and / or mechanical or electrical power. No additional fuel is required for this gain. In operation the waste heat is used to evaporate a special refrigerant which is fed through a turbine / expander to produce recuperated power. The expanded gas is then condensed and pumped back to the evaporator to repeat the closed circuit cycle as may be seen in Fig. 1b. The TER55 gas is non CFC-based, non-combustible and inert.

Fig. 1a. TER System diagram: Thermal Energy Utilization

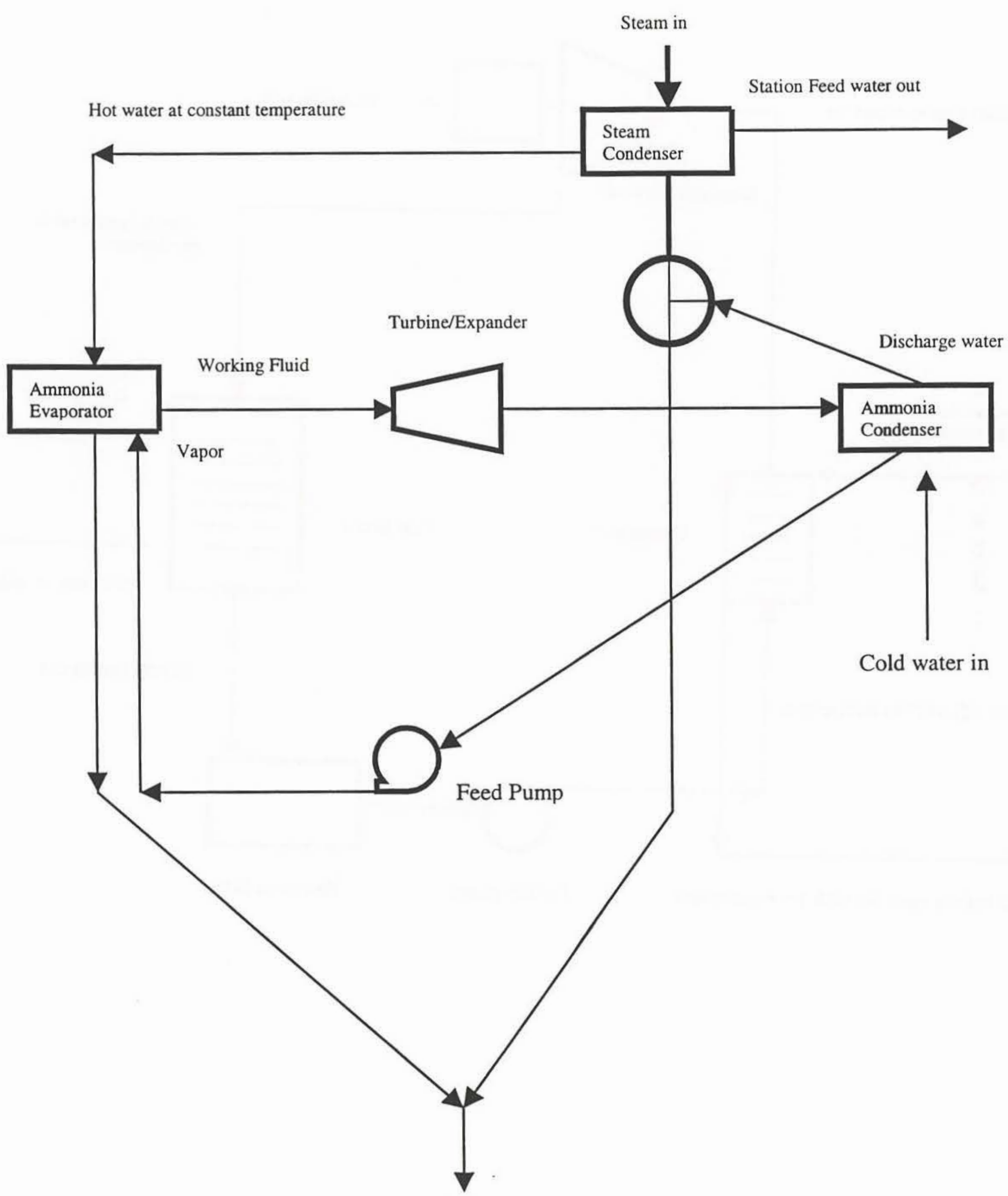
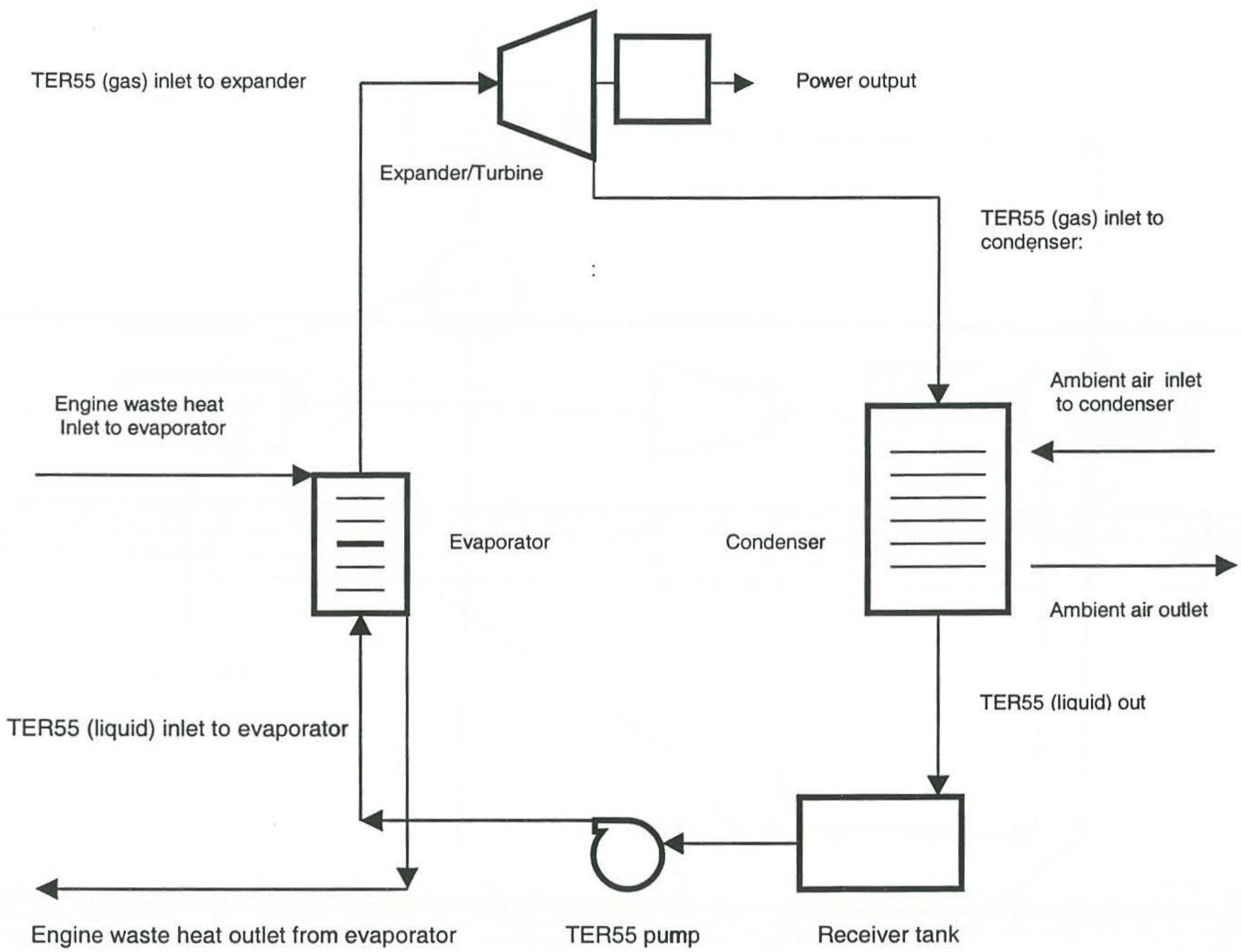


Fig. 1b. TER System Diagram: Engine waste heat utilization



2. Energy Recuperated in Power Generation and Transportation

The application of the TER system to diesel engines and power generating stations and the related gain in fuel consumption for the cycles (2% to 8%) is explored. The potential for emissions reduction worldwide, using TER, is quantified in the following section.

2a. Power Generation

The power generated in power stations in different countries and the power that could be recuperated by the TER system from these stations is shown in table 2a. A total of 602 Giga watts (602,000 MW) of oil, coal and gas fired stations exists worldwide. An additional 197 Giga watts (197,000 MW) of nuclear power is also listed. A potential power recuperation of 12,000 MW to 32,000 MW could be obtained using the TER system.

Table 2a: TER increases the Capacity of Thermal Stations

All figures are in Giga watts (1 million KW)

Country	Capacity Thermal Stations*			Power Recuperated using TER System			
	Conventional (Gas, oil, coal)	Nuclear	Total	Conventional Thermal stations		Total Thermal stations	
				@ 2%	@ 4%	@ 2%	@ 4%
USA	**435**	**99**	**534**	**8.7**	**17.4**	**10.6**	**21.2**
Japan	**96**	**29**	**125**	**1.9**	**3.8**	**2.5**	**5.0**
W. Germany	**25**	**24**	**49**	**0.50**	**1.0**	**1.0**	**2.0**
France	**-**	**28**	**28**	**-**	**-**	**0.6**	**1.2**
UK	**35**	**3**	**38**	**0.70**	**1.4**	**0.8**	**1.6**
Canada	**11**	**14**	**25**	**0.22**	**0.44**	**0.5**	**1.0**
Total	**602**	**197**	**799**	**12**	**24**	**16**	**32**

- Presentation to European Union EU Committee members on energy by Nisymco Inc., 1999, Lynemouth.

2b. Transportation

The energy consumed vis-à-vis the Giga watts that could be saved using the TER system in the transportation sectors of Canada and USA is illustrated in Table 2b. The energy consumed by transportation is of the same order as the total power generation capacity in the USA. A potential energy recuperation of 14,000 MW to 28,000 MW could be obtained (equivalent to 15,000 millions liters to 30,000 millions liters of fuel).

Table 2b: TER Saves Giga Watts in Transportation Engines

Country	Giga Watts Consumed		Estimated Savings using TER System	
	1995	**1997**	**@ 2%**	**@ 4%**
USA*	**-**	**675**	**14**	**28**
CANADA**	**230**	**-**	**5**	**10**

* Reference: 1999 US/DOE report
** Statistics Canada 57-003 report

3. Typical Ozone Emissions Data

The actual CO_2 emissions in different sectors have been extracted from various studies and are shown in Table 3a. They are consistent with the US/DOE report " Scenario for a clean Energy Future" issued in 1997 as well as the US Energy Information Administration EIA report " AEO 98 projections to 2020.

The CO_2 emissions from transportation and through electric generation are similar in quantities (USA). The industrial and buildings sector produce slightly lower quantities. The trend of total CO_2 emissions has increased from 1827 to 2157 million metric tonnes or by 18% from 1990 to 1998.

The potential CO_2 reduction using the TER system could be 27 to 36 million metric tons for power generation and transportation.

Table 3a.

U.S. CO_2 Emissions (in million metric tonnes)*			Pollutant reduction at 3% fuel economy using TER System (in million metric tonnes)	
Source	Actual			
	1990	**1998**	**1990**	**1998**
Electric Generation	**477**	**660**	**14**	**20**
Transportation	**432**	**534**	**13**	**16**
Industrial	**458**	**473**	**14**	**14**
Buildings	**460**	**490**	**14**	**15**
Total	**1827**	**2157**	**55**	**65**

*Obtained from ASME General Position Paper presented to U.S. Congress – February 1999

Table 3b shows the emissions of CO_2 in Canada due to transportation during 1989 and 1995 and the corresponding reduction of pollutant at 3% fuel economy by using a TER system.

Table 3b.

Emissions of CO_2 in Canada Due to Transportation (in million metric tonnes)					
1989*				1995**	
Emissions due to human activities	Share of Transportation	Emissions of CO_2	Pollutant reduction at 3% fuel economy using TER System	Emissions of CO_2	Pollutant reduction at 3% fuel economy using TER System
471	**33%**	**155**	**4.7**	**111**	**3.4**

There is a potential of 3.4 million (1995) metric tonnes of CO_2 that could be saved in Canada alone. This is to be compared to 16 million metric tonnes (1998) of CO_2 reduction for the USA.

* Hay, E. and N. Hay, 1995, " Thermal Energy Retrieval (TER) System for Road Vehicles", SAE/ImechE # C496/055
** Statistics Canada 57-003 report

4. Capital Cost of The System

Capital and operating costs for a TER 3 recuperation system in a coal fired thermal station are summarized in Table 4. The reduction in cost of the specialized range of equipment has greatly contributed to making this fuel-free power generation more affordable [Ref.2]. The downward trend in capital cost to 1500 dollars per KW installed is presented.

Table 4: Recuperated Power and Income: Power generation

Case	Base	Case 2	Case 3	Case 4
Efficiency	**87**	**80**	**87**	**80**
Gross power (MW)	**4,778**	**4,016**	**4,317**	**4,142**
Net Power (MW)	**4,192**	**3,43**	**3,731**	**3,556**
Capital cost ($/KW)	**2,200**	**1951**	**1742**	**1514**

The capital cost per KW of power installed, although higher than oil or gas generating stations, can be quite competitive as there is no fuel cost to be added to the operating costs.

5. Conclusions

1. The TER system has great potential in assisting countries to comply with the Kyoto Protocol
2. By reducing fuel consumption @2% to 8% in the power generation and transportation sectors, the TER system could contribute significantly in the reduction of CO_2 emissions
3. As no additional fuel is needed to operate the TER system, it could be very competitive on a life cycle basis

References

1. Thermal Engineering Joint Conference ASME, JSME, Mauii 1995 – volume 4. Paper by E. Hay, B.R.Clayton, & N. Hay
2. Combustion and Global Climate change convention, Calgary 1999, "TER 3: More Electricity Produced Without Burning Extra fuel " by E. Hay, D. Gibbs