# Implementation of a Cold-storage for Ice-cream using Waste Heat from 50 MW APSCL

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# Executive Summary

*Around 1500 TR refrigeration effect suitable for ice-cream storage can be obtained using aqua-ammonia absorption system utilizing waste heat associated with the exhaust gases of gas engines of APSCL when producing 30 MW output. The tonnage is sufficient enough to provide refrigeration effect required for a cold-storage for ice-cream storage accommodated in the available space next to the plant. Detailed economics of the project must be analyzed in case of selecting appropriate equipment for the project.*

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## Preamble

Renewable Energy and Energy Efficiency Programme (REEEP) of GIZ, Bangladesh has conducted a feasibility study to support the vision of conservative energy solution of the Ministry of Power, Energy & Mineral Resources of Bangladesh Government. Accordingly, a task force have been formed by the Power Division and the task force prepared a preliminary report addressing the possibility of a cold storage facility for the storage ice- cream using recoverable waste heat from the power station gas engines. Initially, some privately owned land beside the power plant was considered as suitable site for the installation; however it not available at present. So, in the present study, a cold-storage facility suitable for the storage ice-cream is analysed using the available energy and space.

## Waste Heat Recovery Potential of Gas Engine Plant, APSCL

Gas engines, used in captive and small scale power plants, reject significant amount of heat energy (associated with exhaust gases and jacket water) to the surroundings at temperatures high enough above ambient and in sufficient quantities to make heat recovery economically attractive. The heat energy loss has become known as waste heat, if not removed immediately mixes with the atmosphere and becomes unavailable for any further use. In case of power generation units, large amounts of heat are rejected to create thermal pollution.

The 50 MW Gas Engine Plant, APSCL consists of 16 Jenbacher J620 GS-NL, F101 engines of 124.8 litre capacity arranged in V 60$^{o}$ configuration with an operating speed of 1500 rpm (Fig. 1). The output power of each engine is around 3.35 MW. Each engine produces around 18000 kg/h of exhaust gases releasing at around 400$^{o}$C. These engines require energy input of 7.35 MW from natural gas, from which 3.55 MW mechanical power is produced by the engine, losing 2.0 MW heat as jacket water heat and 1.8 MW heat with exhaust gases. Hence, around 1.25 MW heat energy can be recovered from each engine at full load operation, when finally releasing exhaust gas leaving the system at around 150$^{o}$C. It is also observed that all the units exhibit very similar data for full load operations (Fig. 2).

Fig. 1. Roof top view of the Gas Engines, APSCL

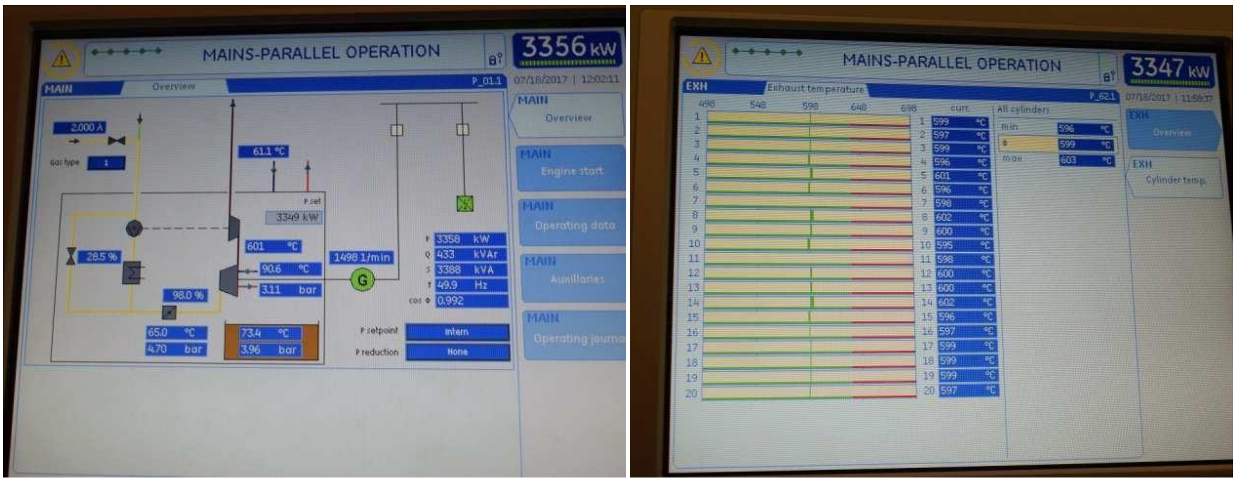


Fig. 2. Control panel exhibiting operating data of gas engines.

A detailed thermodynamic and energy audit is carried out for a full load operation of a single unit, and the findings are reported in Fig. 3.

Environmental and economic analysis provides the major impetus for heat recovery. Two major paths can be followed to recover significant fractions of the energy associated with the exhaust gases of the gas engines by producing steam using waste heat recovery boilers (HRSG) and using the steam for:

1. Production of electricity in combined cycle application
2. Production of refrigeration/chilling effect by using absorption chillers.

Economic incentives have led to increased use of heat recovery technologies in recent years. Many such techniques are well developed and equipment is commercially available. Equipment costs are moderate with short payback period and the systems are reliable. In the present study, cold-storage for ice-cream storage using aqua-ammonia vapour absorption refrigeration system is analysed as per guidance provided by GIZ, Bangladesh.

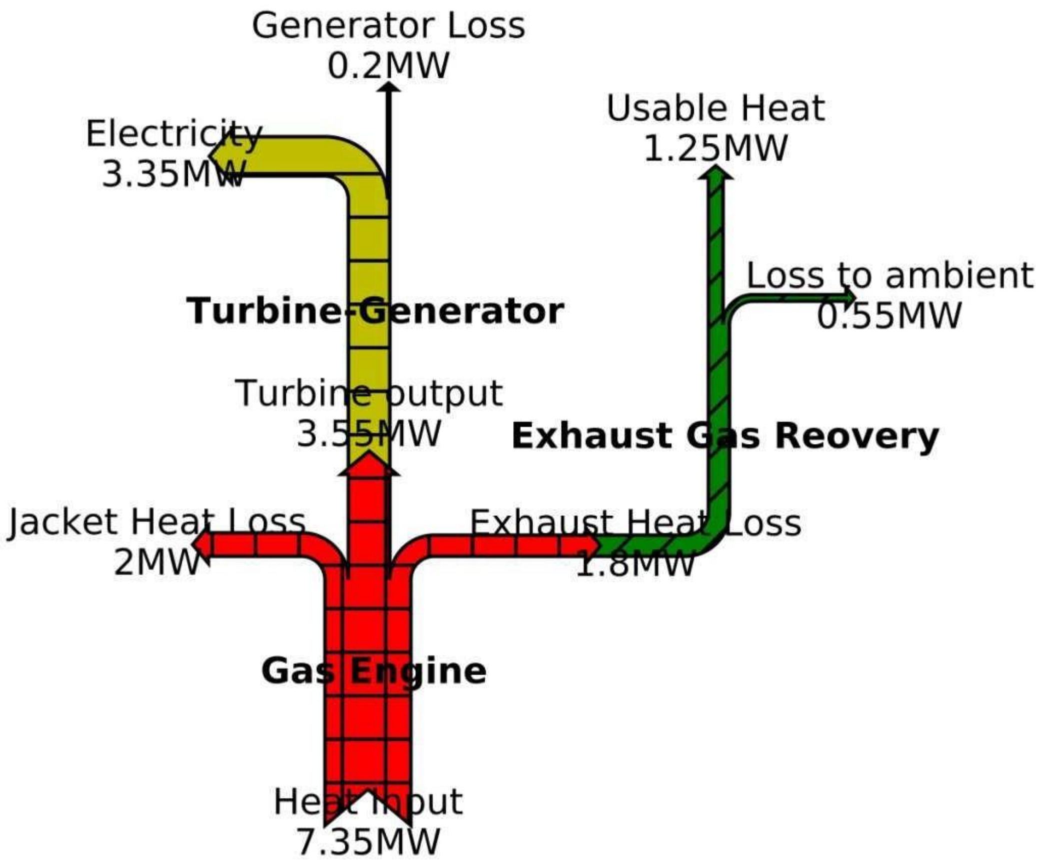


**Fig. 3. Thermodynamic and energy audit data of a single unit gas engine, APSCL.**

## Cold Storage for Ice-Cream storage using Waste Heat

Absorption chillers utilize fluids that are solutions of two components. The basic principle of operation of absorption chillers is that once the solution is pumped to condenser pressure, low grade energy (moderate temperature heat source) can be used to vaporize one component of the solution and the vaporized fluid is condensed in the condenser to work as the refrigerant of the system. Two types of vapour absorption refrigeration technologies are now widely used: (1) LiBr system, (2) Aqua-ammonia system. In LiBr absorption chillers, LiBr is the absorbent and the water acts as the refrigerant. Hence, the system cannot be used to produce sub-zero temperatures and therefore limits it application as cold-storage chiller for many applications e.g. ice making and storage, fish and meat storage etc. However, in aqua-ammonia based vapour absorption system, water is the absorbent and ammonia is the refrigerant. The system has the capability of serving refrigeration at temperatures well below $0^{o}$C, and therefore is the suitable choice for ice-cream storage facility. Ammonia is colourless gas of low density at room temperature with a pungent smell that can be detected by humans in concentrations of very few ppm and therefore very small leaks can be easily detected with a significant incentive for early detection and repair of leaks.

Proposed configuration for waste heat recovery unit for gas engines of APSCL is shown in Fig. 4. Hot exhaust gases at $400^{o}$C is to be used in waste heat recovery boiler to produce steam and the produced steam is to be used in the aqua-ammonia absorption system generator. Direct fired aqua-ammonia systems are also available, however, these are usually short lived. Comprehensive thermodynamic analysis is carried out to estimate the achievable refrigeration effects per MW of waste heat available, and the findings are reported in Fig. 5. Analyses reveal that, coefficient of performance (COP) and refrigeration effects are strongly dependent on the evaporator temperature and therefore optimum storage temperature must be selected for optimum operation of the system.

Ice-cream is a very complex product, containing milk components, emulsified fat, protein in colloidal solution and a solution of lactose and salts. Furthermore, sugars, emulsifiers/stabilizers and flavorings are added during processing. Water can be found as a salt and sugar solvent and as ice crystals. Finally, air is incorporated into the product as finely-distributed air cells protected by a layer of fat globule agglomerates.

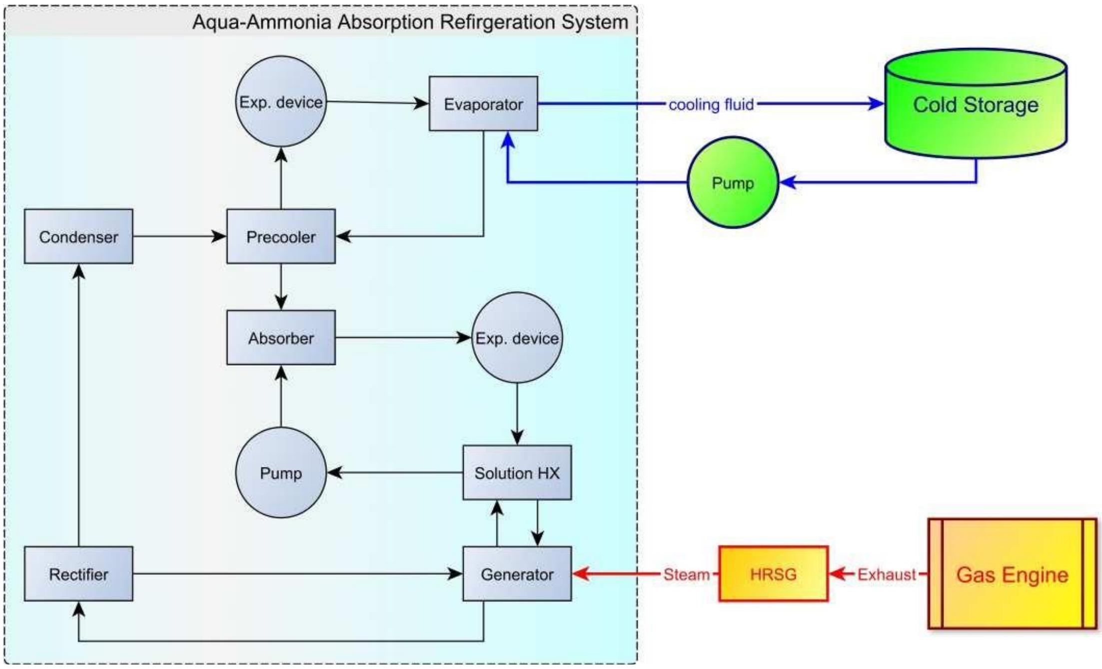


**Fig. 4. Proposed aqua-ammonia refrigeration system for the ice-cream storage using waste heat of the gas engines of APSCL.**

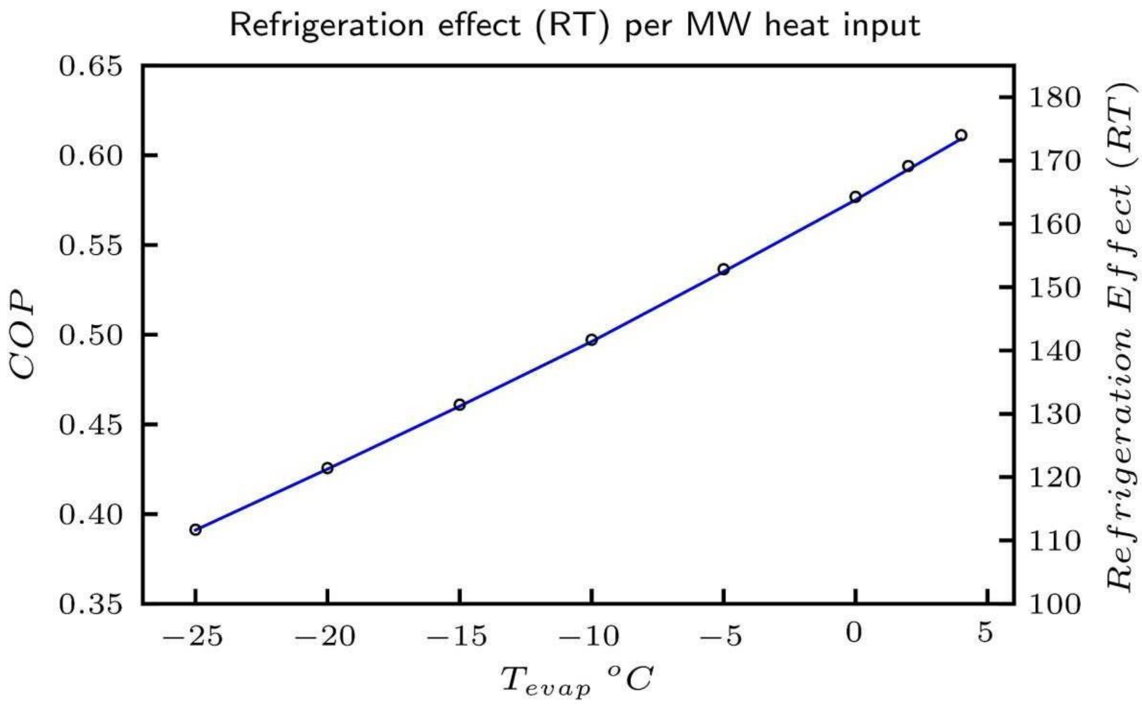


**Fig. 5. Coefficient of performance (COP) and refrigeration effect of aqua-ammonia system.**

A temperature of -15$^{o}$C or lower is the goal during ice-cream hardening. During storage, however, the temperature should be kept even lower, typically -25 to -30$^{o}$C. At this temperature, approx. 90% of the water in the ice cream is frozen into ice crystals, the remaining 10%, containing sugars and salts, is in an amorphous, frozen condition.

To store ice-cream at -10$^{o}$C, it is required to cool the secondary cooling fluid like ethylene glycol at around -15$^{o}$C. So, to produce secondary coolant at -15$^{o}$C, only 125 TR is achievable per MW of waste heat associated with exhaust gases. Hence, for 30 MW output of the gas engines, approximately 1500 TR is achievable when losses due to heat transfer is considered. Additional but significant cooling capacity can also be achieved using waste heat associated with the jacket water; however these units are associated with much higher cost because of lower thermodynamic efficiency.

The waste heat recovery boiler and aqua-ammonia system can be placed next to the gas engines, and the chilled secondary fluid can be carried through insulated pipe to the cold-storage site. Total installation and operating costs of such systems depend on the total capacity, operating load, design and brand of the chiller units as different energy efficiency devices are incorporated in these devices and in general, higher initial cost is associated with high efficiency units.

## Implementation of Cold Chain for Ice-Cream Storage

Ice cream must be kept at low temperature right up to the point of final consumption. If it is allowed to soften, the entrained air bubbles may escape and the original texture will be lost. If it softens and is then re-frozen, a hard, solid skin forms, making the product inedible. Ice cream must always be handled quickly when passing through transit stages from the factory to consumer. So, appropriate cold chain must be maintained.

Temperature controlled storage chamber is one of the key components of the cold chain. Typical temperature controlled storage is shown in Fig. 6. Opening the door of the cold storage pose threats to the cold-chain maintenance (Fig. 7). Hence, cooled trailer must be loading directly against the cold storage or adequate thermal barriers should be employed to limit the heat losses (Fig. 8).

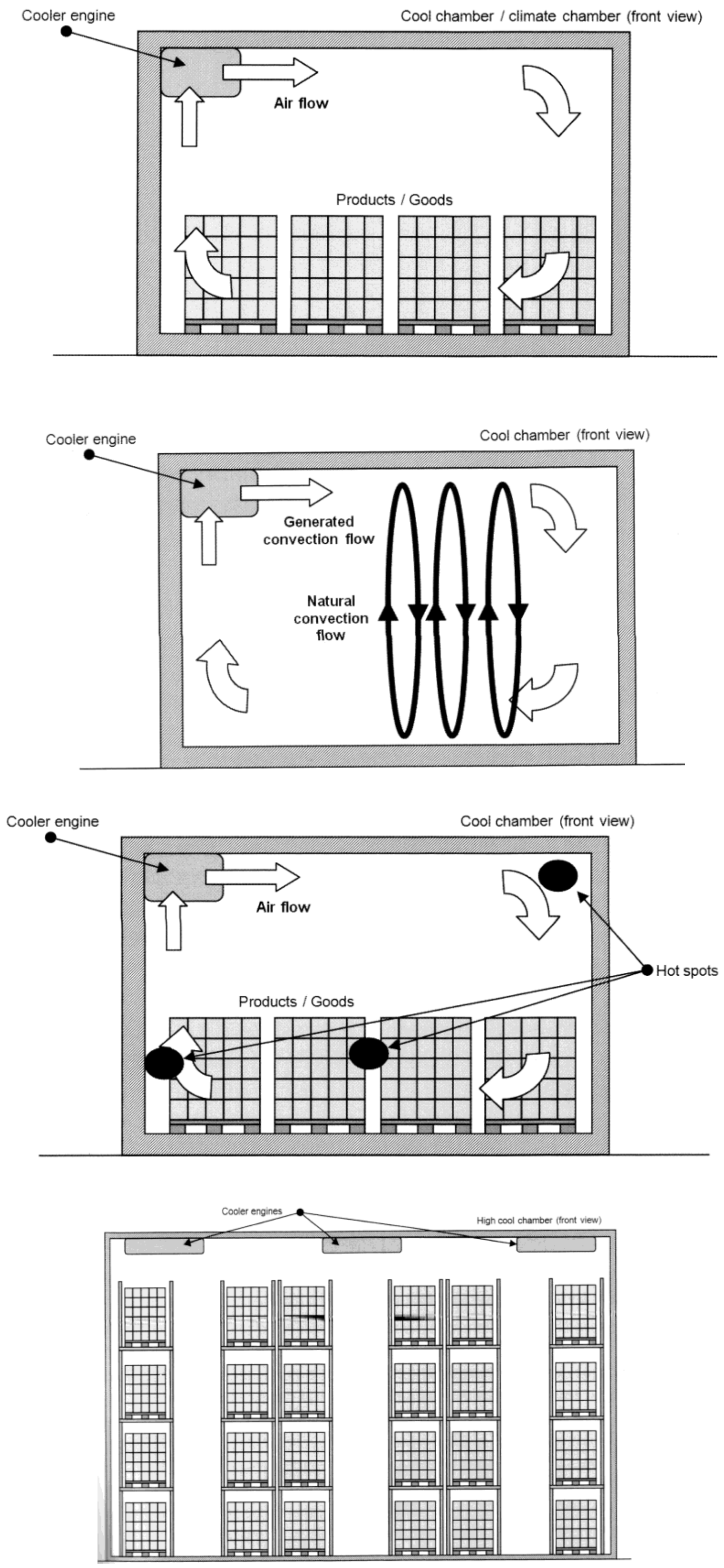


**Fig. 6. A) Ideal temperature controlled cold-storage, B) Heat flow within cold-storage, C) Development of hot spots in cold-storage, D) Cold-storage with multiple storage layers.**

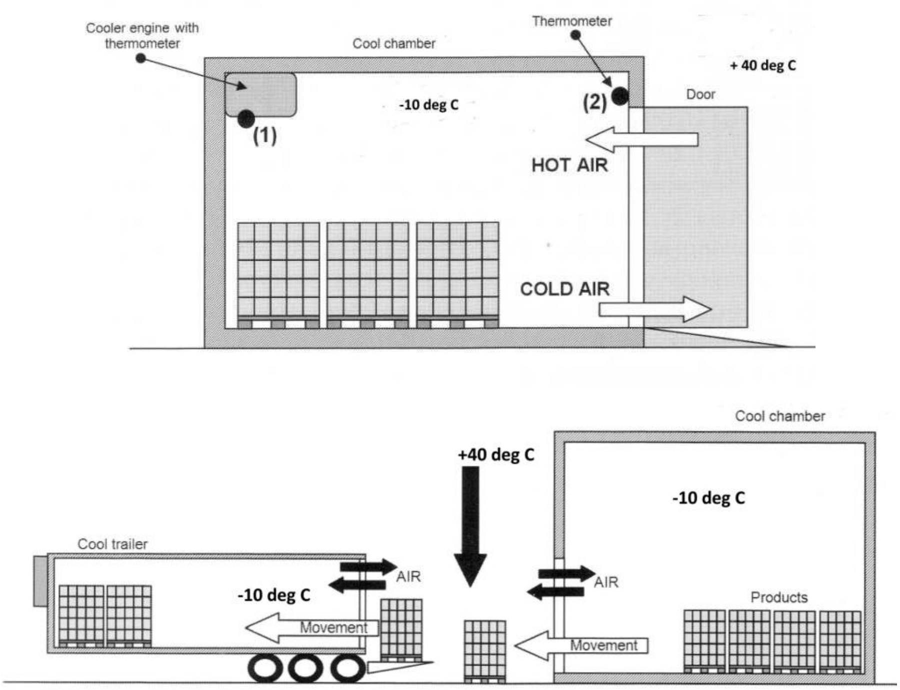


**Fig. 7. Threats to cold-chain maintenance.**

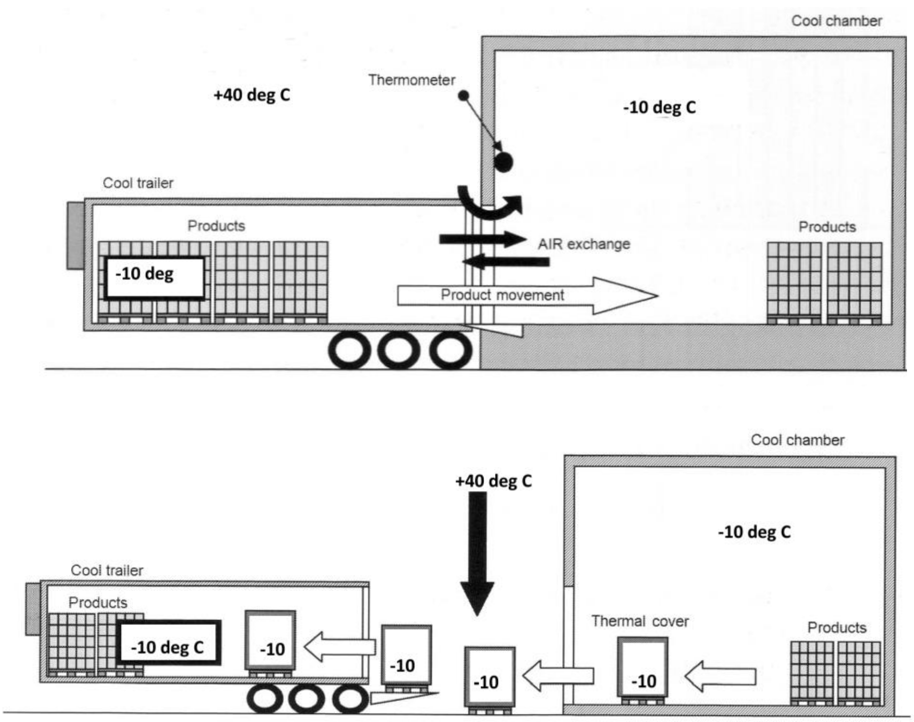


**Fig. 8. Some measures to address threats to cold-chain maintenance.**

## Conclusions

Around 1500 TR refrigeration can be obtained using aqua-ammonia absorption system utilizing waste heat associated with the exhaust gases of gas engines when producing 30 MW output. The tonnage is sufficient enough to provide refrigeration effect required for a cold-storage for ice-cream storage accommodated in the space available next to the plant. Technology is well defined and can be implemented fairly quickly. However, space limitation may pose as the main barrier, because if full potential of the waste heat is not used, installation of such units may not be economically viable. Therefore, detailed economics of the project must be analyzed in case of selecting appropriate equipment.