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Research on the Standardised Cold-container System Based on One Vehicle with Multi-Temperature Control

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Abstract

This paper analyses the current transportation requirements and product quality assurance in the cold chain logistics industry. It proposes the idea of drop-and-pull transportation, based on one vehicle with multi-temperature control, namely the standard cold-container system. It further elaborates on the advantages of the standard cold-container system, which improves transportation efficiency, while greatly cutting down costs at the same time.

Keywords

Cold Chain Logistics; Standardised Cold Container; Drop; Pull Transport

Introduction

As the economy develops and residents' living standards improve, the demand for cold chain products is becoming increasingly higher. Problems like how to ensure product quality while meeting the various temperature requirements in the long-distance transportation industry have to be solved urgently in the cold chain logistics industry.

1. Demand Analysis for a Standardised Cold-container System

The standardised design of the cold container facilitates the subsequent transportation and convergence of different vehicles in response to the national advocacy of standardised transport. The standardised design of the cold container applies for example to more models of vehicles and more situations, which contributes addressing the problem of unnecessary multiple sorting, and reducing the food rot damage rate[1].

Avoid Duplicated Sorting, Save Time, Improve Efficiency

Multi-sorting wastes a lot of manpower and resources in the logistics process. This is a critical issue in cold chain logistics. It often leads to temperature changes and affects the quality of products, therefore preventing multi-sorting. Controlling the temperature becomes practically important in cold chain logistics[2-3].

Isolate the Smells from Different Products

Mixing different types of products during transportation can stimulate ripening or produce odour. Examples are papaya, which ripen other fruits, and durian, which has a strong odour. These will have a huge impact on the quality of cold chain products, resulting in poor customer experience, and even accelerating decay, causing serious economic losses[4].

Facilitate the Loading of One Vehicle with Multi-car Temperature Control

Different categories of goods have various temperature demands. The current cold chain transportation and distribution industry can only retain one temperature, whether it is refrigerated trucks, cold chain-dedicated containers or cold chain transportation bags. Goods with different temperature demands that are mixed under one temperature will greatly affect the freshness of goods[5].

2. Standardised System Design of Cold Containers

Design of Dimensions

Standardised cold containers of different sizes need to meet the stowage requirements of different vehicles and have consolidation requirements. The dimensions of the containers are shown in Table 2.1

TABLE 2.1: SIZES OF STANDARDISED COLD CONTAINERS

	Class 1	Class 2 (big)	Class 2 (small)	Class 3
External dimensions (metre)	2.4*2*2.4	2*1.2*2.4	1.2*1*2.4	0.6*0.4*0.8
Internal dimensions (metre)	2.24*1.84*2.1	1.84*1.04*2.1	1.04*0.84*2.1	0.55*0.35*0.75

These four dimensions are within multiple relations, so they can suitably be combined, such as two or four Class 2 containers can be combined into a Class 1 cold container. Class 1 cold containers are mainly used for line-haul freight transportation, but can also be used for regional transportation and the distribution needs of large customers. Class 2 cold containers are mainly used for regional transportation and distribution for small and medium end-customers. They can also be combined with a Class 1 cold container in line-haul freight transportation. Class 3 cold containers are used for end-distribution for individual customers[6-7].

Through line-haul freight transportation, goods are transported to the cold chain regional distribution centre. Loadable flatbeds of the size 5 000 mm*2 050 mm* 2 400 mm are mainly used for regional transportation and distribution for large customers. When freights in Class 1 cold containers have been sorted and packed in the cold chain hub, no additional sorting is needed at the regional distribution centre. Cold containers can therefore be loaded directly onto the distribution vehicles.

For line-haul freight transportation trucks, 12 m low flatbed semi-trailers will be used. The same transport distance, same horsepower and the use of LNG power can save30 to 40% more than the use of diesel power. LNG power products can recover cost differences for buying an LING power vehicle in eight to 10 months and are more environmentally friendly, saving energy. Furthermore, 12 low-level semi-trailers can be loaded with six Class 1 cold containers. Class 1 cold containers can be consolidated with Class 2 cold containers[8].

Shape Design

A forklift needs to be used to load and unload cold containers. The fork, though, is designed at the bottom of the cold container. According to the research, the thickness of the fork is around 8 cm, so the cold container is equipped with 10 cm feet. This design is not only convenient for forklift operations, but the gap between the containers can also accommodate a staple-type buckle convex part (see Figure 2.1).

FIGURE 2.1: EXTERNAL MODEL OF COLD BOX

Polyurethane foam has been selected as a thermal insulation material as polystyrene has a thermal conductivity of only 1/3. It also has a certain strength and good adhesion. Therefore, the use of a polyurethane foam material can

improve the load-bearing capacity of vehicles and simplify the vehicles' skeleton structure to ensure the compartment's thermal insulation ability. The insulation layer will not age easily, so it is a good insulation material[9-10].

Design of Fixed Connection between Cold Containers

In cold chain transportation, cold containers easily fall from the transport vehicle because of the high speed at which the vehicles travel. In order to solve such problems, corner fittings will be installed in the four corners of the cold containers. The hollow radius of the corner fittings is 20 mm and the depth is 100 mm. As shown in Figure 2.2, the left and right connections of the cold box will be fixed with the staple-shaped buckle to connect two cold containers (see Figure 2.3). The up-and-down connection will be used as a cylinder. The radius of the cylinder is 15 mm and the height is 300 mm.

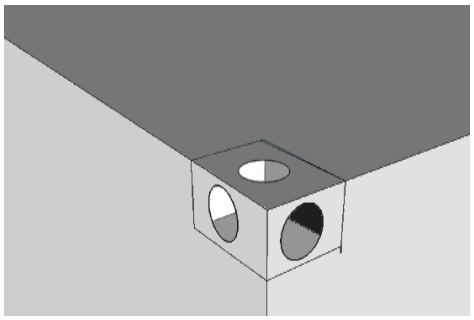

FIGURE 2.2: STANDARDISED COLD CONTAINER (FOUR CORNERS OF THE DEVICE)

FIGURE 2.3: HORIZONTAL CONNECTION FIXTURE FOR THE COLD CONTAINER

Single-temperature Cold Container Modified into a Temperature- and Space-controlled Cold Container

The standardised cold container series has fulfilled the demand for cold chain transport modularisation and one vehicle with multi-temperature control. The existing vehicle with one temperature will be modified into a multi-temperature vehicle to reduce costs. The usual cold container will be equipped with mobile insulation board, mobile shelves and a refrigeration system. This design, through the multi-point cooling system and air tightness to strengthen the separation, will achieve different temperatures and product isolation[11-12].

The Calculation of the Cold Container Space Utilisation Rate

1) Cold Container Capacity Utilisation Rate

According to the investigation, the carrying capacity of a low flat semi-trailer is 30 000 kg. The empty container weights of each Class 1 cold container, Class 2 large container, Class 2 small container and Class 3 cold container are 800 kg, 450 kg, 220 kg and 10 kg respectively. There are approximately 13 different kinds of cartons for cold chain logistics transportation, and about 13 specifications for woven bags to load meat, fruit, seafood, etc. Based on the Class 3 cold-container freight-loading experiment, imagine that it is required to load freights in 13 different kinds of cartons and woven bags. The experimental results are as follows:

Class 1 cold container volume utilisation rate is 89.76%, as shown in Figure 2.4.

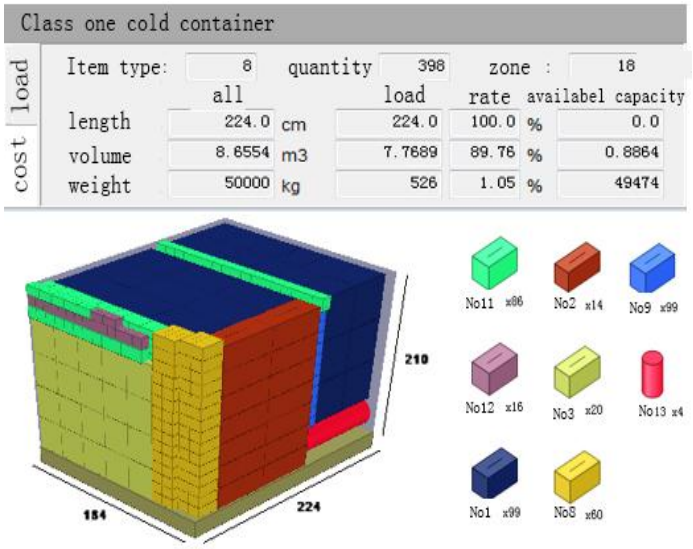

FIGURE 2.4: CLASS 1 COLD CONTAINER VOLUME UTILISATION RATE

B. Class 2 big cold container volume utilisation rate is 89.55%, as shown in Figure 2.5.

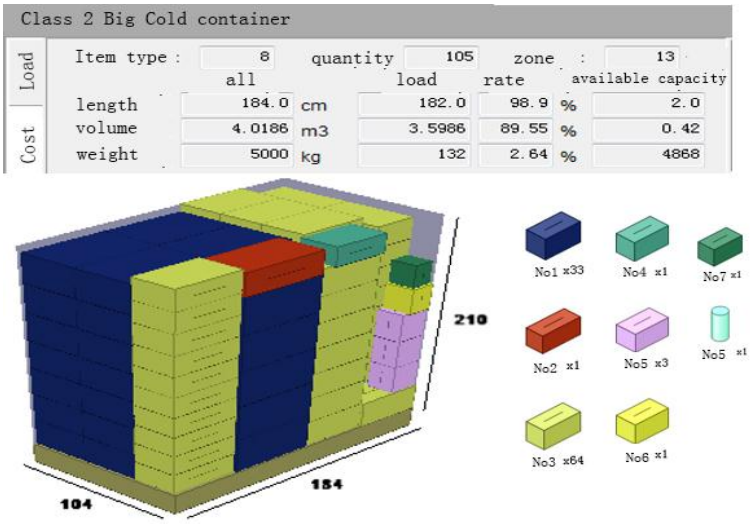

FIGURE 2.5: CLASS 2 BIG COLD CONTAINER VOLUME UTILISATION RATE

C. Class 2 small cold container volume utilisation rate is 82.34%, as shown in Figure 2.6.

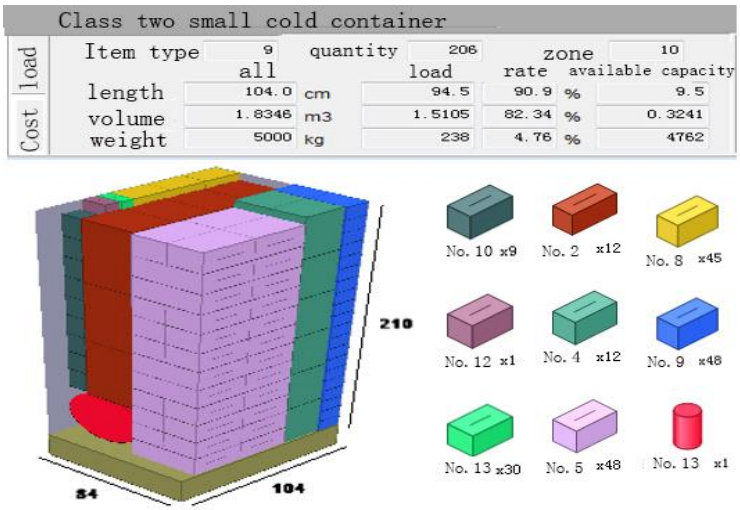

FIGURE 2.6: CLASS 2 SMALL COLD CONTAINER VOLUME UTILISATION RATE

D. Class 3 cold container volume utilisation rate is 97.76%, as shown in Figure 2.7.

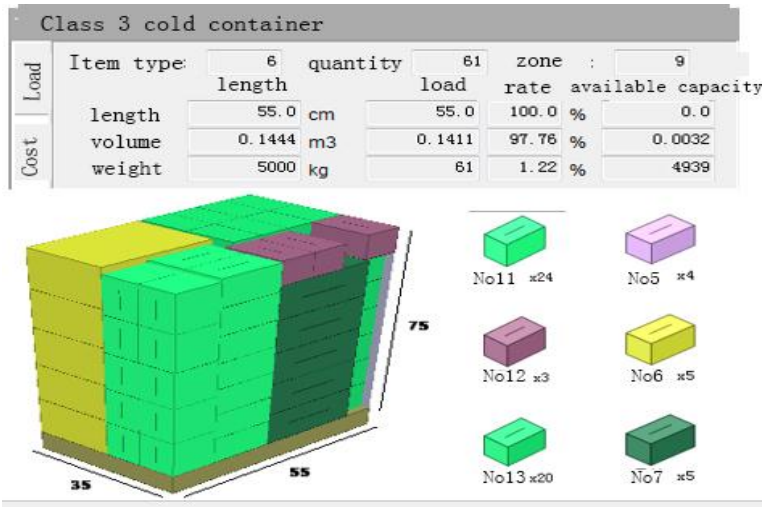

FIGURE 2.7: CLASS 3 COLD CONTAINER VOLUME UTILISATION RATE

2) *Cold Box Weight Loss Rate*

A.When using a Class 1 cold container for line-haul transportation, a vehicle can load six Class 1 cold boxes. This results in a loss of 4 800 kg load capacity, which means that it can only load 25 200 kg freights, as shown in Figure 2.8.

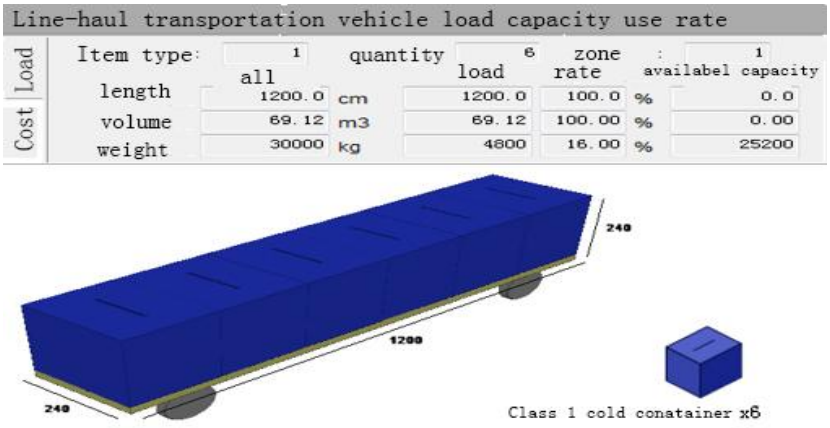

FIGURE 2.8: CLASS 1 COLD CONTAINER LOADING RATE

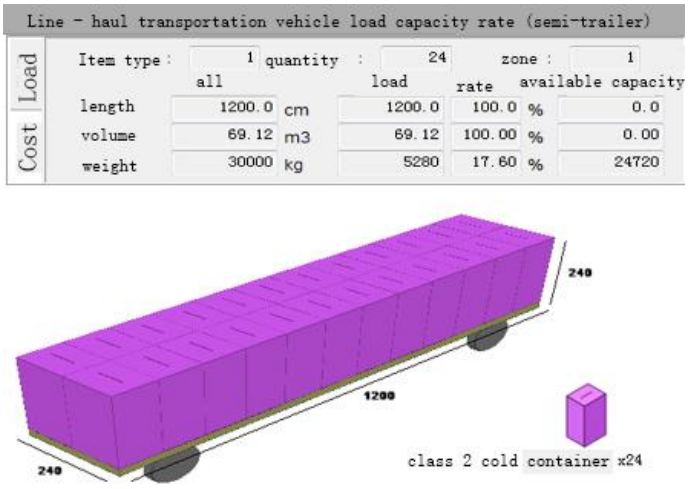

FIGURE 2.9: CLASS 2 SMALL COLD CONTAINER LOADING RATE

B.When using Class 2 small cold containers for line-haul transportation, a vehicle can load 24 Class 2 small cold boxes. This results in a loss of 5 280 kg load capacity, which means that it can only load 24 720 kg freights.

At the same time, Class 1 cold containers, and Class 2 large and small cold containers can be combined to load freights, with a loss of 4 800 to 5280 kg of cargo. This means that they can load 24 720 to 25 200 kg of goods, as shown in Figure 2.9.

C.Terminal delivery load loss rate Regarding the end distribution for small customers, in order to calculate the loading rate for mini-vehicles carrying Class 3 cold containers, this paper takes the micro-car Dongfeng Xiaokang K01 as an example. The car curb weight is 880 kg, with a full load weight of 1 790 kg and a load capacity of 910 kg. The vehicle body size is 4 390 mm x 1 560 mm x 1 825 mm, and the allowed loading dimension is 2 700 mm x 1 440 mm. The weight of an empty Class 3 cold container is 10 kg. When loading, the side door needs to be close to the outside for the easy unloading of goods. By calculation, the mini-car can pull up to 16 Class 3 cold containers. It is also capable of loading 750 kg of cargo, which meets the load requirements for terminal delivery, as shown in Figure 2.10.

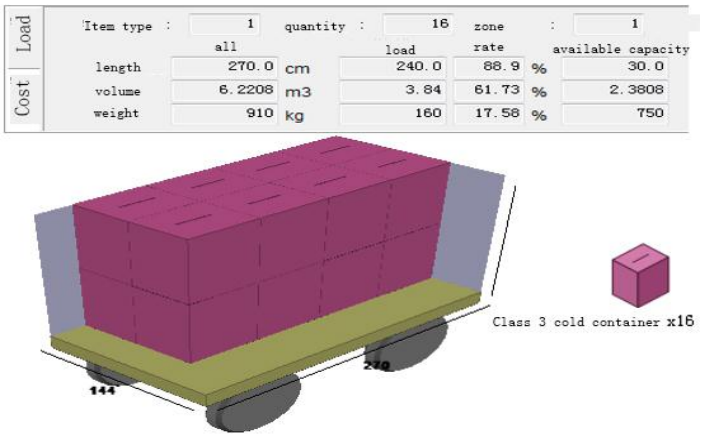

FIGURE 2.10: END-DISTRIBUTION VEHICLE LOADING RATE

Cold Container Loading Principle

1) First in, First out

In distributing cold containers, it is unnecessary to load and unload again and again. These containers only distribute to large customers according to the loading order. For the sake of cutting costs, one would need to make a better choice of the distribution route by planning the distribution order ahead for different enterprises, considering the temperature requirements for different goods, taking the length of the route into consideration, etc. The distribution process needs to be based on enterprises' credibility.

2) Mainly Load Refrigerated Goods and Fill the Rest with General Cargo

Refrigerated goods need to be loaded first in all levels of transport nodes, but when there is still load capacity left, temperature insulation boards can be used to separate the cold container into three different temperature spaces in order to increase the loading rate. This solution not only makes full use of the cold container's loading capacity and increases loading efficiency, but also makes it possible to load general goods and refrigerated goods in the same container, which qualifies as "one vehicle with multi-temperature control".

3) Cold Container Supervision

In order to achieve the real-time monitoring of temperature, a temperature monitoring system is used. Each cold container is equipped with an RFID tag, which is a unique "ID card". To keep track of the real-time status of cold containers, RFID readers are set up at all levels of logistics nodes to connect to the database of cargo details in the information system. The cold containers are numbered, sorted and registered in the database according to cold container classification. Once scanned, all information regarding the container and the goods inside it will be

automatically generated and uploaded to the server, which provides better accessibility to track goods later on. All the information will be checked and registered when it is reported by cold chain hub centres, cold chain regional distribution centres, Zhengming chain stores and Zhengming convenience stores in order to monitor cold containers and cargo, as well as to avoid missing them.

3. Drop-and-pull Transportation Operation Process under a Standard Cold-container System

In practical operations, drop-and-pull transportation is used for standard cold containers. A 12 m low flatbed semi-trailer can load six Class 1 cold containers (2 m*2.4 m*2.4 m) for line-haul freight transportation. A vehicle with a loadable size of 5 m*2.05 m*2.4 m can load two Class 1 cold containers (2.4 m*2 m*2.4 m) for regional transportation or distribution for large customers. A 12 m low flatbed semi-trailer can pull six primary cold boxes (2 m*2.4 m*2.4 m) for truck transport. A truck with a loadable size of 5 m for a standardised cold box and a truck of 2.05 m*2.4 m can pull two Class 1 cold boxes (2.4 m*2 m*2.4 m) for regional transport or distribution for big customers. Small trucks can be loaded with Class 1 or Class 2 cold containers for small- and medium-sized customers' distribution. Various types of transport vehicles just need to drop down the whole container when they arrive at the cold chain transport nodes, which saves a lot of time sorting, loading and unloading.

Line-haul Freight Transportation

Two ends on the main road nodes will be used to conduct drop-and-pull transportation. When the vehicle arrives at Node A, the tractor tows the trailer loaded with cold containers, then transports the cold container to Node B and drops the trailer (loaded with cargo). It then tows an empty or loaded trailer back to the hub at Node A for the next round of transport. This not only reduces vehicle waiting time and cuts the costs of refrigeration, but also reduces the allocation of vehicle resources at both ends, which greatly reduces the cost of fixed asset investment. The ratio of tractor to trailer at both ends is generally 2:3 or 1:3. This depends on the distance between both ends. When the distance is under 450 km, a ratio of 1:3 is recommended. A ratio of 2:3 is taken when the distance is over 450 km.

Branch Line Transportation

A circular container dropping mode is used in branch line transportation. An urban delivery vehicle with a loading size of 5 m*2.05 m*2.4 m can carry this service. It drops parts of the cold container or the whole container from the last node and then loads the cargo onto containers when it reaches a transport node. It repeats this process at the next destination. This circular container dropping mode greatly improves the customers' freight turnaround time, therefore assisting customers to improve service response time, and enhances service value and quality.

End-distribution

Standardised cold containers are used in the end-distribution so as to reduce the number of steps in the sorting process, insulate the cold container into different spaces to transport general and refrigerated goods together, and reduce the food spoilage rate.

For B2B end-distribution for large customers, a flatbed vehicle with a loading size of 5 000 mm*2 050 mm*2 400 mm or a 12 m flatbed semi-trailer for drop-and-pull transportation can be used. The cargo in the cold box has been sorted and packed. Each code container corresponds to a big end-customer, which does not need to be sorted and packed again. Cargo can be directly transported to the customer by the transportation vehicles. Vehicles with a loading size of 5 m*2.05 m*2.4 m can be loaded with two Class 1 cold containers. A 12 m flat-plate semi-trailer can be loaded with six Class 1 cold containers, while Class 1 cold containers can also be combined with cold containers of other models. The use of containers in different combinations meets the transportation requirements of the same customers for different types of goods.

End-distribution for Small Customers

The public delivery of the cold chain packages model is used in the countryside and rural areas. Free-time

deliveryman finishes the delivery of goods to receivers and then takes back cold chain goods that need to be sent. The whole delivery and collection process is taken into consideration when determining salaries. For excellent delivery staff, a long-time corporation contract can be signed to ensure stable service. The emergence of a free-time delivery service provides an opportunity for those who have fragmented free time to make better use of the internet platform and achieve their social values.

4. Conclusion

This paper elaborates on the standardisation of the cold-container system, which can achieve one vehicle with multi-temperature control. It can reduce the food spoilage rate by classifying goods into different categories based on their characteristics. When the cold chain goods cannot fill one container, insulation boards can be used to make it possible to load common cargos in the same container. This solution also facilitates the follow-up transportation processes, increases sorting efficiency and reduces logistics costs. The use of drop-and-pull transportation makes it very efficient to load and unload goods. This design of a standardised cold-container system has a great advantage in the whole logistic operation system. China encourages the standardisation of transportation in order to adapt to various models and situations.

The consolidation and modification of cold containers have greatly improved cold chain transport efficiency and product quality.

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