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Solid carbon dioxide (CO_2), better known as "dry ice," is a most fascinating and interesting chemical. Having a temperature of 109 degrees below zero (Fahrenheit) it is one of the coldest things on earth. It is a product which possesses properties that make it paradoxical in nature. A person may "burn" his hand by holding a piece of it for only a few seconds. The hand is not really burned but is frostbitten. The sensation of such a frostbite is that of burning. When a piece of dry ice is placed in water, the water "boils." It bubbles furiously and vapor with the appearance of steam comes from it. In reality the water does not boil. If you place your finger in it you will find that the water becomes colder instead of warmer. This seething of the water is caused by the rapid disintegration of the dry ice on contact with water. It expands tremendously when it evaporates, the ratio being about 750 cubic feet of gas to one cubic foot of dry ice. This vapor, with the appearance of steam, is caused by the cold carbon dioxide gas striking the air and condensing moisture from the atmosphere. Again, dry ice, as we generally see it, is not an ice; it is carbon dioxide snow compressed together in the form of cubes. These are only a few of the many interesting peculiarities of this product.

Dry ice is the solid state of the gas most of us know as carbonic acid gas—the gas from which soft drinks, ginger ale and soda waters are made. Carbon dioxide is a colorless and practically odorless gas which we exhale from our lungs and is formed whenever any of the common fuels (coke, coal, oil, etc.) burn in oxygen or air. It is present in the open air to the extent of about 3 parts in 10,000. Although this is a relatively small proportion, it is nevertheless a very essential part of our atmosphere, as plant life could not exist without it. It is also one of the heaviest of gases—1.5 times as heavy as air.

Another interesting fact about carbon dioxide is that unlike water it contracts when it freezes. Ice is one-seventh lighter than water, whereas dry ice is nearly twice as heavy as liquid carbon dioxide. This is one of the chemical features of this product that has made it a commercial success.

Due to the extreme cold of dry ice it is difficult to keep it from evaporating. Because of this evaporation, which is technically known as sublimation, there is a real problem in accounting for dry ice after it is produced. This is known as the shrinkage problem and is encountered not only by the producer but also by every user of dry ice. There is another loss between the amount of carbon dioxide gas consumed in the manufacture of dry ice and the amount of dry ice produced, but as this loss comes wholly in the manufacture of the product it is not to be confused with shrinkage of dry ice after it is produced.

To present a picture of the whole cycle of the manufacture of dry ice, a brief description of the salient features in making and handling of this product follows:

Raw carbon dioxide gas used in the manufacture of dry ice may be obtained in a number of ways, some of which are the following:

(a) From the fermentation of molasses or corn in the manufacture of alcohol.
(b) From the burning of coke.
(c) From the manufacture of lime, soda ash, etc.
(d) From the manufacture of carborundum.
(e) From the decomposition of vegetable matter.

After the raw carbon dioxide gas is produced or procured it is usually stored in a large gas-holder similar to the gas-holders used by the manufacturers of illuminating gas. From this gas-holder it is drawn as needed in the production of dry ice, through a series of tanks containing carbon, water and sulphuric acid, which are known as purifiers. All or practically all of the impurities in the gas are removed by this process and it is then drawn into huge compressors where it is compressed through several stages to a pressure of from 900 to 1,200 pounds. Because of the terrific heat generated in the gas in subjecting it to this pressure, it must be cooled, at intervals, in the process. This is done by passing cold water, as well as cold carbon dioxide gas, around in the jackets surrounding the pipes that hold the hot carbon dioxide gas. After the compressed gas has been sufficiently cooled it becomes a liquid and is then allowed to pass into a very strong steel compartment in which it is flashed down to atmospheric pressure. The carbon dioxide in dropping down from a pressure of 900 pounds or more to atmospheric pressure partly turns to carbon dioxide snow and the remainder flashes back into a very cold gas. This cold gas is re-introduced into the manufacturing

cycle and further helps to cool the other carbon dioxide gas made hot by compression.

The carbon dioxide snow which was made in the steel compartment mentioned above, known as a snow machine or converter, is generally hydraulically compressed into cakes of approximately one cubic foot in size. The compressed cake after being ejected from the snow machine is wrapped in kraft wrapping paper and stored in storage boxes, refrigerator cars, silos, or other specially prepared places, where it will not sublime (shrink) too rapidly, there to await shipment and sale.

From the instant dry ice is made until it is sold it shrinks in weight. Accordingly the amount of shrinkage must be carefully ascertained and recorded. To accomplish this each cake or block of dry ice is weighed as soon as it is produced and a record is made of the weight. This record is known as the production record and is the basis of all the cost calculations. As shipments are made from the factory a record is made of the weight and number of cakes of dry ice in each shipment. A continuous inventory is kept at the factory and at all storage points and warehouses in both number of cakes of dry ice and in pounds. This is necessary as, in order to ascertain the daily shrinkage, physical inventories have to be taken at the end of each day in both number of cakes and pounds. These inventories are compared with book inventories to ascertain the amount of shrinkage in weight. Inventories in number of cakes are taken and kept daily in order to guard against theft.

The above description of the more important features of the product "dry ice" and its manufacture has been presented in order that the accounting methods set forth below may be more thoroughly understood.

In determining the cost to produce dry ice the principal steps in the manufacturing process have been chosen as costing points. These costing points or steps, in general, are:

Cost to:

(a) Manufacture raw carbon dioxide gas.
(b) Purify the raw carbon dioxide gas.
(c) Liquefy the purified carbon dioxide gas.
(d) Solidify the liquefied carbon dioxide.
(e) Pack and store the manufactured dry ice.

There is another costing point to be considered, *i. e.*, the cost to distribute or ship dry ice. This cost, however, must be con-

sidered separately as it is not a part of the production or manufacturing cost.

In those instances where raw carbon dioxide gas is a by-product of some other manufacturing process, as in the manufacture of alcohol, caustic soda, etc., the cost assignable to step (a) would be the purchase price of the raw carbon dioxide gas. If the transaction is an intercompany one, the cost to be used would be the amount apportioned to the by-product (carbon dioxide gas) from the principal product manufactured.

In some cases carbon dioxide is bottled and sold in the liquid form as well as in the form of dry ice. When this procedure is followed another costing point, known as the cost to bottle liquid carbon dioxide, is added to the above mentioned steps.

Each one of these steps is clearly defined in the manufacturing process. This is evidenced by the different types of machinery used in each of the steps in the manufacturing process. For instance, in the purification process the machinery through which this part of the manufacturing cycle is accomplished has a definite location and is attended to by a definite type of labor. The liquefaction process is accomplished by huge compressors, condensors and heat exchangers which have a definite location in the plant and are also attended to by a specific type of labor, and so on. Therefore it is quite a simple matter to assign the material and labor as well as the overhead costs to each step.

A comparison of the processes of manufacturing water ice and dry ice discloses certain accounting similarities.

In the manufacture and distribution of water ice the main cost classifications are:

(a) Engine-room expense.
(b) Tank-room expense.
(c) Storage expense.
(d) Distribution expense.

The engine-room expense in the water ice industry is comparable to the cost to liquefy carbon dioxide in the dry ice industry. These processes are similar because in each they have a common ground, compression. Compressors are required in the water ice industry in order to compress and re-compress the ammonia. When the ammonia is permitted to expand in the coils in and surrounding the brine tanks, it absorbs heat from the brine, which in turn absorbs heat from the freezing tanks, thereby allowing the water contained in the latter to solidify into ice.

In the dry ice industry compressors are necessary in order to compress the carbon dioxide gas into liquid carbon dioxide. When this liquid is allowed to expand it forms a solid: carbon dioxide snow.

Tank-room expense in the manufacture of water ice closely resembles the cost to solidify carbon dioxide in the manufacture of dry ice. Water is changed into water ice in this process and likewise carbon dioxide is changed to dry ice.

The expenses making up the storage expense and distribution expense in the cost to manufacture and distribute water ice are practically the same as those making up the cost to pack and store dry ice and cost to distribute or ship dry ice in the latter industry.

As stated above, the basic record in the manufacture of dry ice is the production record. As each cake or block of dry ice is ejected from the converter, or snow machine, where it is manufactured, it is weighed, and its weight is recorded on the production record. At the end of each hour the total number of cakes and the total weight of dry ice manufactured during that time are computed, and a record thereof is turned into the factory office. This information, besides being a basic record, serves to inform the plant manager and others charged with the operation of the plant whether or not the machinery is operating up to its proper efficiency. Any number of things, such as a freeze-up in the pipe lines, leaks in the CO_2 gas line, etc., etc., may be taking place and cause a drop in the efficiency of the operation as well as a reduction in the amount of the manufactured product.

After the dry ice is weighed, it is wrapped in kraft paper. This is done not only to facilitate its handling but also to help insulate it from the outside atmosphere and retard as much as possible its evaporation, or sublimation.

The dry ice wrapped in kraft paper is then placed in storage to await shipment. It is sometimes stored in large, heavily insulated storage boxes or it may be placed in refrigerator cars, automobile trucks or in large storage bins known in the industry as silos.

When the product is withdrawn from storage to be shipped or when a refrigerator car or automobile truck, in which it has been stored, is dispatched to a warehouse, a record is made of the weight of the product, in order that the amount of shrinkage in storage at the plant may be computed. This record also serves as a base in determining the shrinkage of the product in transit.

As the dry ice is generally shipped to a warehouse in another

part of the country, in order to establish records at that warehouse the weight of the product on arrival must be ascertained. From this record not only is it possible to find the shrinkage en route but it also serves the purpose of establishing the weight (and also the number of cakes) for which the warehouse is to account.

When the product is shipped from the plant a shipping ticket is made out and the weight is inserted thereon. This shipping ticket is made up in triplicate. The original is sent with the shipment, the duplicate is forwarded to the home office and the triplicate is retained at the factory. The weight of the shipment and number of cakes shipped are inserted upon the duplicate and the triplicate copies but omitted from the original. This is done so that the warehouseman will be compelled to weigh and count the cakes of dry ice upon their arrival at the warehouse. The warehouseman enters the number of his count, as well as the weight upon arrival, on the original shipping ticket and then forwards it to the main office where it is compared with the duplicate to see that the figures as to number of cakes, etc., correspond. This is an important safeguard against theft.

A continuous inventory of dry ice on hand is kept at the plant as well as at each warehouse. Each day a statement is forwarded from these places showing the number of cakes and weight of product on hand at end of preceding day; number and weight of product produced at plant or received at warehouse that day; the shipments and / or sales for that day, together with the actual inventory at the end of the day. The balancing figure in this statement is the shrinkage in weight for the day. Any shrinkage in number of cakes requires a satisfactory explanation upon the back of the statement by the person in charge at the place in question.

This statement is known as the shrinkage report and the data contained therein are checked, reconciled and posted daily to the shrinkage ledger. At the end of each month shrinkage percentages are computed and compared with previous results. In this way fairly accurate standard percentages are computed. These standards are helpful in guarding against theft.

There are many instances where special handling of the accounting records are required. However the treatment of these cases will present itself as the occasions arise.