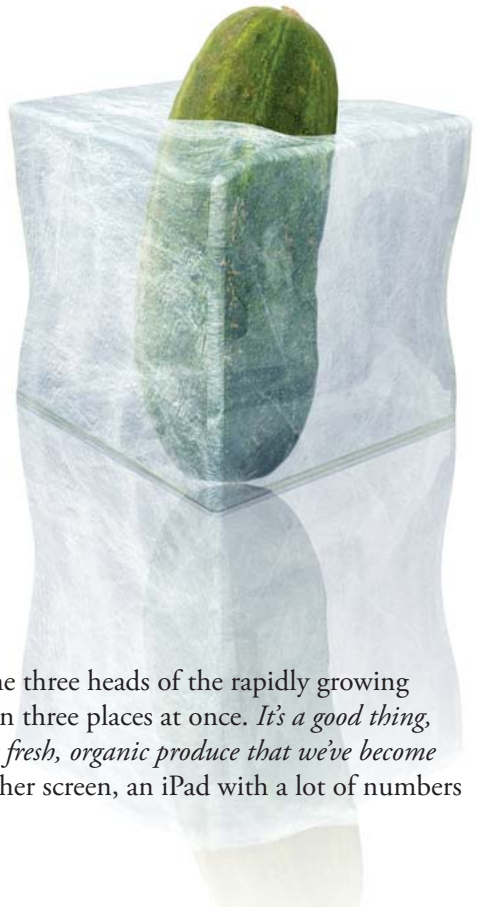
NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Cool as a Cucumber:
Designing a Refrigeration System



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Part I – Not So Cool, and in Need of a Makeover

"Rick, take a look at this."

Rick gave a mental sigh and looked up from his computer screen. As one of the three heads of the rapidly growing Appleyard Produce Company, it seemed like his attention was always needed in three places at once. *It's a good thing,* he tried to remember, *that our once-tiny company has such a great reputation for fresh, organic produce that we've become so popular and had to expand so much.* What was in front of him now was another screen, an iPad with a lot of numbers on it.

"Hi Bev. What am I looking at?" he asked.

Bev smiled. "Proof of how inefficient all those cooling systems for our warehouses are. Do you know we have *eight* separate cooling systems for our four warehouses? Do you know that some of those systems are over 20 years old? They're wearing out, Rick. Some of them are incredibly inefficient. And the fact that we have eight different systems running when we could have one or two that do the same work but require a lot less energy…"

"Okay, okay, I've heard this before," sighed Rick. "Yes, we should probably get a new cooling system."

"Especially if we want to start frozen storage, like Nick has been talking about," broke in Bev.

"I know," said Rick. "It's just a major expense right now. How much are we talking about for a new refrigeration system? And how much money would we save in the long run? And what's the downtime while we're getting a new system put in?"

"Depends on the new system we get, but based on the numbers I have here, this system will pay for itself in two to three years, maybe three and a half if we really go crazy with the cooling," said Bev. "Want me to send you this spreadsheet so you can show Nick and Laurie?"

"Sure, that'd be great. Two to three years, hmmm. Well, we can talk about it at the meeting tomorrow," said Rick.

"Okay, will do. I'll send it to you after I check the ammonia level for the system on warehouse three. It's leaking. *Again*."

Rick sighed. "Patch it up the best you can. Aren't engineers supposed to be good at fixing things?"

Bev smiled. "Yeah, but that dinosaur is so old that it's mostly made out of duct tape and hope. I'll do what I can, but this is one of the reasons why we should get a brand new system. That, and I keep having to tell Matt not to put ammonia in the R134 units. Why did we ever get systems with different refrigerants?"

"It was the best option at the time," Rick said with a wry smile. "Go feed the dinosaur and I'll take a look at what we can do about getting you a new system."

Questions

1. Discuss what could be contributing to the inefficiency of the various refrigeration systems.
2. Discuss ways to increase cooling capacity. Think about the refrigerant, the conditions in the refrigeration system (temperature, pressure, etc.), and the refrigeration cycle.
3. A warehouse for storing frozen product requires significantly more cooling capacity than a warehouse of equal size that is at refrigerated temperatures. Discuss the reasons behind this.
4. To increase cooling capacity, would you purchase a new system? Would you modify the current system? Would you consider other options? Justify your answer.

Part II – How to Make Things Cooler?

Bev was delighted to be told that Appleyard Produce would be purchasing a brand-new refrigeration system for their four warehouses, one of which would be converted to frozen storage. She was currently in the process of selecting a new system. There were a lot of available options.

"Let's see…we have four warehouses that are each 25 m long, 28 m wide, and 6 m tall. Right now, they're at 5°C, but we need to take the one for frozen food down to –18°C to keep our quality up. So these systems by Cooltrol are out; they're too small."

"Working on picking your new toy?" Bev looked up to see Julie, the operations manager for the warehouses. Julie had been a lot of help in getting Bev the numbers she needed.

"Yeah, I'm trying to narrow down the options," said Bev. "How much product can the warehouses hold?"

Julie looked thoughtful. "When filled with as much stuff as we can put in them? Probably about 4 or 5 million pounds of product."

"Argh, English units," mumbled Bev. "Why can't we just use one unit system?"

"Because then you engineers would have nothing to do," laughed Julie.

"Yeah, yeah. You're welcome, by the way, for me getting you a new refrigeration system. And for me keeping the old ones going this long," grumbled Bev.

"Oh, you always complain about units," said Julie with a smile. "And thanks. Oh, that's four or five million pounds per warehouse, by the way."

"Good to know," said Bev. "While you're here, what's our insulation thickness on the walls? About 2 cm?"

"That's like ¾ of an inch, right?" asked Julie. "Yeah, that's about how thick it is. There should be a spec sheet for it on the shared drive.

"Oh, good, that'll help me size this thing," said Bev. "This new system should be able to handle all four warehouses by itself."

"Cool…literally!" said Julie with a laugh. "Let me know what you come up with and when we can get it installed. I'm going to make sure that new shipment of peaches ends up in the right place."

Questions

1. The refrigeration systems need to be able to keep the warehouses at constant temperature. Discuss potential sources of heat/heat transfer that could contribute to the overall refrigeration load.
2. Is your team going to use a single-stage or multi-stage refrigeration system? Explain the reasons you selected this option.
3. What information do you need to design the refrigeration system that has not already been given to you? Where will you find this information?

Part III – Cool by Design

Bev looked at her spreadsheet. "I think this covers most of where the heat can come from. Now I just need to play around with the options and see what works best."

Your team has been given Bev's spreadsheet that can calculate the cooling load from the different warehouses and various refrigeration system parameters. You will use this spreadsheet to design your refrigeration system. Try a couple of different options. Please change only the cells highlighted in green, or the calculations will not be correct.

You may select any fruit or vegetable you like for frozen storage.

Questions

1. You will need values for your process that are representative of fruit and vegetable physical properties (see Part II, Question 3). For every property that you enter, justify your selection of the particular value. For example, is it an average? Is it a worst-case scenario?
2. Are you using the same type of system (single-stage vs. multi-stage) as you selected in Part II? Why or why not?
3. What refrigerant did you select? Explain your reasoning for choosing this refrigerant.
4. What condenser and evaporator pressures did you select? Explain why you selected these pressures.
5. Is your system ideal or nonideal? Justify your selection. If your system is nonideal, how much subcooling and superheat do you have? Explain why you chose the amount of subcool and superheat.
6. What is your compressor efficiency? Why did you select this value?
7. What is the COP of your system? What does this COP indicate about the efficiency of the refrigeration system? Explain your answer.
8. What might happen if the system is oversized? What if it is undersized? Would you choose an oversized or undersized system? Explain your choice.
9. Are you satisfied with the system you created or would you consider other options? Discuss some of the other options available (consider your answer to Question 4 in Part I) and explain why you are satisfied with your system or why you would consider other systems.

Supplementary Questions

1. Contact at least one HVAC manufacturer to see how much your system costs. Compare your estimate with another group. Were you surprised at the cost? What items were included in the estimate? What could you do to decrease the amount quoted?
2. Aside from refrigeration, what other factors need to be considered for the production and storage of frozen foods?
3. How might the processing steps used to create the frozen product affect the cooling load in the warehouse?
4. Most produce needs to be stored at high humidity to maintain quality. How does the humidity affect the heat load in the refrigeration system? What might happen in the warehouse if the temperature fluctuates more than a few degrees?
5. Produce continues to respire under refrigeration. Discuss how to handle the production and consumption of gases by produce respiration in the warehouse.
6. One warehouse contains apples, oranges, bananas, pears, and cantaloupes under refrigeration. How should this product be stored so each variety of produce remains at peak quality?
7. Refrigerant leaks can be a serious health and safety hazard. Depending on the refrigerant, OSHA, the EPA, or other government regulatory agencies may need to be contacted after a leak is discovered. Discuss the potential health and safety hazards of your selected refrigerant. What steps would need to be taken in the event of a leak?

Executive Summary Assignment

Prepare a one-page executive summary of your findings for your supervisor. Your summary should incorporate your answers to the questions. Be sure to include:

- The current problem(s) the company is having with the refrigeration systems and probable causes of the problem(s)
- How the problems are affecting the system and operating costs
- The refrigeration system you designed and the assumptions you used to create it
- The temperatures at which your new system will keep the warehouses
- Why you believe your designed system is a good option for replacement of the current systems

When you are writing the summary, assume that your supervisor is fairly familiar with engineering. However, your supervisor likes to know your thought process behind the decisions you make, so be sure to justify your statements appropriately. For example, why did you select a certain refrigerant or select a certain degree of subcool and superheat? Why would you want to replace the existing refrigeration systems with a single system?

Attach your calculations from the worksheet as an appendix. These attachments do not count towards the one page limit, nor should they appear in the executive summary itself.

Note: Only one summary per group needs to be submitted, but all group members' names must be on the summary for credit. Indicate which group member prepared the report by bolding or underlining the name of the writer.