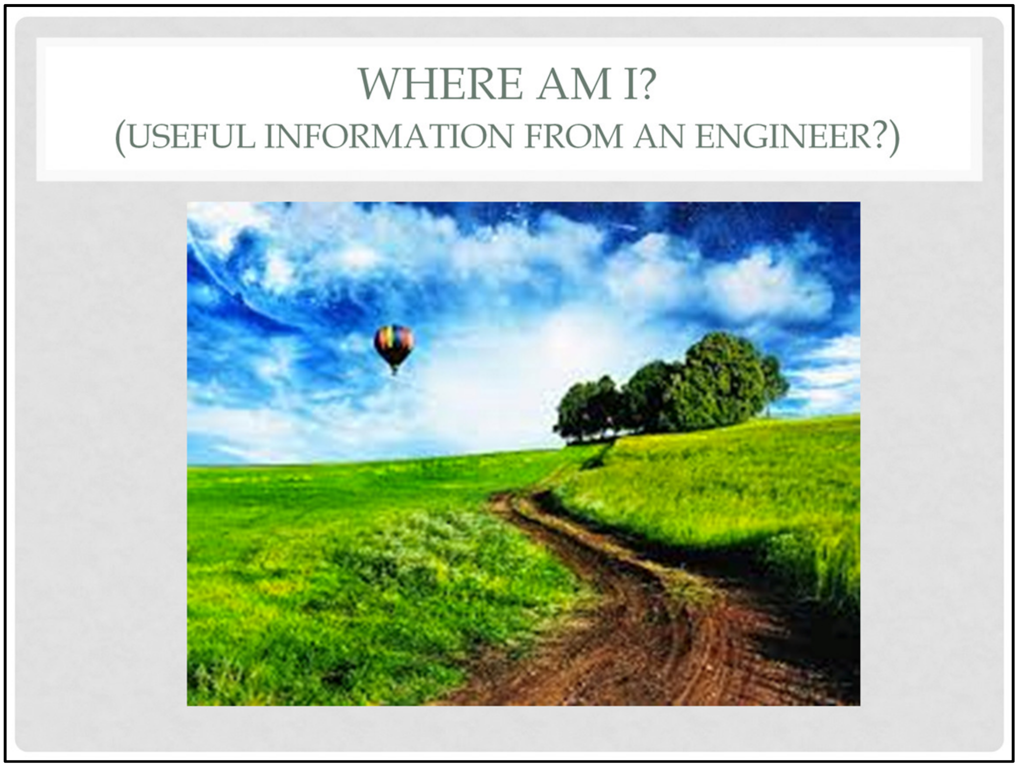
CHARACTERISTICS OF DEICERS

HOW DEICERS WORK (AND DON'T)

DEICER CHARACTERISTICS

I'd like to begin this presentation by sharing a story – with apologies to all managers and engineers in attendance…



I’d like to start the presentation with a short story – with apologies to all engineers and managers in the room…

A man in a hot air balloon realized he was lost. Spotting a man walking on a road below, he descended shouted, "Excuse me, can you tell me - where am I?
The man on the road startled at the voice from above, then squinting up he said, "You're in a hot air balloon hovering approximately 30 feet above the ground.”

Frustrated by the reply the balloonist shouted “NO! I meant WHERE am I??”
The man on the road below replied –” Oh… You're at 47 degrees north latitude and 115 degrees west longitude."

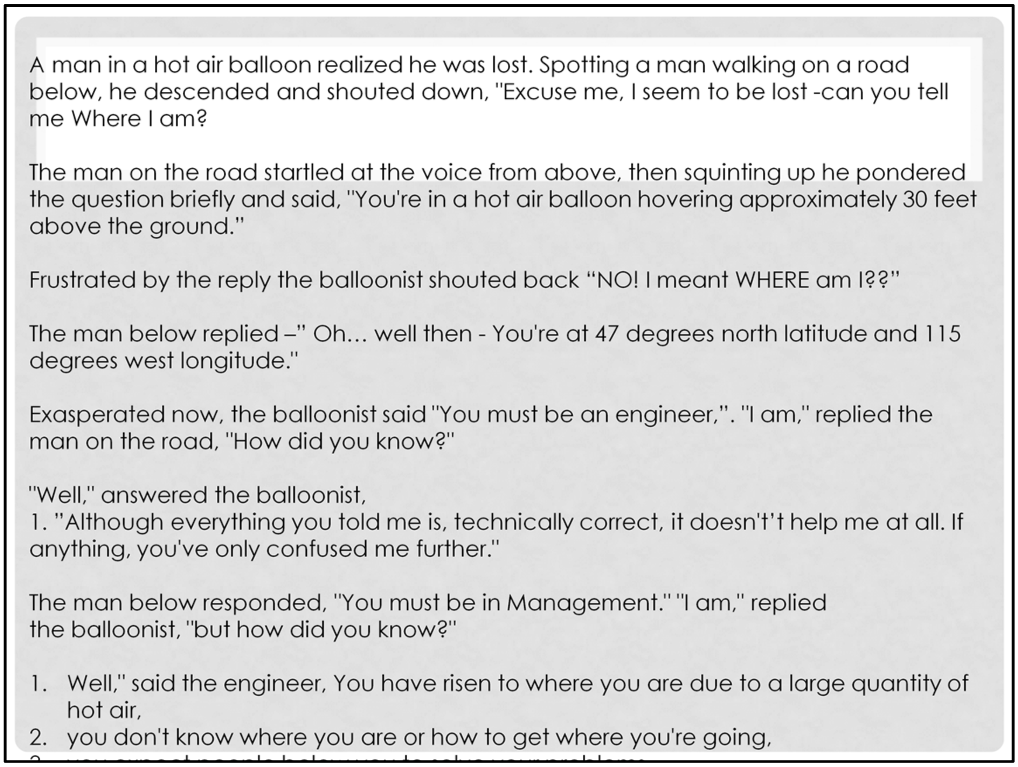
Exasperated now, the balloonist said "You must be an engineer,”. "I am," replied the man, "How did you know?”
"Well," answered the balloonist, “everything you told me is, technically correct, but doesn't’t help me at all. If anything, you've only delayed and confused me further."

The man below responded, ”Oh, You must be in Management." "I am," replied the balloonist, "but how did you know?"

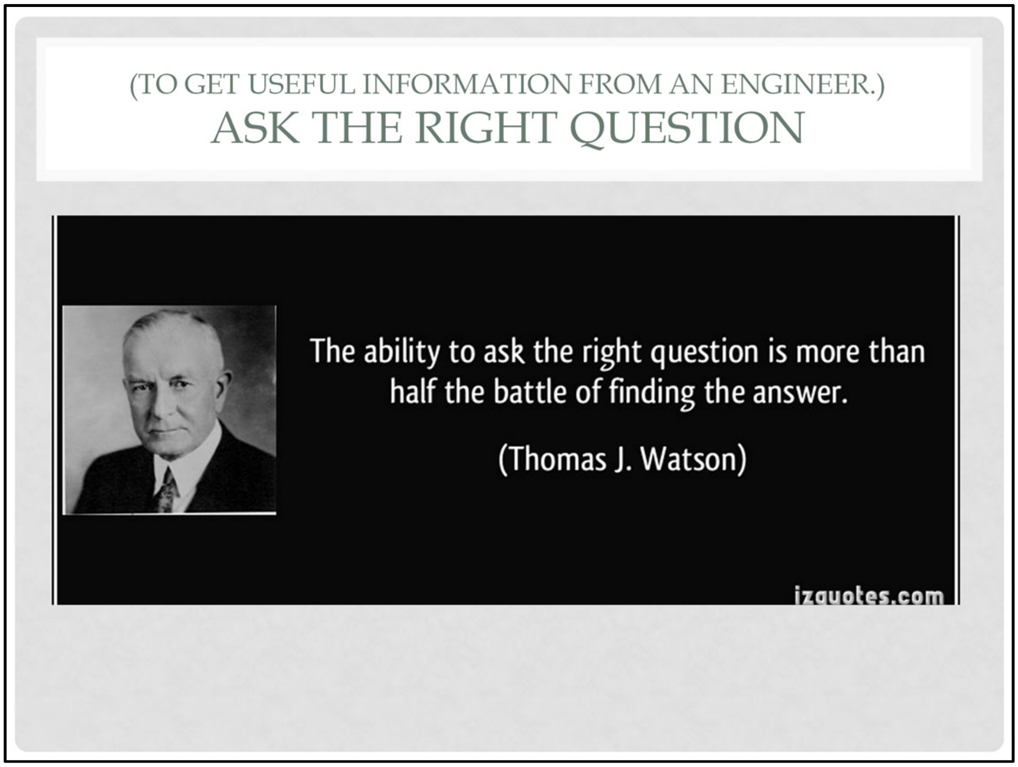
1. Well," said the engineer, You have risen to where you are due to a large

quantity of hot air,

2. you don't know where you are or how to get where you're going,
3. you expect people below you to solve your problems,
4. And even though I’ve answered your question precisely – you aren’t satisfied with the information I’ve given you."



The moral of that story? Engineers are smart folks but sometimes have trouble communicating with management.
It also illustrates the importance of asking the right question… If the manager had asked the engineer which direction is New Town, the engineer would probably have simply pointed the way.
So my goal today is to communicate clearly – while trying to address the right question…



The moral of that story? Engineers are smart folks but sometimes have trouble sharing information with management. And management sometimes has trouble asking the right question.
If the manager had asked the engineer - which direction is New Town? - the engineer would probably have simply pointed the way.
So my goal today is to share some useful information and address the right questions…and in discussing the topic of Deicer Characteristics – What is the Right Question?

THE RIGHT QUESTION… ABOUT DEICERS

- What Are Deicers?
  (No… I mean what ARE Deicers?)
- How do deicers Compare? (Performance)
- How are deicers characterized?
- How Do Deicers Work?

Bottom Line mangers just want to know – Which Product Works Best and Costs Less – and How Soon Can we Get it? But that requires some technical discussion.

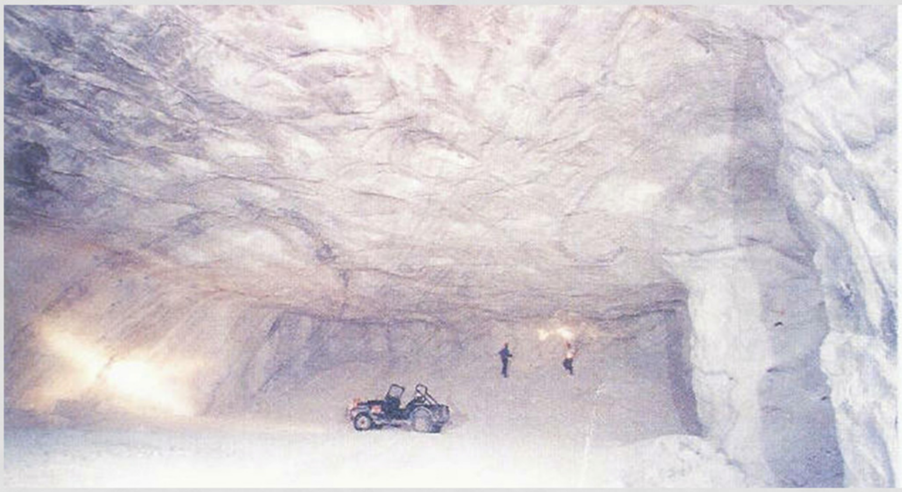
I will apologize again to the engineers in the room – my presentation won't contain all the details you want. And I apologize to all the managers in the audience – my presentation will contain more detail than you want… But to begin our discussion, lets talk about what deicers Are…

WHAT ARE DEICERS?
SALT

Solar Salt from Brine

Ask people outside of our industry for one word to describe Deicers and they are likely to do one of two things – return a blank stare, or say “Salt”.
There are now many other chemicals we use for Deicing, but the Beginnings of Deicing is Salt Usage. And this is a good place to start our discussion.
Salt is a $2.3 Billion dollar industry with 43% going to Winter Road Deicing. We use a lot of salt in deicing operations..

MINED SALT

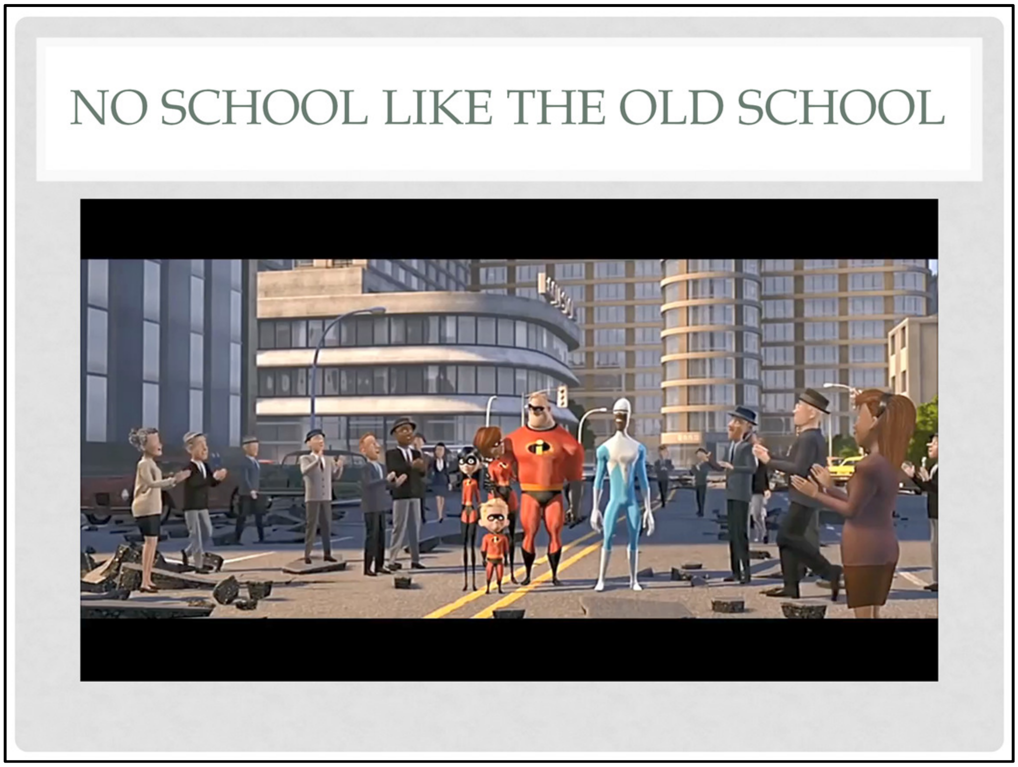


Salt is used because it is abundantly availability and relatively low cost and it works pretty well for melting snow and ice.

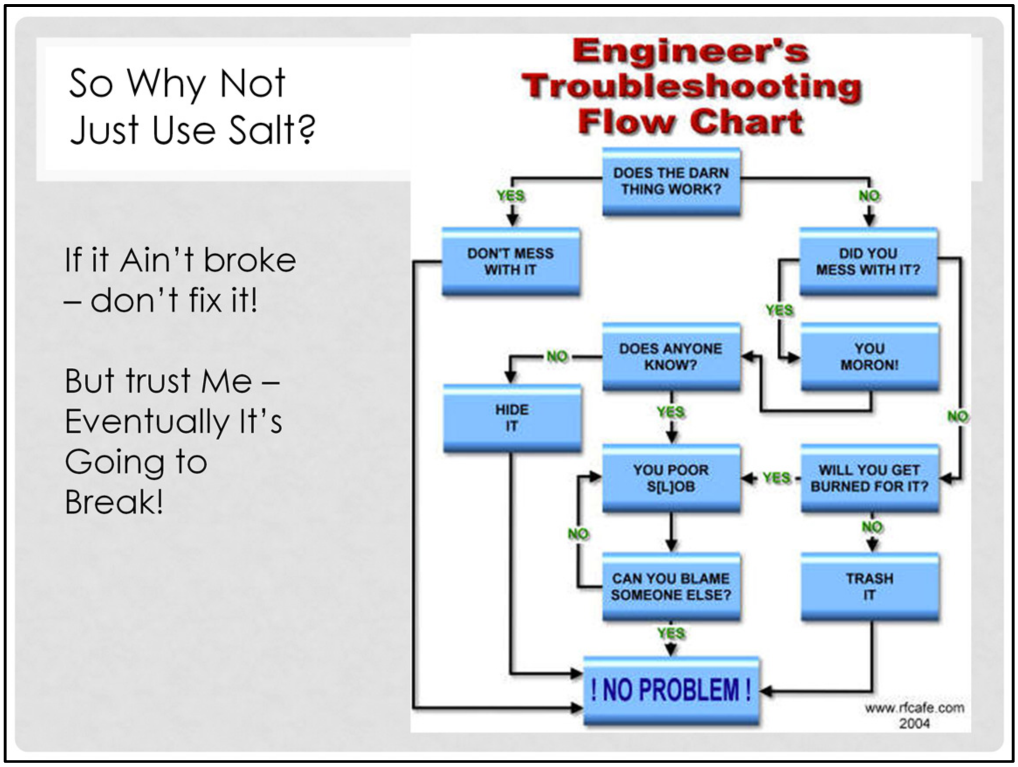
TRIED AND TRUE

…Salt or Salt/Sand is an Old Standby - But the best you can do?

More than that, salt application is pretty well understood by deicing practitioners.
It owes its popularity to the fact that Road Crews have always been expert in solid material handling.
The same equipment used to build and maintain gravel roads in the summer could be used for salt application in the winter.
And at the end of the day, we are creatures of habit and prone to do things the way they’ve always been done.



Just as Frank and Ollie say in this clip from the movie The Incredibles – there's no school like the old school. (play Clip) Salt is still the backbone of many deicing programs, but changing times lead to changing priorities… Levels of Service have risen due to public demands. The Economic Impact of Road Closures in a Metropolitan Area is Enormous. Our Society now has a critical dependence on transportation and infrastructure. Failure of the transportation system is not an option. Old School, for all its virtues – is not up to new standards.

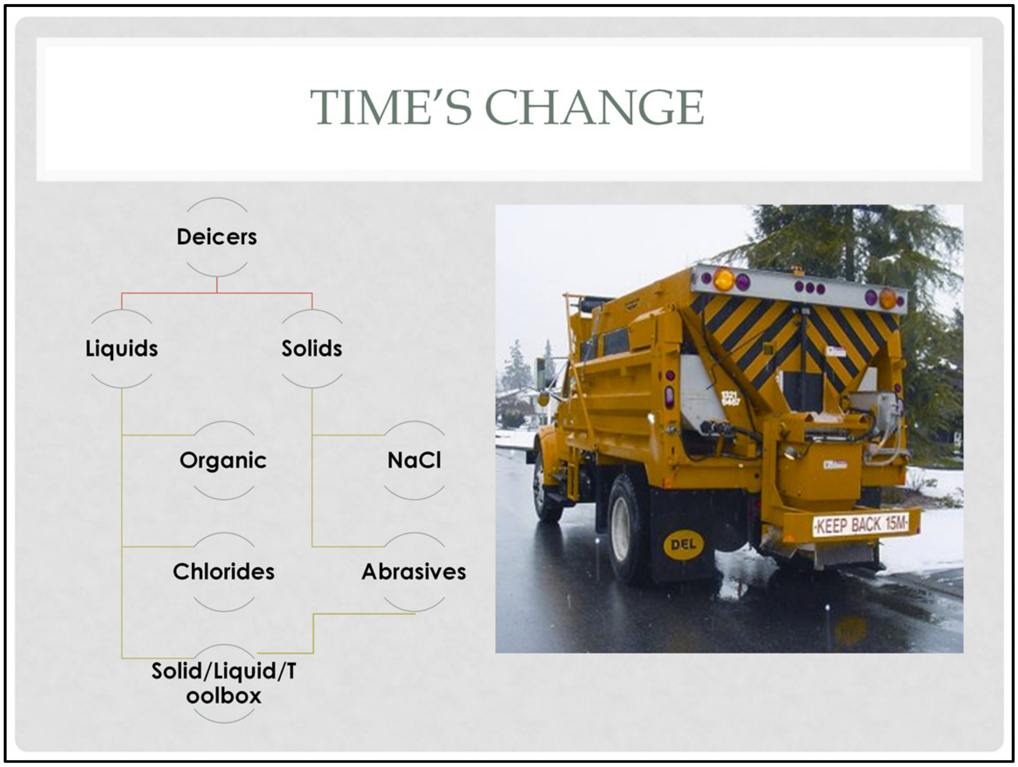


Why Then Do We Stick with Old Ways? People are naturally risk averse. When it comes to our jobs, we want to avoid becoming trapped in the Engineer's Troubleshooting Flowchart…

There is a genetic reluctance to change – especially if something is working ok.

The problem is that even if you don't "mess with it" – eventually a winter storm will get the upper hand and you will be pulled into the flowchart trap shown here…

So staying current with new technology is now part of the job of winter maintenance, and new Deicers are a big part of that technology.



What is the New Technology in Winter Deicing?

Perhaps the biggest change to winter deicing practice has been the incorporation of liquid deicers into the overall deicing program. The old dump trucks used to spread solid salt and sand have been replaced with sophisticated, computer calibrated, dual application equipment such as shown here. These rigs typically apply liquid deicer to solid salt as it is being spread, or depending on conditions liquid only, solid only, or combinations of these products as situation on the roadway demands.

Adding Liquids to your deicing program has many advantages.

Improved Safety! Lower Total Costs of Operations. Higher Level of Service. Reduced Total Deicer Application (Anti-icing) and a Smaller Environmental Footprint are among these.

These liquids can be used as stand-alone products or combined with solid salt to enhance performance… In the vernacular of modern deicing practice – we now have a Toolbox of Deicers.

CASE STUDY

Thompson Falls Section

Plains Section

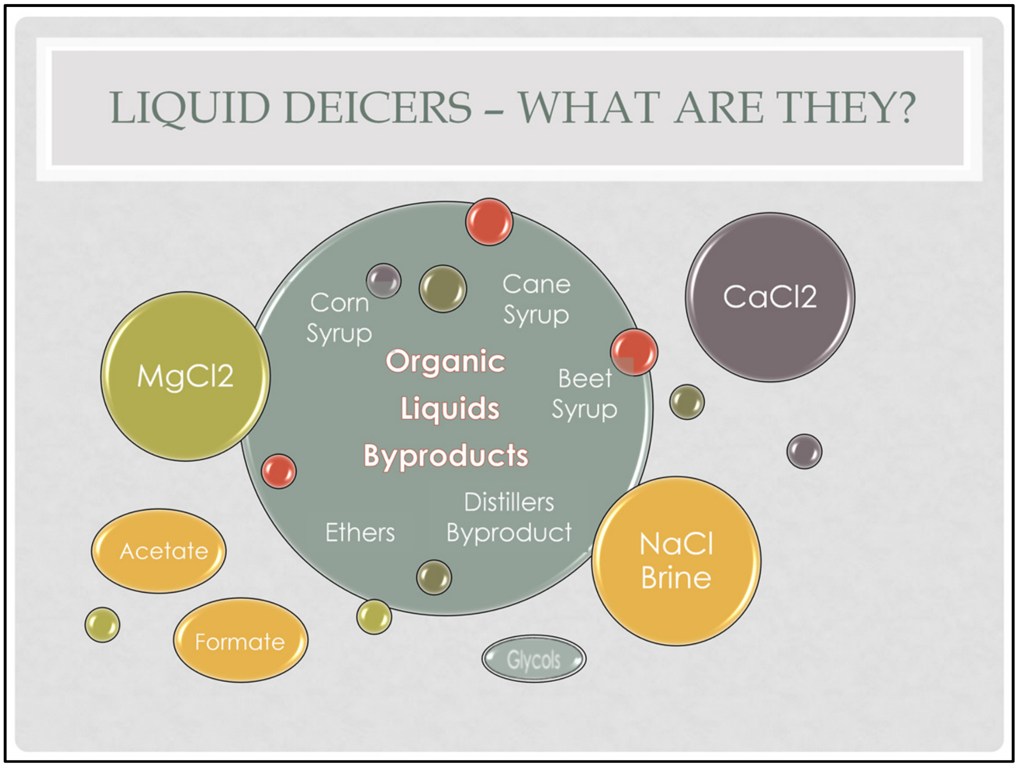
- Winter 2000
- State Route 200 NW Montana
- Liquid MgCl2 vs. Salt/Sand/MgCl2
- PS – 3000 gal Mg / TFS – 1500 gal + abrasives

Montana DOT Winter Maintenance Annual Averages

	Thompson Falls Section	Plains Section	Percent Difference
Sand Quantities	73 cubic yards (56 cubic meters)	43 cubic yards (33 cubic meters)	41%
Sand Costs per lane mile	$724	$407	44%
MgCl Costs per lane mile	$136	$233	N/A
Material Costs per lane mile	$860	$640	26%
Equipment Costs per lane mile	$327	$182	44%
Labor Costs per lane mile	$564	$273	52%
Total Costs per lane mile	**$1,750**	**$1,095**	**37%**

http://www.ops.fhwa.dot.gov/weather/Publications/Case%20Studies/11.pdf

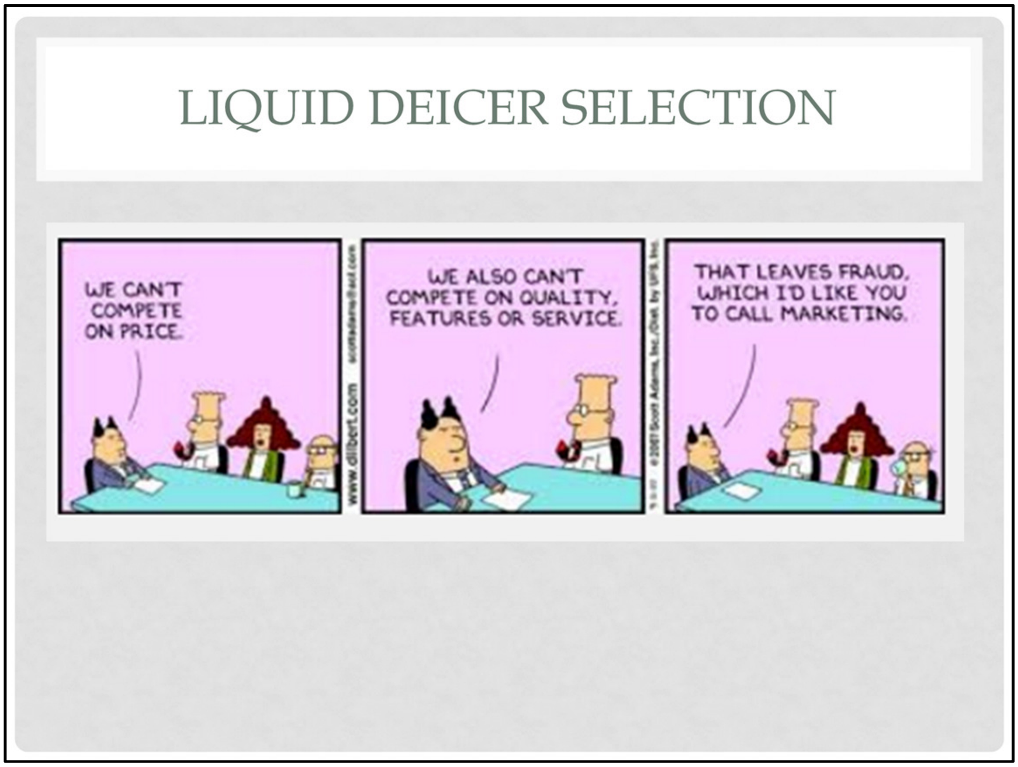
Here is a case study showing that Doing things “Old School” cost more and delivered lower level of service, than adopting a new practice.
Two sections of a highway in NW MT were evaluated. One used predominantly MgCl2 Liquid with some abrasives, the other used predominantly abrasives with some MgCl2.
The Public Called their commissioners and complained about the roads in Thompson Falls and suddenly the Maintenance Chief in charge of this section was looking for a way out of the Engineers Troubleshooting Flow Chart… If you “Don’t Mess With It” – you still wind up looking for solutions…



And “Solutions” are what I’d like to talk about now.
When it comes to Liquid Deicers There are PLENTY of Choices… A Manager might legitimately look at this situation and declare that this long list of “Improvements” – Only Confuses Him Further…
How are these products similar and what are their differences? When should they be used – and when should they be AVOIDED? What Are the Cost Implications in terms of Equipment, Training, Man Hours, Liability Issues for these “Chemicals”, and what about Environmental Factors?

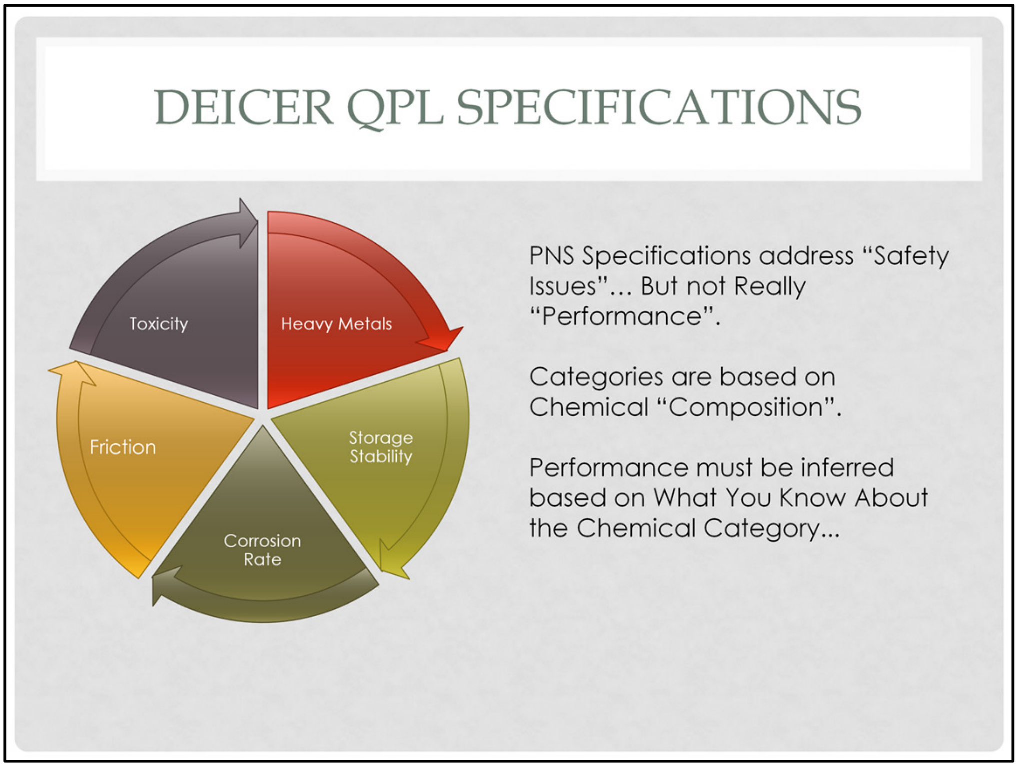
LIQUID DEICER SELECTION

Wading into the pool of liquid deicers really **<u>is</u>** complicated. And its understandable that management might have reservations about turning over the success of their deicing program, and possibly even their own job tenure, to an engineer or shed foreman that recommends “improving” their program with an unfamiliar product. In conversation, as Dilbert illustrates, and sometimes in practice, engineers are often prone to jumping the gun when something new and “better” comes along..



Worse still, you may have a steady stream of vendors stopping by with Marketing Information for their latest and greatest deicing product… so how do you determine if these products really are good deicers, or just good marketing?

Fortunately, to help agencies sort through the product options the PNS has developed specifications for several categories of liquid and solid deicers.
These specifications result in products that are “Approved” for use by the PNS and placed on the QPL or Qualified Products List.
Adhering to this list will help engineers and managers come to an informed decision on the use of new deicing products.



The QPL is a great asset for Agencies looking to purchase Deicing Chemicals. QPL Products have passed a battery of testing that assures they are safe and meet minimum performance requirements.

But unfortunately, these Categories are Based on Composition – Not Performance. They tell you WHAT you are purchasing, but not "HOW They Will Work". The QPL Assumes You Have a Minimum Level of Understanding Regarding Deicing Chemical Performance… based on what is "in" the product.

So I'd like to focus your attention now on the relationship between deicer performance and what is in these products.

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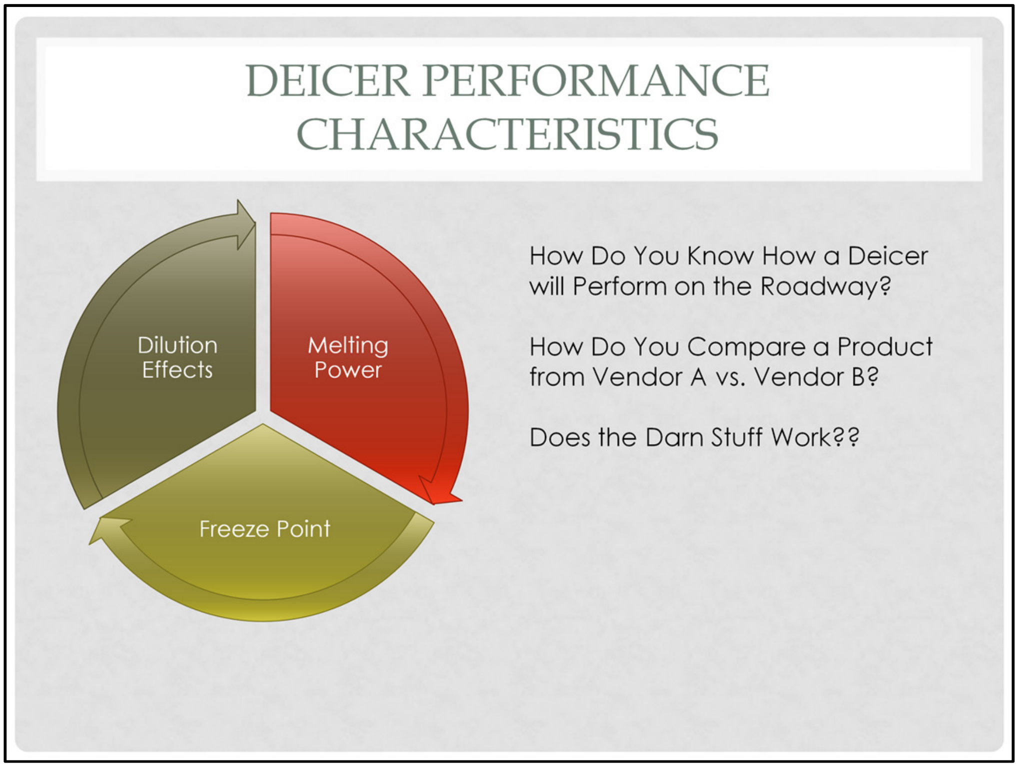
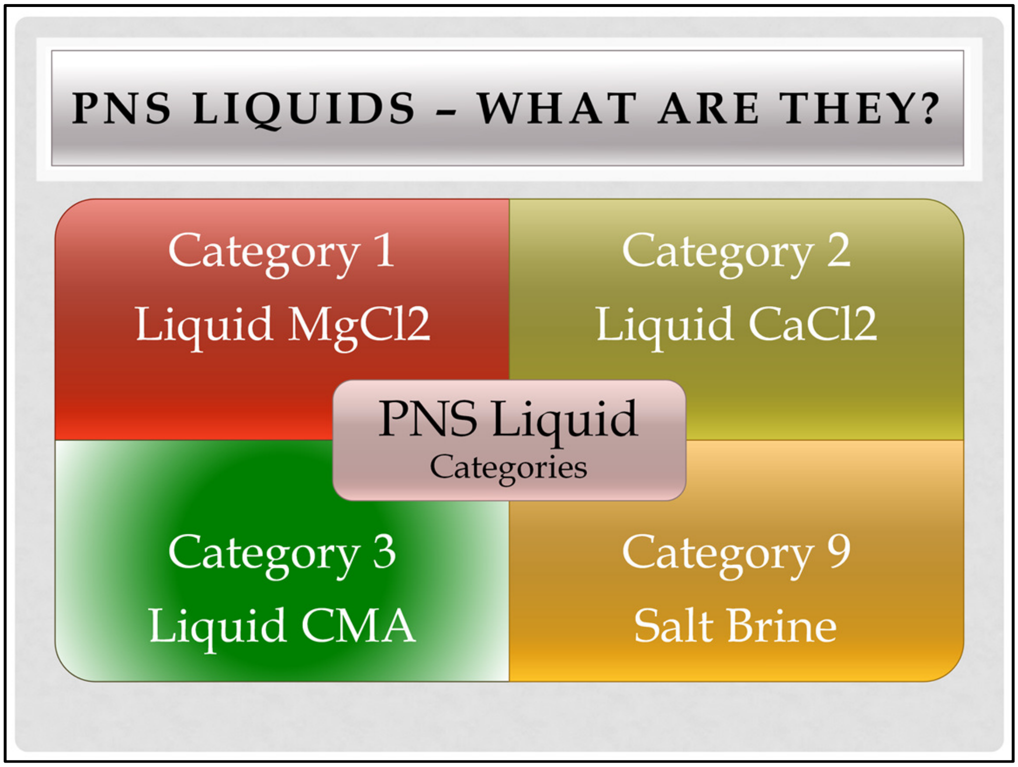
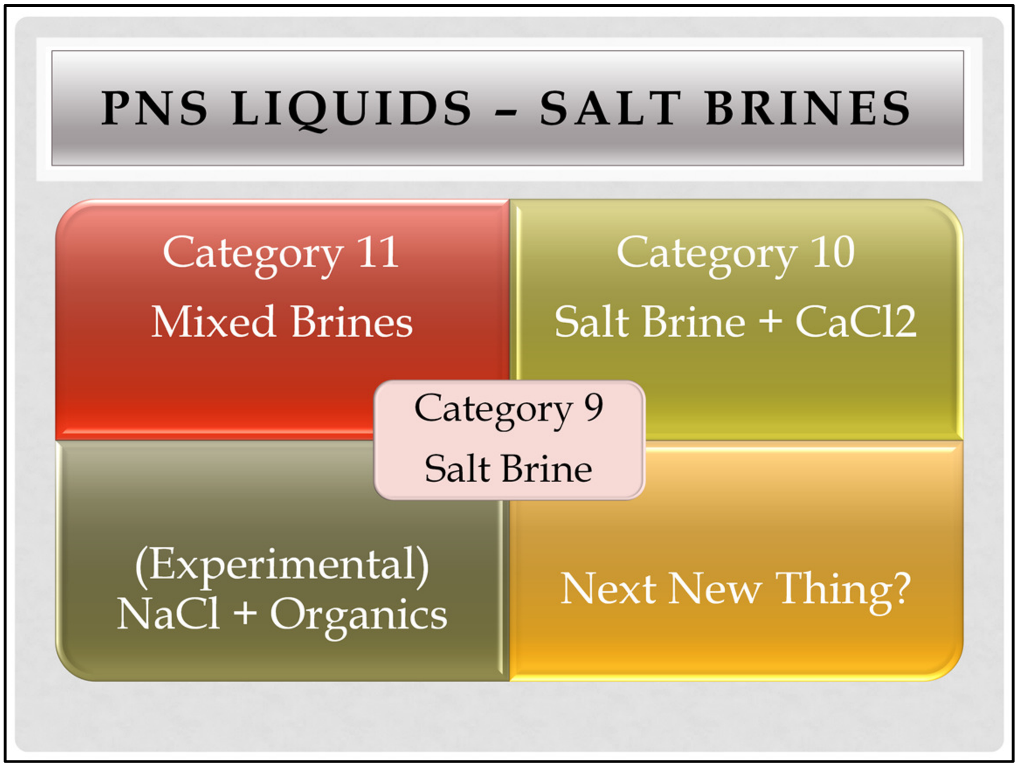


Some of the Performance Characteristics of Deicers are shown here…
At the end of the day – what you really need to know is if the product will work for you under the conditions unique to your climate and road conditions…
Melting Power, Freeze Point, and Dilution Effects are all related and key to understanding the performance potential of various deicers.
Lets start with a brief overview of potential choices…



The PNS QPL Lists Several Categories of Liquid Deicers as shown on this slide. The Calcium Magnesium Acetate product is the only Non- Chloride with its own PNS category, the rest are all Chlorides of one type or another.



Salt Brine (Category 9) has become a popular liquid deicer for many of the same reasons that Rock Salt has been popular.

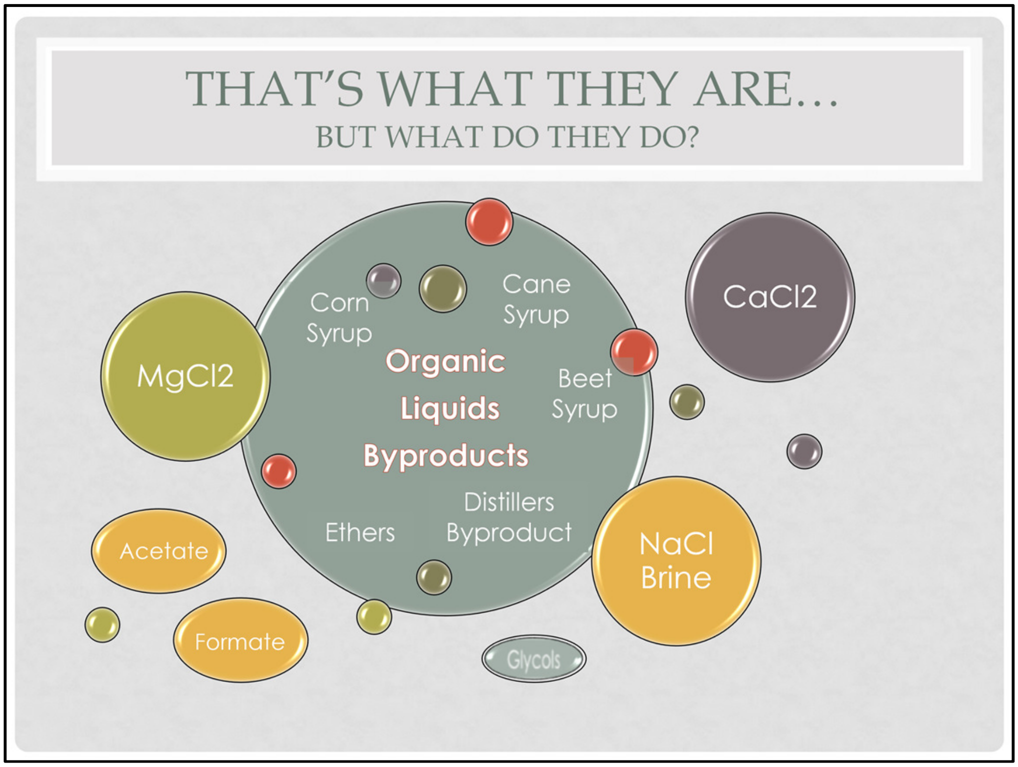
If you have a salt pile – like most agencies do – and a good water source, and a capable crew that likes building tanks and plumbing, you can make your own liquid brine deicer.

Success breeds spin-offs so there are now a few other PNS categories of Salt Brine mixed with other deicers.

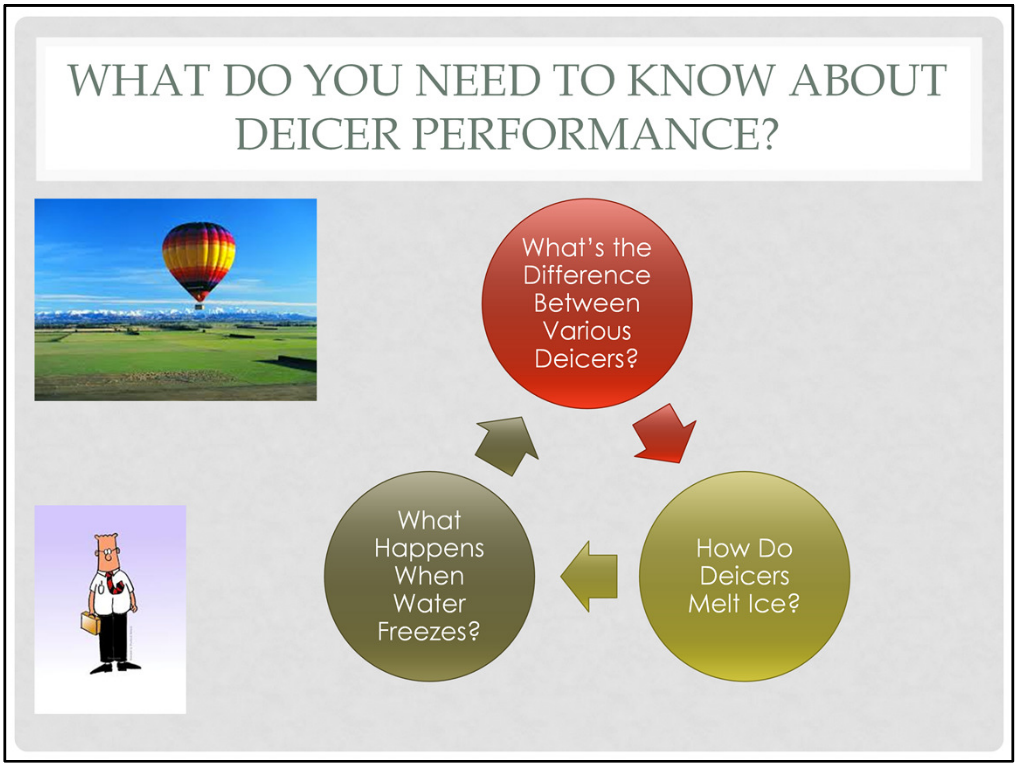
It is worth mentioning that Most of these mixed brines were developed to address shortcomings in the straight salt brine product, such as lower melting power and higher freeze point.

Salt Brine has replaced MgCl2 and other liquid deicers in many places due to its perceived or perhaps actual lower cost. Sometimes this is a good idea, other times an expensive mistake… WADOT discovered this the hard way a few years ago when they implemented a salt brine operation in the Seattle-Tacoma region. There, the lower concentration of salt brine led to rapid dilution and refreeze in the high humidity and precipitation climate of coastal Washington.

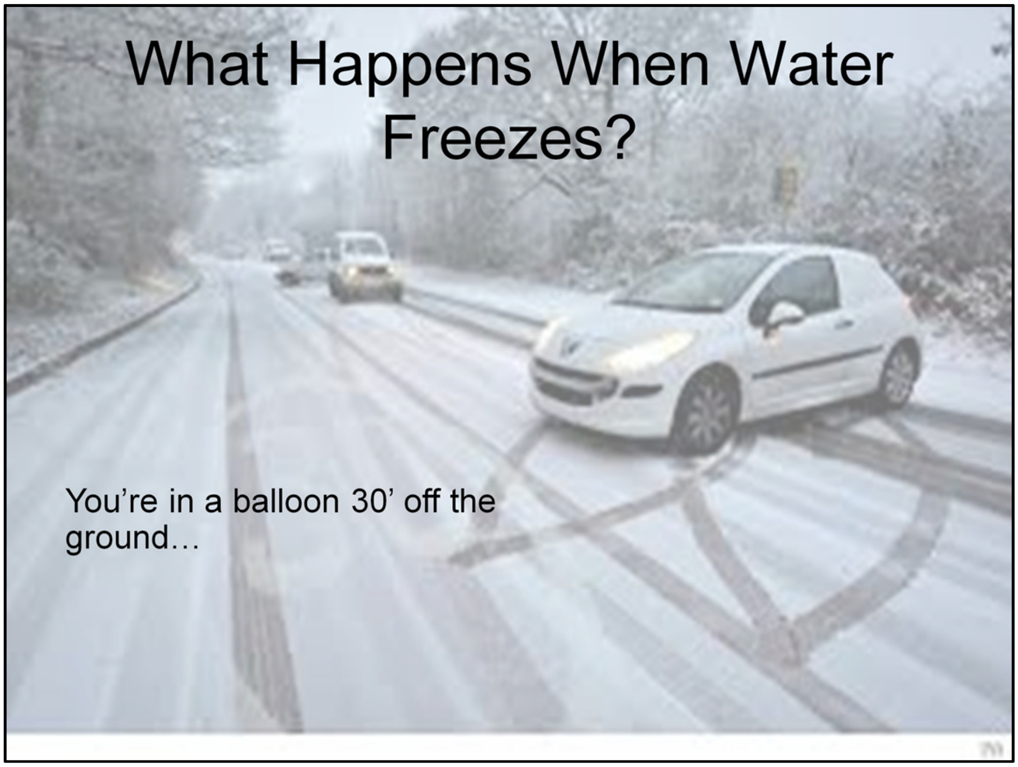
Understanding WHAT these liquid deicers are, and how they work can help avoid the latter… and the engineer's troubleshooting maze.



Liquid deicers are the “kitchen sink” of the deicing world. There’s a little of everything in this group, from food quality corn syrups to other products that border on industrial waste.
----- Meeting Notes (6/4/16 18:14) -----
The way to tell the good from the bad is to evaluate their performance. This will distinguish between good products and good marketing. So what do you need to know about performance?



A Basic question for this seminar is What's the Difference Between Various Deicers. Before we can answer that we need to look a little deeper to refine the question...
To know what the differences are, we need to consider how deicers work to melt ice, and to understand that we should start with what happens when water freezes.



We all know what happens when water freezes. Seems like a pretty silly question with an obvious answer…
But it is something that is really worth considering.
Because I don't mean "what-happens-when-water-freezes", I mean "WHAT" happens when water freezes?

And its really important that those responsible for deicing our roadways understand this…
For all the joking around and Dilbert Humor, What we do is really serious business.
Using the Right Deicer, at the Right Application Rate, at the Right Time – can prevent scenes like this…
So Understanding the basics is really important, whether you're the truck driver, the shed foreman, the section chief, or the Winter Maintenance Manager for the State.
(pause)
There is in fact a well defined science that describes deicer performance... And tells us what we need to know.

HERE'S HOW DEICERS WORK

Blagden's Law $\Delta T_F = K_F \cdot b \cdot i,$

Kf = cryoscopic constant of water – 1.853
b = molality (chemical conc. of deicer)
i = van't Hoff factor

Ge & Wang (2009)

$$\Delta T_{\mathrm{F}} = \frac{\Delta H^{\mathrm{fus}}_{T_{\mathrm{F}}} - 2RT_{\mathrm{F}} \cdot \ln a_{\mathrm{liq}} - \sqrt{2\Delta C_p^{\mathrm{fus}} T_{\mathrm{F}}^2 R \cdot \ln a_{\mathrm{liq}} + (\Delta H^{\mathrm{fus}}_{T_{\mathrm{F}}})^2}}{2\left(\frac{\Delta H^{\mathrm{fus}}_{T_{\mathrm{F}}}}{T_{\mathrm{F}}} + \frac{\Delta C_p^{\mathrm{fus}}}{2} - R \cdot \ln a_{\mathrm{liq}}\right)}.$$

Really about everything you need to know about deicer function is included in these two equations –

----- Meeting Notes (6/4/16 18:21) -----
But unless you are an engineer that speaks this language your reaction to this information is bound to be that shown on the next slide...

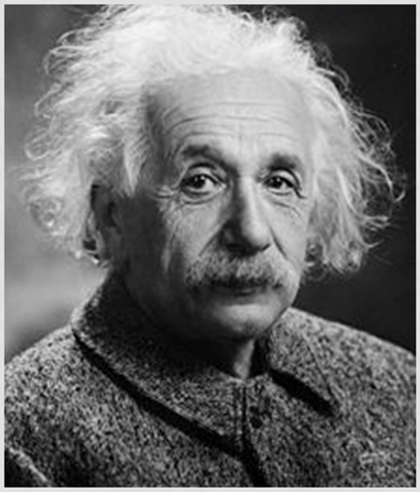
… And Here's Your Response.

Don't Worry and Please Don't Run for the Door – This Seminar is not going to devolve into a lecture on Physical Chemistry.

SOMETIMES THE DETAILS ARE LESS IMPORTANT THAN THE BIG PICTURE…

Blagden’s Law and the Ge/Wang’s Formula actually DO Tell Us with Good Accuracy the Difference Between the Various Deicers and How they perform.
But not in a way that will Help the average practitioner understand the Practice of Deicing… and Keep The Roads Bare and Wet during a Storm.
----- Meeting Notes (6/4/16 18:28) -----
So relax - we will take a"big picture" approach in discussing this science. Actually we will rely on some advice from a recognized genius...

EINSTEIN'S RAZOR

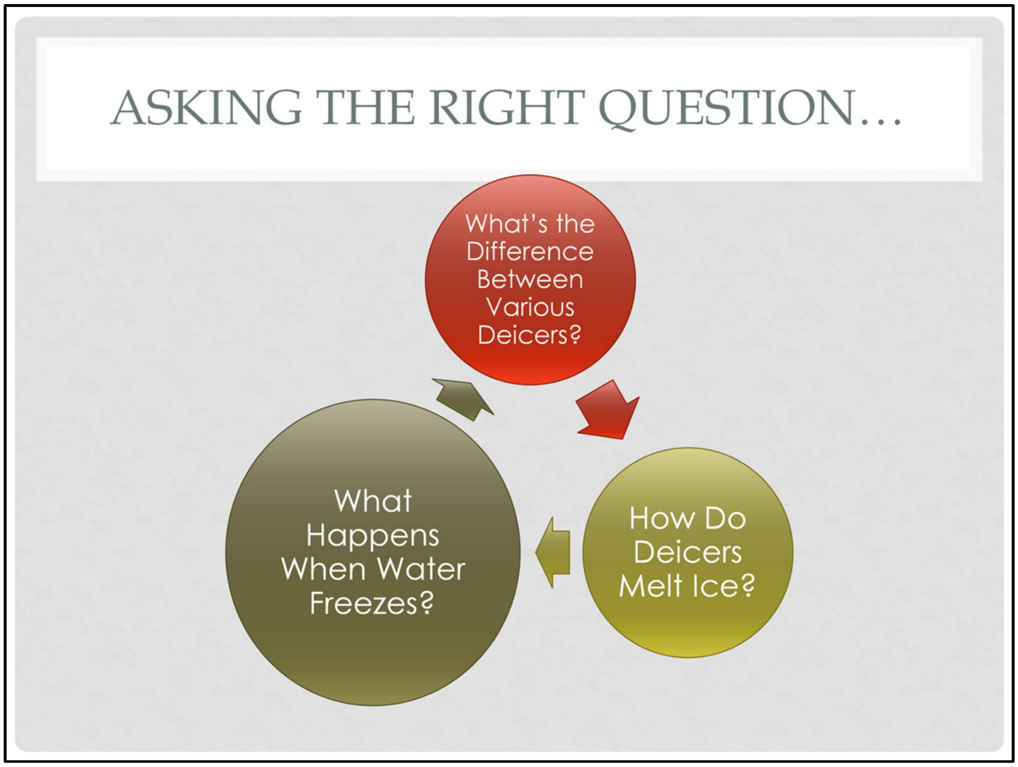


"Everything should be made as simple as possible, but no simpler."

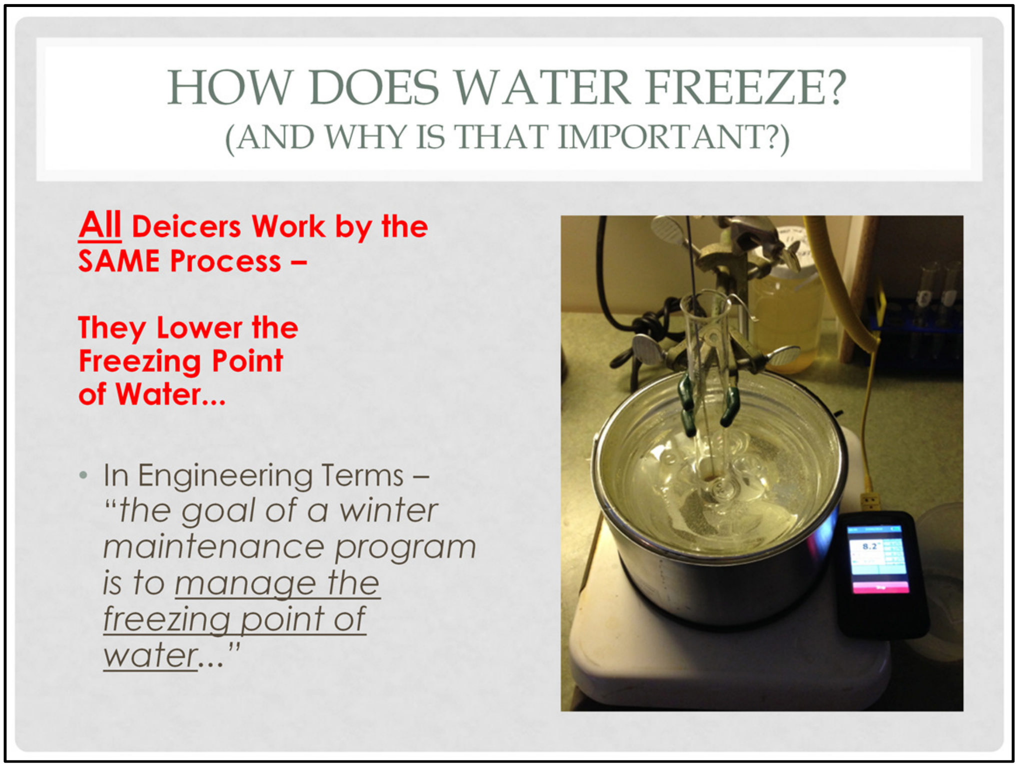
What are the Basic Facts We Need to Understand About How Deicers Work?

Einstein's Razor says that Everything should be made as simple as possible (but no simpler).

Paraphrasing this - Any idiot can take a simple thing and make it seem complicated, but only a clever man can make something complicated easy to understand.
So lets rely on what some clever men have to say and see if we can discover some simple facts we need to know about deicers.

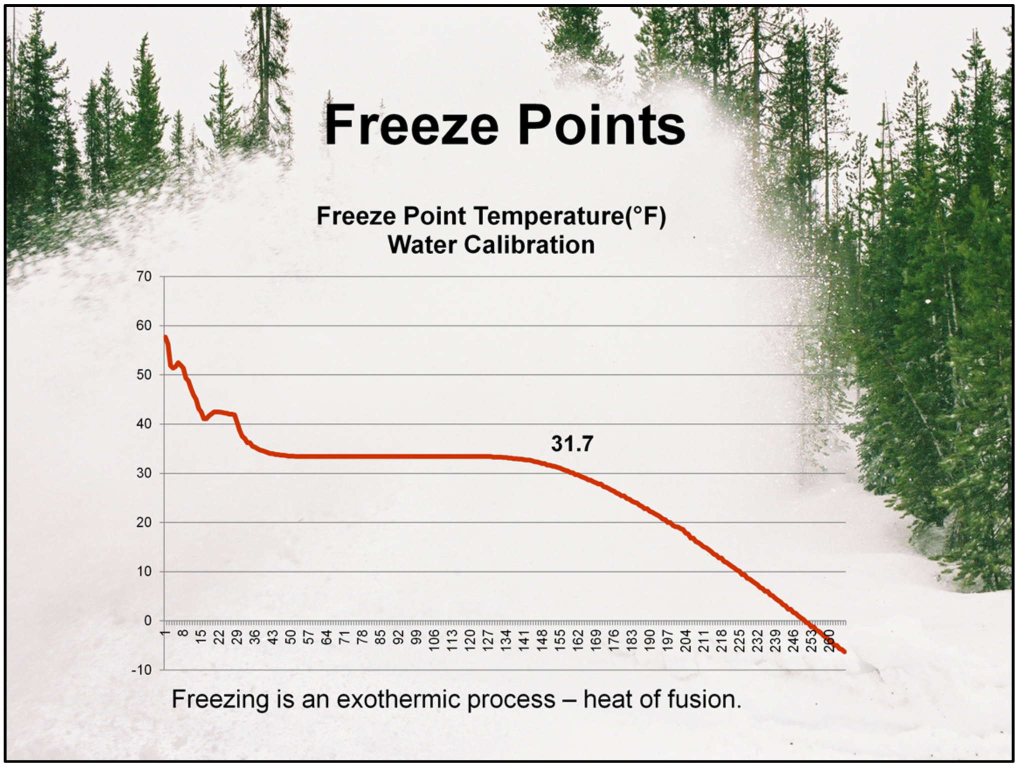


Let's start again with the simplest question – and consider what happens when water freezes.
----- Meeting Notes (6/4/16 18:28) -----
If you want to understand deicers you have to start by understanding "how" water freezes.



This is a Key Point…All Deicers Do Exactly the Same Thing In the Same Way – they lower the freezing point of water. If you can appreciate this statement – you have the basis for choosing and using deicers.
In Engineering Terms – the goal of a winter maintenance program is to manage the freezing point of water.
We Do that by applying Chemical Deicers and Changing the Freeze Point of Water – which is another way of saying Preventing Ice Formation and Melting Snowpack.

To Determine the Freeze Point of a Deicing Brine – we do a simple test. A deicer is placed in a test tube, the tube placed in a dry ice bath, and the temperature recorded as the product cools and freezes. This procedure mimics what happens on the roadway. The results of this test are shown on the next slide…



What we see is a bit surprising! The temperature decrease within the deicing brine (the temperature of the liquid in the test tube) is interrupted in its cooling process by a temperature plateau… This is fundamental to understanding the freezing process and how deicers work.

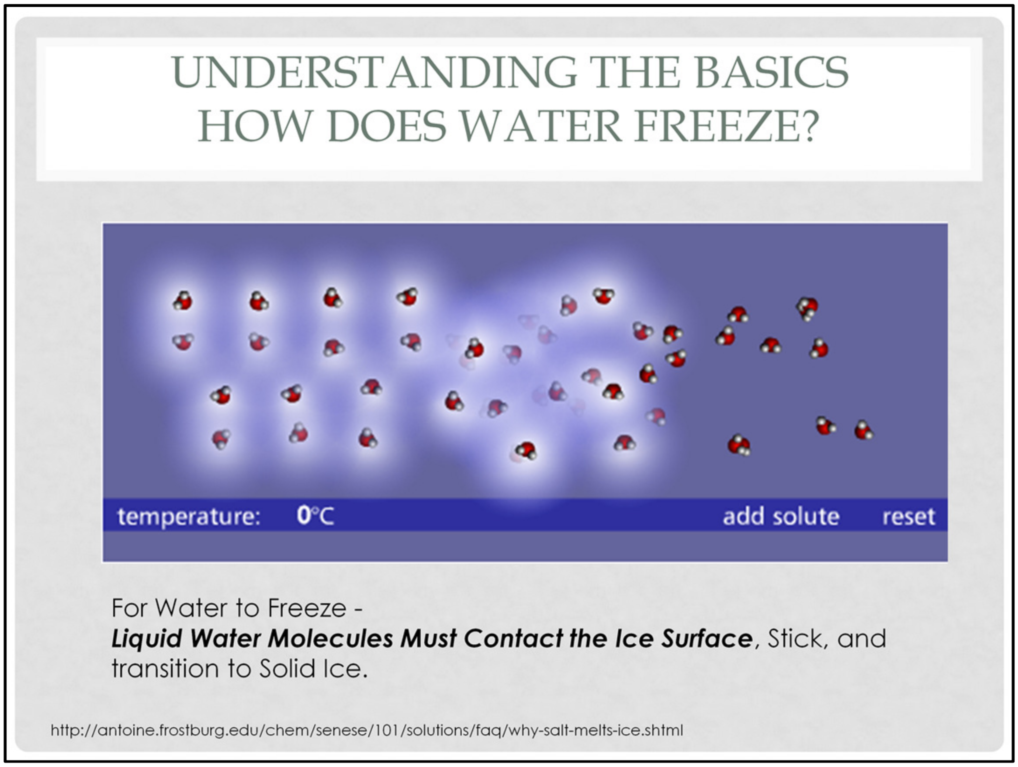
As Ice forms – the water molecules lose kinetic energy and release heat into the system.

It makes perfect sense right? The ice is colder than the water, so for water to become ice it must cool, or give off heat.

We see this released heat in the freeze chart as it counterbalances the cooling from the ice bath. The freeze point is at this plateau in the temperature curve.

At this plateau, liquid water is undergoing the transition to solid ice.

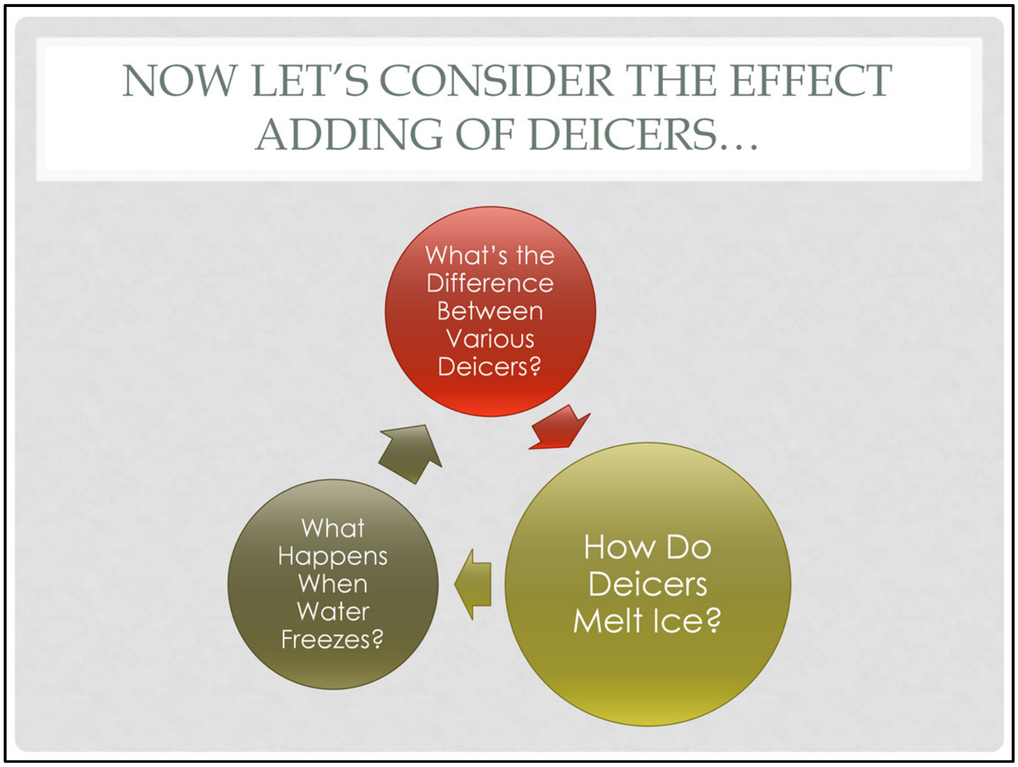
A practical application of this principle is why orchards spray their trees with water when frost is forecast… The orchardist is using this chemical principle to warm his blossoms by pulling the heat from the liquid water as it turns to ice. This is the same process that occurs on the roadway when water freezes to ice.



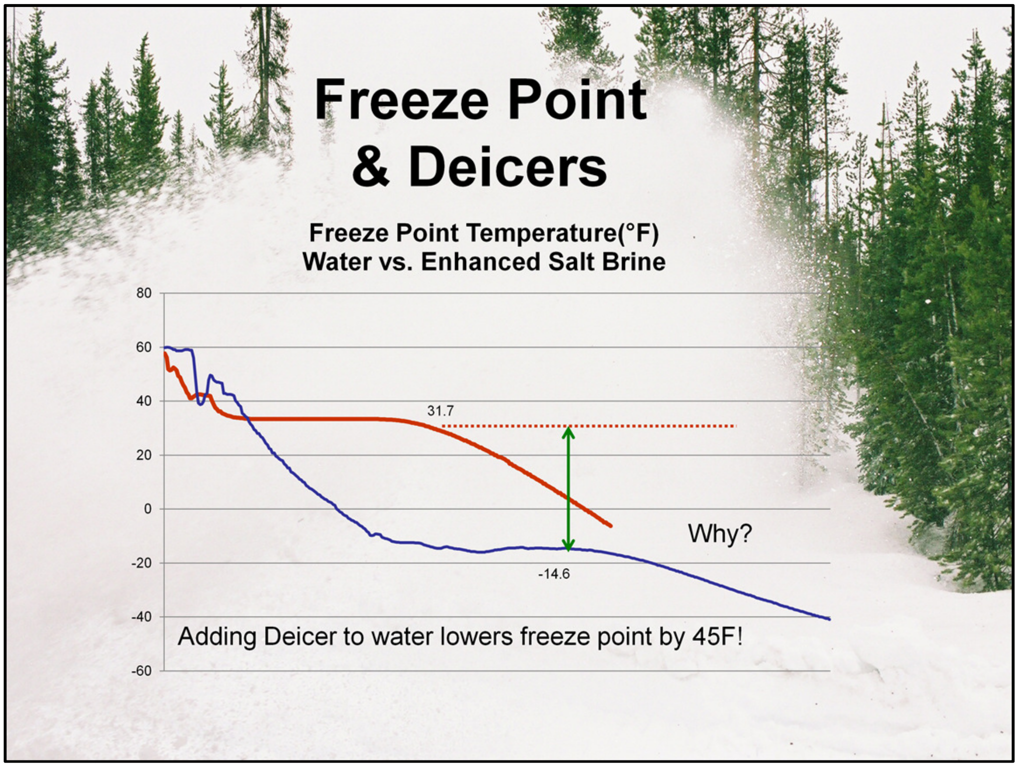
This illustration shows the freezing process of water at the molecular level.
In this process - Liquid water (shown on the right) must “cool” – Converting its Kinetic Energy to HEAT. Kinetic energy is the energy of a particle in motion. When liquid water transitions to solid ice – it joins the ice crystal lattice and its motion is greatly reduced. This is called a PHASE TRANSITION to a solid state.
Another Key Point is that for this process to occur -Liquid water molecules must contact and stick to an existing ice crystal – This is important in understanding how deicers work…

ICE CRYSTALS FORM ON EXISTING EDGES

We Know that the Physical Process of freezing involves liquid water molecules attaching themselves to existing nucleation sites on the ice to extend the ice lattice. (pause) So the easier it is for liquid water molecules to contact and stick to the existing ice – the easier and faster ice will form. Or in other words – the easier it is for liquid water to get to the ice surface the higher its freeze point will be. That’s an important point.

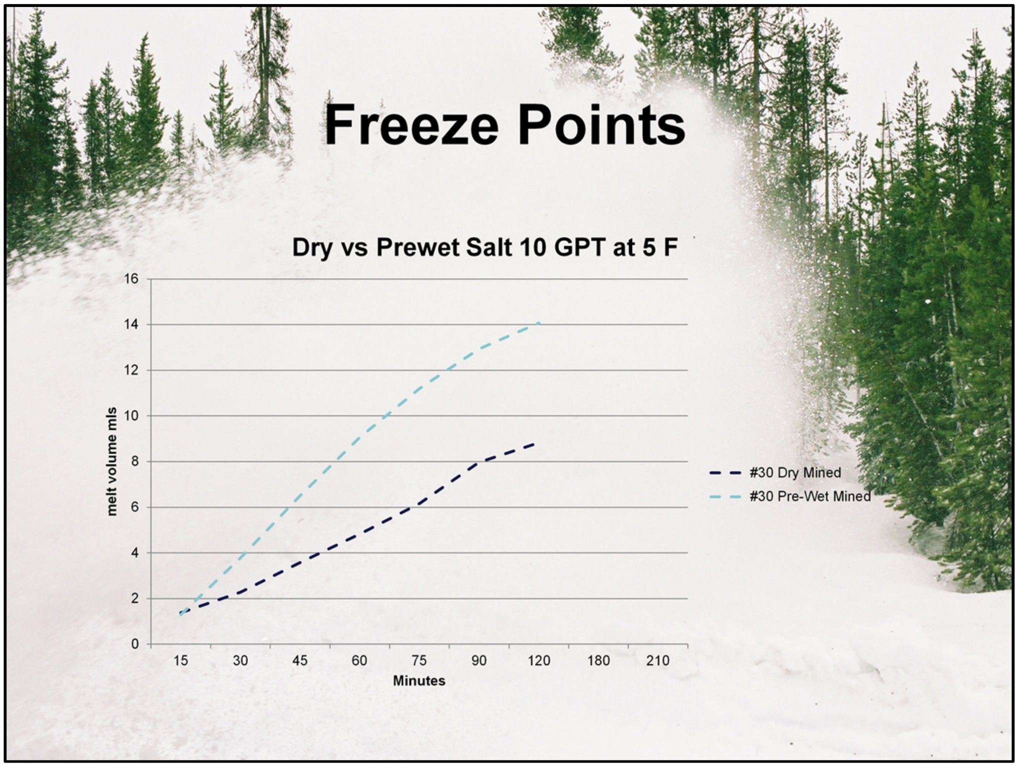


So with that basic understanding of how pure water freezes, lets consider what happens when we add a deicer…

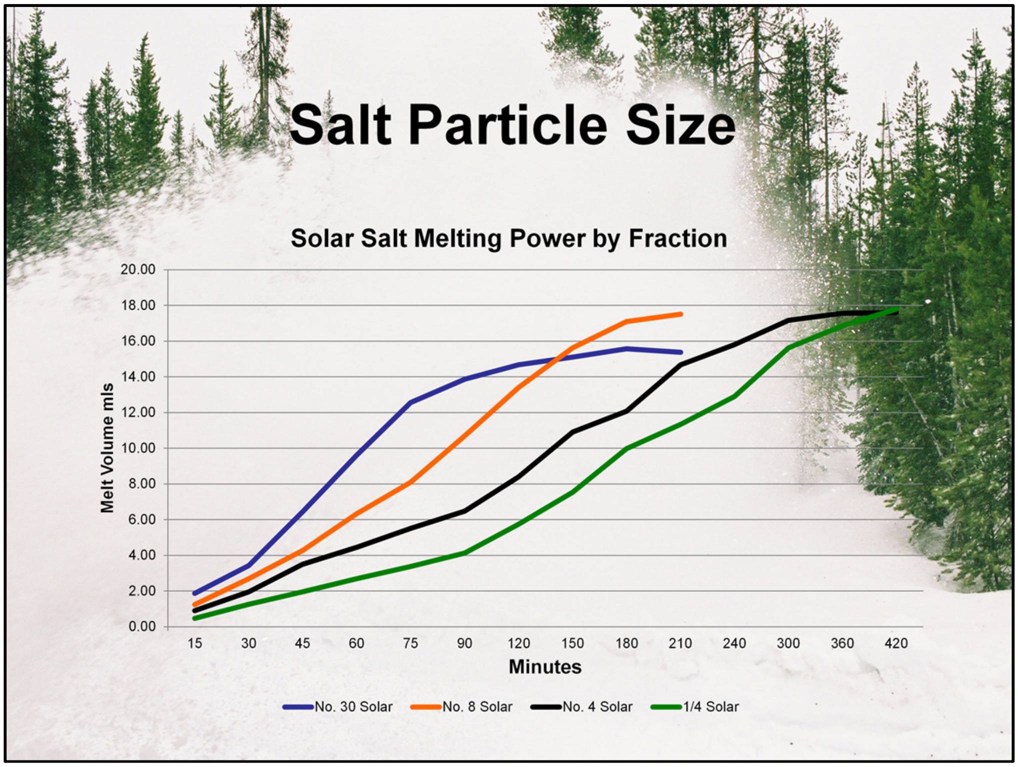


When we add a deicer… and run this same freeze point test on a salt brine solution…
What we see is that the freeze point decreases by 45F.
Think about that – if it you were dressed for a 45 degree day and the temperature dropped to zero, would you still be comfortable? That is actually a huge change in the freeze point of the water.
The Shape of the Freeze Curve is very similar to that of pure water, indicating that the same physical process is occurring, and freezing of water is still exothermic.
But the freezing process now occurs at a much colder temperature – this is the Essense of how Deicers Function!
We Deice Roadways by Lowering the Freeze Point of Water. Remember that in engineering terms - "*the goal of a winter maintenance program is to manage the freezing point of water...*"

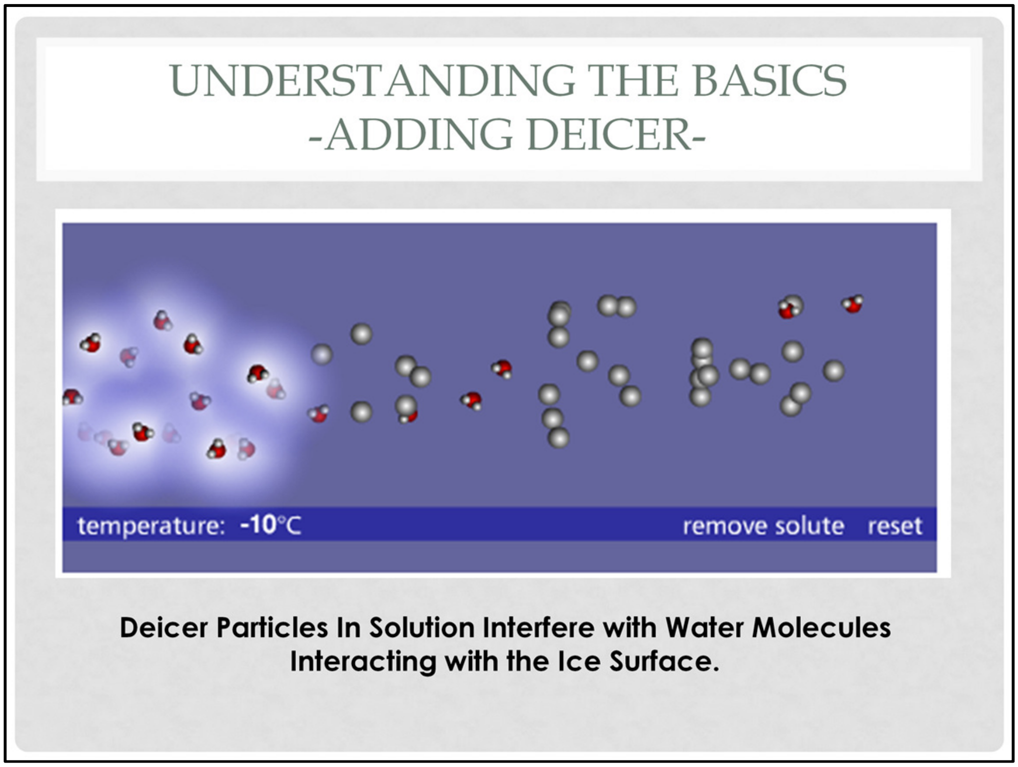
All Deicers Function by this Process.



Testing at several concentrations shows the behavior of the deicer as dilution occurs.



Testing at several concentrations shows the behavior of the deicer as dilution occurs.

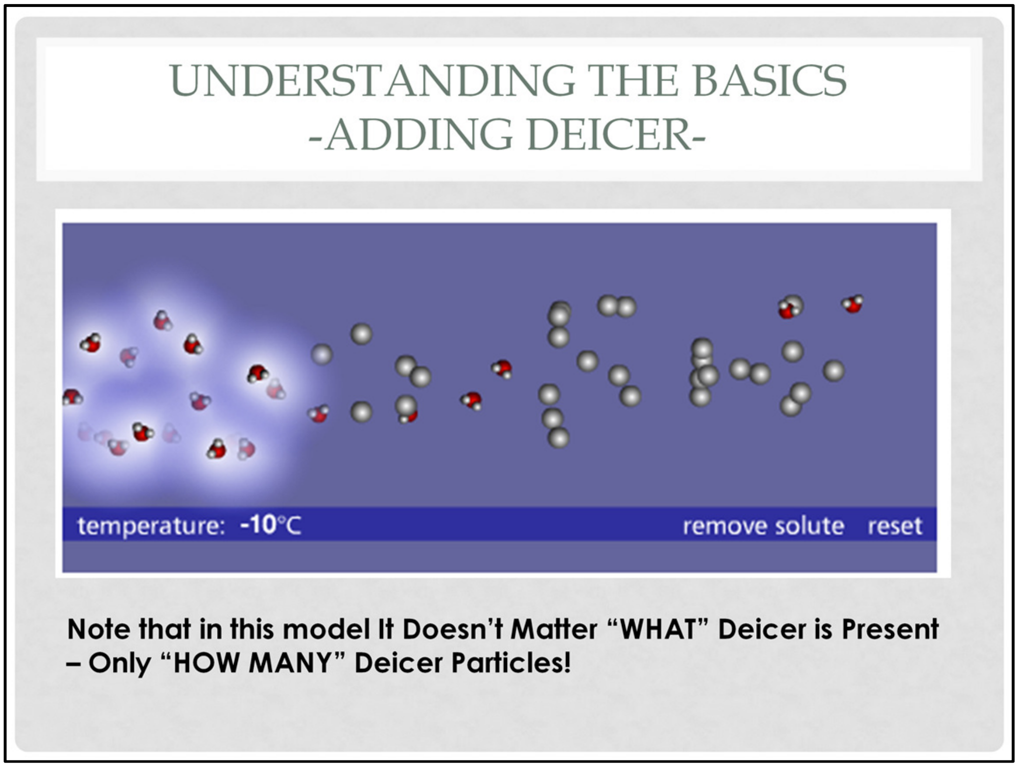


The easiest way to describe this effect is that when the deicer particles are added to the water, the deicer makes it more difficult for the liquid water to reach the ice surface and undergo a phase transition to the solid. There are more complicated chemical explanations involving thermodynamics and free energy – but conceptually this is an accurate description. And it helps visualize how deicers work. Basically we have to cool the system further, and lower the energy of the liquid water further– to induce the phase change from liquid water to solid ice. In short, when we add deicers the freeze point of the solution is decreased due to deicing particles interfering with the freezing process.

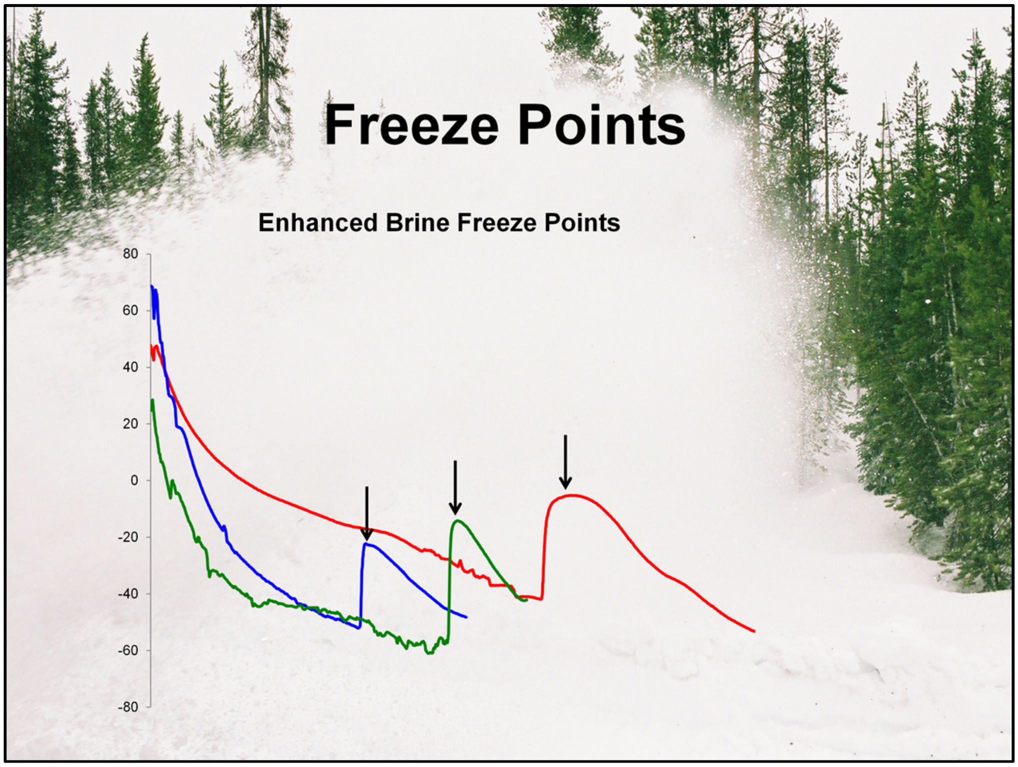
UNDERSTANDING THE BASICS
AND THE POINT IS ???

The Next Slide has something you need to understand…

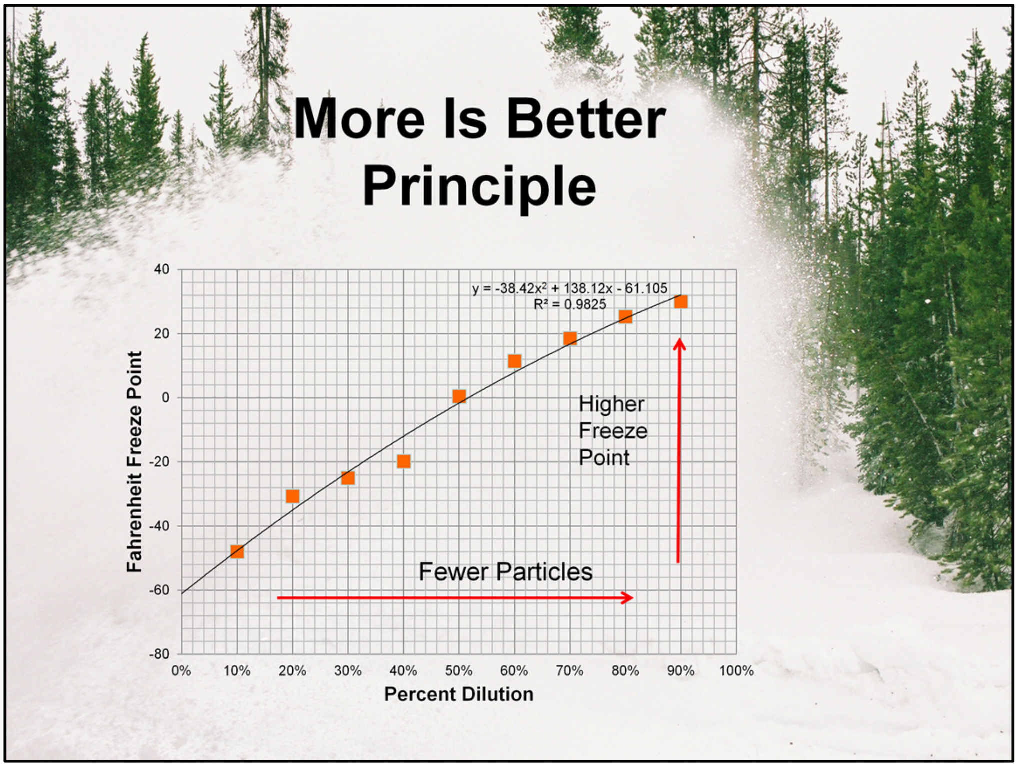
I know at this point at least some of you are brain golfing and wondering if I am ever going to get to the “Useful Information” part of the seminar… so this is a wake up call – I’m about to tell you something important about Deicer Characteristics…



Note that in this model, The Freeze Point of Water is Determined by the Number of Deicer Particles in Solution – NOT by the Chemical Identity of the Particles…
The freeze point depends on the number of deicing particles, NOT by what those particles are. Ice Doesn't Care "WHAT" you apply to the road – ONLY HOW MUCH!
This is one reason the compositional basis of the PNS Categories is less than ideal.
This concept of particle count is really Important to Understanding Deicer Characteristics and Comparing Performance.



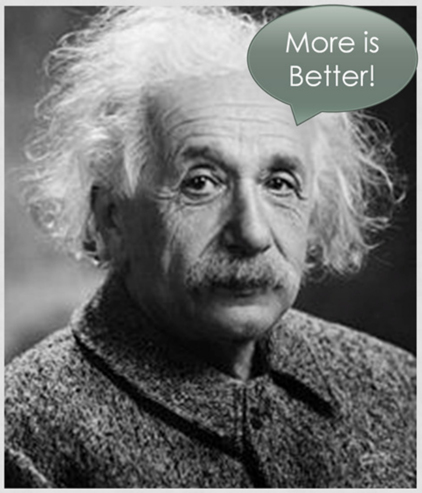
If we perform the freeze test we just examined at several different dilutions, we obtain a series of freeze points and a temperature/concentration correlation. Collecting these freeze points into one chart gives us a chart like the one shown on the next slide.



So now if we take a deicer and start diluting it with water (which is what happens when a decier is applied to snowpack) and measure the freeze point as it becomes progressively more dilute, we generate a chart that looks like this.
That leads us to the "More is Better Principle" (which is another way to say what Blagden's Law says mathematically)
The more deicer particles we have in the brine the lower its freeze point, or conversely as a brine is diluted the freeze point increases.
It shows us the relationship between deicer concentration, and the freeze point of that brine.
… that as Dilution Occurs – The Concentration of Deicer Decreases – and Freeze Points Increase.

Practically, this shows that to "Manage the Freeze Point of Water on the Roadway" We Need to Manage the Concentration of Deicer in the Brine on that Roadway.
If we fail at this and too much dilution occurs for that temperature – the road will refreeze.

HOW DO DEICERS AFFECT FREEZE POINT?



Blagden's Law Says:

Freeze Point Depression is Determined by:

- The Number of Deicing Particles Present in the Brine.
- More Particles → Lower Freeze Point.

Remember we talked about Einstein's Razor? Make things as simple as possible - but not simpler…
Blagden's Law talks about the importance of the number of deicing "particles" – and how that affects the freeze point (Or how effectively the deicer will melt ice.)
But there's a hitch… to the "More is Better" principle…
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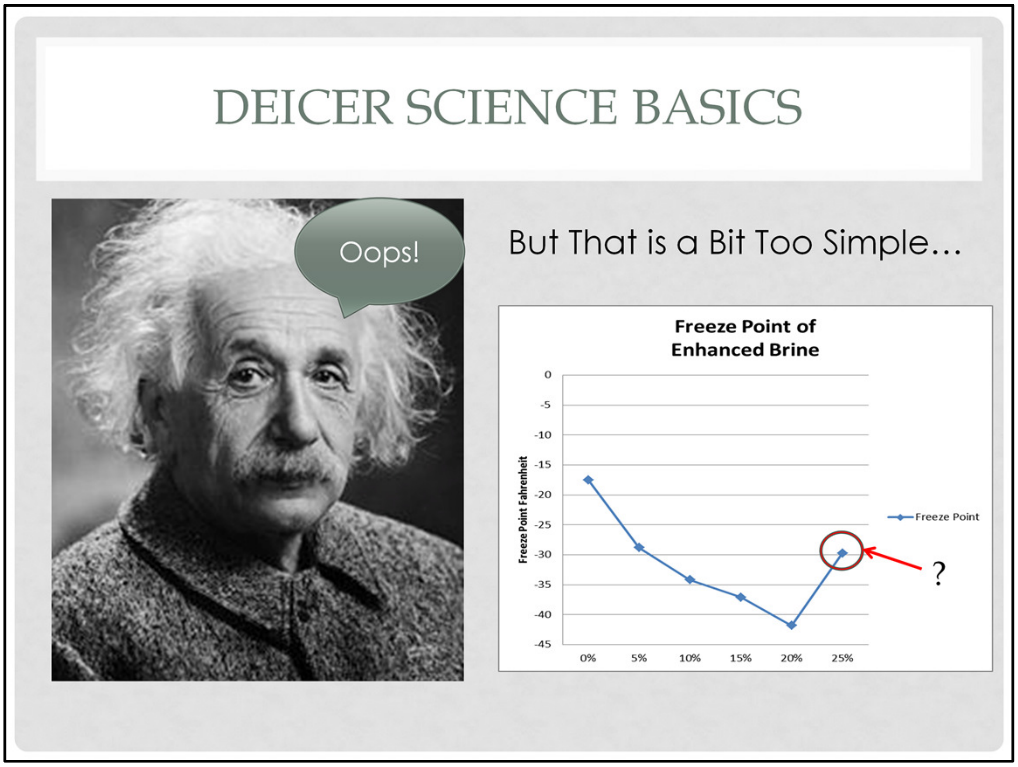
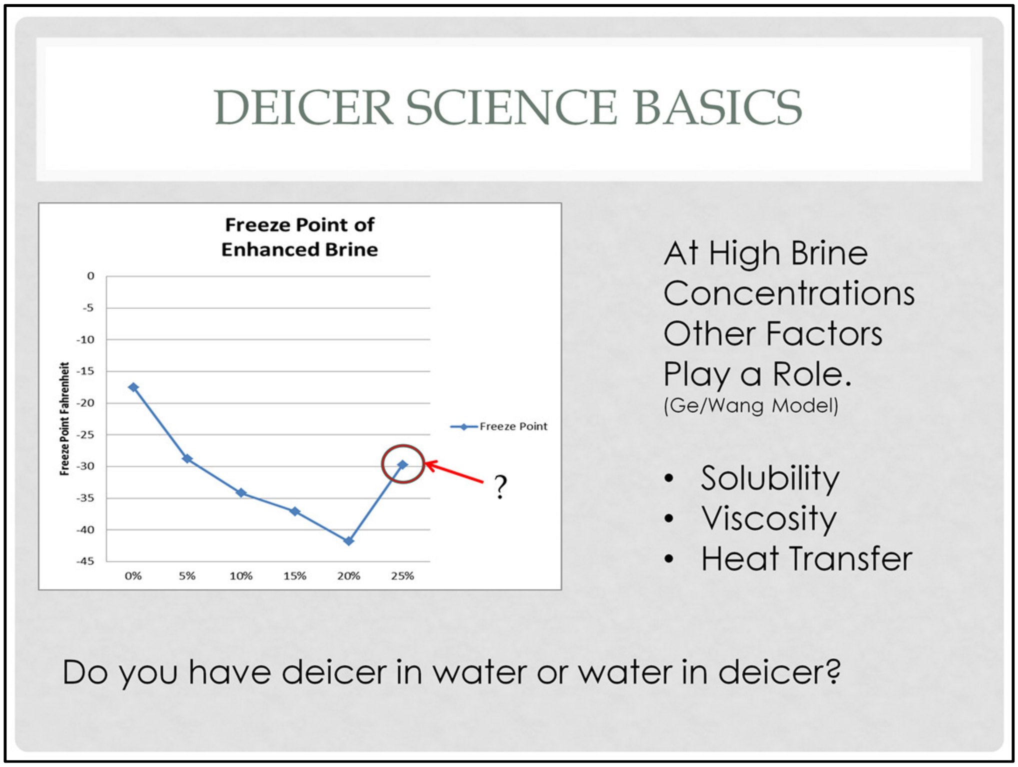


But that turns out to be a little oversimplified.
A freeze curve of most Deicers will show a “V” shape with minimum freeze point, or “Eutectic Point”, that is followed by an INCREASE in Freeze Point at HIGHER Concentration. So More is NOT always better. How can we explain that?



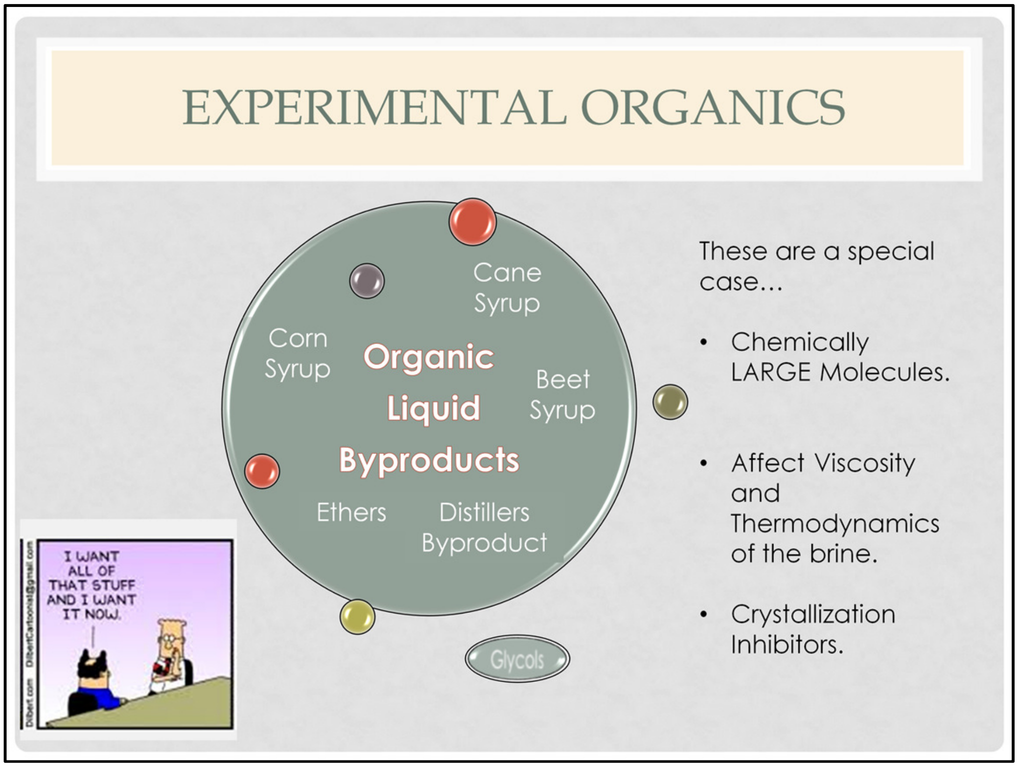
The Chemistry underpinning the science is developed for IDEAL Solutions – which means very low concentrations – where water still acts like water.

Let me put it to you like this - If you have a 50% Solution of Deicer in Water– Does the Solution Act like Water with Deicer in it, or like Deicer with Water in it?

At some point in the freeze curve, the solution stops acting like pure water and we see an inflection where adding deicer INCREASES freeze point –

And MORE is NOT Better. There are several chemical and thermodynamic reasons for this – as listed here, but fundamentally it is due to changes in the properties of the water.

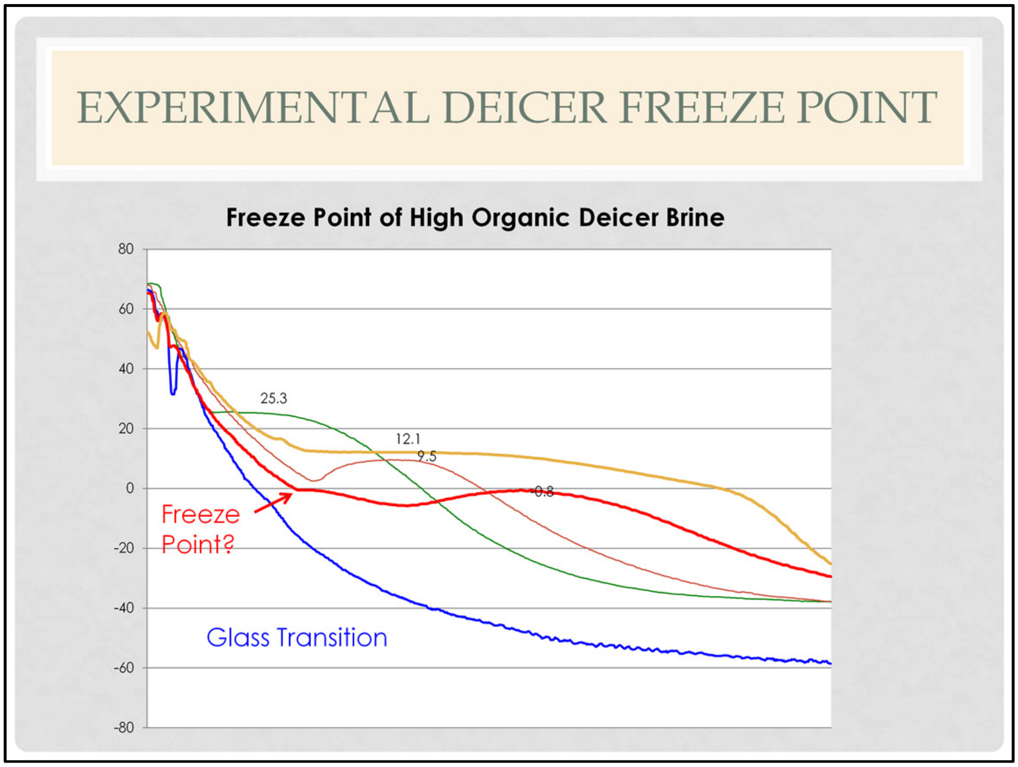
Another explanation involves ion pairing of the deicing particles at higher concentrations that reduces their practical particle “count” – but conceptually the point remains that at high concentrations deicers don’t behave like pure water.



This is a good point to mention something about the group of liquids in the "PNS experimental category". Due to their molecular size and chemical make up, they tend to make significant changes in the ability of water to act like water. The carbohydrate deicers in this category inhibit the ability of liquid water molecules to join the crystal lattice of ice and transition to the solid state – just the same as the chloride deicers. But In high concentrations, they prevent ice formation entirely – causing instead a "glass transition" to occur.

This is where a liquid brine becomes thicker and thicker until it is frozen hard – but it hasn't really undergone the liquid-solid phase transition through crystallization.

The following slide illustrates this through the freeze curve of one of these experimental deicers at several concentrations.



When these experimental products are tested at high concentrations in brine, complex curves result.
At low concentrations – water acts like water – and a typical freeze curve results (green line)
However as the product becomes more concentrated we see the freeze point decrease – as predicted by Blagden's Law – but we also see supercooling induced by the change in the physical properties of the water – such as increased viscosity and changes in heat capacity and heat flow.
At high concentrations – blue line – notice that there is no plateau! The material cools, becomes viscous, and becomes a hard glass – without ever allowing the water molecules to come together and undergo a phase transition to the solid state.
Notice too, that at intermediate concentrations – the red line – we see an extended plateau with a "wobble" of sorts in it. When you observe this liquid mixture what you see is also different. The solution does not freeze rapidly, or become very viscous. Rather it forms a liquid slush that does not really "freeze" for an extended period. You might ask – What is the freeze point of that mixture? Darned if I know! Is it when the first crystal of ice forms? Because the deicer remains a flowable liquid well past that point, or is it at some point down the road when the slush has become thick enough that it is no longer "flowable? All I can say is that these products are unique and don't fit well into the existing test method.

DEICER BRINE FREEZE PROCESS

High Organic Experimental Category Liquids Can Enhance Salt Brine Performance…

Persistency – Sticky Factor??

When Salt Water (or a deicer brine) freezes …

PURE Water Ice Forms.

This Concentrates the Remaining Brine – and lowers the freeze point.

Only Pure Solutions have Sharp Rapid Freeze Points.

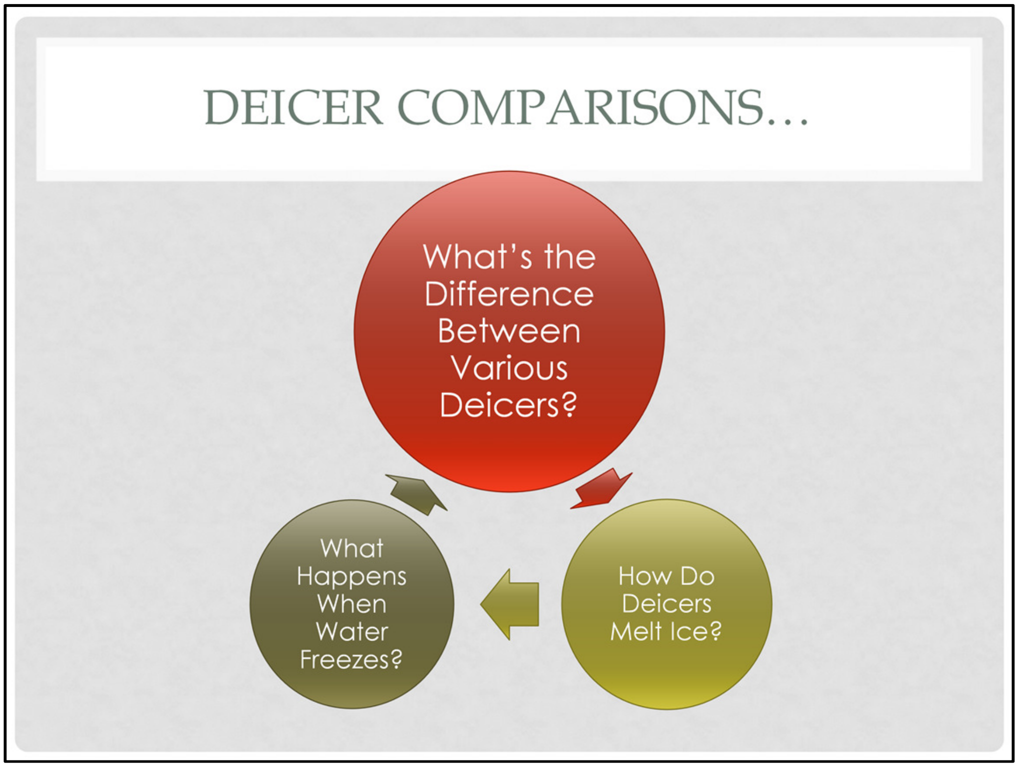
Concentrated Organics either undergo a glass transition (really cold) or create a slush of pure ice and viscous deicer…

Bottom line is that the Organic Deicers work as freeze point depressants like the salt brines, but also as crystallization (ice) inhibitors.

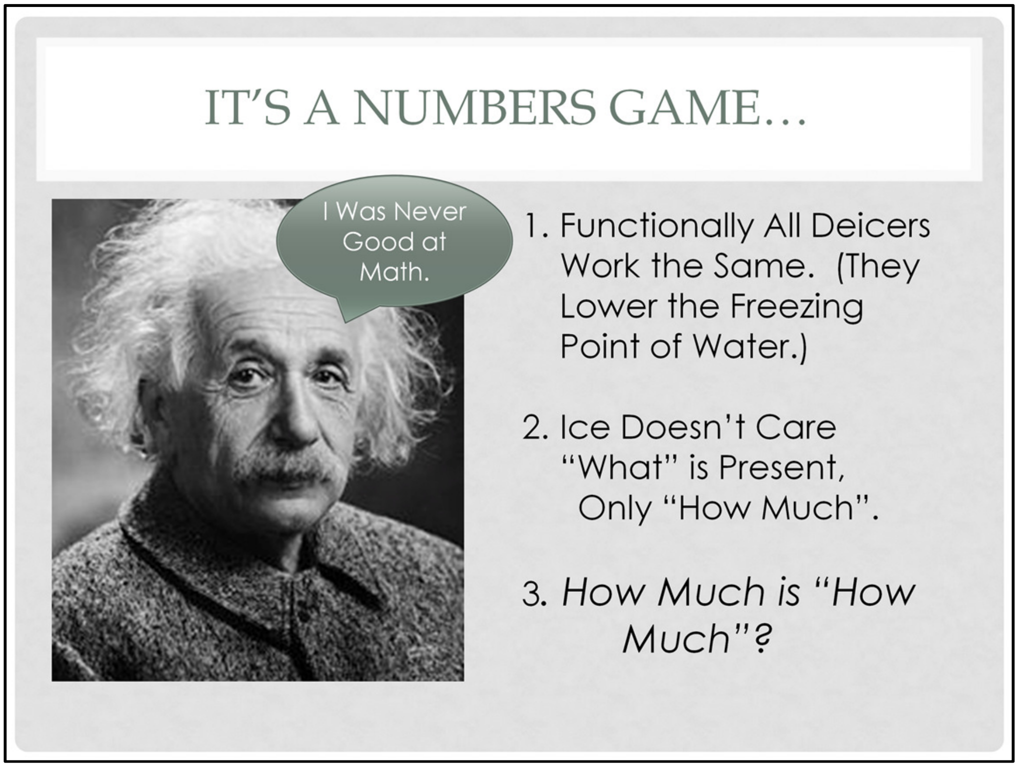
Another point to ponder that you may have already picked up on – is that when a brine solution freezes, the crystallization process actually purifies the water. The Ice that forms is essentially pure water-ice, leaving behind the dissolved salt in the brine solution.

In Chloride Deicers their limited solubility causes the solid deicer to start falling out of solution when their saturation point is reached. At this point both water ice and solid deicer begin to form.

The Organic Deicers that are essentially completely soluble in water do not crystallize from solution however. They tend to stay in an ever more concentrated brine with the water. Functionally, they form a slush of pure ice and very concentrated organic-water liquid. So these products tend to prevent a hard-pack ice from forming on the road surface. Used either alone or in combination with Chlorides as additives, these products are very useful in maintaining roadways during winter storm events.



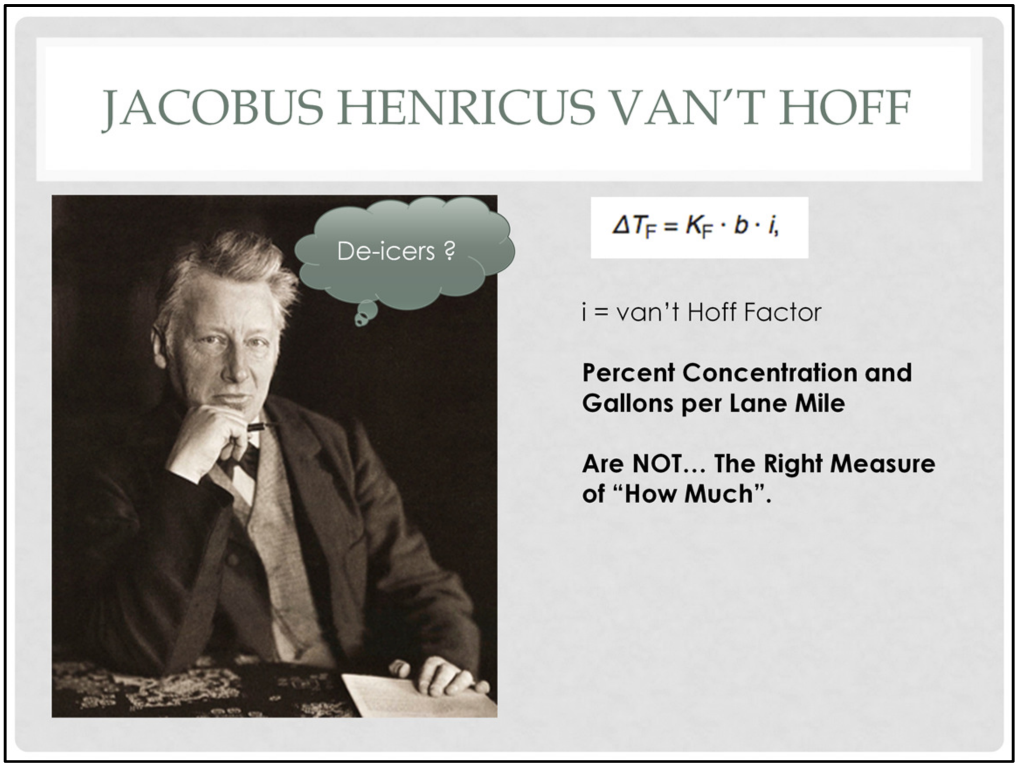
So this brings us to the key question – How do various deicers compare?
Based on what we've just learned about the way water freezes and deicers affect that process – and how Blagden's Law Applies,
you should appreciate that **Deicer Concentration plays a critical role in determining performance** and in comparing their performance…
So it should come as no surprise that when comparing deicers the number of deicing particles each product delivers will be a major factor… and its just a numbers game.



So Lets Recap...
Remember that functionally all deicers work the same way – they lower the freeze point of water.
A corollary to this is that "Ice Doesn't Care What is Present – Only How Much"
But How do we Measure "How Much"?

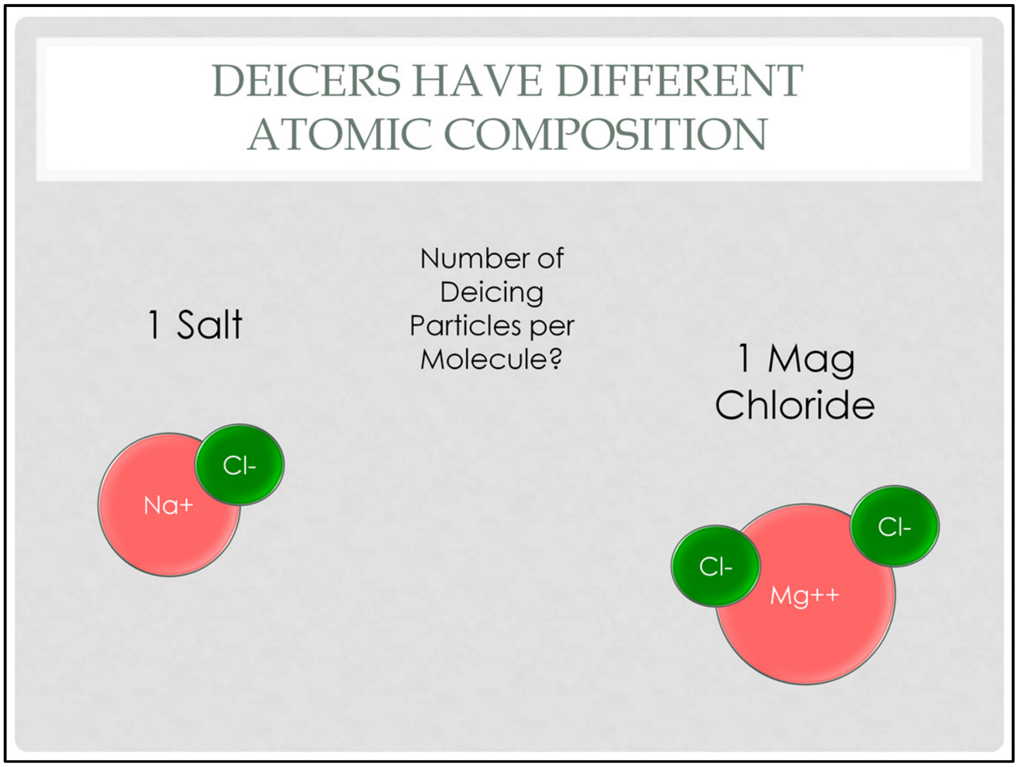
That's' where we have a problem… All Deicers are Chemicals – and to Understand and Compare them we Need to Count them by the atom… not by the pound or by tons per lane mile.

This is actually easier than it sounds…



This Handsome Devil is Jacobius Van't Hoff – A Dutch Chemist that lived in the 1880's. He was the First Winner of Nobel Prize in Chemistry. He won his Nobel Prize studying this very issue. How do we measure concentration of chemicals when we want to know the freeze point of the resulting solution?
Unlike Einstein, Van't Hoff was very good at Math and his research showed that freeze point depression is determined by THE NUMBER OF "PARTICLES" Present.
Vant Hoff discovered that the size of the freezing point depression (how far the freeze point was lowered) depends on the chemical concentration of the deicer AND a little factor called "i" which was named the van't Hoff Factor.
What do I mean by that and what does it have to do with which deicer you should use? Let me explain…

Why Does this Matter you You When You Buy and Apply Deicer?
We purchase and apply deicers by the pound or the ton…
But the Chemistry of Deicing is DETERMINED NOT BY THE POUND but by the PARTICLE COUNT.
It Turns out that Van't Hoff Figured out How to Count Deicer Particles by "i" – the van't Hoff Factor.



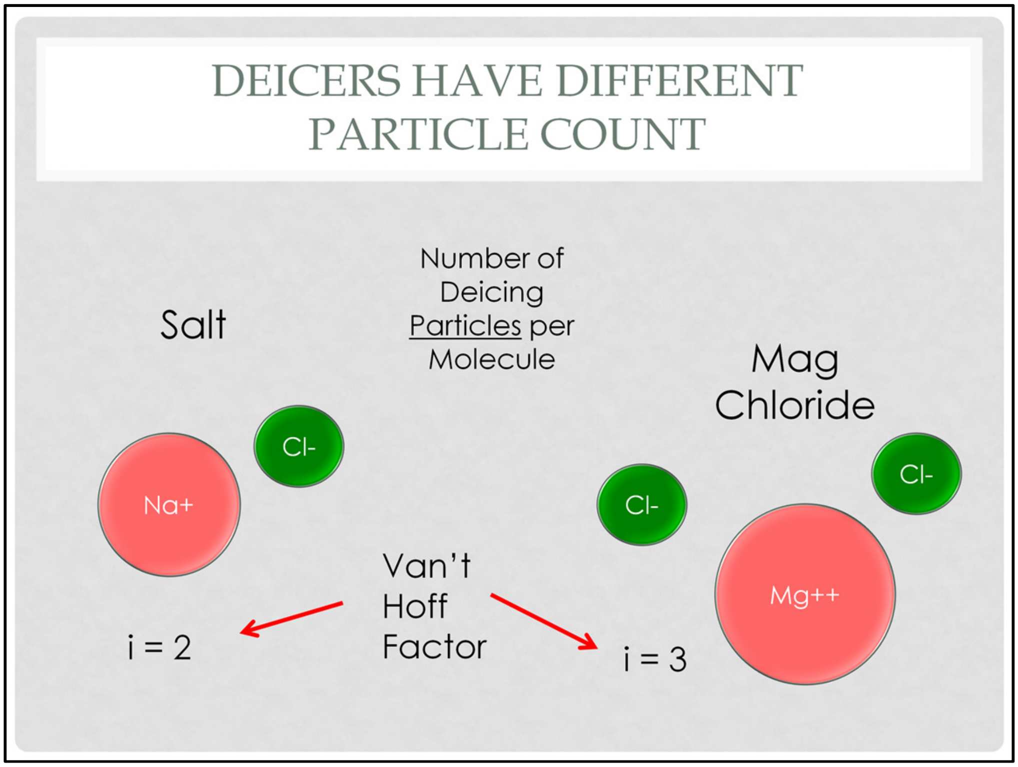
Not anything you didn't already know, but deicing chemicals have different atomic compositions – hence the PNS Categories. Sodium is different than Magnesium is different than Calcium etc..

NaCl is composed of one Na and one Cl. MgCl2 of one Mg and two Cl.

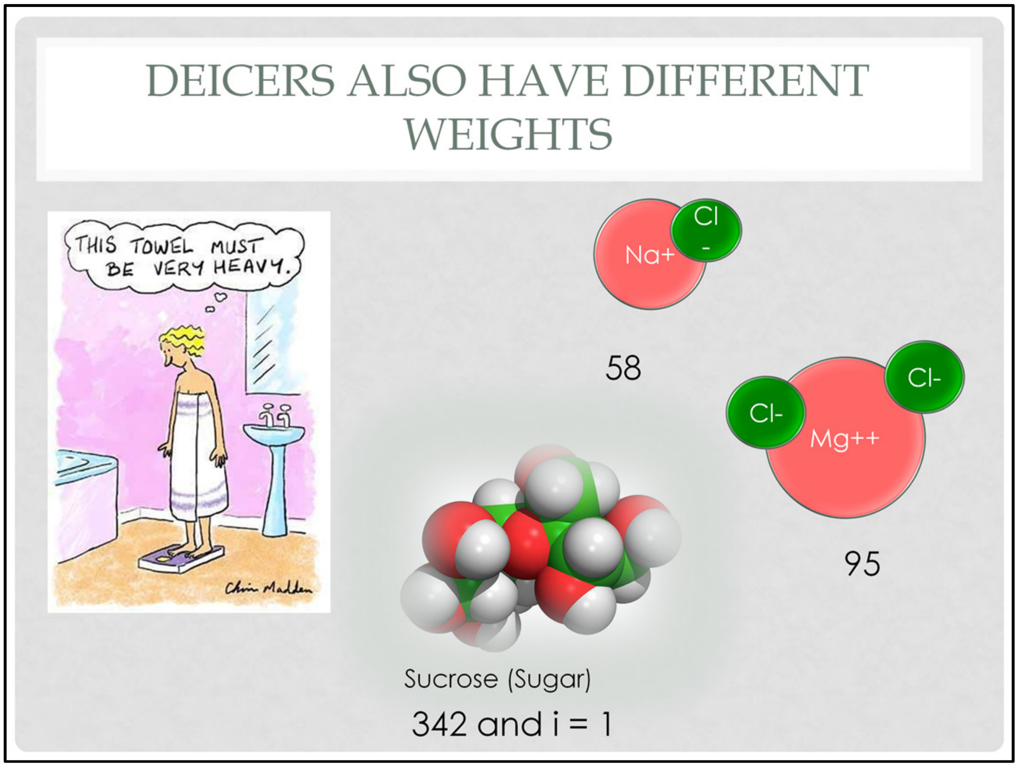
The van't Hoff Factor "I" Counts How Many "Deicing Particles" a Particular Deicer provides for every molecule of deicer present. It is a MAJOR factor in comparing Deicers.

Different Deicing Chemicals Contain Different Number of Deicing Particles – and therefore have a greater or lesser effect on Freeze Point Depression.

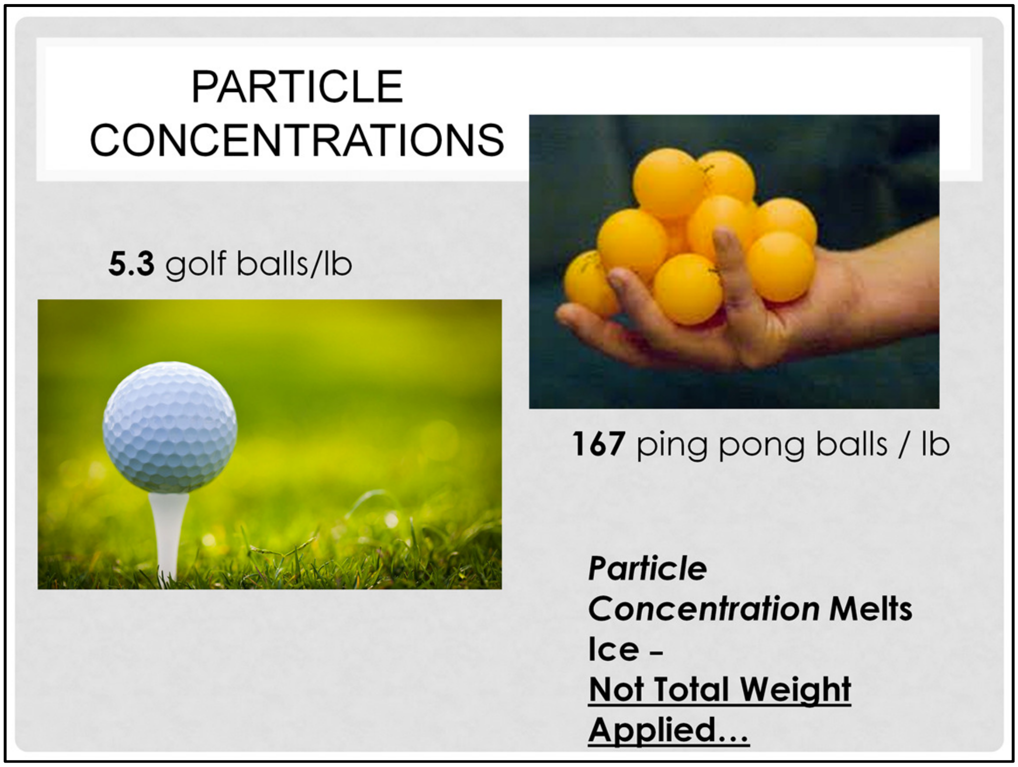
Compare NaCl to MgCl2…(next slide)



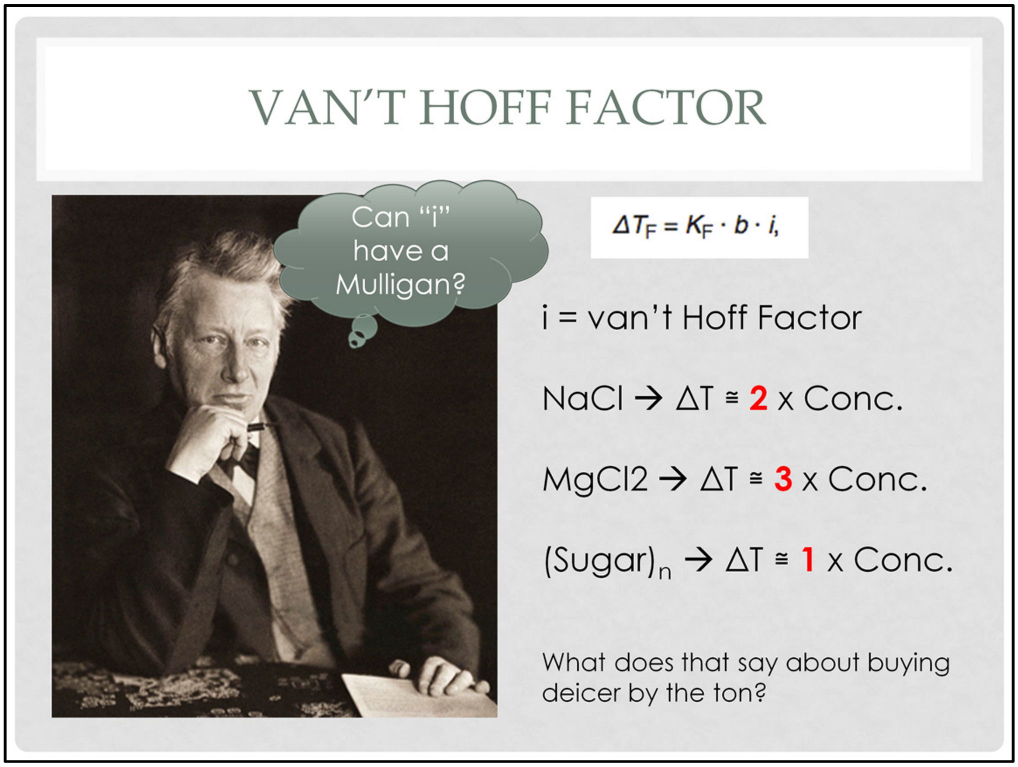
When dissolved in water sodium chloride produces 2 deicing particles – one chloride ion and one sodium ion.
Magnesium Chloride however produces 3!
Remember that it isn't the number of pounds per lane mile that melt ice – it is the number of deicing particles per lane mile…



Different Deicing Chemicals also have different atomic weights. This is where the pounds per lane mile measure falls apart.
An Equal weight in pounds of two chemical deicers will contain DIFFERENT numbers of deicing particles…and have different freeze points and melting powers.
Even if we compare two deicers at the same volume and concentration, due to the van’t Hoff factor they will deliver different numbers of deicing particles to the roadway.

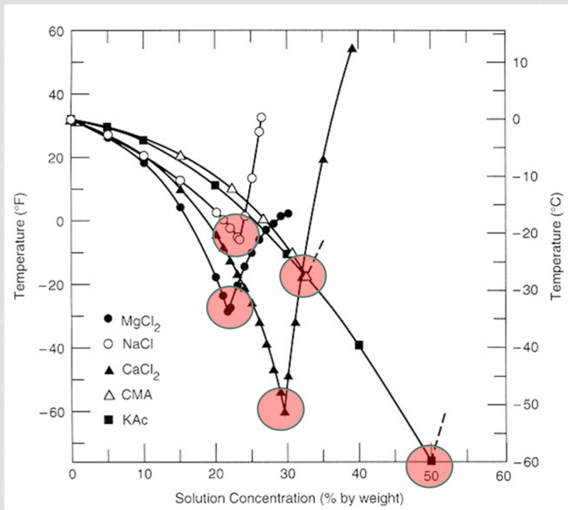


Consider this example… If golf balls and pong balls were “deicers” – and you applied an equal weight of each (lets say 300 lbs per lane mile) to a snowy
roadway, which would melt more ice? Remember – van’t Hoff said it isn’t the weight of deicer present – it is the number of deicing particles…
----- Meeting Notes (6/4/16 20:46) -----
Obviously at equal applied weights, the ping pong balls are going to melt much more ice. The same effect is seen for deicers with different molecular weights.



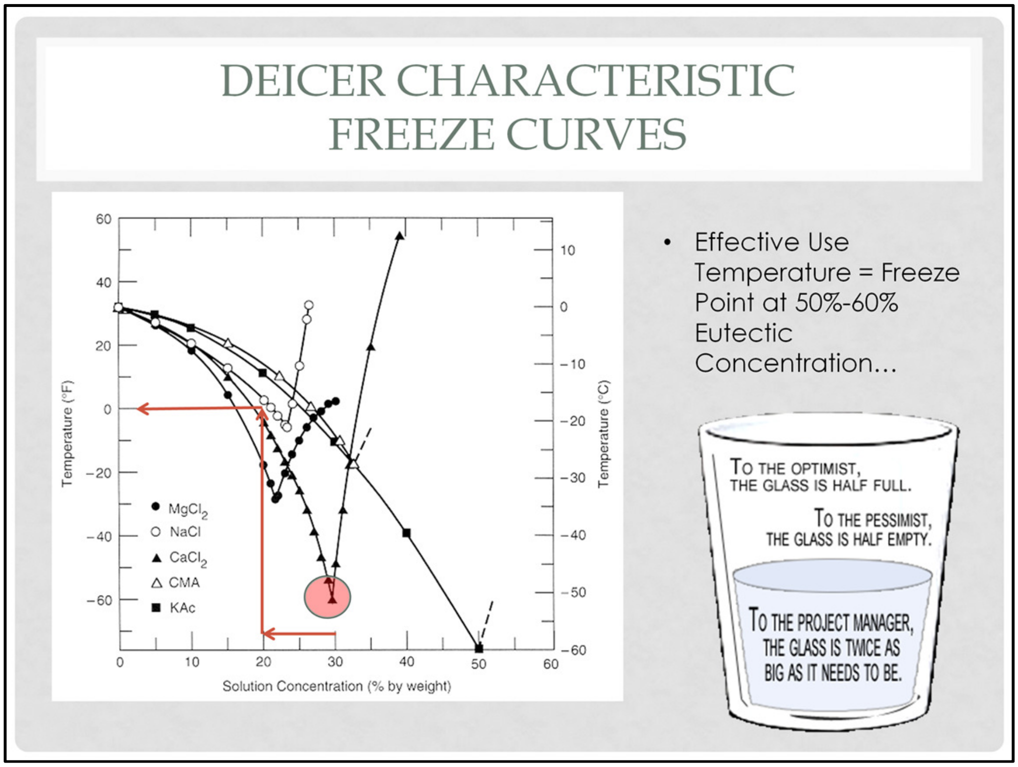
So van't Hoff showed that different Deicers Provide Different Numbers of Deicing Particles for the SAME Weight of Deicer.
This affects your Cost of Use, and the Melting Power of the Product you Apply.
----- Meeting Notes (6/4/16 20:48) -----
So that about covers the basic facts that determine deicer performance. Now lets look at some practical comparisons.

DEICER CHARACTERISTIC FREEZE CURVES



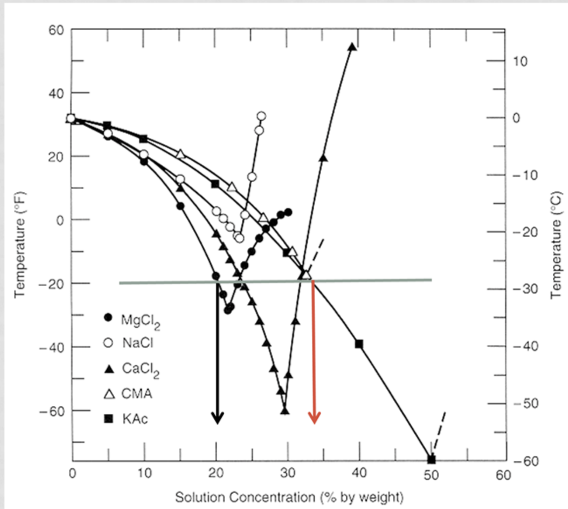
- All the Freeze Curves have the same shape/behavior.
- All Have differing Eutectic Points. *(Solubility & Chemical Potential)*

Here is an overlay of freeze curves for several PNS QPL Liquid Deicers. What Practical Information Does this Provide? We see that their freeze curves all have the same shape. This is because they all undergo the same physical process of water freezing. We also see that although they have the same shape, they have different eutectic points. This is essentially due to how these deicers interact with the water at or near their maximum solubility. The point at which water stops acting like water varies by deicer.



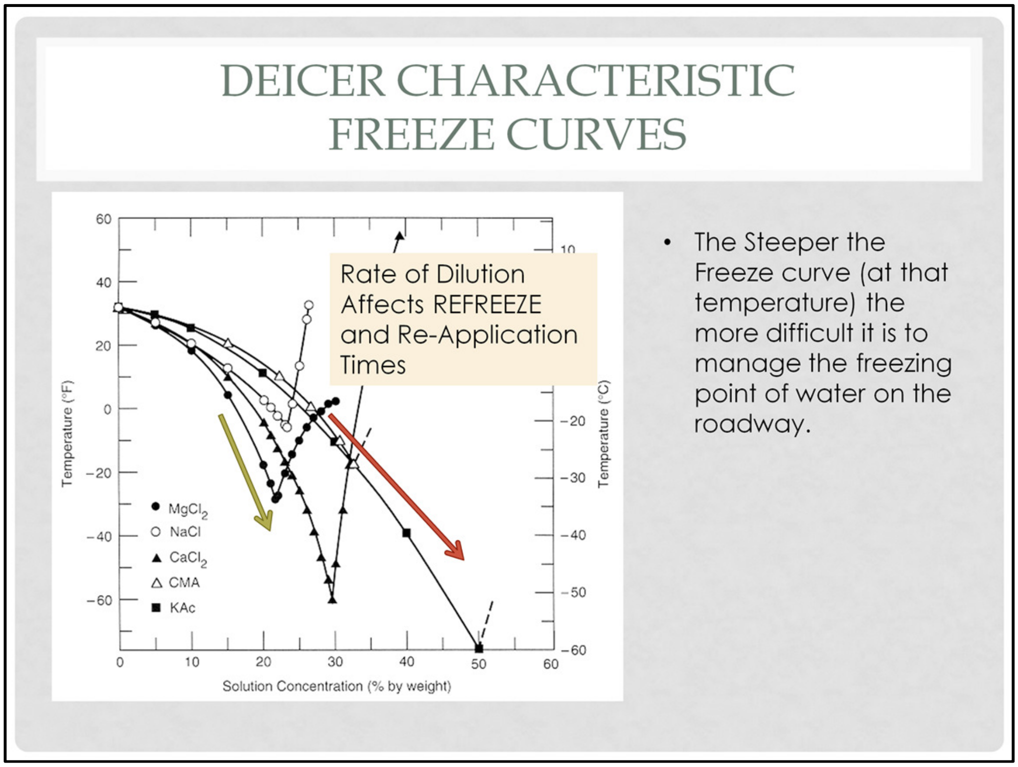
There is also more useful and practical information on display here… Although technically each deicer will still melt ice at its eutectic point – it does so very inefficiently!
As a result the "Effective Use Temperature" is typically chosen somewhere near the half way concentration of the deicer's eutectic concentration. So for CaCl2, this would mean the lowest temperature it should be applied is about 0F.
----- Meeting Notes (6/4/16 20:55) -----
This provides a margin of safety and improves cost effectiveness of the deicing program.

DEICER CHARACTERISTIC FREEZE CURVES



- Fit the Product to the Temperature Range of the Roadway…

Compare MgCl2 to KAc – Both Melt Ice at -20F, and MgCl2 works at 20% concentration while KAc at about 35% – So MgCl2 is a better product right? (Well not really…)
First off -20F is past the Effective Use Temperature for MgCl2 as we just discussed. While it is about "at" the Effective Use Temperature for KAc.



Due to a higher solid content in the KAc, and a greater number of deicing particles in solution, KAc resists dilution better, meaning you don't need the man hours to reapply as often, and in a critical setting like a bridge deck or runway where refreeze is not an option – KAc might be a better choice.

----- Meeting Notes (6/4/16 20:55) -----

The slope of the freeze curve indicates how sensitive the deicer is to dilution at that temperature, and how easy or difficult it will be for the highway to refreeze. Generally speaking the steeper the slope of the freeze curve, the greater attention must be paid to avoid refreeze.

The Effectiveness of your Deicer is Determined by the Particle Count of that Deicer on the Roadway.
The Particle Count is A Function of the CHEMICAL CONCENTRATION of Your Deicer – and the van't Hoff Factor.
That is really the bottom line when it comes to comparing the performance of deicers.

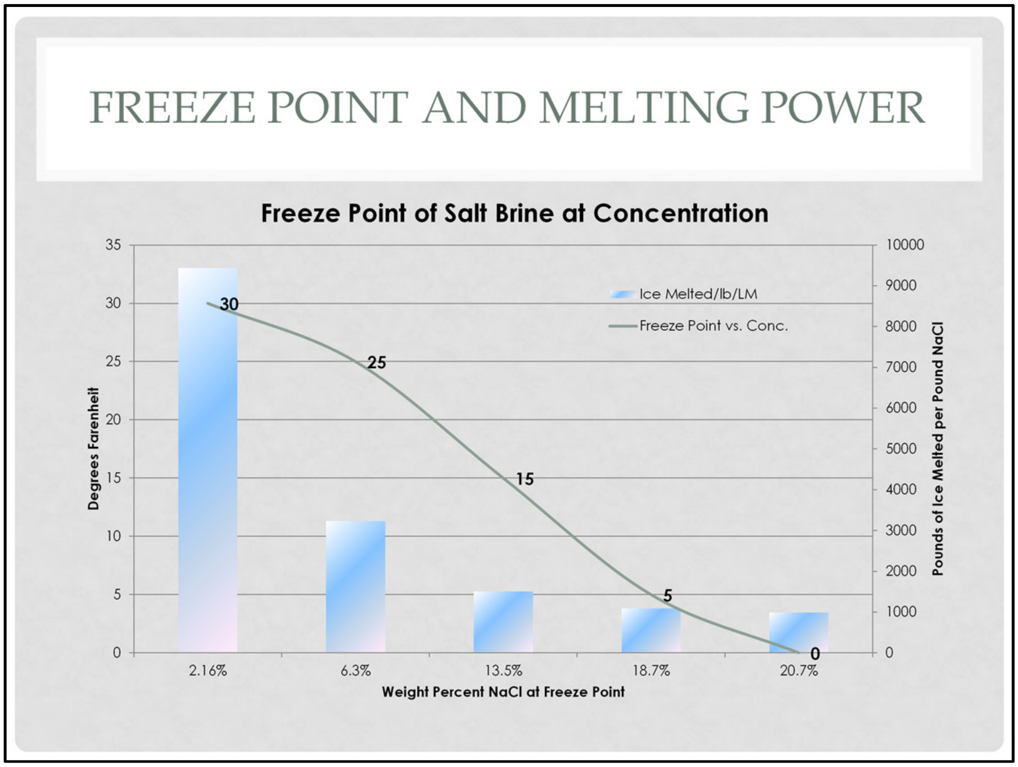
Freeze Point Depends on Product (I value) & Concentration.

Product Concentrations & Freeze Point

Product ID	Freeze Point F	As Delivered Wt% Concentration
Salt Brine	-6 (23%)	23%
MgCl2	-28 (20%)	28%
CaCl2	-60 (30%)	32%

Weight Percent of Product ➔ Chemical Concentration x "i" ➔ **Melting Power**
Formula Weight of Deicer

More to the story… Some Deicers are Delivered at Concentrations ABOVE their Eutectic Concentration – We are Depending on DILUTION to Occur to Facilitate Deicer Performance.

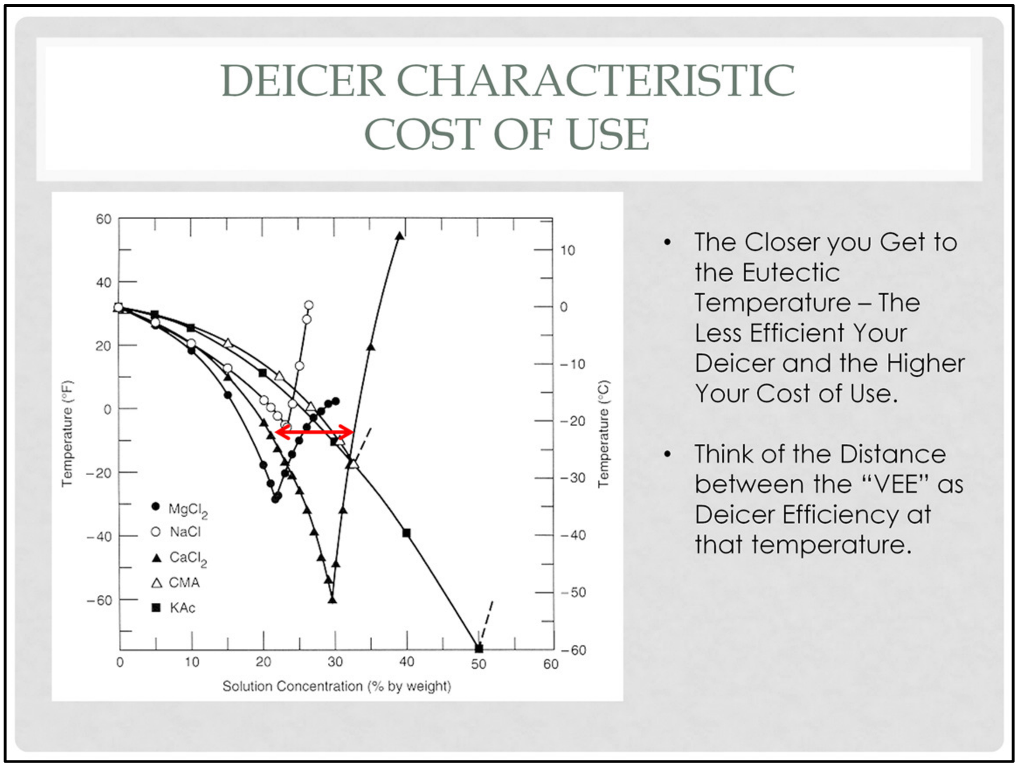


One final point applies to the comparison of deicers – and for the managers in the room, that is the bottom line cost of use.

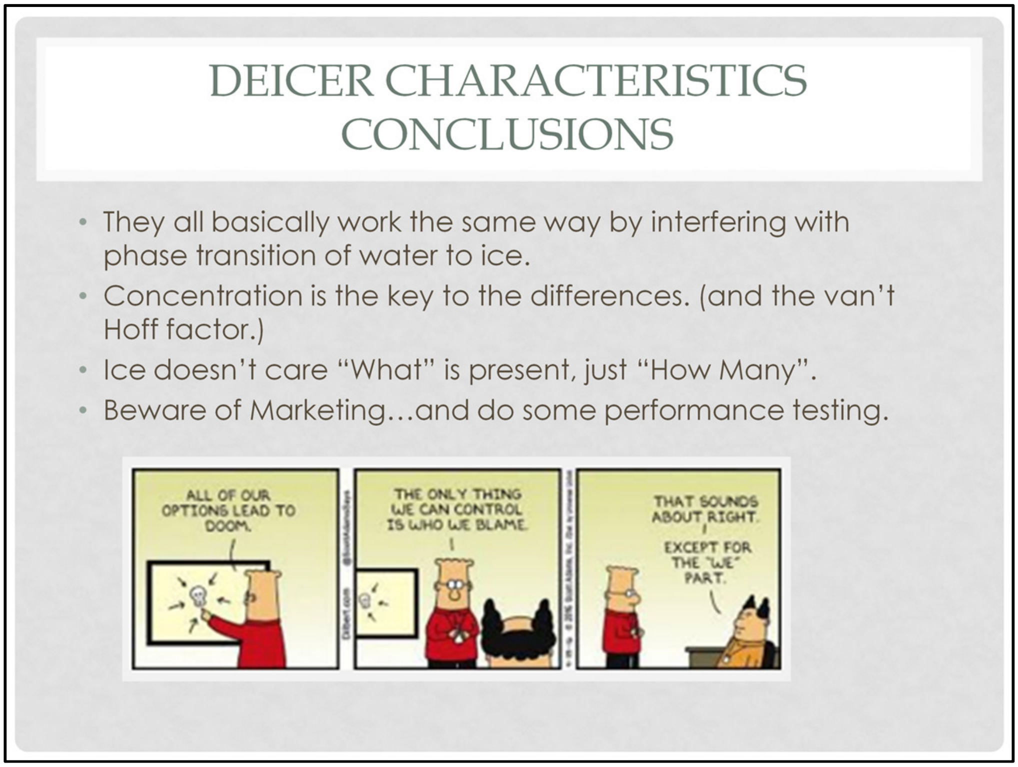
The Amount of Ice Melted Per Pound of Deicer Changes with Temperature. In other words, as temperature goes down, the cost of ice melted per pound of deicer goes up.

Remember I said that deicers become increasingly INEFFICIENT as they near their eutectic point – requiring more product and higher concentrations to maintain a liquid brine condition.

So Your Cost of Use Goes Up asTemperature Goes Down. And this efficiency varies by deicer since each has a differentr eutectic point.



The efficiency of a deicer can be approximated by the distance between the "VEE" in its eutectic curve.
The closer you get to the eutectic point, the narrower the "vee" and the more costly that deicer is to use at that temperature.
Of course a cost comparison also has to factor in the delivered cost of the product – but this calculation can help you economize your decing program while selecting a deicer that is appropriate for your temperature and level of service.



Hopefully there was some useful information in that and you have a better idea now how deicers work and how to compare them.
Thanks for your attendence.


ALL OF OUR OPTIONS LEAD TO DOOM.
THE ONLY THING WE CAN CONTROL IS WHO WE BLAME.
THAT SOUNDS ABOUT RIGHT.
EXCEPT FOR THE "WE" PART.