solxenergy

Why Solar Thermal HVAC-R Works

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1 PREFACE

The purpose of this document is to explain in relevant detail **why** solar thermal HVAC works within the area of modulating or inverter refrigerant systems. The information to follow is in no way intended to educate the reader on how to install or incorporate solar thermal technology into the refrigerant process. The detail below is provided as an information platform, designed to help educate the reader as to why solar thermal technology can benefit the modern-day refrigeration process.

2 INTRODUCTION

Today's HVAC-R systems include logic controls designed predominantly to measure thermal energy and modulate the speed and/or stages of the compressors accordingly. *This element is covered in more detail under Section 3, Point #1 of of this document.* This is a process markedly different than that of older generations of fixed speed, fixed flow systems, which were mainly controlled based on pressure and/or room set point temperature alone.

In today's modern HVAC-R systems, the thermal energy impact at the condenser (generated by the compressor(s)) is continually monitored by the logic control continually modulating the speed and/or stages of the compressor(s), as required to meet the cooling demand. This logic is influenced by the collective data gathered from the thermistor sensors designed into the system, at relevant points around the cycle. As such, the logic controls are constantly assessing the load and adjusting the compressor(s) as required—bearing in mind also that the vast majority of the refrigerant mass flow is generated by the early stages of the modulating rack system or variable speed compressor. *This element is covered in further detail under Section 3, Point #3 of this document*. The solar assisted system uses renewable solar-thermal energy to offset a portion of the thermal energy that would normally be generated by the compressors. Keep in mind that the condenser is in all cases designed to manage the compressor(s) thermal capacity when running at full load. In fact, in the vast majority of cases, the condenser is designed at up to 10% above the compressor capacity. The condenser's feedback logic to the compressor(s), ensures that the combined thermal energy stays within the system's manufactured design points. *This is also covered in additional detail under Section 3, Point #4 of this document*. As the amount of solar-thermal energy increases, the logic controls recognize that the now combined thermal energy in the system is more than sufficient to meet the systems requirements and consequently will signal for the compressors to slow down or drop stages. When the compressor is running at part load, the input of free thermal energy now increases the system's capacity closer to its full potential. In short, the herein detailed technology uses solar thermal energy to reduce the workload normally supplied via electro-mechanical compression alone, thereby reducing energy consumption.

It is also important that the reader understands that solar assisted cooling is only compatible when partnered on systems with a variable capacity ability. It would be beneficial for the reader to hold at least a basic understanding of variable capacity technology. If this is not the case, we would strongly recommend the reader takes steps to grasp, at the very minimum, a familiarity of such (particularly the compressor and the logic controls) prior to reading further into the information below. *Important* – our experience attests that a lack of understanding on how the variable system differs from the increasingly antiquated, fixed speed system of yesterday, will almost certainly result in the reader failing to comprehend or appreciate the thermodynamics and physics of how solar thermal cooling realizes the additional efficiency.

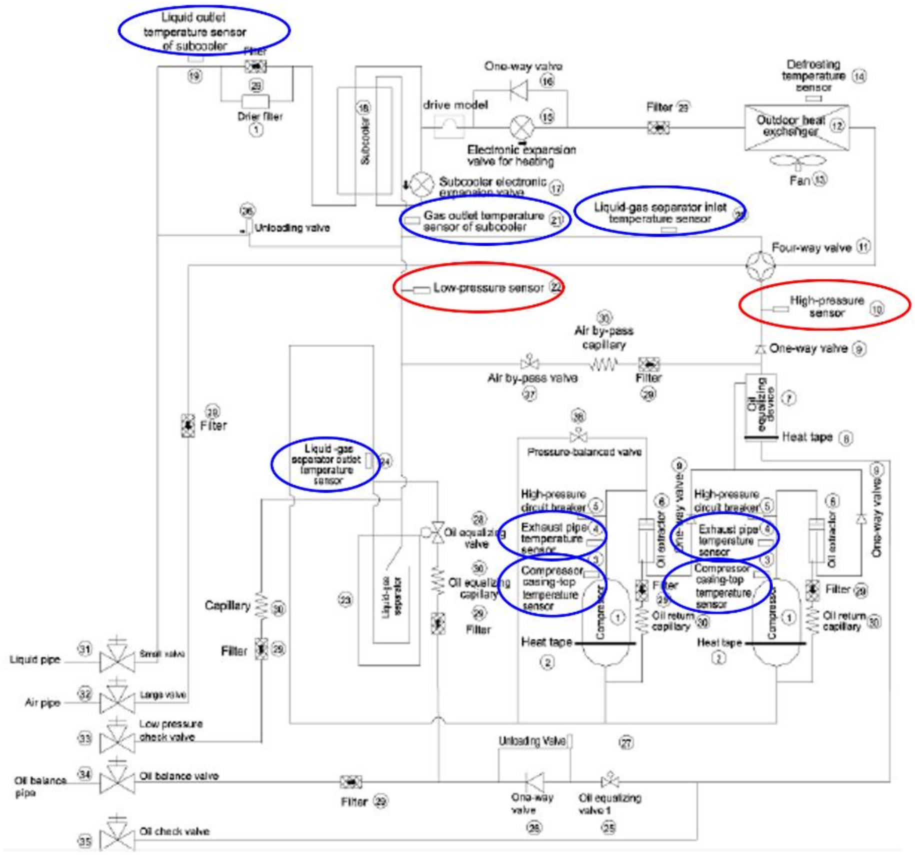
Please note – the reference to ΔT throughout this document is in all cases referencing the DeltaT at the condenser; i.e., ambient air temperature to condenser coil temperature differential.

3 UNDERSTANDING & ADDRESSING POTENTIAL PRECONCEPTIONS

Point #1: Heat = Pressure

A common misperception is that the control of modern HVAC-R systems is still based on pressure, when in fact the logic control is predominantly driven by thermal energy measurement. To further emphasize this point, the vast majority of today's VRF/VRV/MDV systems are manufactured without a single pressure transducer linked to the operational logic controls. *These are now predominantly thermistor sensors, this is not because the thermistor sensors are a more cost-effective alternative to pressure transducers.* This misperception can then lead to the incorrect conclusion that heat is essentially an unwanted by-product of the pressurization process, which is factually incorrect. The reality is that's it is the pressure that is less significant, although obviously a necessary pre-condition. Without thermal energy, the cooling effect could not, nor cannot be achieved. Pressure and thermal energy are collectively vital sources in the refrigerant process; but it is also important to comprehend that in the modern-day modulation system, the thermodynamic method is vital for efficiency improvement and therefore these two factors rarely align for prolonged periods. The manufacturers of these technologies came to recognize this fact some time ago.

To further emphasize this point, the schematic below is that of a typical Variable Refrigerant Flow system.



The blue circles highlight the temperature sensors in the system. These are linked to the logic controls, which make the decisions on how hard or not the compressors work. The red circles are the pressure transducers, one for high pressure and one for low pressure. These have zero impact on the logic controls, other than to protect the compressors.

Point #2: Heat is the unwanted

In conventional air-cooled systems, as the compressor operates to achieve its required mass flow, it must drive beyond just its mass-flow requirements. This builds the additional pressure/temperature necessary to deliver enough refrigerant effect—ensuring the required heat transfer at the condenser across all potential OAT dry bulb conditions.

Heat is not just wanted, it is a requirement.

In comparison, a water-cooled compressor is ideally sized and operated to only achieve the required mass-flow without unnecessary additional heat, taking advantage of a consistently much lower condenser pressure/temperature. Perhaps yet another way to look at it would be to say it's the equivalent of adding horsepower to the condenser fan to achieve commensurate heat transfer.

Point #3: On a modulating system, each compressor's capacity corresponds to an equal propulsion of Mass Flow

It is commonly assumed that each compressor will deliver equal amounts of mass flow as they are called upon to enter the cycle by the system's logic controls. In other words, it may be assumed that a 4-stage compression system will deliver 25% of the systems available mass flow from each compressor. This is by no means the case. The reality is that the early stages will deliver most of the mass flow, which can be as high as 75%.

The fact is, a compressor is a pump. Those trained in the 'art' will confirm, a pump both sucks-in and forces-out.

If we take the example of two identical pumps in series, both having the same pumping capacity and responsible for moving a low pressure 'pushed' volume of water at say 120°F. With one of the pumps operating it will move a 'certain' amount of water. Now the second pump enters the cycle – does the combined system now move twice the amount of water? Not necessarily, and if the first pump was slower, the second could not move more than what it was being fed. If the first were faster, the second would just have pressure against its intake. Combined, what they *can* do is move the water further (head lift), but not necessarily more volume per say. In fact, under the same circumstances, 100 pumps in a row cannot ever move more than what the first pump let's through.

Granted, this is in no way a perfect analogy as in our case we are dealing with a gas. A gas with pressures and temperature changes throughout the process. That said, the result however is not as much about mass, as it's the density/volume that changes more dramatically. There is a fixed amount of refrigerant within the system. So, when we talk about mass flow, we are really talking about the system's capability to circulate the refrigerant through its phases, and whether it can keep up. Absolutely, more or less gas can and does move through the compressors; however, the amount is far from the result of a basic multiplier.

Today's HVAC/R systems will always need a compressor. What they don't necessarily need are all the compressors. If we could disconnect the un-required, that would be great. But we can't, as they need to be always ready and online for the times when the system does need them.

Point #4: Solar thermal adds heat to the refrigerant, which in turn, the condenser is required to remove

In reality, there is no 'additional' heat being added to the system. Factually, the variable speed or modulating system's built-in logic controls safeguard the system against the thermodynamic boundaries being breached. In today's modern systems, the logic controls are designed to recognize and meter the thermal energy. This is accomplished via a thermistor sensor rather than through the previous method of using a pressure transducer, with the logic control required to extrapolate the temperatures. This control logic then modulates the required compressor's speed accordingly and as such, the process allows the solar array to replace an element of the necessary thermal energy that would normally be generated by the compressor/s alone. In other words, the process of partnering solar thermal into the refrigerant loop on a modulating refrigeration system is not to increase the temperature above the existing design conditions of the condenser, nor the refrigerants' manufactured set points.

Solar thermal correctly integrated into the cooling process of a modulating system, along with true thermodynamic logic controls, will operate efficiently with most refrigerants. The added benefit derived from the renewable, readily available thermal energy may vary in comparison to the above illustrations, dependent on the refrigerant in use, along with the normally anticipated variables within any cooling system. The condenser transfers heat from the refrigerant to the ambient air. The rate of heat transfer in a condenser is a function of its design properties, mass flow of the refrigerant, pressure, condensation temperature and saturation of the refrigerant.

The solar thermal supported system retains the above process. The single difference now being that on a system with the ability to modulate, the method increases the refrigerant's temperature following the discharge from the compressor, while maintaining the pressure generated via the compressor. Thus, improving the ΔT at the condenser point, with a lower energy consumption at the compressor.

The alternative being a compressor working harder to raise the pressure, subsequently raising the condensation temperature, along with an increased condenser fan speed.

Point #5: Solar thermal HVAC works, but is only viable in high ambient temperatures

Although it is generally accepted, by those who understand variable refrigerant technology, that a solar thermal assisted system would be beneficial in high ambient temperatures environments, (due to the ambient air to cooling coil ΔT benefits), a common misconception is that this would not be the case in the considerably more temperate or 'normal' ambient environments.

Consider this: When the sun is available, the thermal collector continues to provide thermal energy to the refrigerant. The variable system's logic control recognizes this fact via thermistor sensors, as if this thermal energy is provided by the compressor. *For example*: To achieve the required ΔT (liquid production) the system's logic control measures data supplied via the thermistor sensors located at the condenser. Let's postulate that this specifies an increase in compressor demand, which on this occasion equates to a discharge temperature of say 65°c (149°F), along with the equivalent mass flow via the compressor. The temperature generated from the compressor and the solar array combined, however, is say 70°c (158°F), maintaining the mass flow. The condenser logic sensors reasonably assume that the discharge temperature and subsequent mass flow is born only from the compressor output.

The reality is that the actual temperature discharged from the compressor may only need to be 40/45°c (104/113°F), with the expected mass flow, due to the solar thermal supplementation. As such, the logic control may conceivably communicate to the compressor to slow down or maintain its position, dependent on available solar input, whilst maintaining mass flow of the refrigerant from the compressor.

The temperature generated via the compressor is determined by the logic to have increased, allowing the compressor to reduce its load, while providing an ambient air to cooling coil ΔT in line with what would normally be achieved with the compressor working at a higher energy consumption rate. Ultimately this results in an improved liquid refrigerant mass flow through the metering device, with an observed, measured and recorded reduction in energy consumption. The culmination being reduced flash gas, or in most cases – zero flash gas. See example solar assisted liquid line here .

Of course, pressure remains an important and necessary component in the liquification process. In today's modern thermodynamically determined systems however, pressure is monitored primarily to ensure system protection, but rarely measured in relation to impacting the logic of the control's decision-making procedure. The solar assisted cooling system produces efficiency gains by allowing the compressor to slow down to stages as low as its lowest possible design point, due to the utilization of the same method. Remember, however, that the condenser is designed to manage the circuit's full capacity.

Point #6: A solar thermal array cannot produce efficiencies on a cooling system during the hours of darkness

The sheer nature and design of the technology dictates that the solar thermal collector would generate zero additional 'heat' energy following the discharge from the compressor, during the hours of solar blackout. Consequently, it would be reasonable to surmise there are therefore zero additional efficiencies gained during this period.

To the contrary, although to a lesser degree, further efficiencies achieved are now derived from the opposite effect, with the solar array now acting as an oversized condenser, dissipating an element of the refrigerants heat prior to the condenser. The solar panels essentially reverse their role, again resulting in an improved liquid refrigerant mass flow through the metering device, delivering an observed, measured and recorded reduction in energy consumption.

4 MOLECULAR KINETIC THERMAL ENERGY TRANSFER

4.1 The process of adding thermal energy to the refrigerant gas via solar thermal is only to replace an element of the thermal energy normally generated by the compressor. The technology does not work to significantly increase the gaseous temperatures created when the compressor is in high capacity mode. Hence the reason why solar thermal cannot be installed on single fixed speed systems. No modulation means there is virtually zero ability for the compressor to unload an element of the heat created.

4.2 Since all liquids and gases consist of molecules, an additional explanation on a molecular level is required. *Under no circumstances are we suggesting a replacement of thermodynamic principles*, to the contrary, this technology takes advantage of the very same principles. The way the molecules of a substance transfers heat is defined by the theory of Kinetic Energy. Each molecule has a mass, when colliding into each other they exchange an impulse and then deflect apart again. This colliding process transfers heat. Therefore, more heat equals a higher velocity and more heat transfer. As we have septillions of molecules, we also have an abundance of collisions and heat transference. With an increased temperature, the molecules collide at a faster rate, an acceleration process caused by the sensible thermal energy produced by the solar collector, therefore producing an increased heat transfer. Remember – this very same process occurs when the compressors are running at high capacity

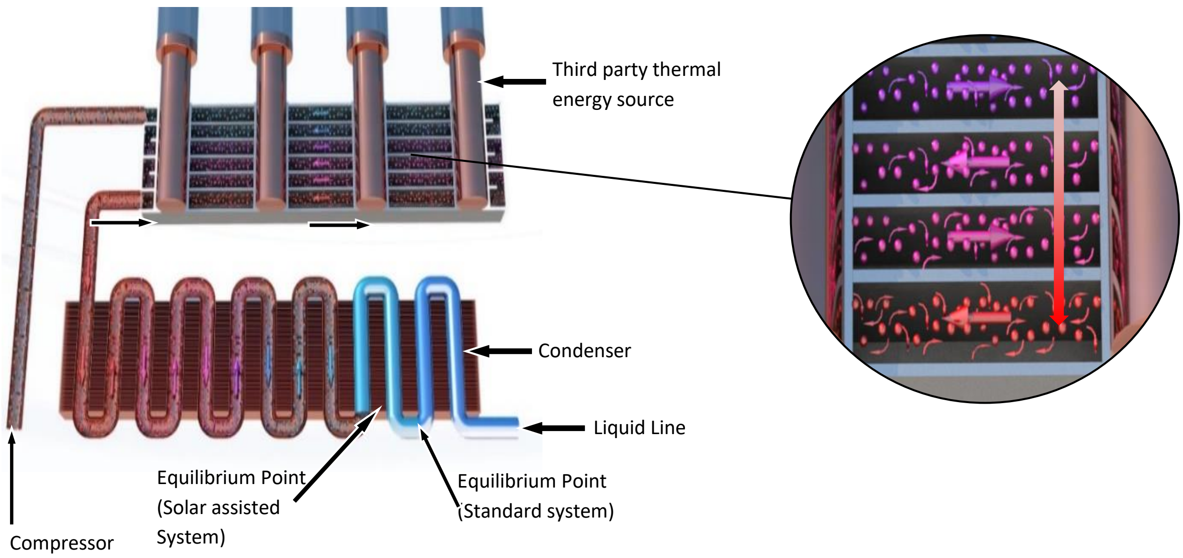
4.3 The molecules themselves do not store heat or give away heat through their masses. The forces in the process do not store or exchange any heat, and the molecules do not change in diameter with the heat. The only source of heat is the collision process of the molecules.

4.4 What this means within the Solar Thermal Cooling process:

I. The heat and the transfer of such is only defined by the number of collisions of the molecules. The key point here is that this colliding activity is not restricted to each other, but also occurs with the surrounding border – the pipe work. This colliding activity, creates a velocity increase of the refrigerant through the condenser, resulting in an increase in the associated heat transferring into the surrounding pipe work of the condenser in a more effective manner. As the ambient air to cooling coil ΔT is maintained or better still increased, the outcome becomes an improved liquid refrigerant mass flow through the metering device. **As if the compressors were operating at a higher capacity.**

Note – the condenser is still the same size as manufactured. The refrigerant temperature only peaks in line with the systems manufactured design points.

Process Illustration



- Liquid volume stability
- Kinetic energy increase
- Molecular collision increase

- Accelerated, exothermic reaction
- Delta T Increase
- Improved heat transfer
- Improved sub cooling

5 THE MOST EFFICIENT POSITION FOR AN INVERTER COMPRESSOR

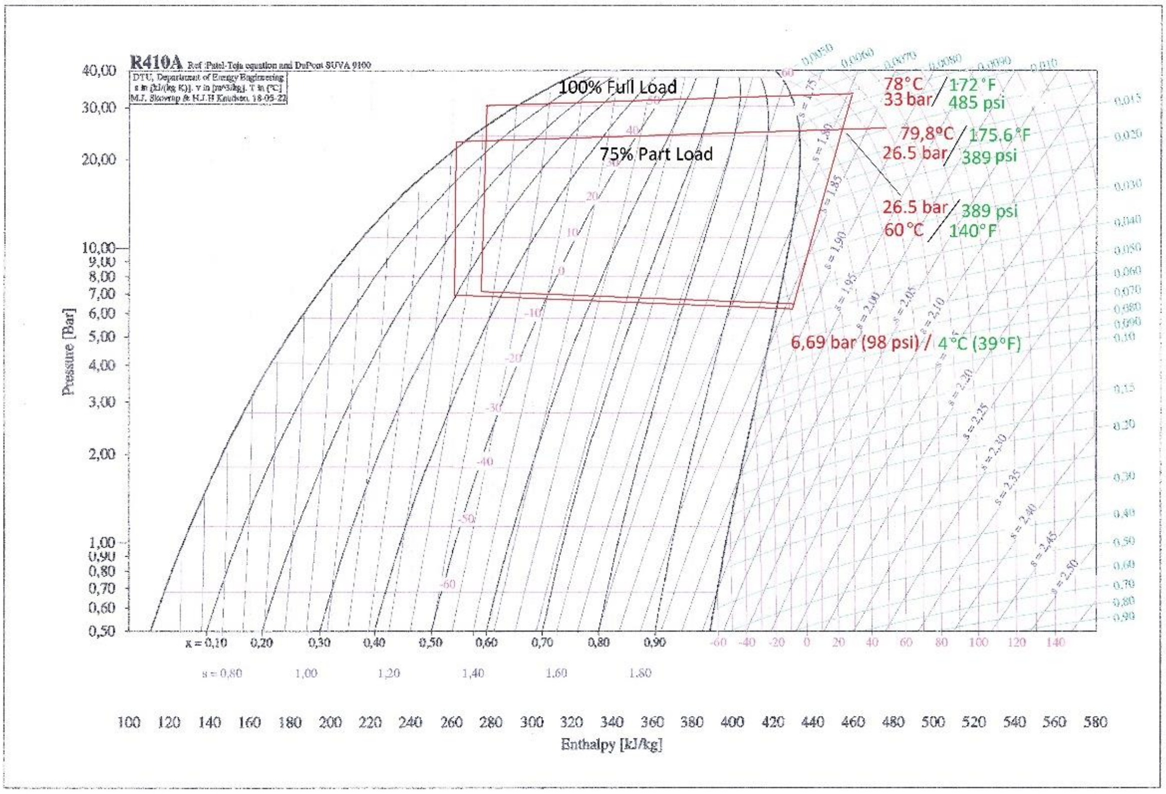
Speak with any of the top developers and manufacturers of the Inverter compressor, and they will confirm the most efficient position for this compressor technology is when the compressor is operating at 75% of its capacity. Why?

The simple fact is that, at 75% of its available capacity, the compressor is already providing the vast majority or 100% of the available mass-flow [*Preconception #3]. Therefore, the only reason the compressor would need to increase its capacity, would be to provide the additional pressure/temperature into the refrigerant to satisfy the required ΔT at the condenser (air to coil temperature differential). The reality is, we don't need the *additional* pressure, just the additional heat *[*Preconception #2].* However, the nature of the compression process means we get both.

The addition of solar thermal technology allows the compressor to provide the required mass-flow and pressure, while the solar thermal system provides the additional required temperature into the refrigerant (without the addition of pressure), normally achieved by the compressor running at a higher capacity. The process can be achieved through all stages of the compression process, from low to high.

The question is, why would you ever want to run this type of technology at 100% capacity, when the thermal energy gain can be provided 100% gratis from natural resources?

The enthalpy diagram below illustrates an inverter compressor running at 75% capacity, partnered with the solar thermal technology, vs. the stand-alone inverter compressor providing a similar level of sub-cooling.



An increase in liquid molecules within the evaporator equals a higher capacity. This is detected by the modern-day system's logic controls signaling for a reduced rpm of the DC inverter compressor; or, in the case of multi-stage systems, a delayed switch-in point of additional compressors. The major difference between the old, single, fixed speed systems and the modern-day variable speed systems is not just about the compressor technology, but includes the sensing method, the logic controllers of the system, and how they measure the temperatures and react to them. The sensors consider the differences, as they measure the parameters of the system versus what is expected and adjust accordingly.

6 CONCLUSION

The primary impact of additional stages of compression is that they impart the additional required thermal energy needed by the system to create a credible ambient air to cooling coil ΔT .

Understanding the solar thermal technology is also about understanding the most important components of the modern-day variable or modulating system controls, the change of state from vapor to liquid, along with the importance of the kinetic energy changes in the refrigerant. Variable refrigerant systems have changed several of the fundamentals in the refrigerant process over recent years. The solar thermal addition to this process further improves the effectiveness of these systems by creating an improved efficiency via the two crucial components in the cooling and refrigeration cycle: the heat exchanger and the metering device.

The sensible thermal energy added by the solar thermal array replaces an element of the thermal energy normally completely generated by electro-mechanical compression. The compressor is the most energy hungry component in the whole process. The addition of solar thermal energy into the process can have credible positive impact on the efficiency of this component.

The combination of reducing the compressors' workload, while maintaining the refrigerant temperatures required to deliver an efficient ΔT, achieves a more rapid change of state, a more efficient sub-cooling, and in the end an enhanced cooling capacity.

The patent owner has so far developed installations on 6 continents, across 47 different countries over the last five years. Therefore, kWh data savings covering a multitude of differing ambient conditions has been observed and recorded. Although it should be noted that an element of this data was collated by the owners of this patented solution, most were completed by the end user themselves, through their own in-house evaluation of this technology. Those end users include many large corporations such as, but not limited to Cummins, Mercedes Benz, Toyota, DHL, Spar, British Ministry of Defense, Sodexo, Cable & Wireless, Hard Rock Resorts, AutoZone and Intel.

7 WHAT THE EXPERTS SAY

"We have come across this before. The technology appears to be based on workable physics and the case studies appear to show significant efficiency increases which could be expected if the technology is applied correctly and well-engineered" - Specified Solutions Engineer, Daikin UK.

"I do think this is a very cool product. As a 25-year AC guy, the technology seams fairly simple and makes sense to me" - Veteran Trane AC Technician.

"I do agree that the ThermX system does present energy savings potential with the VRF system" - ***Assoc.*** Director Product Strategy and Support | Carrier Ductless & VRF

The sun was always the problem. Today however, we can utilize it as the solution.

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