# A Temperature Data Logger…
# Not Just For Calibrations Anymore!

Speaker/Author: Keela Sniadach
Promega Corporation
5445 East Cheryl Parkway
Madison, Wisconsin, 53711 United States
Phone: (608) 298-4681
Fax: (608) 277-2516
E-mail: ksniadac@promega.com

**Abstract**

In a time when budgets are tight, how can you make the most use of your Metrology department standards? In our Metrology department at Promega, a biotechnology company, we have found many applications where our temperature data logger with thermocouple probes could be used for more than just calibrations. Our department has played an important role in validating existing processes and establishing new product procedures using temperature profiles collected with the data logger. We have collected temperature profiles for products in various size containers and in extreme conditions. This paper will explain some of the ways and methods we have used our data logger for much more than just calibration and a few of the lessons we have learned along the way.

## 1. Introduction

The Metrology department at Promega provides our customers with reliable and timely calibrations, repairs and preventive maintenance procedures on test equipment. Currently, we support 6,225 pieces of equipment, with 3,700 being calibrations and preventive maintenance procedures. Over the five years that we have been in operation we have carefully chosen our standards based on our needs to support the equipment at Promega. At first the data logger was used for a few types calibrations, then we found that we could help others at Promega obtain reliable temperature measurements in ways beyond just calibrations.

Promega is a biotechnology company. The 1,200 products that we sell help researchers around the world explore gene, protein and cellular interactions. [1] A large number of these products are temperature sensitive. This requires our scientists, dispensing technicians, packaging specialists and shipping department to handle these products with optimal temperature conditions in mind. The special projects we performed provided evidence of whether or not products were meeting specifications. Missing the target temperature could result in product loss, which of course means a loss in profit to Promega.

When a customer uses our services to acquire a temperature profile we respond in a systematic manner. We set up an initial meeting to determine the goal of the project and whether we have the capabilities to carry out the project. After determining whether can handle the project, we schedule the test day. The next step is to prepare the thermocouple probes. We have learned many lessons from the projects we have completed; but perhaps the best part of taking on new projects is the helpful data we provide and the suspense of watching the data logger as the temperature details unfold.

## 2. Promega's Data Logger

Promega's data logger is an in-house design. The entire system consists of thermocouples plugged into a cold junction compensation box, which is plugged into a desktop computer. We have placed the whole system on a cart to allow us mobility. The thermocouples we use are type T with 30-gauge wire. For our applications 30-gauge wire gives us flexibility and still provides a good deal of strength. These traits are important requirements for the variety of applications the probes are used in. The data logger has sixteen probes that can plug into the junction box at one time. [2] There are two sets of calibrated probes; one set is five feet long while the other is fifteen feet.

The data logger program is versatile; we can program any parameter. That includes the sample interval time, which probes should be turned on and how many of the probes should be used. When starting a run our first option is setting the interval length. It can be set in hours, minutes or seconds, with the smallest increment being one second. Next we choose which probes to run. We can run as few as one probe or as many as sixteen probes. An exciting feature of the program is its ability to allow us to change parameters during the run with out stopping the run. This trait is useful in long running projects. Frequently at the beginning of a long-term project there is a lot happening so we keep the interval small. Following the initial events there is an overnight incubation at a steady temperature. We have the ability to increase the interval during the incubation with out stopping the run. While the data logger is running, we can view the data it is collecting. The data can be viewed in either a tabular format or a graphical format and can be switched during the run.

The program also has a calibration feature. We calibrate each probe; uniquely identify it and its plug-in location. We do this to assure that the probe is in the same position every time. Our program calibrates each probe to its specific site so it cannot be interchanged without re-calibration.

## 3. The Data Loggers Function

Metrology acquired the data logger for specific calibration functions. Many of those calibrations required us to show a piece of equipment was reaching a specific temperature for a specified period of time. Other calibrations involved straightforward temperature measurements. As a small department with a tight budget we utilize our standards to their capacity in an effort to support our customers. This was the case with our data logger. We were able to see that we could help our company obtain valuable data, in-house, with a standard we already possessed. As one project was complete, word spread throughout Promega regarding the information we could acquire with the data logger, and the special projects keep rolling in. We have now helped our company collect temperature profiles in projects involving the validation of existing procedures, testing possible new processes, comparison studies and stability tests.

## 4. Preparing for a Data Logger Project

As each new project presents itself we have established a procedure for planning and executing the project. Our customers initiate the projects. In our case, customers are the scientists, production staff, packaging specialists and shipping technicians that work at Promega. As a biotechnology company, we produce a great number of temperature sensitive biological reagents, enzymes and buffers. If these products stray from there optimal or storage temperatures it can render them inactive, costing Promega profits.

Once a customer initiates a project our first order of business is to set a meeting time. At this first meeting we discuss the temperature profile the customer is hoping to capture. In most cases we know right away if we will be able to accomplish the project, but there are those projects that require a bit of additional thought as to whether we have the capabilities to achieve it. Our next step is to set-up the data logger and thermocouple probes for the project.

Preparing the thermocouples can be quite an extensive task, depending on the project. The set-up can be anywhere from simply placing the probe in a container and collecting temperature to threading the probe through hosing hooked up to a dispensing machine. When we set up the thermocouples we like to use the actual product if possible. That way we can get real world results. There are instances where using the actual product is not an option, so we try to use a composition similar to the product. Many times we end up preparing a water sample or a percentage of water/glycerol solution to mimic the product being tested.

After set up is complete, we can start the project run. During the run we collect a temperature profile of the entire project. When the project is complete we organize the data and incorporate all the notes taken during the run and any other important events. The data is then presented to the customer. The customer is the one responsible for analyzing the data and determining any courses of action.

## 5. Data Logger Projects

5.1 Since we have begun using the data logger for project work we have completed quite a few projects where the customer needs to validate an existing process. They come to us when they need to verify a process is achieving a temperature in the manner that it is described. One of the first projects of this type we performed was regarding a production process. A scientist was manufacturing a product that had an incubation period extending overnight. While they were fairly confident that the product was maintaining the temperature, they could not prove it. The scientist recorded the temperature at the start of the run and checked it at intervals throughout the day and the next morning. The problem was the giant gap overnight where no temperature checks were taking place. When he came to us for help we knew we could capture a temperature profile for the process with a tool we already had on hand–the data logger.

This step in the process was not sterile, so we were able to secure the probe to one side of the bucket used for manufacturing the product in. We programmed the data logger at the start of the incubation and collected data at one-minute intervals during the entire incubation period. When the process was complete we were able to show the customer a graphical and tabular representation of the run. They were easily able to evaluate whether or not the product reached the target temperature. (See Figure 1)

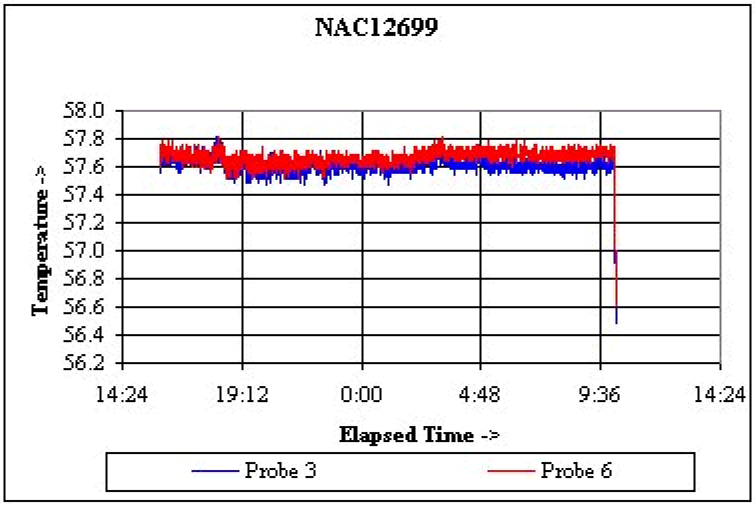


Figure 1: An example of the graphical and tabular data collection from the datalogger.

| NAC12699 Temperature Data | | |
|---|---|---|
| Elapsed Time | Probe 3 | Probe 6 |
| 15:54:39 | 57.670 | 57.689 |
| 15:55:09 | 57.670 | 57.689 |
| 15:55:40 | 57.670 | 57.719 |
| 15:56:10 | 57.561 | 57.600 |
| 15:56:40 | 57.670 | 57.759 |
| 15:57:10 | 57.581 | 57.630 |
| 15:57:41 | 57.700 | 57.739 |
| 15:58:11 | 57.670 | 57.689 |
| 15:58:41 | 57.720 | 57.789 |
| 15:59:11 | 57.611 | 57.650 |
| 15:59:42 | 57.651 | 57.739 |
| 16:00:12 | 57.631 | 57.689 |
| 16:00:42 | 57.631 | 57.689 |
| 16:01:12 | 57.670 | 57.719 |

We received a request which involved freezing 650mls of product in one liter bottles with liquid nitrogen. The process involved placing twenty-five one-liter bottles in a cage that was lowered into liquid nitrogen. The bottles were left in the liquid nitrogen for a set period of time. After the product was believed to be frozen it was removed from the liquid nitrogen and placed into a -70°C freezer. This customer wanted to know when the product actually froze and if they were allowing the bottles to sit in the liquid nitrogen long enough to freeze the product.

In order to find out when the product was entirely frozen we needed to place the thermocouple inside the center of the liquid level in the bottle. We drilled a hole in the lid of the bottle to thread the thermocouple probe through; we did not want to crimp the thermocouple between the lid and the bottle. By filling the bottle with 650mls of water and measuring the level line we determined the center of the liquid. Once that was figured out we knew how much thermocouple to thread through and where the junction should be located.

We did not have a high level of confidence that the thermocouple would not move around during testing. We decided to secure the thermocouple probe by first threading it through the hole drilled in the cap, then threading it through the shaft of a long cotton swab. The swab was trimmed to length so just the thermocouple junction protruded. (See Figure 2) The set-up was secured with silicon sealant by resting the swab flush against the inside of the lid. Sealant was also added on the outside of the lid to seal any leaks.

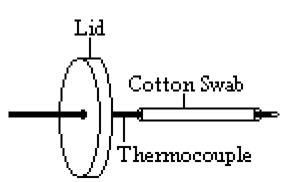


Figure 2: One liter lid set-up.

When the sealant dried, the lid set-up was sturdy enough we felt confident the probe would stay where it was positioned. We did this for several bottles because we wanted a good picture of what was happening at different areas in the cage. We made probe lids for a corner, edge, center and other randomly placed bottles. The rest of the cage was filled with the one liter bottles with 650mls of sample, but with no probe. We set the collection interval to three seconds and started the data logger before the customer was ready to begin so we could obtain baseline readings. When the run was complete, we collated the data and presented it to the user. From the data they were able to determine if the liquid in the bottles was freezing and if they were leaving the bottles in the liquid nitrogen long enough.

Promega is involved in a lot of work with robotic systems. An inquiry was made as to whether we would be able to check the heat block portion of a system commonly used by our scientists. They wanted to see exactly what was going on temperature wise during different conditions when using the heat block function. The challenge was the sample holder. It was a 96 well plate. We were able to do the testing by securing the thermocouple wires to the top of the plate and around the wells with silicon sealant. (See Figure 3) By attaching the probes in this manner we prevented them from moving during the test and it positioned them in the center of the well. Data was collected at several different temperatures and then repeated with the shaking function of the heat block on. The robotic users were able to analyze data we presented and see how their product was reacting to the temperatures and conditions set.

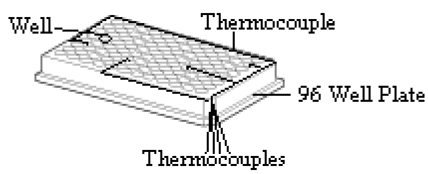


Figure 3: 96 well plate set-up for heatblock on robotic system.

5.2 Frequently we are involved in requests for comparison studies. In these tests the customer wants to compare one product/process to another so that they can achieve optimal performance. A customer came to us with a request regarding the performance of one type of microfuge tube to another. The customers concern was whether a thin-walled microfuge tube performed better in a heat block than a siliconized microfuge tube. They wanted to use the tube that allowed the product to reach the programmed temperature of the heat block best. The thin-walled tubes were assumed to be better, but they preferred the siliconized tubes because the product did not ‘stick’ to the sides of the tube. With the customers help we set up an experiment to see which tube gave optimal results.

We ran two experiments with the only difference being which type of tubes were used. Holes were carefully punched into the lids of the microfuge tubes. The thermocouple probe was threaded through the hole far enough into the tube that the junction was completely covered with the sample but not so far that it was touching the bottom of the tube. This proved to be a bit of a challenge due to the size of the tube. The tubes we used were 0.5mls and filled with 50µls of sample. We secured the thermocouples using silicon sealant. (See Figure 4)

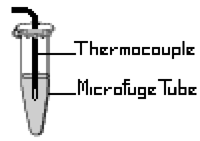


Figure 4: Microfuge comparison set-up

One set of microfuge tubes were placed into the heat block in pre-determined locations and the testing began. After the first run was complete the second set of tubes was placed into the heat block in the same fashion and again data was collected. The customer was presented with the data. They were able to compare the temperature profiles of both tubes. They had actual data to support the decision on whether one type of tube out performed the other.

Our most fascinating comparison study involved two different departments. Each of the departments packaged the same temperature sensitive product. The quantity requested in the shop order determined which department received the work. The problem was each department worked independently and the exact method in which the product was packaged was different. The supervisors wanted only one department to handle the packaging of the product. They needed to determine which departments method led to the best environment for the product.

We collected the temperature profile for the entire packaging process for each of the departments independent of one another. For the first department we set up the thermocouple probe in microfuge tubes. We sealed and secured the thermocouple in the lid of the tube with silicon sealant. After the thermocouple tubes were prepared they were frozen overnight in a -70°C freezer. The tubes were placed into a bag containing real sample ready to be packaged. It was at this point the data collection began.

The product was packaged by placing several tubes into a foil bag. Ahead of time we prepared 3 bags for the samples including the thermocouple probes. We cut a hole in the side of the bag, close to the bottom, so the thermocouple tubes could be placed in the bag with the probe exiting out the hole. We placed one bag near the top of the packaging run, one in the middle and one near the end. The technician was informed that when the bags with holes were encountered one of the tubes placed in it had to be a tube with a thermocouple probe. (See Figure 5)

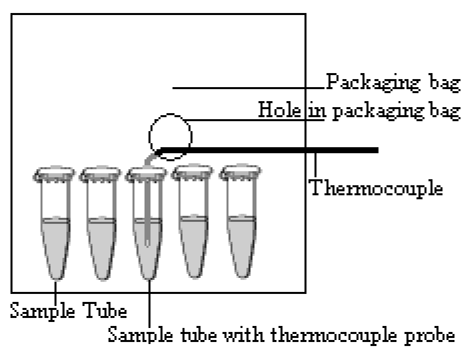


Figure 5: Packaging set-up for department comparison study

The technician was instructed to do all the practices he normally would do during the run. After the technician filled a bag with a thermocouple probe, we placed a piece of tape over the hole so that the bag could be vacuum-sealed. After the order was packed the bag was vacuumed sealed. The bag was placed in the vacuum sealer with the probe out the side of the unit. The probe did not come in contact with the heating element, so we were able to continue collecting temperature while the bags were sealed. (See Figure 6)

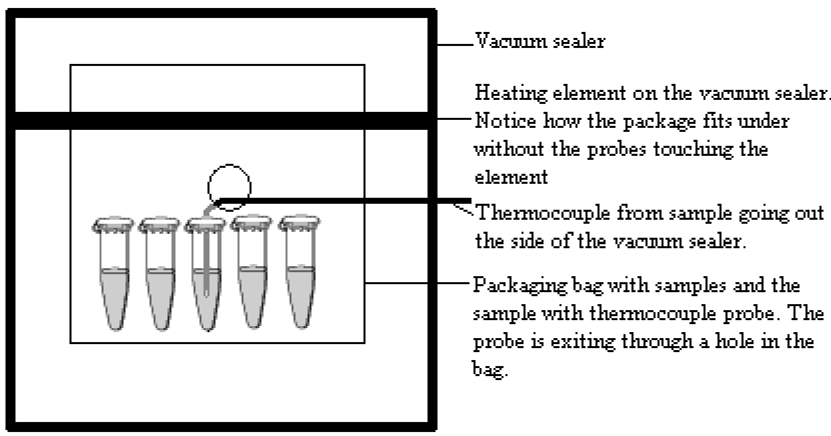


Figure 6: Vacuum sealing the bag with the thermocouple probe for the department comparison study.

After the bags were sealed they were placed in a -70°C freezer for storage. We were able to collect the temperature profile during the entire process. We then repeated the testing for the other department. Even though the critical steps were completed the same, there were some differences in how the process unfolded and the exact equipment used. We were able to gather temperature profiles for each of the departments. The departments were able to assess the data and determine which of the departments should package the product.

One of Promega's departments has a wide variety of products that they fill and must freeze immediately after dispensing. They came to us to see if we could help compare different methods of freezing. On our end it was fairly easy to help, all we had to do was prepare several microfuge tubes with different compositions of products to be tested. We placed the thermocouple probe through the top of the tube and secured it with silicon sealant. The tubes were then subjected to several freezing methods.

The first condition involved placing the tubes directly on dry ice. We began data collection before the tubes were placed on the dry ice and continued collection until the product passed its freezing point. The testing continued in the same manner for several other freezing methods. These methods included placing the tubes in an aluminum box chilled in dry ice, a dry ice/ethanol mixture, an aluminum block chilled in a dry ice/ethanol mixture, liquid nitrogen and an aluminum block chilled in liquid nitrogen. This testing did not require a great deal of set up time, but it was a time commitment to run all the tests. In the end, the department used the data we provided to determine which of the quick freezing methods would work best for them.

5.3 Perhaps the most exciting and thought provoking projects we have completed involved testing possible new products and new processes. The customers come to us when they need to be assured their product will reach or stay at the correct temperature when subjected to new processes, whether it be in research and development, production, packaging or shipping.

In an effort to instill a sense of security and safety with consumers purchasing our kit products, Promega has become involved with shrink-wrapping kits and products. The main draw back to shrink-wrapping for our company is the high amount of heat involved in shrinking the plastic film. A few of the products that were slated to be shrink-wrapped were temperature sensitive products. Packaging had to be positive that when the kits ran through the shrink wrapper that the product inside was not adversely affected.

The manager of the packaging department came to us to see if we would be able to accomplish the project. When we initially considered it, we did not think that we would be able to complete it. We had issues with how to get the probes through the shrink-wrapper. At that time we only had five foot probe lengths, which were not long enough to carry out some of the steps in the project. It struck us like a lightening bolt; we could complete the project if we had longer probes! From that point we were able to design a set-up to meet both our requirements and packaging needs.

Packaging gave us a sample kit that was to be tested in the shrink-wrapper. The main concern was the actual product temperature, but we did realize other temperatures were important. We first placed a thermocouple probe into the product contained a microfuge tube. A hole was poked into the cap of the microfuge tube. The probe junction was placed in the center of the fluid not touching any sides or the bottom of the tube and secured by placing silicon sealant around the probe on the tube lid. While it dried the packaging box was prepared.

The packaging box consisted of a five-sided box that fits into a sleeve cover. We were able to attach a probe to the inside center of the box and one on the inside edge of the box. This was done so they could see how much the air temperature inside the box was affected by the shrink-wrapping. The probes were snaked out of the box and through the open end of the sleeve after the sample product was placed into the box. We also placed a probe on the outside of the sleeve to get an impression of the temperature outside of the box. The box was stored in a -20°C freezer overnight. (See Figure 7)

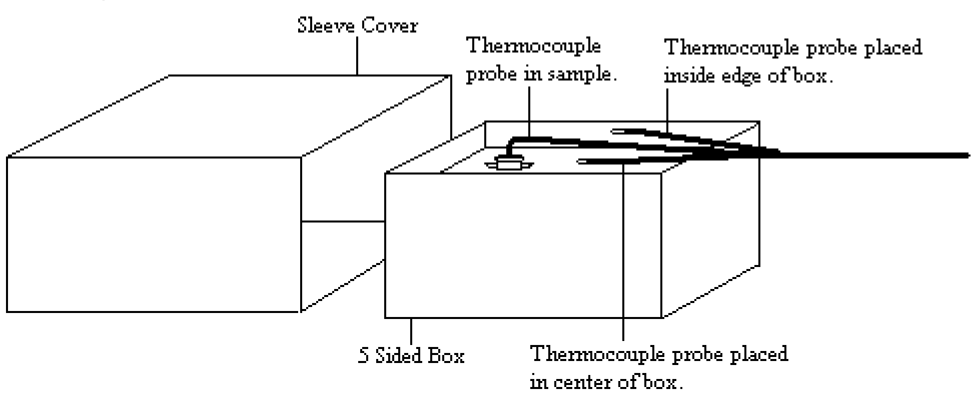


Figure 7: Set up for shrink wrapping project.

Once we were ready to begin the project, we got the data logger set up. We plugged in the probes while the box was still in the freezer, to establish a base line. The project began when the box was removed from the freezer. We wanted the process to be carried out as ‘real world’ as possible so the box was left to sit for five minutes on dry ice. In a normal shrink-wrapping run there would be many boxes to run through the shrink wrapper, but no box would set out for more than five minutes.

The box was placed in the plastic film on the shrink wrapper. The film was already folded once on the roll and sealed on the side closest to the shrink wrapper from the previous heat-sealing. The boxes that go through the shrink wrapper have to be enclosed with plastic film before hand, so the two open ends are heat sealed right before they are sent through the shrink wrapper. We were able to handle this, by placing a hole big enough to fit the thermocouple connector through the film on a side that did not need to be heat-sealed. (See Figure 8)

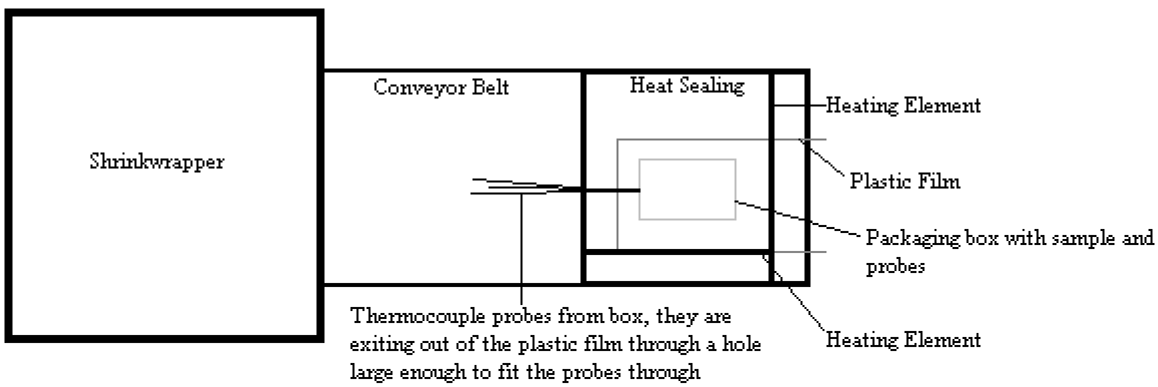


Figure 8: Packaging box set up before going through shrinkwrapper.

At this point in the project we had to act expediently. We did not want the box to sit out any extra time. Once we placed it in the film, we unplugged the thermocouple probes so we could thread them through the film. While they were unplugged we sent the connectors through the heat tunnel, when they came through they were immediately plugged in. The box was sent through the shrink wrapper and allowed to sit on the conveyor belt, as it would during an actual run. The box was returned to the -70°C freezer for storage. We allowed the data logger to run until the product equilibrated. Having a mobile data logger and long probes allowed us to capture data on the entire process except the brief disconnection as the probes were sent through the shrink wrapper. This data allowed packaging to determine if the product would be a candidate for shrink-wrapping.

Another department presented us with a rather unique project. They purchased a new dispensing line and wanted to dispense a temperature sensitive product. They needed to know if they would be able to keep the product between its optimal temperatures during dispensing. This proved to be a complex set-up. Fortunately the tubing that connected the product to the pumps and out the dispensing tips was disposable, which gave us a good amount of freedom in setting up the probes. We decided that we could poke a hole in various locations along the route to monitor product temperature. The thermocouple probes were bent to a 90 degree angle approximately 4 mm before the junction and secured to the tubing with lab tape, but not covering the hole. The junction end was placed through the hole and covered with silicon sealant. We knew that during the run there would be a bit of pressure in the lines so we wrapped metal tape around the tubing covering the hole. The tubing set up was allowed to dry overnight before the test. (See Figure 9)

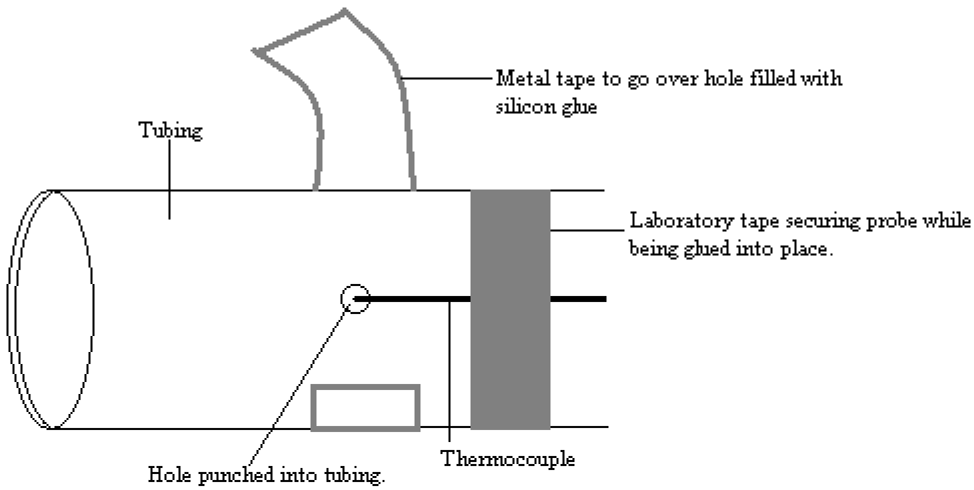


Figure 9: Tubing set-up for dispensing project.

The tubing was connected to the dispensing line with great care. There were a total of sixteen probes measuring different locations in the tubing. All the probes were secured to appropriate locations where there was no force pulling on them and possibly dislodging them. The technicians were able to run the dispensing line with no differences from any other run. Temperature collection was started shortly before the test began so we could obtain a baseline temperature to compare with run results. Data collection continued until the entire product in the normal batch size was dispensed. When the testing was complete we were able to present the customer with a temperature profile of the product through out the dispensing run.

At this time we have been involved with the development of one product. The product manager contacted us early in the planning to see if we would be able to help them design of a bench-top cooler that would meet specifications they envisioned. Our first step was to research coolers with specifications similar to what they wanted to achieve and test them.

The coolers were tested using a microfuge tube with a thermocouple probe threaded through the top and secured with silicon sealant. The test involved a duplicate run with all variables the same except tube contents. For the first run we used a water-based solution to mimic product and for the second run we used a glycerol solution. The first set of tubes was frozen overnight in a -20°C freezer, as product normally would be. The coolers were placed into -20°C freezers as the directions stated. Shortly before the testing began the thermocouple probes were plugged in and a baseline temperature was captured while the samples were in the -20°C freezer.

The coolers were removed from the freezer and the tubes were placed into them in pre-determined locations. Temperature was collected for a twelve-hour time frame while the coolers sat on a bench-top. The entire test was repeated for the glycerol-based tubes. When all the data was collected the product leader assessed it. The data had to show that both the water based product and the glycerol-based products performed to the expected levels. The coolers that meet the criteria were further evaluated by others in the design control line-up.

5.4 Our department has also done quite a few stability tests for our customers. This kind of test is usually a straightforward project that requires us to collect temperature for an extended period of time. The majority of these tests involve placing a product in an incubator or freezer and charting the temperature of the product over an extended period of time.

## 6 Lessons Learned

Our department has been performing special projects for several years now as a service to our customers. After each project we complete its seems we learn one helpful tidbit of information or another. Probably one of the most helpful lessons we learned was numbering our probes with flags at various points along the probe. Most importantly at the connection site and at the end of the probe. This helped us identify the probe during set up without having to trace it to its source every time. This saved us a lot of time during complex and extensive set-ups using many probes.

As was stated earlier in this paper we have two sets of probes, one five feet long and the other fifteen feet long. The five-foot long probes are relatively easy to manage when wound into a circle and secured, but the fifteen-foot ones are another story! We found it very difficult to manage the incredible length of these probes until we came up with the idea of winding the probes on a cylinder. On one side of the cylinder there is enough length to access the connector plug in and on the other the probe junction is available. During set up or a run, we can roll or unroll the cylinder as necessary, avoiding time consuming knots and frustrations.

Designing a procedure to meet the customer's needs is a very important element that can either make the project a success or cause you to fail in capturing the data needed. It is important to formally sit down with the requestor to discuss their goals for the project. Often times if a request is made in passing, we may think we know what the customer wants, but usually we do not have a full grasp of the project or the data needed. When it is formally discussed with the customer we can go over point-to-point what they are looking to capture, how the process will be carried out, any items that need to be set up in advance and supplies needed. It also helps eliminate "scope creep" if both parties know what the project entails and the data they will obtain from it.

As a part of the set up process or right before testing starts, it is useful to diagram or chart the location of the probes in the set up. This information is important because the customer needs to accurately evaluate the data that is collected. If they do not have the correct probe location, they cannot accurately evaluate the project. It is also helpful to have the diagram on hand during the project run. We work directly with the customers during the projects and almost every time they see the data logger display they ask: Which probe is this? Where is this probe?

Frequently, after the initial meeting with the requestors and our set-up is complete and we believe we are prepared to start, we are not. It is beneficial to do a dry run through the project. In some cases we may be able to see problems we had not thought about during preparation. We account for these problems before the actual run, which can save time. In most of the projects we have performed start with frozen product, if we make an error in the procedure we have to stop the run. In order to restart we need the product to freeze and get down to temperature again, in most cases that requires postponing the project until the following day.

To ensure that the data we present to the customer is valuable it has to be complete as possible. This not only includes probe locations but also any notes collected during the run. As the data logger operator we need to take notes of important events that happen during the run. This can include anything from the starting time, the ending time, any problems encountered, when certain processes occurred and even interval changes. In order to accurately assess the information the customer needs to know every detail regarding the run.

Finally, the last bit of advice to offer, we present the data in a professional, organized and usable manner to the customer. If they cannot read or understand how the data is displayed it will not mean anything to them and they will not use it, wasting the time of everyone involved.

## 7 Summary

Our Metrology department has tried to use the department standards to their full capacity. That is the case with our data logger. We use it not only for calibrations, but also for special projects that benefit Promega. As each new project presents itself, we tackle it in a systematic manner. First we meet with the requester to determine what is needed and if we have the resources to complete the project and a date is set carry out the project. Our next step is to prepare the thermocouple probes for testing. The testing is then carried out. The final step is to present the data to the requestor so they can evaluate and analyze it. As a project is completed we also evaluate the process and glean any lessons that were learned in the process.

## 8 References

1. Promega. *Promega Overview.* 2002. http://www.promega.com/about/overview/.
2. Mezei, Louis. Personal communication. March 6, 2002.