Final Report

submitted to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

April 1992

for Contract NAS8-36955

Delivery Order 106

entitled

FNAS Modify Matric and Transparent Experiments

by

Guy A. Smith
Research Associate

Sue E. Kosten
Research Associate

and

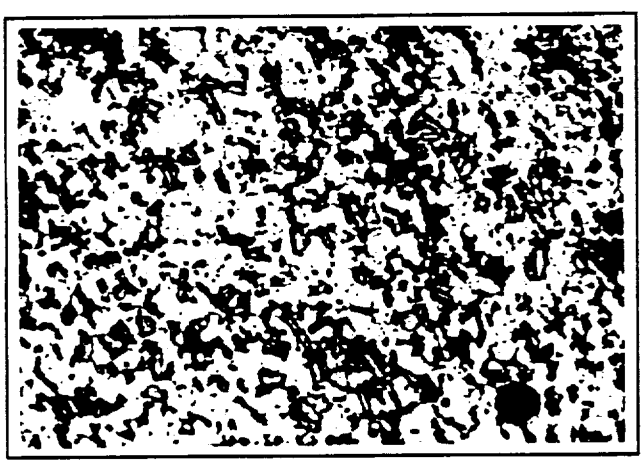
Gary L. Workman Ph. D.
Principal Investigator

(NASA-CR-184442) FNAS MODIFY MATRIC AND TRANSPARENT EXPERIMENTS Final Report, period ending Nov. 1991 (Alabama Univ.) 50 p

N93-13311

Unclas

G3/24 0127392



Low-g solidified MMC

One-g solidified MMC

Materials Processing Laboratory
Center for Automation & Robotics
University of Alabama in Huntsville
Huntsville, Alabama 35899

*** TABLE OF CONTENTS ***

*** TABLE OF FIGURES ***

I. Introduction

Metal matrix composite materials have the potential to improve upon the capabilities of current engineering materials in a number of ways. In particular, new materials with improved strengths, stiffness, and high temperature performance are needed for the next generation high technology accomplishments in aerospace propulsion systems, and to start up new commercial enterprises. Although there are not many commercial products being manufactured using metal matrix composites at this time, it is anticipated many new products will be developed as this technology matures.

The metallurgical study of metal matrix composites has evolved over the last twenty years, with primary interest from the aerospace industry in search of new light-weight, high strength materials for air frame and spacecraft structures. More recently other industries have begun taking a look at metal matrix composites, including the automotive and electronic industries. The two categories currently in use are the continuous filament and the discontinuously reinforced materials using predominantly aluminum matrix alloys. Reinforcement materials include a number of matrix materials, such as aluminum, magnesium, copper, titanium, nickel, etc.

Research studies dealing with metal matrix composites have to be concerned with solidification phenomena in which the melt will generally exist in more than one phase. Whether the liquid is monotectic or simply particulates distributed in a melt, density differences will be affected by gravity. For this reason there is considerable interest in the microgravity materials processing community to study metal matrix composites.

Silicon carbide is the most widely utilized discontinuous ceramic reinforcement today. This reinforcement is available in a range of sizes and morphologies. Transmission electron microscopy studies of SiC reinforced MMC's has shown that, depending upon the preparation process, the resulting morphology of the MMC may be heavily faulted. For this purpose further research with this material is important.

For the purposes of this work, we have chosen to work with aluminum-silicon carbide as a representative system. This work was performed in conjunction with Dr. Don Morel of Applied Research Corporation.

Processing metal matrix composites in reduced gravity provides an environment in which the gravity driven processes are greatly reduced or eliminated. For instance, in the case of particulate reinforced composites, Stokes forces that dominate segregation processes for large particles in 1 g, do not influence the process. Also, reduced buoyancy driven convection in reduced gravity will enable Brownian motion to dominate the thermal flow characteristics of small particle dispersions.

For this study, monotectic alloy materials are created by rapid melt/rapid solidification processing on the NASA KC-135. Separation of the uniform liquid into two liquids may occur by either of two processes; spinodal decomposition or nucleation followed by growth. In the first case, the liquid is unstable to composition waves, which form and grow, giving liquids of two different compositions. In the latter process discrete particles of the second liquid phase form via thermal fluctuations and then grow by diffusion. The two processes are very different, with the determining process being dictated by temperature, composition, and thermodynamic characteristics of the alloy. The first two quantities are process variables, while the third is determined by electronic interactions between the atoms in the alloy. In either case the initial alloy decomposition is followed by coarsening, resulting in growth of the particle size at nearly constant volume fraction.

In particular, reduced gravity experiments on monotectic solutions have shown a number of interesting results in the KC-135. Monotectic solutions exhibit a miscibility gap in the liquid state, and consequently, gravity driven forces can dominate the solidification parameters at 1 g. In reduced gravity however, the distribution of the phases is different, resulting in new and interesting microstructures.

The Rapid Melt/Rapid Quench Furnace allows one to melt a sample and resolidify it in one parabola of the KC-135's flight path, thus eliminating any accumulative influence of multiple parabolas to affect the microstructure of the material.

II. Experimental

The samples used for this study were prepared as a fine distribution of silicon carbide in an aluminum matrix by Dr. Don Morel at Applied Research Corporation. The preparation was performed by mechanically mixing powder starting materials until the mixture appeared to be homogeneous. The mixture was then hydraulically pressed into a rod from which the flight and ground samples were cut.

Prior to any research activities using the RMRQ furnace could begin several modifications and repairs were required to make the system operational for both ground and flight activities. Having flown once during the month of January 1990 a number of problems were determined and had to be resolved prior to another flight. The final report for the contract of that time period (NAS8-36955 D.O. 21) provides the details of those problems and therefore will not be discussed in detail here. However the single most important problem involved the temperature control system for the three heater cores within the furnace.

A. Hardware modifications

Initially the RMRQ system used the single AT grade (80286-8MHz) computer to provide all of the control and data collection activities associated with the operation of the system. Included in the software was the ability to control the three DC power supplies through three digital to analog output ports. By controlling the 0 to 5 volt DC control signal to these power supplies the DC current to the three furnace heater cores could be regulated. This method of control presented several problems. First the AT computer it self was overtaxed with the responsibility of controlling the entire RMRQ system and as result could provide only limited house keeping for the temperature control algorithm. This resulted in too few a number of loops to determined what the temperature was of the three heater cores, average out the noise levels and then provide a process control signal to the DC power supplies. Since this furnace system uses type B thermocouples (Pt-30%Rh vs. Pt-6%Rh) the problem with the signal to noise ratio is important. Type B thermocouples have one of the lowest millivolt output signals of all the thermocouples (only 11.257 mv at 1600°C) and therefore EMI and RFI noise superimposing upon the thermocouple signal becomes a major impact on the system accuracy. A 0.5 mv RMS ripple on the signal will induce approximately a ±45° error. In addition to tne software the control algorithm did not incorporate a PID (proportional-integral-derivative) function which is required for good temperature control. The outcome was a furnace temperature which was subject to drifts of 30° centigrade and inaccuracies of 30 to 40 degrees.

To correct this problem the relatively simple addition of off-the-shelf temperature controllers was implemented. Three Eurotherm model 818S digital temperature controllers along with three 461 SCR power controllers were installed . The power controllers were set to provide phase angle firing control of the current supplied to the heater cores. While this provides one of the most accurate methods for controlling temperature its main disadvantage is the increase in EMI noise generated by the quick voltage spikes during firing. This does not present a problem to the temperature controllers themselves since they are specifically designed to manage such problems. However the data acquisition board in the computer does not contain the components to filter out such noise and the result is a noisy signal recorded on the hard drive.

Necessary changes to the software were also performed. This involved rewriting the C code for both the control file edit and RMRQ control programs. The routines associated with temperature control actions were simply deleted. Additionally in the original design of the RMRQ the capability of a directional solidification furnace (which failed to work properly) was included. Since the mechanism for directional solidification was removed earlier the C code associated with directional solidification was also deleted.

Improvements to other aspects of the system included the thermocouple signal lines. Much of the existing wiring had to be replaced with shielded cabling resulting in an improved signal to noise ratio. Several intermittent connections which had plagued the operation in the past were tracked down and repaired. The AT computer itself had an intermittent problem with its power supply. Attempts to have it repaired by an on site contractor failed. Finally several cold solder joints on the power supply board were found and repaired. In addition to repairing the power supply a high density floppy drive was added to the system. This allowed easy downloading of the experiment data for later processing.

The next problem involved the furnace heater cores. In the existing design the cores were comprised of 0.020" diameter Pt/30%Rh wire wrapped evenly over the length of the alumina core. This size of wire was too small in regard to the watt densities per surface area units needed to reached operating temperatures of 1600° C or higher. As result premature burnouts occurred. Also the wire wrap spacing around the alumina cores being evenly spaced failed to produce any isothermal zone condition within the heater cores. During the fabrication of the new heater cores wind spacing was held between 0.050" and 0.075" for a distance of 1.00" at each end of the core and is then exponentially increased to the center of the alumina tube. This produces a simulated guard coil arrangement that helps to provide a more isothermal zone through the core. In Figures 1 and 2 a comparison of thermal gradients between the old and new core designs indicates an improvement in the isothermal zone of the Rapid Melt Core. Figure 3 is a cross section of the furnace canister indicating the relative position of the heater cores.

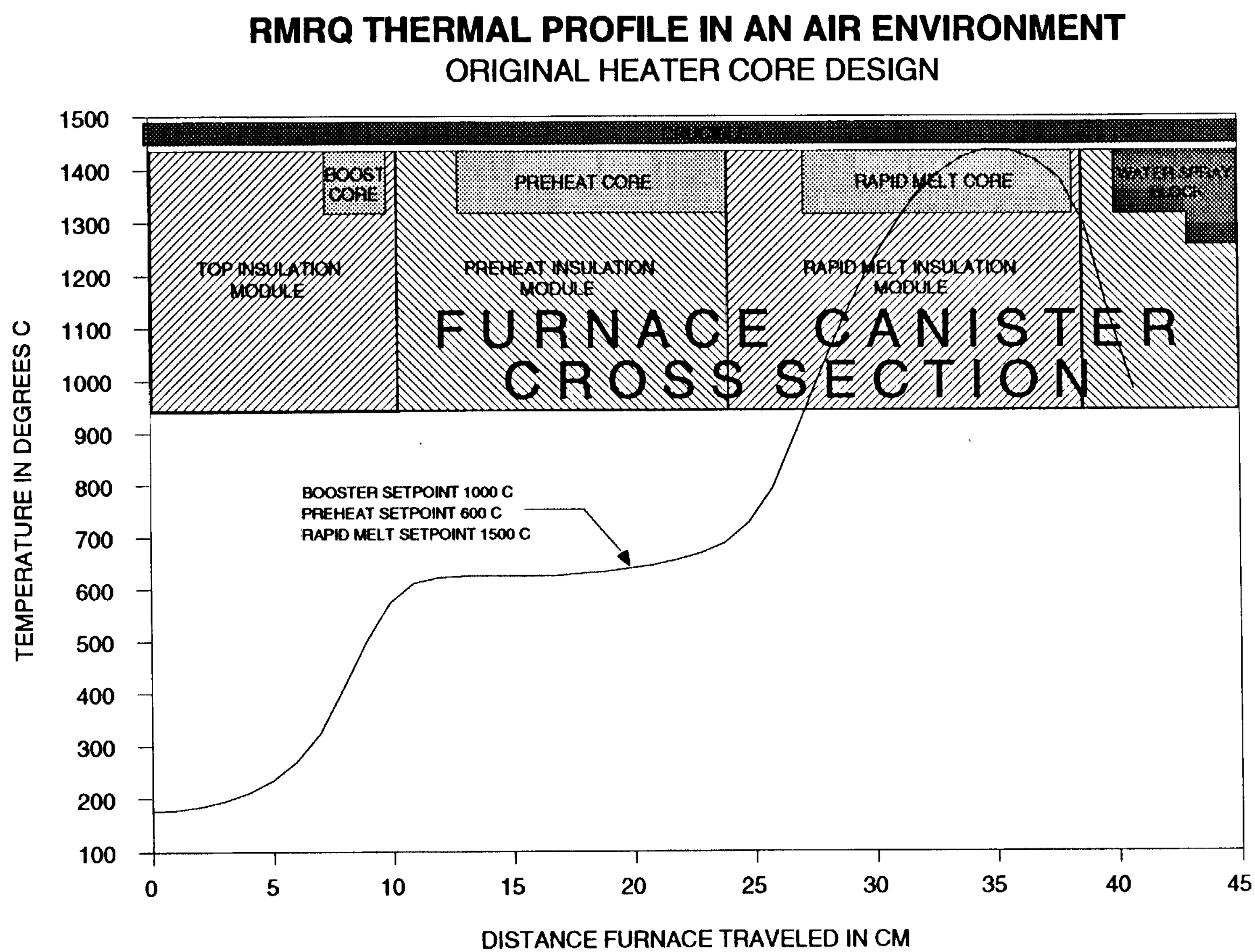


Figure 1: Thermal profile using old heater core design.
Note how there is no isothermal zone in the Rapid Melt Core.

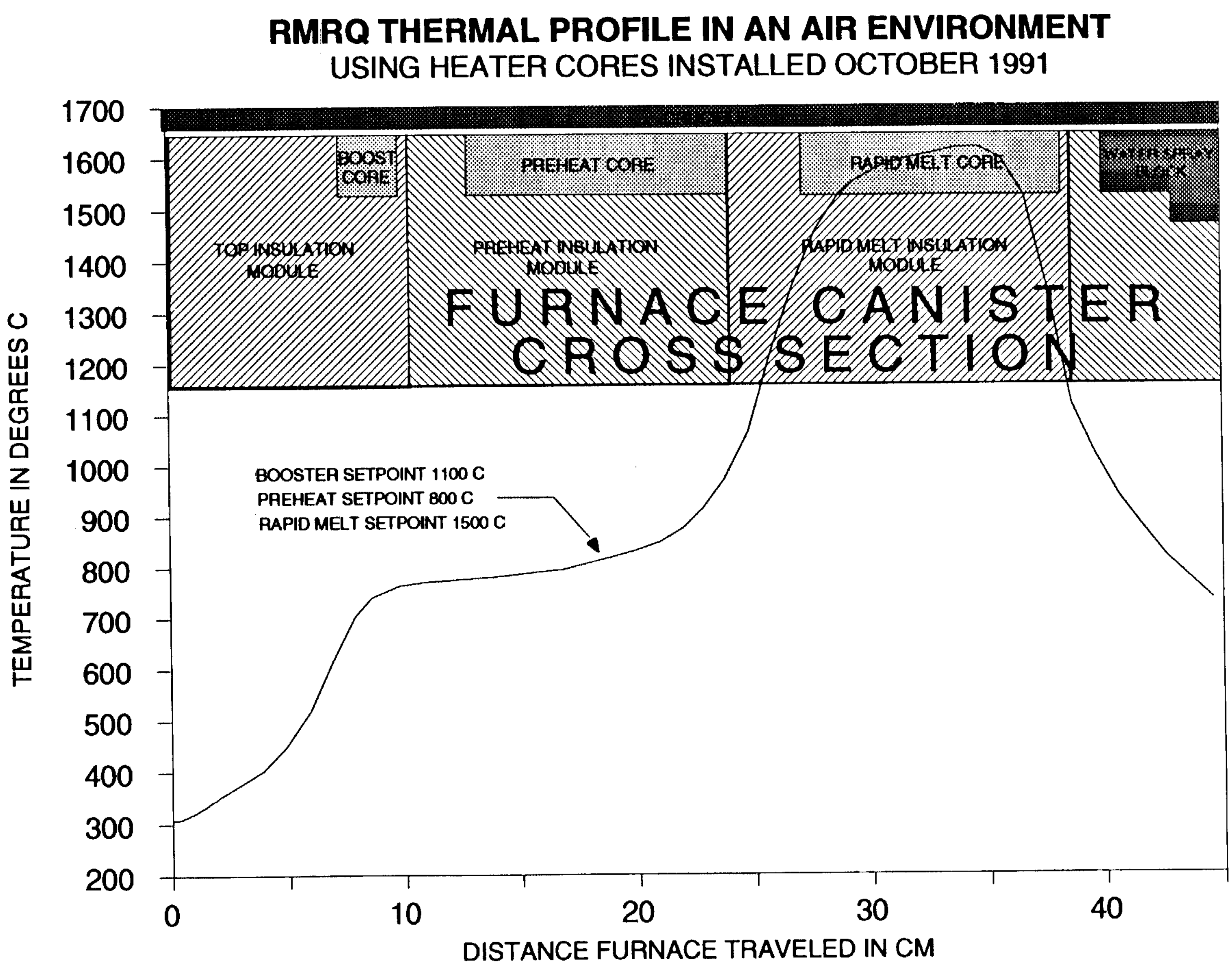


Figure 2: Thermal profile of new heater core design.
Note better isothermal zone within the Rapid Melt Core.

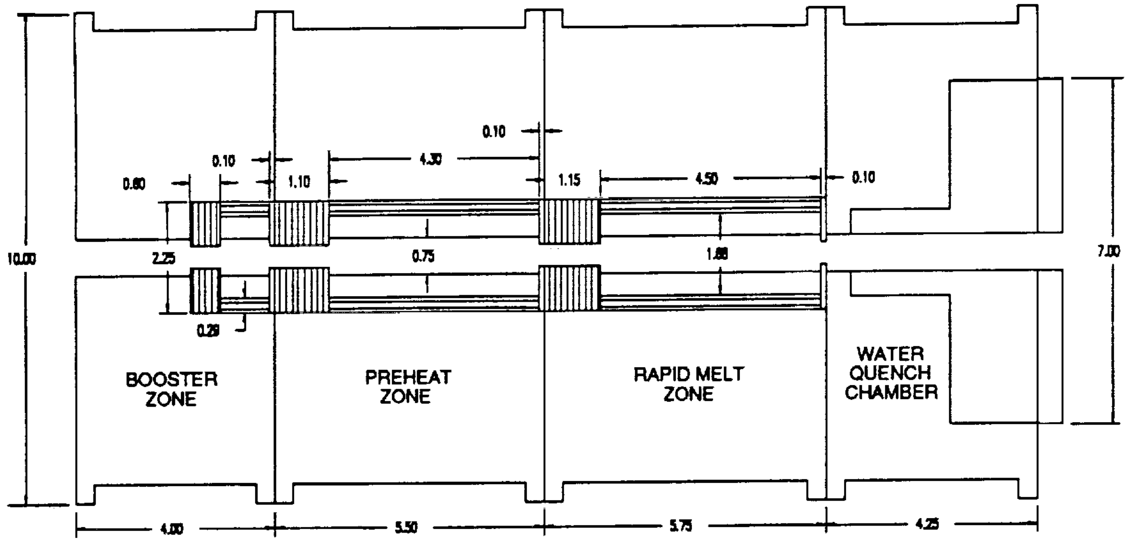


Figure 3: Cross section of the RMRQ furnace canister.

In the new design 0.032" diameter Pt/30%Rh wire was used which met the watt density requirement. Also the maximum operating temperature of the Rapid Melt Core can now be rated to 1700° C. Premature burnout is now no longer a problem especially when considering that the heat up rate is now ramped at a rate of 1 degree per 3 seconds by the Eurotherm controller. Heating rates much faster than this when starting out at ambient temperature will increase the failure rate of the cores.

Each heater core had two type B thermocouples located at the center of each core. Failures were common having been fabricated from too fine a gauge wire (0.008" diameter) . Often a failure would occur simply due to the thermal shock of rapid translation during a sample processing run. The new cores were fabricated with 0.028" diameter thermocouple wire which provides the necessary strength to survive. One thermocouple signal is routed to the Eurotherm temperature and the other provides a signal to the computer for data acquisition of the core temperatures. This signal however is subject to considerable fluctuation on the computer display due to the lack of signal conditioning within the A/D board and software.

B. Summary of flight sample processing

After having completed the modifications and testing to the RMRQ on October 4th, 1991 the system was loaded for transport to Ellington Air Field, Texas. Arriving Monday, October 7th at Ellington the system was checked out on the ground and subsequently uploaded into the KC-135. Since this system had flown once before there was no need for a technical readiness review (TRR), however there was still an informal review by JSC Safety.

On the following day preparations were completed to the RMRQ for a flight run. Upon powering up the system it was determined that the current draw of the three heater cores was exceeding the power ratings of the aircraft's 400 Hz to 60 Hz power converter. This converter is limited to 20 amps of 120 VAC at 60 Hz. In order for the RMRQ furnace to heat up rapidly enough to be ready for flight the current draw was exceeding the 20 amp limit. As result there were no samples processed during the initial flight. Subsequent to the flight a larger more powerful converter was uploaded onto the aircraft. This unit owned by the Life Sciences section of JSC easily provided all the necessary power to heat the furnace at the required rate.

During the course of two flights on Wednesday two aluminum alloys reinforced with SiC particulates were processed. They were approximately 2 cm in length and 0.4 cm in diameter. Their melting points were defined as somewhere between 660° and 670° C. During the morning flight the first sample (file ID: RMRQF3) was processed during the second parabola of the flight with no problems encountered during the run. Ultra high purity Helium gas was used in all three runs to purge the sample crucible at approximately 2 to 3 liters per minute while it was being heated.

There was one problem that plagued the operation during the entire week. Since the rapid melt core is located below the preheat core there is a significant heat flux from the rapid melt core. Normally this would have caused the preheat zone to exceed the temperature setpoint however by increasing the argon purge gas flow rate through the crucible the sample temperature was kept below the melting point. In all three flight runs the power to the preheat was turned off once reaching temperature.

Referring to Appendix A the sample temperature, furnace position and vertical gravity level is plotted. Data point resolution is 1 reading per second. (It should be pointed out that only the time period of the actual sample processing is provided in all of the appendixes. The warm up and soak periods and not included however are available elsewhere.) Also just prior to the start of the rapid melt phase of the run the power to the three heater cores was turned off. Two reasons for this were (1) to eliminate any magnetic field around the sample while it was being processed and (2) by powering down the Eurotherm SCR power controllers the EMI generated by the phase angle firing was eliminated. This action then provided a cleaner thermocouple signal to be recorded by the computer. This action of powering down the heaters was performed on all three runs. Only one sample per flight could be processed due to the time requirements for cooling down the furnace, reloading a new sample and then reheating the furnace back to the require temperatures.

Subsequent to landing the sample was removed from the crucible and examined. It had the appearance of never melting, therefore it was decided to change three of the experiment parameters for the next run, namely the booster and rapid melt temperatures and the dwell time in the RMZ. It was later determined in Huntsville that in fact the sample had melted. Increasing these three parameters on the next flight provided a processed sample which clearly indicated it had melted. In addition there was a heavy oxidation layer with large 1 to 2 mm pores and pits present over the entire surface of the sample. Refer to Appendix B for the plot of the data during the run. It appears that during the quench phase of the run the sample thermocouple failed, probably due to thermal shock. After reviewing the data acquisition print out of this run the failure was confirmed to have happened.

During the next day the third and final sample (RMRQF5) was processed using the same sample parameters as used in run RMRQF4. Referring to Appendix C indicates no evidence of any problems during the run however this sample shows the same level of oxidation, pores and pits as RMRQF4. Solidification of the sample is indicated just prior to exiting the low g period.

C. Summary of ground sample processing

In February of 1992 the ground based samples were finally prepared after a long delay. Samples were cut from the same stock material used in the flight samples however they were from a different hot press run. They were then machined to the same dimensions as the flight samples and subsequently cleaned in pure isopropyl alcohol. Ground based samples were processed using the same sets of experiment parameters used during the processing of the flight samples.

The results of the first ground based run RMRQG8 were unlike any previous -- either flight or ground based. Referring to Figure 9 indicates that the sample expanded or foamed approximately 3 times the original length of 2 cm. Even though this sample was processed at the lower RMZ temperature of 1400° C, sectioning revealed an extremely porous condition similar to flight samples RMRQF4 and F5 however much worse. At present there is no clear explanation as to what caused the "foaming" action. Possibilities include:

(1) The presence of water trapped within the sample at the time of hot pressing the raw powders.

(2) The possibility that the sample superheated and boiled.

(3) Other impurities present with the stock materials.

(4) Due to the slow reaction time of the present data acquisition system it is possible that the sample reaches a higher temperature during the rapid melt phase than is indicated by the data -- how much higher is unknown. Appendix D provides a plot of the temperature profile of the sample during the processing run and is comparable to flight run RMRQF3.

Run RMRQG9, using the same parameters as in RMRQG8, produced the same results. In referring to the plots of the these two runs there is a predominant endotherm reaction as these two samples are being melted in the rapid melt zone. This endotherm is not evident in any of the three flight runs.

In a separate test using a Lindberg oven a small piece of the remaining stock material was heated slowly (approximately 1° C/sec) to a temperature of 820° C in an air atmosphere. After cooling the sample and polishing one side it was determined not to have any of the typical foamed morphology found in RMRQF4 and F5 and RMRQG8 and G9.

In an effort to understand what is causing the sample to foam, tests were performed using thermal gravimetric analysis (TGA). Since one possibility for the foaming includes the off gassing of either trapped water or impurities during the rapid melt phase, by the processing of a small sample in the TGA any off gassing would show up as a change in the sample's mass at a particular temperature. Identifying at what temperature the off gassing occurs will help to determine what contaminants may be present within the sample.

On March 18th, two identical TGA runs were perform on the ground sample material. The process parameters simulated to some degree the RMRQ run parameters used on RMRQG8 and G9. This included a heat up rate of 20°C/minute to 520°C where the temperature was held constant for 20 minutes. The ramp was then increased to 200° C/minute to 820°C, held for one minute then cooled to ambient. Both runs were performed in a nitrogen atmosphere and not helium as in the RMRQ runs. The results of both runs did not indicate any off gassing of the material. Instead there was a mass increase of 0.093 mg and 0.256 mg. It is believed that this increase in mass is due to the reaction of the nitrogen gas with the silicon carbide causing the formation of silicon nitride. Referring to Figures 4 and 5, both TGA plots indicate a mass increase starting around 350° C and continuing at a

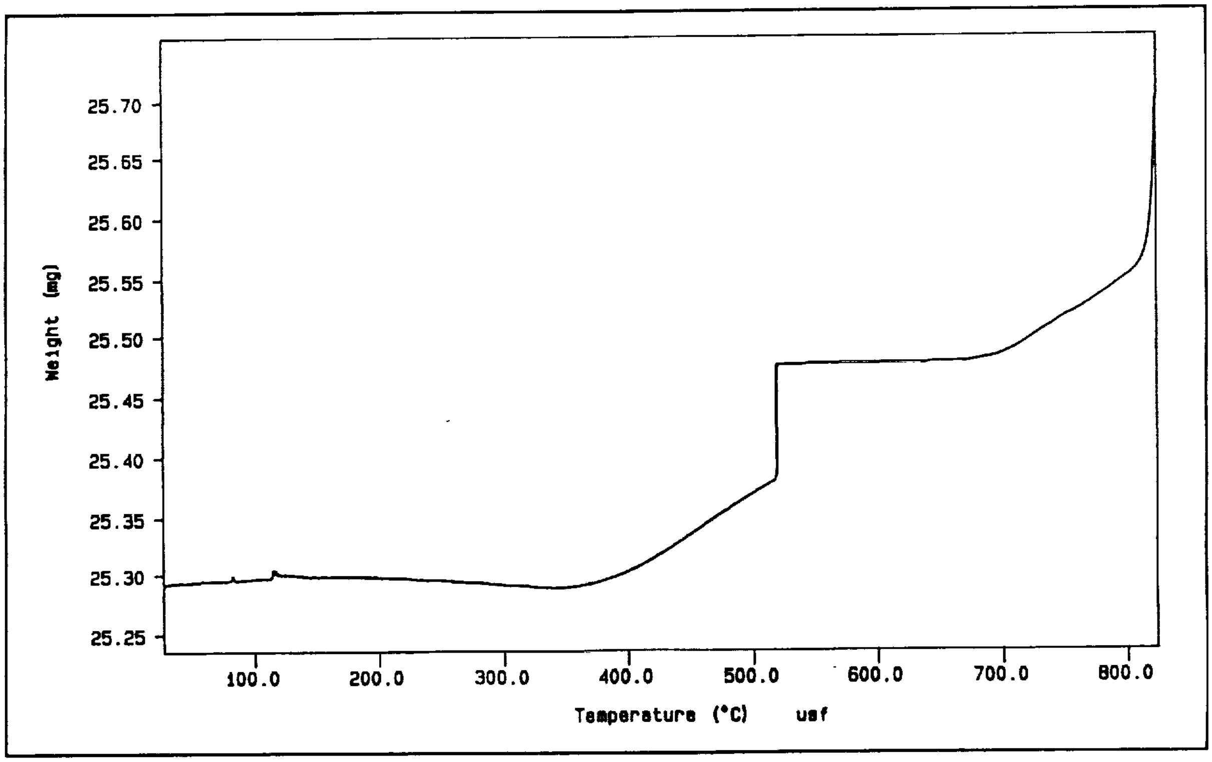


Figure 4: TGA plot run number one of Al+SiC material simulating RMRQ ground runs RMRQG8 and G9.

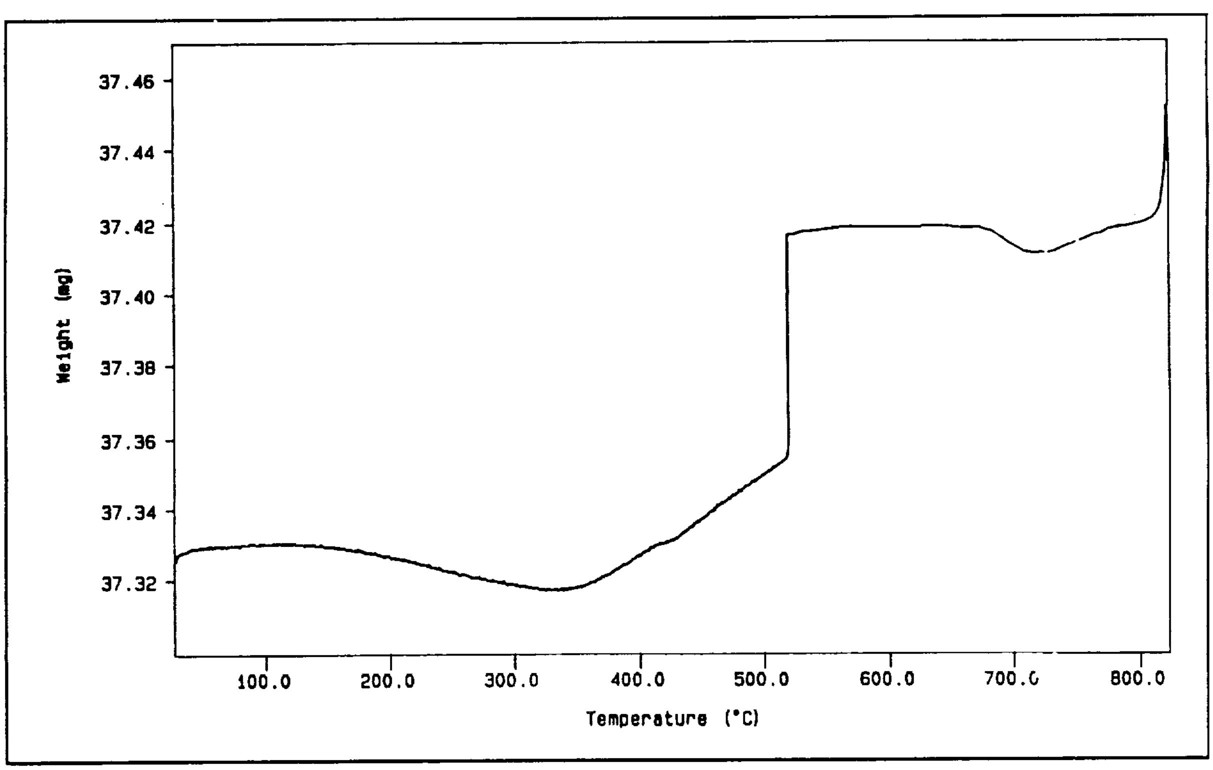


Figure 5: TGA plot run number two, repeat of the first run.

constant rate until reaching the rapid melt phase of 820° C where the rate greatly increases. Since these two samples were processed in nitrogen instead of argon it is difficult to determine conclusively that there was no off gassing occurring during the runs.

Subsequent to the TGA runs both samples were examined under a stereo microscope and were found to have foamed. Relatively large pores were present within each of the samples. The amount of expansion seems to be inconsistent in the three axes with preferred direction of growth in the longitudinal or long axis. This result is inconsistent with the sample that was heated in the Lindberg oven. As mentioned earlier that sample showed no signs of foaming.

In a last ditch effort to provide a valid ground based processed sample it was decided to remove the only remaining piece of unprocessed flight sample material from its mounting compound. The sample was then cleaned ultrasonically in acetone and isopropyl alcohol and then dried at 50° C overnight. In order to guarantee a good flow rate of purge gas through the crucible a 1 mm hole was diamond drilled through the crucible just above the sample location. To increase the odds of success the thermocouple and crucible were baked out at 1200° C for several hours to remove any possible contamination.

On April 3rd, 1992 the sample was processed in the RMRQ with limited success. Since it is believed that the foaming problem is due to overheating the sample the dwell time in the rapid melt phase was reduced to 9 seconds. According to the previous thermal data it was determined that this would keep the sample from exceeding 800° C. What was not thought of at the time was the fact that this sample was only one half the mass of the previous flight and ground samples and as such would heat up quicker. After reviewing the thermal data the sample reached 821° C. After sectioning and polishing it was determined to have foamed up although not as severely as the previous two ground runs. There was one small area of the sample free of voids of which photomicrographs were taken. Appendix F provides the thermal plot and data file print out of ground run RMRQG10.

III. Metallurgy Results.

To provide a record of their exterior morphology the samples were first photographed along side a scale. Figures 6, 7, and 8 are of the three flight samples and figures 9, 10, and 11 are of the ground processed samples. They were then sliced longitudinally using a 0.030" thick diamond blade. One half of the samples were sent to Dr. Morel unmounted. The other halves were mounted and polished to a 1 micron finish in preparation for photomicrography.

Figures 11 through 20 provide various views of the flight and ground sample microstructures. Two levels of magnification were used -- 200X and 400X at the photograph. This was determined by taking calibration photographs. Location of each photograph is identified by the graphic representation of the sample cross section beside each figure. All photographs were taken using polarized light to increase contrast.

Photographs of Flight Sample Exterior Morphology

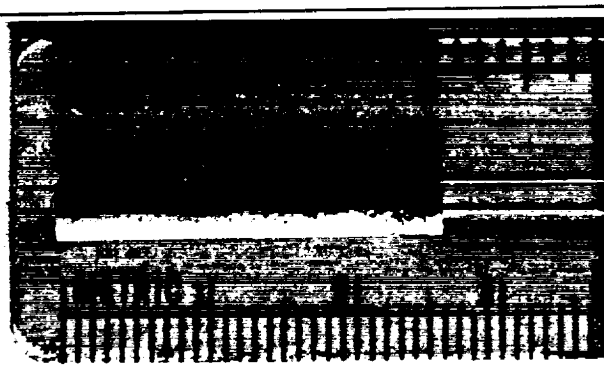


Figure 6

RMRO flight sample ID RMROF3
Processed during morning flight on 10/09/91
Rapid Melt Zone Temp = 1400°C
Preheat Zone Temp = 400°C
Booster Zone Temp = 800°C
10 second dwell time in RMZ prior to 10 second.

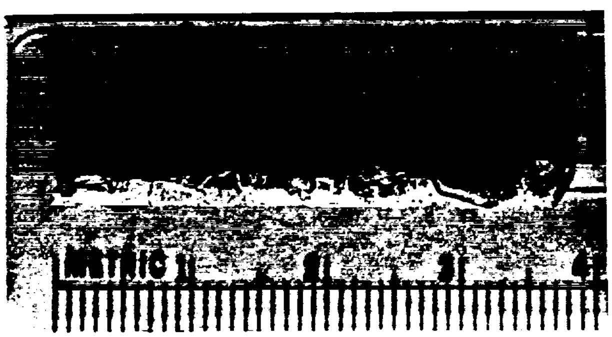


Figure 7

RMRO flight sample ID RMROF4
Processed during afternoon flight on 10/09/91.
Rapid Melt Zone Temp = 1500°C
Preheat Zone Temp = 500°C
Booster Zone Temp = 800°C
15 second dwell time in RMZ prior to 10 second quench period.

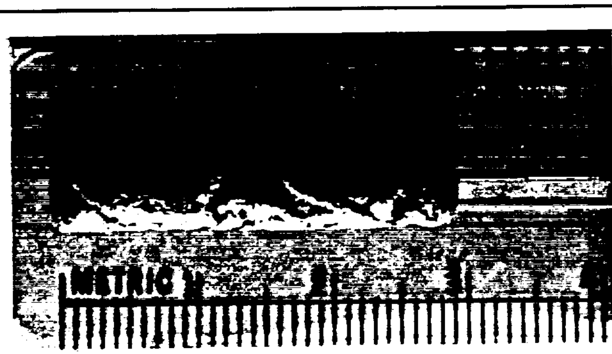


Figure 8

RMRO flight sample ID RMROF5
Processed during morning flight on 10/10/91.
Rapid Melt Zone Temp = 1500°C
Preheat Zone Temp = 500°C
Booster Zone Temp = 800°C
15 second dwell time in RMZ prior to 10 second quench period.

Photographs of Ground Sample Exterior Morphology

RMRO ground sample ID RMROG8

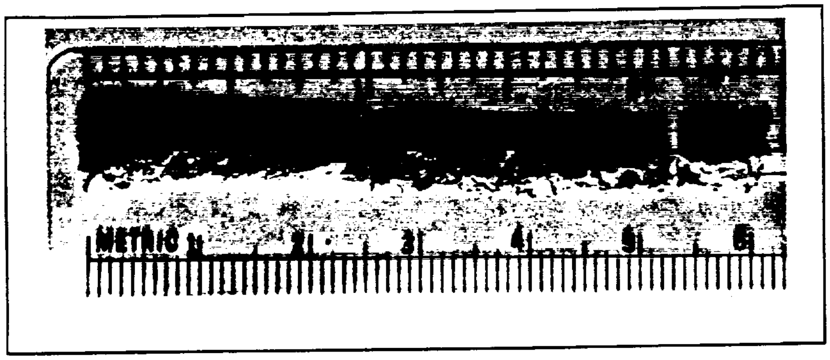


Figure 9
Processed 02/26/92.
Rapid Melt Zone Temp = 1400°C
Preheat Zone Temp = 400°C
Booster Zone Temp = 800°C
10 second dwell time in RMZ prior to 10 second quench period.

RMRO ground sample ID RMROG9

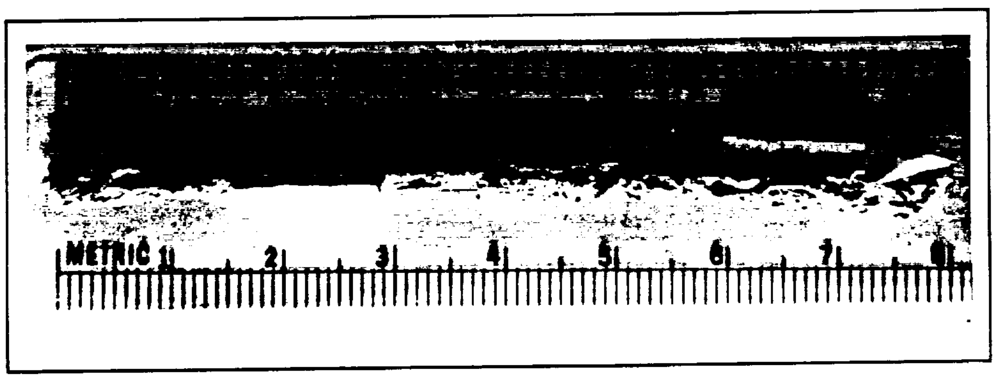


Figure 10
Processed 03/11/92
Rapid Melt Zone Temp = 1400°C
Preheat Zone Temp = 400°C
Booster Zone Temp = 800°C
10 second dwell time in RMZ prior to 10 second quench.

RMRO ground sample ID RMROG10

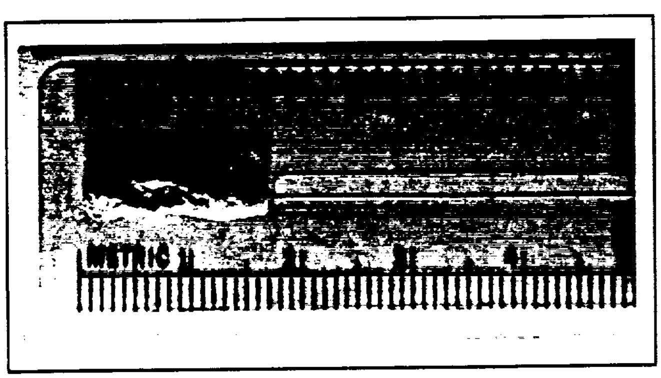


Figure 11
Processed 04/03/92.
Rapid Melt Zone Temp = 1400°C
Preheat Zone Temp = 400°C
Booster Zone Temp = 800°C
9 second dwell time in RMZ prior to 10 second quench period.

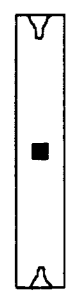
Photomicrographs of Flight and Ground Samples

Figure 12

Flight Sample RMRQF3
200X magnification

Figure 13

Flight Sample RMRQF3
200X magnification



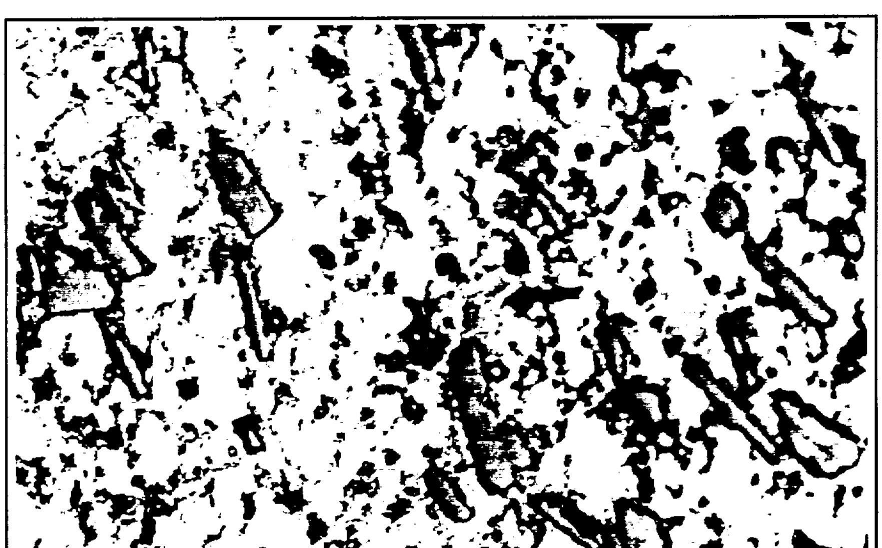


Figure 14

Flight Sample RMRQF3
200X magnification

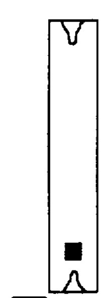


Figure 15

Flight Sample RMRQF3
400X magnification

Figure 16

Flight Sample RMRQF3
400X magnification

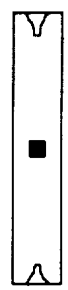
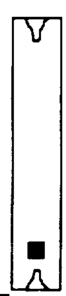


Figure 17

Flight Sample RMRQF3
400X magnification



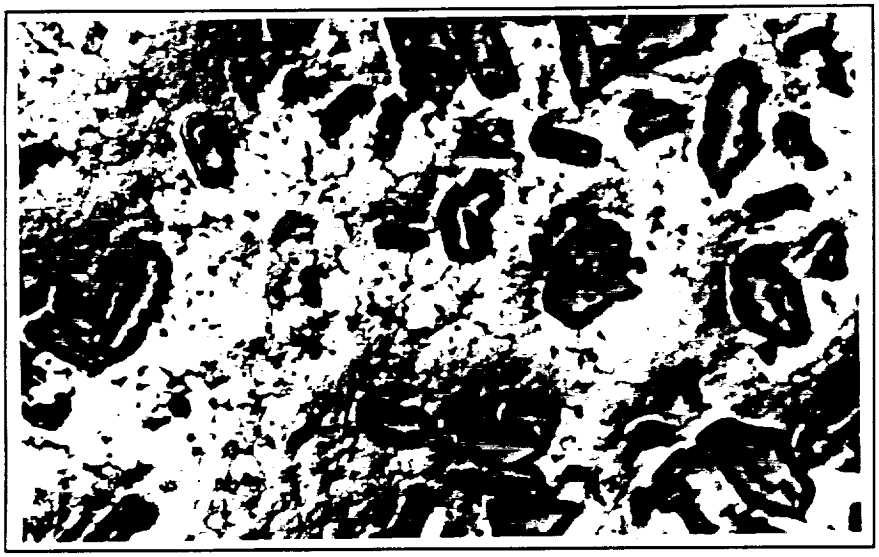


Figure 18

Ground Sample RMRQG10
200X magnification

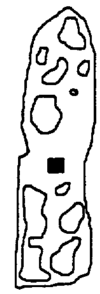


Figure 19

Ground Sample RMRQG10
400X magnification

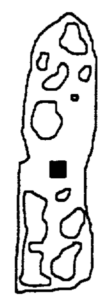
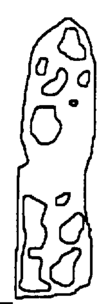


Figure 20

Ground Sample RMRQG10
10X overall view showing voids.



Results of Observations

In view of the lack and uncertainty of the data the following offers only generalized statements regarding the observed microstructure of flight sample RMRQF3 and ground sample RMRQG10.

1. In the flight sample there is a definite orientation of the silicon carbide particles with respect to the apparent direction of solidification. The long axis of the particles are parallel to the grain growth. The angle of the solidification front varies from 80 to 30 degrees from the longitudinal axis. While there are areas where the particle orientation is random, overall there is a preferential alignment of the particles especially when they are rectangular in shape. In the ground sample there was no evidence of any preferred orientation of the silicon carbide with respect to direction of solidification. This may have been due to the effect the voids had on solidification.

2. Particle distribution is not even through out the flight sample when compared to the orginal unprocessed stock material. Beginning at the top of the sample the particle density increases steadly towards the bottom. In the ground sample there are random areas were the particle density is also slightly higher. However again this may be due to the effect the void areas had on the sample during solidification.

3. Formation of the voids or pores started at the grain boundries as submicron sized bubbles and then coalesced to form up to 2 mm diameter sized pores within the sample. As to what caused the formation of the bubbles is unknown.

4. The first two ground samples (RMRQG8 and G9) foamed approximately twice as much as the flight samples.

5. There is evidence that the flight sample did not melt 100% through out the total length. The bottom edges, unlike the top, are not rounded over. If it had melted then surface tension should have pulled in sharp 90° corners.

V. Conclusions

Through the course of this project there were numerous hardware problems which had to be overcome prior to the beginning of any science research. In fact the majority of the time was spent repairing and modifying the hardware so that samples could simply be processed in the RMRQ furnace. Additionally during the course of processing samples several problems developed which ultimately resulted in little science being collected. The primary problem which led to this situation was the "foaming up" of the samples. It is believed to have been caused by simply overheating the samples during the rapid melt phase of the run. The microphotographs of flight sample RMRQF3 clearly indicated that at most of the grain boundaries micron to submicron size bubbles began to develop. Had the sample been heated for 15 seconds as were RMRQF4 and F5 it too probably would have developed the same large porous morphology.

One additional unknown which could be a factor in explaining why RMRQF3 did not foam as much as the other samples is whether or not it was actually in the rapid melt zone during the rapid melt phase of the run. In reviewing the vertical acceleration data there is a seven second period where the sample was in a slight negative g period. This could have resulted in the sample floating up and out of the rapid melt zone and back into the preheat zone, therefore the sample would never have been heated to the temperatures indicated by the sample thermocouple. While it is clear that the sample did melt and if in fact it did float up from the rapid melt zone, then there is no way to determine exactly what temperature the sample reached. Since every other sample did foam, this scenario must be considered as a possibility.

Having only 7 samples to work with for both the flight and ground sample processing left no margin for error and as such actions to investigate cause, effect and the proper corrections could not be implemented at this time.

Since every sample having been processed in the RMRQ in either the ground or flight mode foamed, very little can be said as to the effects that gravity has on the solidification of this particular alloy system. If we limit the results to only flight sample RMRQF3 and ground sample RMRQG10 then some comparisons can be presented. It does has to be assumed however that the micron size pores in the flight sample and the large pores in the ground sample did not significantly influence the results under consideration.

In reviewing the events of this project there is one change to the hardware that is simple in nature and would make the controlling of the experiments considerably easier. In the present version of software used to control the RMRQ system the dwell time of the sample within the rapid melt zone is controlled simply by a time factor of 1 to 15 seconds. There is no present way to accurately control how hot the sample actually gets. By modifying the software to control on the sample temperature and not simply on a time interval would allow future samples to be melted to a certain temperature. This would prevent over heating of the sample which could have caused the primary loss of data in this study.

IV. Video Convective Flow Analyzer Activities

A separate project from the RMRQ study involved the recently developed KC-135 Video Convective Flow Analyzer. The following documents that activities performed on this system.

In early summer of 1991 efforts began to modify the KC-135 Video Convective Flow Analyzer. This involved upgrading the VCFA experiment cell to include the capability of directional translation. This would as a result convert the stationary Bridgman furnace into an actual directional solidification furnace with the capability of video monitoring the melt interface. The primary thrust for this modification was for studying macro cellular convective flow in a thermal modeling system. Requirements were received from UAB in March detailing desired translation rates, video magnification and thermal gradients. The following is a listing of those requirements for such an experiment.

1. Stable translation of speeds down to 0.1 micron/second.

2. A maximum operating temperature of 100° C for the hot zone and -40° C in the cold zone.

3. Temperature stability of 0.1° C in both the hot and cold zone and uniform lateral temperature gradient across the sample.

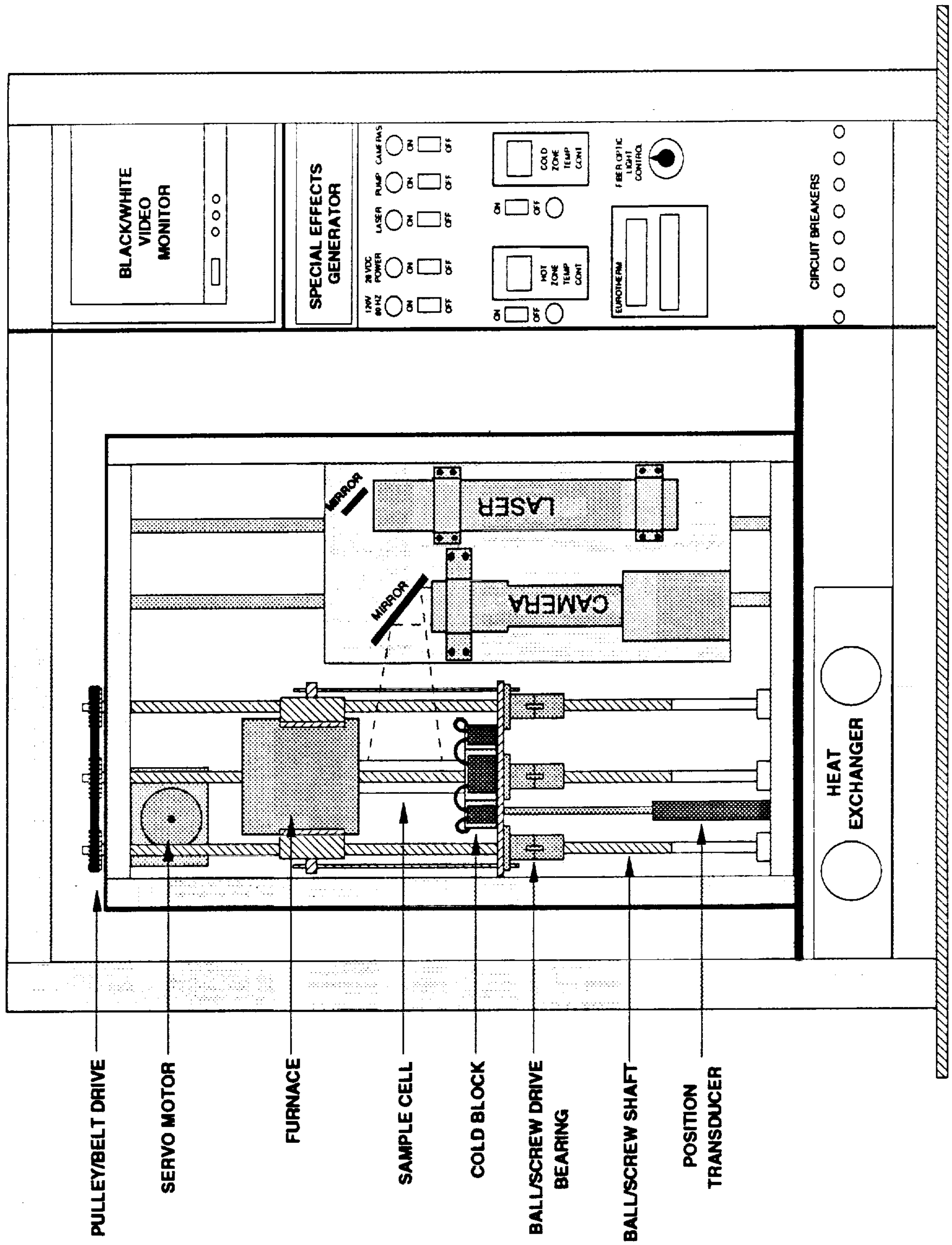


Figure 21: KC-135 Video Convective Flow Analyzer indicating new translation drive system

4. High resolution video capable of resolving 1.0 micron.

5. Video magnification of 200 to 400x at the video monitor.

6. Ability to position the camera in two directions as needed for focusing.

Due to time constants with other contracts work did not actually begin on the CFA until September. At that time the three precision ball/screw drives were order from THK Co. These were stock items and as result required some modification upon arrival. Work then turned to installation of the three drives into the existing CFA experiment cell. A precision pulley and belt system was developed to provide the transfer of power from the servo motor to the ball/screw shafts. The lead on the shafts was 0.5 mm per revolution. In order to provide a smooth 0.1 micron/second translation rate a 60 to 1 gear box reducer was added into the transmission scheme. This will actually provide a bottom end translation rate of 0.08 microns/second - if ever needed. Figure 21 provides some details of the drive system.

The next major task involved the upgrading of the cold block cooling system to provide temperatures down to -40°C. Presently the system uses six Melcor thermoelectric modules each with a maximum of 35 watts pumping capability each. In the present configuration temperatures as low as -15°C could be reached. By cascading two modules it is estimated that the pumping capacity will increased to approximately 350 watts total. If this in itself fails to provide the -40°C cold block temperature then there is the possibility of flowing liquid nitrogen vapor over the heat exchanger used in the closed loop cooling system for the hot side of the thermoelectrics. This would lower the temperature of the coolant well below that of ambient and provide a sufficient temperature differential to the hot face.

In controlling both the furnace and cold block temperatures two Eurotherm model 808 temperature controllers are employed. Using RTDs to sense temperature a 0.1° C resolution and stability is possible. In addition, the large mass of the hot block and cold block provides improved thermal stability by acting as a thermal damper.

Work on this project was stopped in November of 1991 due to ending of the contract. Plans are now underway to secure additional funding to complete this task in time for the first KC-135 flight sometime during the summer of 1992. Tasks remaining to complete include final assembly of the translation system, fabrication of the hot and cold block to fit the sample configuration, installation of a position transducer system, electronics integration, and minor software modifications.

APPENDIX A

Data file of flight sample RMRQF3 processed on
October 9th, 1991 on board the
KC-135

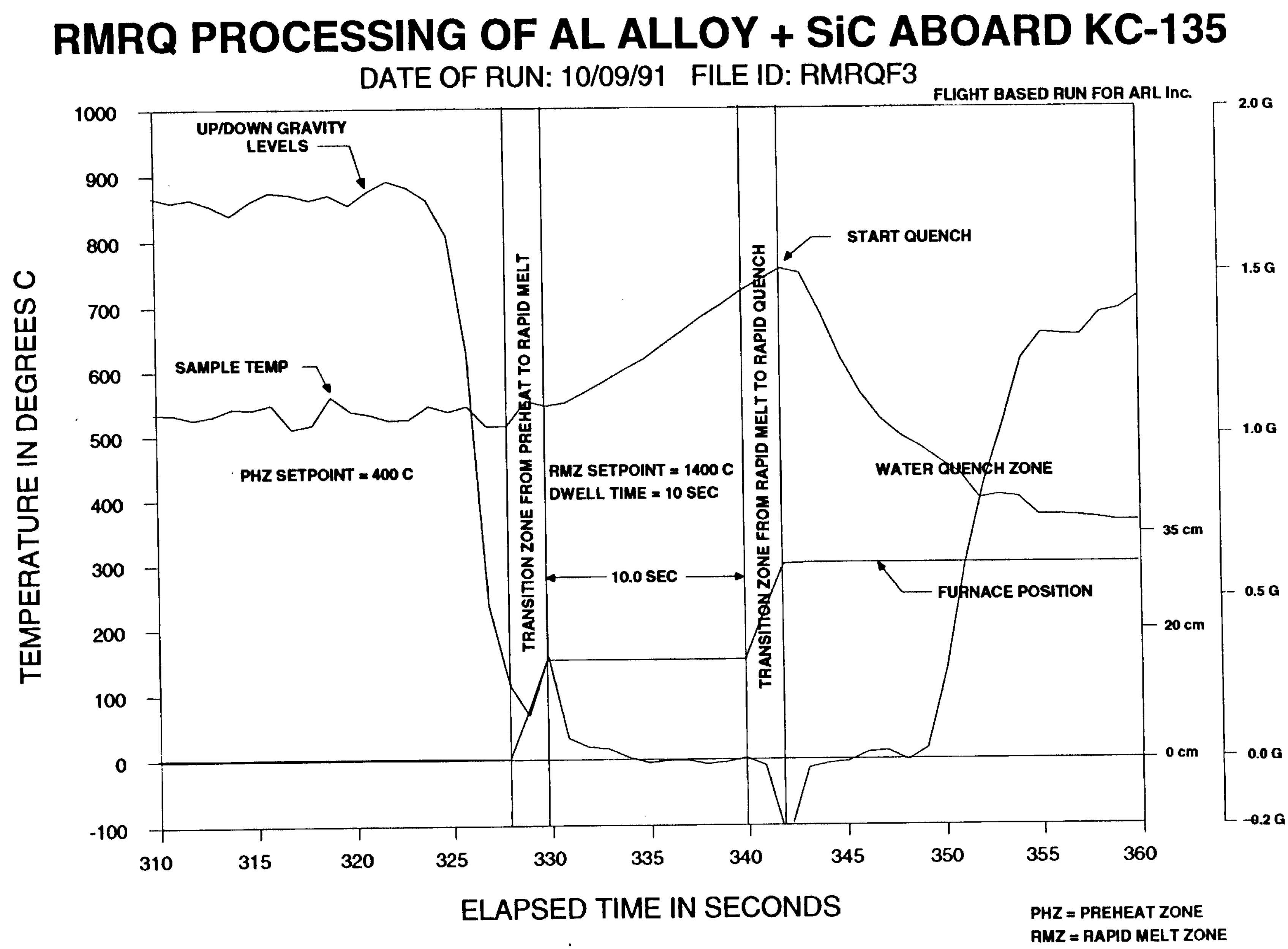


Figure 4: Plot of flight sample RMRQF3 results.

RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - FLIGHT BASED RUN

File Name: RMRQF3.WR1
Data of Sample Processing: October 9th, 1991
Rapid Melt Zone Setpoint = 1400 C
Preheat Zone Setpoint = 400 C (NOTE: PHZ power was turned off due to heat flux from RMZ)
Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel
Sample was 3.88 mm in diameter and 20 mm long.

NOTES: First flight sample processed since new heater cores and temperature control system installed.
DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp, RMZ is rapid melt temp.
Translation distances were 15 cm for each stage with 10 second dwell time at RM phase.
Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
300	0	0	3	526		845	0.009	0.023	0.998	536	
301	0	0	3	526		845	0.009	0.023	0.998	536	
302	0	0	3	526		828	0.003	0.016	1.030	538	
303	0	0	3	526	1472	847	-0.010	-0.004	1.080	526	
304	0	0	3	528	1489	840	0.013	0.007	1.092	524	
305	0	0	3	530	1439		0.008	0.011	1.298	554	
306	0	0	3	523		837	0.008	0.028	1.450	536	
307	0	0	3	534		827	0.007	0.017	1.513	541	
308	0	0	3	525	1477	852	0.005	0.020	1.640	522	
309	0	0	3	530	1485	832	0.001	0.009	1.680	519	
310	0	0	3	526			0.008	0.028	1.738	559	
311	0	0	3	521		858	0.009	0.019	1.732	533	
312	0	0	3	539	1482	824	0.016	0.043	1.718	533	
313	0	0	3	532		831	0.001	0.050	1.726	525	
314	0	0	3	520		858	0.007	0.043	1.706	530	
315	0	0	3	528			0.034	0.036	1.675	542	
316	0	0	3	528		824	0.020	0.056	1.719	540	
317	0	0	3	528	1488	844	0.001	0.059	1.745	548	
318	0	0	3	528	1479	846	0.011	0.063	1.739	510	
319	0	0	3	537	1480	822	-0.005	0.064	1.724	516	
320	0	0	3	528			0.000	0.097	1.738	559	
321	0	0	3	520		859	0.007	0.093	1.707	537	
322	0	0	3	538		815	0.009	0.114	1.747	532	
323	0	0	3	530		836	0.018	0.117	1.777	522	
324	0	0	3	521	1487	857	0.012	0.128	1.759	524	
325	0	0	3	524		836	-0.001	0.128	1.721	544	
326	0	0	3	529		825	0.020	0.109	1.612	535	
327	0	0	3	537		811	0.008	0.108	1.257	544	
328	0	0	3	534	1472	832	-0.007	0.041	0.474	512	
329	7.408	100	4	521	1486	855	0.008	0.025	0.226	512	**START**
330	14.815	100	4	528		824	0.026	-0.071	0.131	551	**RAPID**
331	15	100	4	522		841	-0.092	0.078	0.315	543	**MELT**
332	15	0	4	532	1460	828	-0.004	0.000	0.062	548	
333	15	0	4	528	1465	835	0.020	-0.001	0.035	563	
334	15	0	4	534	1461	819	0.016	0.009	0.030	581	
335	15	0	4	534		806	0.013	0.000	0.003	599	
336	15	0	4	530		827	0.004	0.014	-0.014	616	
337	15	0	4	539	1460	812	0.005	-0.001	-0.007	638	
338	15	0	4	532	1461	828	0.001	0.006	-0.005	658	

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
339	15	0	4	532	1463	821	0.003	0.005	-0.018	680	
340	15	0	4	532			0.005	-0.001	-0.013	699	
341	15	0	4	523		840	-0.004	0.008	-0.001	720	
342	22.408	100	4	535	1471	828	-0.049	-0.011	-0.022	737	START
343	29.815	100	4	525	1469	850	-0.029	0.014	-0.239	754	QUENCH
344	29.996	0	7	523	1467	847	0.094	-0.038	-0.032	747	
345	29.996	0	7	520		837	-0.002	-0.005	-0.018	688	
346	29.996	0	7	513		862	0.016	-0.003	-0.013	616	
347	29.996	0	7	527	1467	843	0.002	-0.001	0.015	562	
348	29.996	0	7	529	1469	838	-0.005	0.000	0.020	521	
349	29.996	0	7	533	1464	822	0.005	-0.006	-0.009	496	
350	29.996	0	7	529	1479		0.016	-0.013	0.027	478	
351	29.996	0	7	524	1461	835	0.012	-0.010	0.266	457	
352	29.996	0	7		1474	851	0.010	-0.018	0.591	437	
353	29.996	0	7	530	1464	834	0.013	-0.013	0.835	399	
354	29.996	0	7	531	1457	827	0.023	0.004	1.023	404	
355	29.996	0	7	520		836	0.011	0.023	1.227	400	
356	29.996	0	7	520		847	0.013	0.019	1.306	372	
357	29.996	0	7	543	1466	833	0.014	0.005	1.302	373	
358	29.996	0	7	526	1466	845	0.017	0.002	1.299	371	
359	29.996	0	7	529	1464	842	0.015	-0.002	1.368	368	
360	29.996	0	7	529			0.005	-0.002	1.380	364	
361	29.996	0	7	521		847	0.007	0.004	1.420	364	
362	29.996	0	7	536	1461	832	-0.002	0.026	1.444	362	
363	29.996	0	7	527	1462	844	0.026	0.029	1.354	360	
364	29.996	0	7	526	1461	840	0.002	0.030	1.447	361	
365	29.996	0	7	529		821	-0.001	0.051	1.476	358	
366	29.996	0	7	521		843	0.003	0.047	1.520	358	
367	29.996	0	7	526	1458	831	0.006	0.078	1.604	358	
368	29.996	0	7	526	1456	846	0.010	0.057	1.664	357	
369	29.996	0	7	526	1457	842	0.008	0.060	1.709	356	
370	29.996	0	7	525	1450	840	0.011	0.041	1.759	355	
371	29.996	0	7	526	1454	841	0.006	0.053	1.778	355	
372	29.996	0	7	527	1452	830	-0.001	0.058	1.770	356	
373	29.996	0	7	527	1449	841	0.002	0.040	1.804	355	
374	29.996	0	7	526	1451	839	-0.005	0.046	1.789	355	
375	29.996	0	7	528	1440	838	0.018	0.045	1.807	357	
376	29.996	0	7	526	1452	842	0.001	0.033	1.795	357	
377	29.996	0	7	523	1448	836	0.005	0.019	1.784	355	
378	29.996	0	7	524	1448	842	0.006	0.053	1.784	351	
379	29.996	0	7	526	1448	833	0.000	0.024	1.767	346	
380	29.996	0	7	530	1437	821	0.004	0.032	1.766	348	
381	29.996	0	7	532	1436	820	-0.008	0.031	1.756	359	
382	29.996	0	7	527	1439	823	0.009	0.044	1.760	367	
383	29.996	0	7	521	1439	842	0.003	0.034	1.741	361	
384	29.996	0	7	523	1445	846	0.006	0.036	1.749	357	
385	29.996	0	7	521	1442	847	0.004	0.047	1.751	355	
386	29.996	0	7	522	1451	850	0.004	0.064	1.727	352	
387	29.996	0	7	521	1445	838	0.015	0.059	1.739	349	
388	29.996	0	7	524	1443	842	0.000	0.057	1.714	348	

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
389	29.996	0	7	526	1440	835	-0.006	0.074	1.686	351	
390	29.996	0	7	527	1431	828	0.005	0.065	1.713	352	
391	29.996	0	7	527	1435	830	0.009	0.089	1.715	354	
392	29.996	0	7	529	1429	812	-0.004	0.083	1.694	356	
393	29.996	0	7	530	1426	816	0.013	0.089	1.646	357	
394	29.996	0	7	531	1429	815	0.005	0.104	1.706	358	**AC OFF AND**
395	46.36	0	7	530	1386		0.012	-0.001	0.019	350	**FURNACE**
396	46.36	0	7	531	1387		0.019	-0.012	-0.001	358	**RAISED TO**
397	46.36	0	7	524	1399	796	0.013	-0.014	0.021	362	**TOP.**
398	46.36	0	7	523	1396	806	0.003	-0.019	0.296	351	
399	46.36	0	7	523	1399	805	0.007	-0.004	0.634	351	
400	46.36	0	7	526	1389	804	0.007	0.004	0.803	351	
401	46.36	0	7	523	1391	803	0.017	0.005	0.877	351	
402	46.36	0	7	526	1395		0.011	0.015	0.990	351	
403	46.36	0	7	524	1391	800	0.011	0.002	1.089	351	
404	46.36	0	7	524	1395	798	0.013	0.006	1.194	350	
405	46.36	0	7	527	1387	798	0.018	0.009	1.288	352	
406	46.36	0	7	525	1386	800	0.008	0.016	1.334	350	
407	46.36	0	7	525	1397	789	0.016	0.005	1.382	351	
408	46.36	0	7	523	1383	797	-0.003	-0.001	1.424	351	
409	46.36	0	7	527	1393	797	0.000	0.003	1.423	352	
410	46.36	0	7	524	1382	795	0.025	0.022	1.409	350	
411	46.36	0	7	524	1379	798	0.026	0.020	1.362	350	
412	46.36	0	7	523	1387	784	0.030	0.023	1.331	350	
413	46.36	0	7	523	1381	794	0.008	0.037	1.406	350	
414	46.36	0	7	525	1376	793	0.011	0.031	1.483	351	
415	46.36	0	7	522	1374	791	0.003	0.048	1.586	351	
416	46.36	0	7	524	1381	794	0.020	0.032	1.614	350	
417	46.36	0	7	526	1387	782	0.014	0.043	1.699	351	
418	46.36	0	7	525	1374	792	-0.004	0.040	1.759	351	
419	46.36	0	7	526	1380	790	0.006	0.032	1.796	350	
420	46.36	0	7	524	1368	789	-0.001	0.043	1.802	351	
421	46.36	0	7	525	1371	788	0.003	0.048	1.802	351	
422	46.36	0	7	524	1377	779	0.009	0.034	1.826	350	
423	46.36	0	7	523	1370	784	0.010	0.055	1.817	347	
424	46.36	0	7	529	1366	775	0.007	0.053	1.834	350	
425	46.36	0	7	528	1363	777	0.006	0.039	1.843	355	
426	46.36	0	7	523	1367	789	0.014	0.040	1.819	360	
427	46.36	0	7	518	1377	792	0.011	0.038	1.834	355	
428	46.36	0	7	521	1370	797	0.002	0.054	1.799	342	
429	46.36	0	7	526	1368	779	0.009	0.047	1.796	339	
430	46.36	0	7	530	1352	762	0.008	0.041	1.794	347	
431	46.36	0	7	527	1352	764	0.007	0.052	1.791	358	
432	46.36	0	7	522	1360	772	0.005	0.043	1.777	362	
433	46.36	0	7	519	1369	795	0.008	0.062	1.799	350	
434	46.36	0	7	522	1371	793	0.003	0.043	1.778	342	
435	46.36	0	7	523	1359	773	0.007	0.053	1.771	338	
436	46.36	0	7	531	1346	758	-0.007	0.071	1.741	345	
437	46.36	0	7	527	1347	749	-0.003	0.079	1.746	353	
438	46.36	0	7	527	1342	762	0.013	0.067	1.743	357	

APPENDIX B

Data file of flight sample RMRQF4 processed on
October 9th, 1991 on board the
KC-135
Second flight of the day

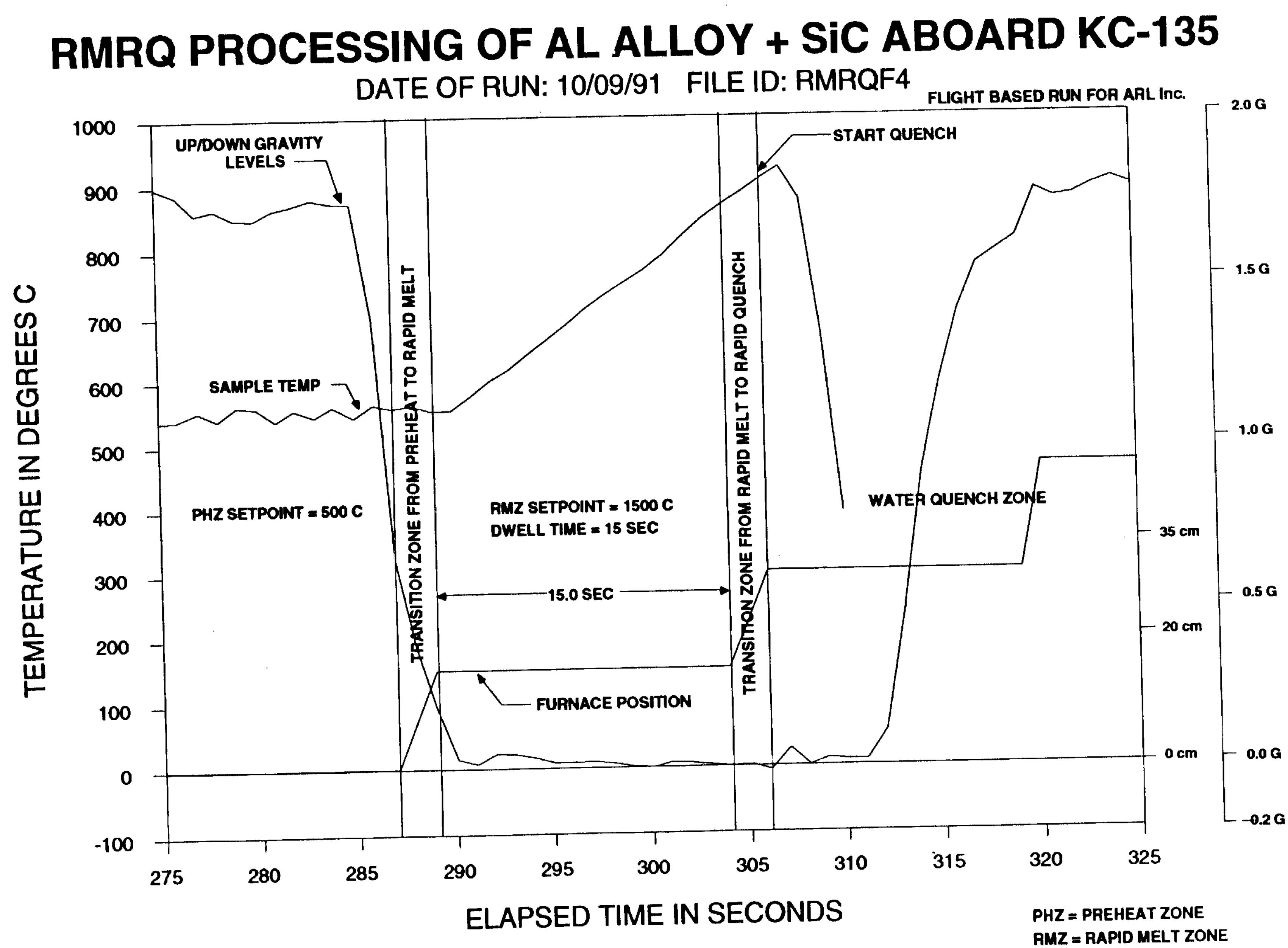


Figure 5: Plot of flight sample RMRQF4 results.

RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - FLIGHT BASED RUN

File Name: RMRQF4.WR1

Data of Sample Processing: October 9th, 1991

Rapid Melt Zone Setpoint = 1500 C

Preheat Zone Setpoint = 500 C (NOTE: PHZ power was turned off due to heat flux from RMZ)

Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel

Sample was 3.88 mm in diameter and 20 mm long.

NOTES: Second sample processsed during the afternoon flight (second flight of the day).

DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp, RMZ is rapid melt temp.

Translation distances were 15 cm for each stage with 15 second dwell time at RM phase.

Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
257	0	0	3	526	1534		0.020	0.033	1.478	535	
258	0	0	3	547	1578		0.016	0.029	1.471	471	
259	0	0	3	548			0.014	0.006	1.351	573	
260	0	0	3	544	1561		0.028	0.024	1.170	453	
261	0	0	3	547	1532		0.022	0.008	1.217	459	
262	0	0	3	549	1535		0.011	0.029	1.283	510	
263	0	0	3	543			0.021	0.028	1.536	369	
264	0	0	3	547			0.027	0.053	1.659	566	
265	0	0	3	534	1588		0.021	0.022	1.743	451	
266	0	0	3	545			0.017	0.027	1.744	465	
267	0	0	3	548			0.006	0.046	1.734	561	
268	0	0	3	510	1537		0.024	0.035	1.735	515	
269	0	0	3	550	1569		0.015	0.045	1.752	580	
270	0	0	3	542			0.032	0.052	1.760	557	
271	0	0	3	546	1531		-0.001	0.053	1.778	369	
272	0	0	3	559	1537		0.019	0.054	1.767	564	
273	0	0	3	545			0.022	0.058	1.732	452	
274	0	0	3	553			0.028	0.067	1.750	464	
275	0	0	3	549			0.021	0.067	1.796	518	
276	0	0	3	677	1569		0.012	0.078	1.773	400	
277	0	0	3	543			0.004	0.083	1.715	519	
278	0	0	3	549			0.011	0.086	1.728	541	
279	0	0	3	521	1548		0.007	0.082	1.701	474	
280	0	0	3	547	1580		0.030	0.094	1.696	559	
281	0	0	3	542			0.025	0.106	1.726	539	
282	0	0	3	544	1539		0.001	0.110	1.739	458	
283	0	0	3	550			0.025	0.149	1.757	546	
284	0	0	3	542			0.019	0.137	1.745	415	
285	0	0	3	541			0.020	0.153	1.743	544	
286	0	0	3	546			0.018	0.116	1.394	563	
287	0	0	3	547	1572		0.006	0.039	0.647	557	
288	7.53	100	4	545	1533		0.004	0.022	0.375	561	START
289	15	100	4	546	1542		-0.071	-0.064	0.182	552	RAPID
290	15	0	4	546	1531		0.046	-0.003	0.030	553	MELT
291	15	0	4	542	1542		0.006	-0.002	0.014	574	
292	15	0	4	543	1579		0.010	-0.007	0.045	598	
293	15	0	4	544	1536		0.017	0.010	0.043	615	
294	15	0	4	544	1575		0.015	0.008	0.032	638	
295	15	0	4	548	1524		0.014	-0.003	0.015	661	

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
296	15	0	4	551	1589		0.009	0.002	0.015	683	
297	15	0	4	545			0.005	0.005	0.019	707	
298	15	0	4	545	1543		0.005	0.008	0.013	729	
299	15	0	4	538	1555		0.021	0.008	0.003	747	
300	15	0	4	544	1531		0.016	-0.002	-0.002	766	
301	15	0	4	549	1548		0.012	0.006	0.014	790	
302	15	0	4	553			0.014	0.001	0.011	817	
303	15	0	4	544	1575		0.015	0.000	0.005	843	
304	15	0	4	540	1534		0.012	0.000	0.001	864	
305	22.53	100	4	543	1562		0.015	0.000	0.004	883	START
306	30	100	4	543	1521		0.029	0.043	-0.014	904	QUENCH
307	30	0	7	544	1545		-0.252	0.062	0.054	922	
308	30	0	7	537	1509		0.002	-0.010	0.001	873	
309	30	0	7	539	1531		0.003	-0.011	0.021	671	
310	30	0	7	537	1548		0.015	-0.012	0.015	391	
311	30	0	7	541	1523		0.009	-0.015	0.018	-267	TC FAIL
312	30	0	7	542	1544		0.014	-0.007	0.105	-1094	
313	30	0	7	542			0.008	0.000	0.464	-1032	
314	30	0	7	542	1555		0.006	0.020	0.898	-869	
315	30	0	7	542	1526		0.021	0.040	1.181	-688	
316	30	0	7	540	1543		0.026	0.061	1.400	-510	
317	30	0	7	540			0.003	0.067	1.544	-83	
318	30	0	7	541	1540		0.023	0.071	1.584	-53	
319	30	0	7	541			0.017	0.066	1.624	-47	
320	46.36	0	7	542	1523		0.020	0.036	1.770	-34	RAISED
321	46.36	0	7	540	1481		0.016	0.045	1.743	-37	FURNACE
322	46.36	0	7	542	1520		0.027	0.050	1.752	-31	TO TOP
323	46.36	0	7	540	1484		0.024	0.059	1.780	-28	
324	46.36	0	7	541	1507		0.007	0.067	1.801	-26	
325	46.36	0	7	546	1480		0.012	0.068	1.777	-26	
326	46.36	0	7	539	1481		0.030	0.071	1.781	-22	
327	46.36	0	7	539	1471		0.016	0.076	1.761	-24	
328	46.36	0	7	541	1477		0.022	0.071	1.745	-30	
329	46.36	0	7	541	1495		0.020	0.087	1.744	-25	
330	46.36	0	7	540	1475		0.020	0.103	1.758	-22	
331	46.36	0	7	541			0.023	0.087	1.736	-30	
332	46.36	0	7	538	1465		0.021	0.102	1.760	-23	
333	46.36	0	7	543			0.010	0.117	1.773	-20	
334	46.36	0	7	538	1467		0.014	0.121	1.742	3	
335	46.36	0	7	545	1482		0.013	0.126	1.749	-9	
336	46.36	0	7	548	1455		0.010	0.148	1.765	-5	
337	46.36	0	7	542	1473		0.010	0.157	1.708	0	
338	46.36	0	7	541	1450		0.017	0.155	1.483	-10	
339	46.36	0	7	531	1466		0.011	0.072	0.709	19	
340	46.36	0	7	545	1465		0.011	0.027	0.352	-13	
341	46.36	0	7	536	1465		0.009	0.014	0.315	-2	

APPENDIX C

Data file of flight sample RMRQF5 processed on
October 10th, 1991 on board the
KC-135

RMRQ PROCESSING OF AL ALLOY + SiC ABOARD KC-135

DATE OF RUN: 10/10/91 FILE ID: RMRQF5

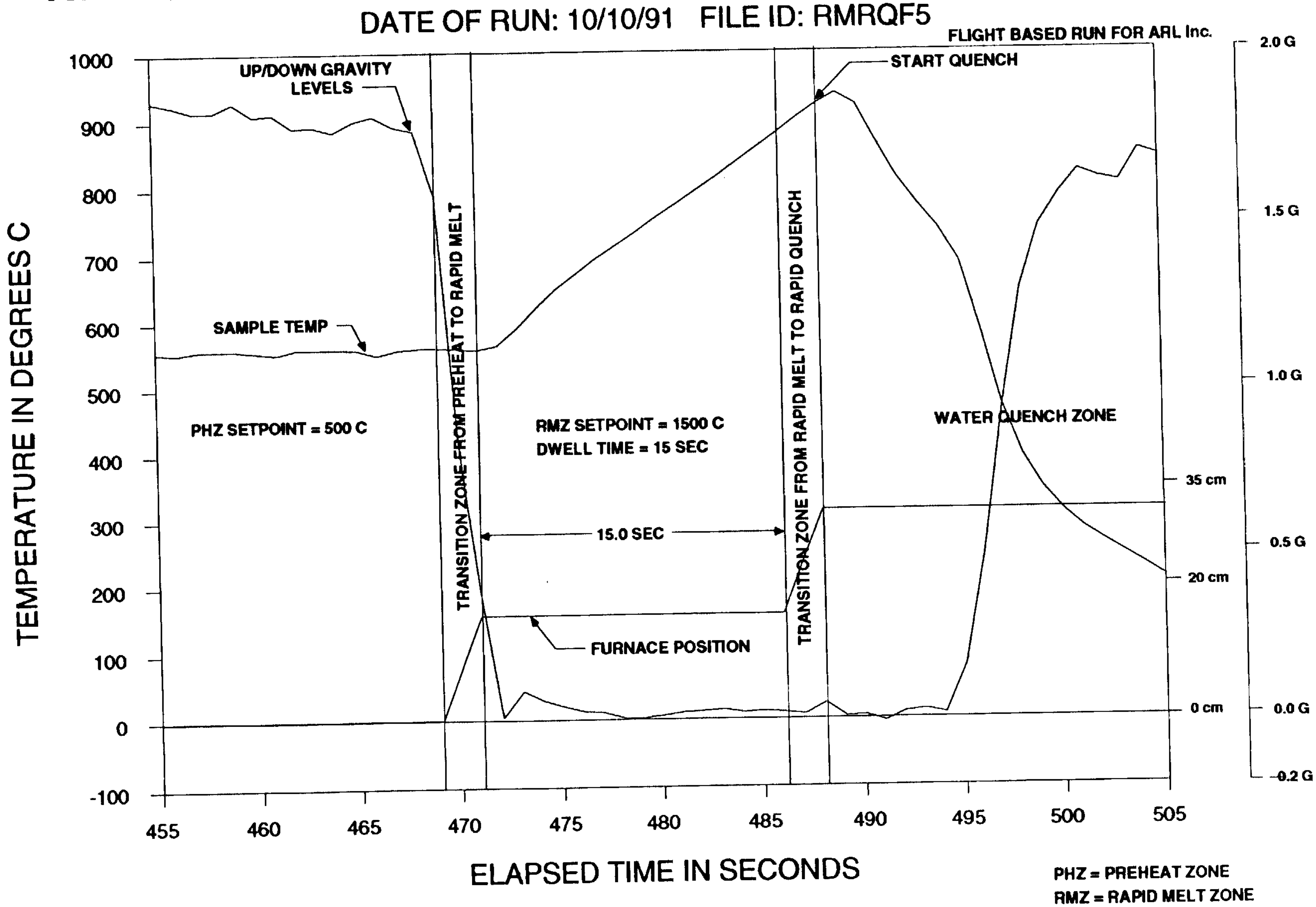


Figure 6: Plot of flight sample RMRQF5 results.

RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - FLIGHT BASED RUN

File Name: RMRQF5.WR1
Data of Sample Processing: October 10th, 1991
Rapid Melt Zone Setpoint = 1500 C
Preheat Zone Setpoint = 500 C (NOTE: PHZ power was turned off due to heat flux from RMZ)
Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel
Sample was 3.88 mm in diameter and 20 mm long.

NOTES: Third sample processed this week, last flight day.
DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp, RMZ is rapid melt temp.
Translation distances were 15 cm for each stage with 15 second dwell time at RM phase.
Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP
357	0	0	3	512	1541		0.023	0.037	0.955	537
358	0	0	3		1542		0.029	0.035	0.947	537
359	0	0	3	510	1570		0.032	0.042	0.979	539
360	0	0	3	509			0.022	0.017	0.985	534
361	0	0	3	506			0.020	0.029	1.018	532
362	0	0	3	505	1535		0.009	0.028	1.045	539
363	0	0	3		1547		0.039	0.034	1.064	540
364	0	0	3	504	1577		0.016	0.021	1.111	539
365	0	0	3	508			0.009	0.025	1.126	534
366	0	0	3	508			0.024	0.041	1.147	535
367	0	0	3	503	1538		0.028	0.021	1.184	539
368	0	0	3		1542		0.038	0.025	1.275	540
369	0	0	3	509	1572		0.025	0.034	1.476	538
370	0	0	3	506			0.029	0.030	1.579	533
371	0	0	3	506			0.028	0.053	1.669	538
372	0	0	3	505	1538		0.025	0.040	1.733	539
373	0	0	3		1552		0.017	0.048	1.772	539
374	0	0	3	508	1563		0.026	0.048	1.781	541
375	0	0	3	507			0.032	0.051	1.780	536
376	0	0	3	505			0.032	0.065	1.785	538
377	0	0	3	510	1540		0.037	0.075	1.786	541
378	0	0	3		1545		0.027	0.070	1.766	538
379	0	0	3	507	1576		0.023	0.056	1.758	540
380	0	0	3	510			0.043	0.067	1.802	540
381	0	0	3	507			0.025	0.055	1.784	537
382	0	0	3	509	1538		0.024	0.074	1.773	541
383	0	0	3		1544		0.029	0.086	1.762	539
384	0	0	3	509	1574		0.015	0.086	1.754	541
385	0	0	3	508			-0.003	0.087	1.779	540
386	0	0	3	507			0.022	0.091	1.777	538
387	0	0	3	507	1537		0.015	0.103	1.723	541
388	0	0	3		1558		0.015	0.128	1.771	537
389	0	0	3	507	1581		0.011	0.112	1.722	537
390	0	0	3	512			0.025	0.115	1.750	540
391	0	0	3				0.019	0.153	1.756	535
392	0	0	3	505	1536		0.006	0.133	1.640	540
393	0	0	3		1550		0.015	0.137	1.501	539
394	0	0	3	509	1578		0.016	0.045	0.803	540
395	0	0	3	507			0.008	0.009	0.411	540

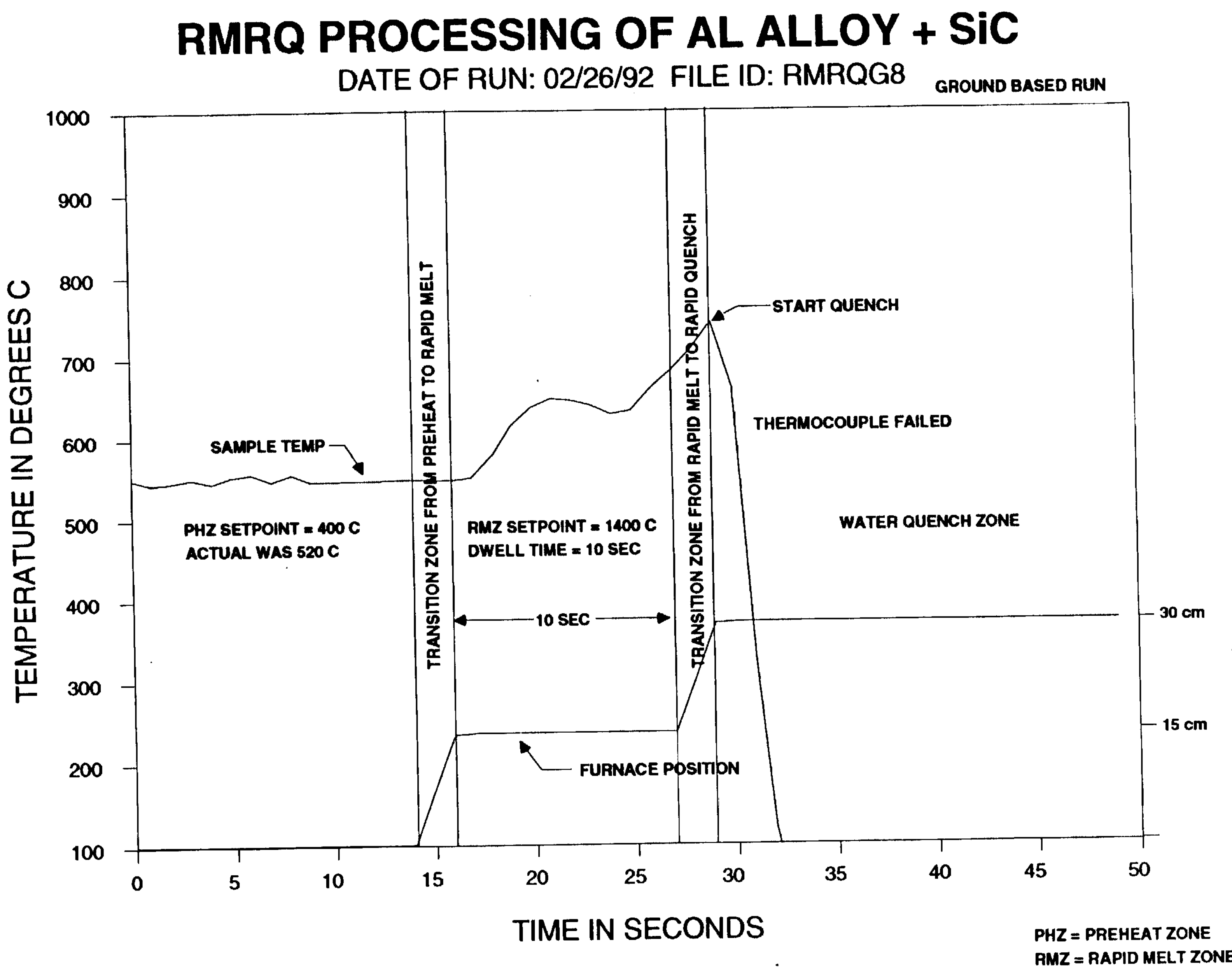
TIME	DIST	VEL	STAT	FURNACE TEMPS PHZ	RMZ	BZ	ACCELEROMETERS Z AXIS	Y AXIS	X AXIS	SAMPLE TEMP
396	0	0	3	505			0.001	-0.010	0.240	533
397	0	0	3	504	1536		0.008	-0.009	0.122	542
398	0	0	3		1541		0.018	-0.008	0.068	537
399	0	0	3	503	1565		0.003	0.000	0.033	541
400	0	0	3	504			0.013	0.000	0.013	533
401	0	0	3	505			0.007	0.004	0.020	533
402	0	0	3	504	1528		0.008	-0.005	0.009	540
403	0	0	3		1530		0.003	-0.005	0.001	538
404	0	0	3	504	1575		0.007	0.004	0.001	541
405	0	0	3	506			0.008	-0.002	-0.003	536
406	0	0	3	507			-0.001	-0.001	-0.005	533
407	0	0	3	511	1540		0.002	0.002	0.008	539
408	0	0	3		1541		0.012	-0.007	0.007	538
409	0	0	3	512	1571		0.015	0.008	0.002	539
410	0	0	3	514			0.017	-0.003	-0.002	531
411	0	0	3	512			0.013	-0.002	-0.006	528
412	0	0	3	507	1534		0.017	-0.010	-0.010	534
413	0	0	3		1537		0.010	-0.007	-0.009	537
414	0	0	3	512	1579		0.008	-0.005	0.010	538
415	0	0	3	509			0.012	-0.004	0.007	534
416	0	0	3	507			0.014	-0.008	-0.011	530
417	0	0	3	505	1537		0.013	-0.008	0.001	537
418	0	0	3		1539		0.019	-0.021	0.022	534
419	0	0	3	517	1575		0.014	-0.012	0.033	534
420	0	0	3	513			0.019	-0.026	0.066	530
421	0	0	3	512			0.019	-0.028	0.414	527
422	0	0	3	510	1535		0.023	-0.004	0.946	535
423	0	0	3		1548		0.016	0.025	1.363	533
424	0	0	3		1563		0.019	0.057	1.582	535
425	0	0	3	507			0.034	0.070	1.671	528
426	0	0	3	510			0.035	0.056	1.738	530
427	0	0	3	509	1538		0.028	0.060	1.805	534
428	0	0	3		1542		0.030	0.057	1.833	536
429	0	0	3		1556		0.038	0.049	1.781	538
430	0	0	3	505			0.032	0.049	1.725	533
431	0	0	3	507			0.052	0.041	1.711	533
432	0	0	3	510	1541		0.026	0.055	1.724	538
433	0	0	3		1541		0.025	0.047	1.762	538
434	0	0	3		1567		0.039	0.053	1.764	538
435	0	0	3	509			0.035	0.043	1.756	534
436	0	0	3	508			0.024	0.056	1.729	534
437	0	0	3	511	1566		0.022	0.048	1.640	537
438	0	0	3		1536		0.029	0.034	1.542	538
439	0	0	3		1571		0.016	0.039	1.438	537
440	0	0	3	511			0.038	0.043	1.440	535
441	0	0	3	507			0.029	0.040	1.498	535
442	0	0	3	509			0.039	0.042	1.512	537
443	0	0	3		1538		0.041	0.035	1.571	537
444	0	0	3	514			0.026	0.058	1.673	539
445	0	0	3	512	1521		0.025	0.051	1.716	536

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
446	0	0	3	506			0.030	0.050	1.735	536	
447	0	0	3	509			0.033	0.049	1.756	538	
448	0	0	3		1533		0.023	0.047	1.749	537	
449	0	0	3	518			0.024	0.054	1.767	538	
450	0	0	3	509	1526		0.032	0.057	1.760	536	
451	0	0	3	509			0.032	0.049	1.756	536	
452	0	0	3	510			0.017	0.059	1.767	539	
453	0	0	3	507	1534		0.019	0.066	1.757	538	
454	0	0	3	514			0.015	0.060	1.789	538	
455	0	0	3	511	1530		0.020	0.069	1.793	536	
456	0	0	3	510			0.011	0.078	1.779	533	
457	0	0	3	509			0.037	0.059	1.763	538	
458	0	0	3	505	1530		0.003	0.070	1.763	538	
459	0	0	3				0.009	0.079	1.788	538	
460	0	0	3	509	1532		0.031	0.085	1.750	535	
461	0	0	3	511			0.034	0.093	1.756	532	
462	0	0	3	511			0.011	0.100	1.716	539	
463	0	0	3	508	1535		0.013	0.091	1.719	538	
464	0	0	3		1538		0.023	0.125	1.702	539	
465	0	0	3	507	1531		0.010	0.123	1.733	538	
466	0	0	3	509	1504		0.003	0.143	1.748	530	
467	0	0	3	516			0.030	0.129	1.718	537	
468	0	0	3	509	1535		0.032	0.169	1.703	539	
469	0	0	3	508			0.015	0.132	1.521	539	
470	7.53	100	4	511	1544		0.001	0.029	0.800	538	START
471	15	100	4	505	1536		0.096	0.000	0.368	536	RAPID
472	15	0	4	503			0.357	0.107	0.007	542	MELT
473	15	0	4	503	1526		0.009	-0.009	0.084	567	
474	15	0	4	500	1579		0.011	-0.005	0.056	598	
475	15	0	4	510	1542		0.014	-0.004	0.039	625	
476	15	0	4	507	1529		0.005	0.000	0.023	646	
477	15	0	4				0.006	-0.003	0.020	667	
478	15	0	4	509	1530		-0.004	-0.001	0.005	686	
479	15	0	4	508	1579		0.002	0.012	0.003	704	
480	15	0	4		1546		0.009	-0.001	0.010	726	
481	15	0	4	511	1528		0.013	-0.006	0.019	744	
482	15	0	4	507			0.014	0.001	0.021	763	
483	15	0	4	507	1521		0.008	0.002	0.027	783	
484	15	0	4	506	1544		0.007	0.010	0.018	804	
485	15	0	4	508	1550		0.000	-0.002	0.022	824	
486	15	0	4	509	1522		0.014	0.005	0.018	845	
487	22.53	100	4	509			0.000	-0.005	0.012	867	START
488	30	100	4	507	1522		0.112	0.005	0.044	887	QUENCH
489	30	100	4	505	1518		0.026	-0.025	0.005	903	
490	29.996	0	7	510	1558		0.190	0.006	0.007	887	
491	29.996	0	7	511	1518		0.018	-0.005	-0.010	834	
492	29.996	0	7	511	1557		0.012	-0.014	0.016	784	
493	29.996	0	7	505	1518		0.007	-0.006	0.023	745	
494	29.996	0	7	502	1503		0.008	-0.009	0.012	710	
495	29.996	0	7	501	1558		-0.001	-0.013	0.147	661	

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
496	29.996	0	7	507	1512		0.005	-0.017	0.465	563	
497	29.996	0	7	507	1556		0.024	0.007	0.882	456	
498	29.996	0	7	507	1515		0.021	0.047	1.241	379	
499	29.996	0	7	505	1508		0.019	0.069	1.422	332	
500	29.996	0	7	508	1551		0.020	0.076	1.512	296	
501	29.996	0	7	505	1508		0.032	0.088	1.580	272	
502	29.996	0	7	505	1542		0.030	0.073	1.558	253	
503	29.996	0	7	506	1505		0.016	0.073	1.546	235	
504	29.996	0	7	505	1512		0.035	0.074	1.638	218	
505	29.996	0	7	507	1550		0.029	0.065	1.619	199	
506	29.996	0	7	508	1506		0.027	0.052	1.560	183	
507	29.996	0	7	505	1533		0.019	0.042	1.514	173	
508	29.996	0	7	508	1503		0.026	0.050	1.489	163	
509	29.996	0	7	502	1506		0.025	0.025	1.526	150	
510	29.996	0	7	510	1548		0.000	0.044	1.612	137	
511	29.996	0	7	507	1501		0.022	0.046	1.625	135	
512	29.996	0	7	505	1526		0.014	0.049	1.584	130	
513	29.996	0	7	506	1530		0.032	0.021	1.460	122	
514	29.996	0	7	503	1496		0.018	0.016	1.396	120	
515	29.996	0	7	507	1546		0.023	0.021	1.326	123	
516	46.36	0	7	505	1489		-0.005	0.081	1.761	149	**RAISED**
517	46.36	0	7	506	1461		0.019	0.106	1.748	150	**FURNACE**
518	46.36	0	7	501	1497		0.029	0.101	1.799	151	**TO TOP**
519	46.36	0	7	505	1465		0.008	0.094	1.752	156	
520	46.36	0	7		1462		0.019	0.110	1.749	165	
521	46.36	0	7	501	1491		0.025	0.140	1.778	155	
522	46.36	0	7	505	1450		0.019	0.124	1.736	143	
523	46.36	0	7	505	1499		0.014	0.153	1.762	148	
524	46.36	0	7	509	1465		0.015	0.159	1.730	151	
525	46.36	0	7	502	1455		0.011	0.095	1.225	145	
526	46.36	0	7	509	1484		0.012	0.009	0.500	152	
527	46.36	0	7	503	1449		0.004	-0.007	0.273	154	
528	46.36	0	7	503	1462		0.010	-0.007	0.155	150	
529	46.36	0	7	504	1488		0.015	0.002	0.069	155	
530	46.36	0	7	504	1453		0.012	-0.001	0.048	152	
531	46.36	0	7	507	1479		0.003	-0.004	0.030	149	
532	46.36	0	7	505	1448		0.011	-0.007	-0.002	146	

APPENDIX D

Data file of ground sample RMRQG8 processed on February 26th, 1992


RMRQ PROCESSING OF AL ALLOY + SiC
DATE OF RUN: 02/26/92 FILE ID: RMRQG8
GROUND BASED RUN
TEMPERATURE IN DEGREES C
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50
TIME IN SECONDS
SAMPLE TEMP
PHZ SETPOINT = 400 C
ACTUAL WAS 520 C
TRANSITION ZONE FROM PREHEAT TO RAPID MELT
RMZ SETPOINT = 1400 C
DWELL TIME = 10 SEC
10 SEC
TRANSITION ZONE FROM RAPID MELT TO RAPID QUENCH
START QUENCH
THERMOCOUPLE FAILED
WATER QUENCH ZONE
FURNACE POSITION
30 cm
15 cm
FURNACE POSITION
PHZ = PREHEAT ZONE
RMZ = RAPID MELT ZONE

RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - GROUND BASED RUN

File Name: RMRQG8.WR1
Data of Sample Processing: February 26, 1992
Rapid Melt Zone Setpoint = 1400 C
Preheat Zone Setpoint = 400 C (NOTE: PHZ power was turned off due to heat flux from RMZ)
Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel
Sample was 4.10 mm in diameter and 20 mm long.

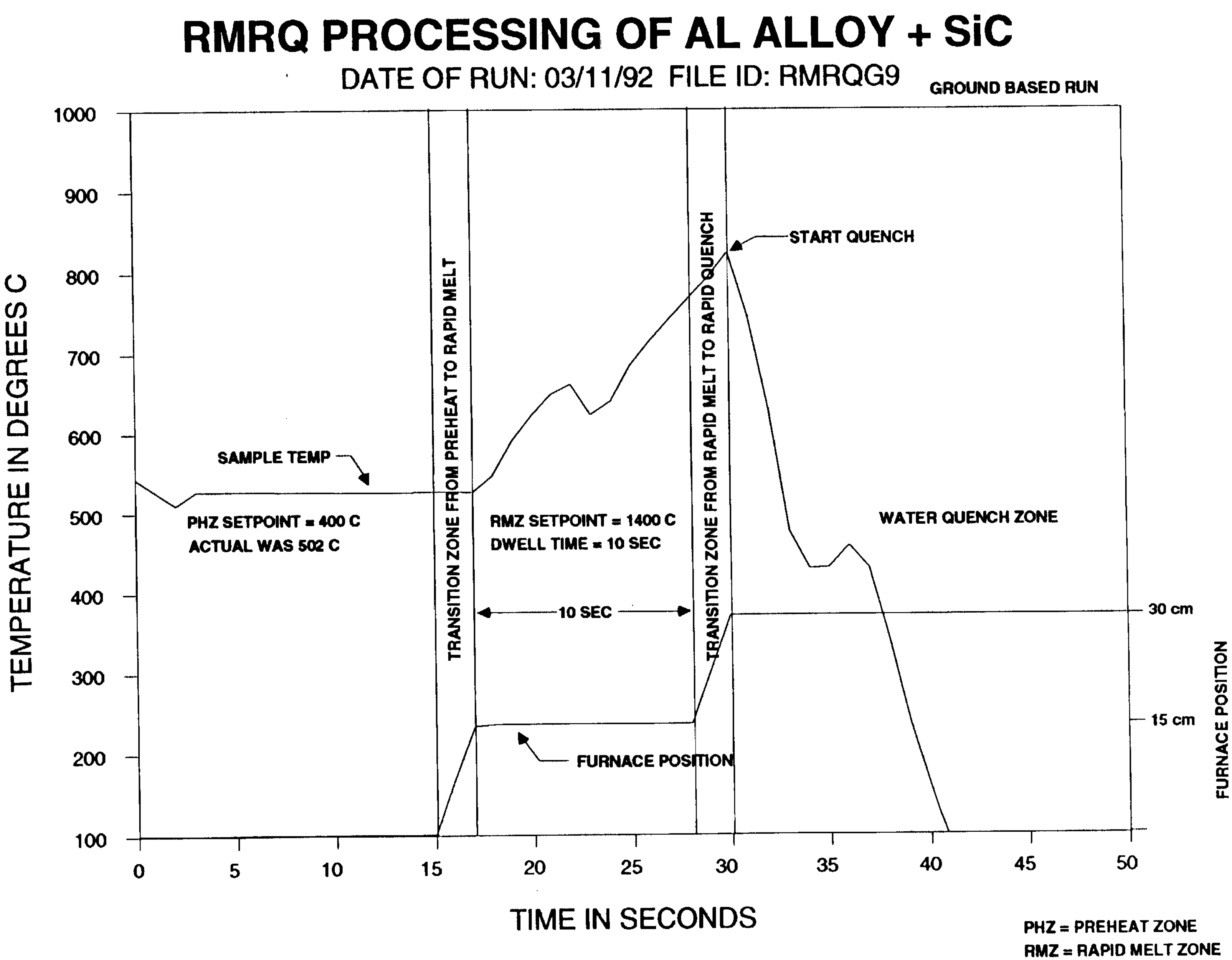
NOTES: First ground based sample processed since October 1991 KC flight.
DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp, RMZ is rapid melt temp.
Translation distances were 15 cm for each stage with 10 second dwell time at RM phase.
Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
5170	0	0	3	514	1419		0.006	0.011	1.000	544	
5171	0	0	3	516	1421		0.005	0.008	0.997	551	
5172	0	0	3	507	1421		0.004	-0.003	1.005	541	
5173	0	0	3	514	1419		0.006	-0.003	0.999	545	
5174	0	0	3	517	1421		-0.003	-0.008	0.998	550	
5175	0	0	3	507	1422		-0.002	-0.002	1.002	543	
5176	0	0	3	516	1419		0.009	-0.004	1.003	546	
5177	0	0	3	516	1429		0.003	0.000	1.005	551	
5178	0	0	3	507	1423		0.010	0.002	0.998	545	
5179	0	0	3	516	1420		0.004	0.002	1.002	553	
5180	0	0	3	516			0.007	0.008	0.994	556	
5181	0	0	3	508	1422		0.005	0.004	0.998	547	
5182	0	0	3	516	1421		0.009	-0.001	1.007	556	
5183	0	0	3	519	1420		0.008	0.008	0.996	546	
5184	0	0	3	516	1423		0.008	0.008	1.003	546	
5185	0	0	3	517	1421		0.008	0.000	1.000	547	
5186	0	0	3	517	1420		0.008	0.000	0.990	547	
5187	0	0	3	518	1422		-0.005	-0.002	1.000	548	
5188	0	0	3	519	1418		0.001	0.001	0.998	548	
5189	7.408	100	4	517	1418		0.007	-0.004	1.007	547	**Start Rapid**
5190	14.815	100	4	519	1423		0.068	0.012	0.987	547	**Melt Phase**
5191	15	100	4	521	1418		-0.108	0.030	1.003	553	
5192	15	0	4	517	1418		0.008	0.010	0.995	589	
5193	15	0	4	518	1420		0.001	-0.005	0.996	621	
5194	15	0	4	519	1419		0.005	0.000	1.002	646	
5195	15	0	4	519	1418		0.000	0.001	1.000	659	
5196	15	0	4	519	1419		0.002	0.003	1.000	656	
5197	15	0	4	520	1417		0.010	0.002	1.007	649	
5198	15	0	4	520	1417		0.003	0.000	1.000	637	
5199	15	0	4	520	1419		0.004	0.006	0.999	641	
5200	15	0	4	520	1416		0.006	0.002	0.999	673	
5201	15	0	4	520	1415		0.004	0.006	1.007	697	
5202	22.408	100	4	520	1416		-0.047	-0.016	0.956	719	**Start Quench**
5203	29.815	100	4	522	1414		0.038	-0.002	0.991	740	**Phase**
5204	29.996	0	7	521	1412		-0.021	0.030	0.978	672	
5205	29.996	0	7	520	1415		-0.001	0.002	0.998	299	
5206	29.996	0	7	520	1415		0.006	0.000	0.998	19	**Thermocouple**
5207	29.996	0	7	522	1413		0.003	-0.009	1.004	-56	**failed**
5208	29.996	0	7	520	1414		-0.001	-0.002	1.001	-71	
5209	29.996	0	7	522	1413		0.005	0.007	1.000	-99	

TIME	DIST	VEL	STAT	FURNACE TEMPS PHZ	RMZ	BZ	ACCELEROMETERS Z AXIS	Y AXIS	X AXIS	SAMPLE TEMP	
5210	29.996	0	7	523	1413		0.006	0.002	1.001	-99	
5211	29.996	0	7	523	1413		0.009	0.005	1.001	-101	
5212	29.996	0	7	521	1411		0.003	-0.001	1.003	-90	
5213	29.996	0	7	523	1410		0.002	0.011	1.003	-54	
5214	29.996	0	7	522	1409		0.010	0.001	1.000	-48	
5215	29.996	0	7	522	1407		-0.003	0.000	0.999	-44	
5216	29.996	0	7	524	1408		0.007	-0.002	0.995	-44	
5217	29.996	0	7	521	1407		0.006	0.003	1.000	-42	
5218	29.996	0	7	523	1405		0.005	0.000	1.002	-40	
5219	29.996	0	7	525	1403		0.004	0.009	1.000	-40	
5220	29.996	0	7	523	1402		0.005	0.005	1.001	-40	
5221	29.996	0	7	522	1402		0.005	0.006	1.004	-41	
5222	29.996	0	7	523	1403		0.002	0.007	1.001	-39	
5223	29.996	0	7	523	1401		0.003	0.007	0.996	-38	
5224	29.996	0	7	522	1404		0.007	0.001	1.003	-39	
5225	29.996	0	7	523	1400		-0.004	0.002	1.000	-36	
5226	29.996	0	7	521	1397		0.000	-0.002	1.001	-35	
5227	29.996	0	7	523	1400		0.005	0.005	1.005	-35	
5228	29.996	0	7	522	1399		0.003	0.000	1.005	-32	
5229	29.996	0	7	526	1398		0.005	-0.008	1.002	-33	
5230	29.996	0	7	524	1396		0.003	0.002	1.006	-30	
5231	29.996	0	7	523	1395		0.001	-0.003	1.000	-32	
5232	29.996	0	7	525	1395		0.010	0.004	1.000	-29	
5233	29.996	0	7	525	1394		0.009	0.000	0.998	-27	
5234	29.996	0	7	526	1391		0.000	0.003	1.006	-24	
5235	29.996	0	7	524	1391		0.003	0.010	1.002	-25	
5236	29.996	0	7	525	1390		0.005	0.004	1.004	-23	
5237	29.996	0	7	525	1389		0.007	0.004	1.001	-23	
5238	29.996	0	7	524	1389		-0.001	0.002	1.005	-18	
5239	29.996	0	7	523	1388		-0.005	-0.003	1.007	-16	
5240	29.996	0	7	525	1386		0.003	-0.002	1.004	-18	
5241	29.996	0	7	524	1385		0.004	0.000	0.996	-14	
5242	29.996	0	7	525	1385		0.006	0.008	1.006	-11	
5243	29.996	0	7	524	1384		0.007	-0.002	0.999	-10	**Raise furnace**
5244	46.36	0	7	524	1360		0.000	-0.004	1.000	50	**to top.**
5245	46.36	0	7	523	1359		0.010	0.002	1.003	38	
5246	46.36	0	7	523	1358		0.009	-0.003	1.002	28	
5247	46.36	0	7	522	1359		0.006	0.003	1.000	36	
5248	46.36	0	7	523	1356		0.001	-0.002	0.996	51	
5249	46.36	0	7	523	1355		0.009	0.007	0.998	48	
5250	46.36	0	7	523	1356		0.003	0.003	1.001	53	
5251	46.36	0	7	524	1354		0.005	0.002	1.002	52	
5252	46.36	0	7	523	1353		0.010	0.008	1.000	58	
5253	46.36	0	7	522	1353		0.008	0.006	0.995	55	
5254	46.36	0	7	524	1350		0.007	0.011	0.999	60	
5255	46.36	0	7	524	1350		0.007	0.001	1.002	53	
5256	46.36	0	7	523	1350		0.006	0.012	0.993	57	
5257	46.36	0	7	523	1350		0.003	-0.005	1.000	68	
5258	46.36	0	7	523	1348		0.011	0.000	1.002	66	
5259	46.36	0	7	524	1347		0.007	0.001	0.998	68	

APPENDIX E

Data file of ground sample RMRQG9 processed on
March 13th, 1992
Repeat run number 1 of RMRQG8


RMRQ PROCESSING OF AL ALLOY + SiC
DATE OF RUN: 03/11/92 FILE ID: RMRQG9
GROUND BASED RUN
TEMPERATURE IN DEGREES C
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50
TIME IN SECONDS
SAMPLE TEMP
PHZ SETPOINT = 400 C
ACTUAL WAS 502 C
TRANSITION ZONE FROM PREHEAT TO RAPID MELT
RMZ SETPOINT = 1400 C
DWELL TIME = 10 SEC
10 SEC
TRANSITION ZONE FROM RAPID MELT TO RAPID QUENCH
START QUENCH
WATER QUENCH ZONE
FURNACE POSITION
30 cm
15 cm
FURNACE POSITION
PHZ = PREHEAT ZONE
RMZ = RAPID MELT ZONE

RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - GROUND BASED RUN

File Name: RMRQG9.WR1
Data of Sample Processing: March 11, 1992
Rapid Melt Zone Setpoint = 1400 C
Preheat Zone Setpoint = 400 C (NOTE: PHZ power was turned off due to heat flux from RMZ)
Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel of ARL.
Sample was 4.10 mm in diameter and 20 mm long.

NOTES: Second ground based sample processed since October 1991 KC flight.
DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp
RMZ is Rapid Melt Zone temperature.
Translation distances were 15 cm for each stage with 10 second dwell time at RM phase.
Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.
Repeat of RMRQG8 run. All conditions were the same except for a new tank of UPH Helium.

				FURNACE TEMPS			ACCELEROMETERS			SAMPLE
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP
900	0	0	3	491	1427		0.010	-0.003	0.996	531
901	0	0	3	492	1424		0.001	0.008	0.996	533
902	0	0	3	496			0.009	0.011	0.997	535
903	0	0	3	492	1427		-0.002	-0.002	0.999	513
904	0	0	3	502	1426		0.006	0.002	0.997	468
905	0	0	3	492	1427		0.003	0.007	0.997	513
906	0	0	3	492			0.006	0.006	1.004	378
907	0	0	3		1430		0.000	-0.002	0.997	536
908	0	0	3		1427		0.003	0.004	0.993	430
909	0	0	3	494			0.007	0.002	0.997	505
910	0	0	3	498			-0.002	0.005	0.998	512
911	0	0	3	484	1425		-0.004	0.006	1.006	521
912	0	0	3	493	1414		0.007	0.008	0.998	502
913	0	0	3	496	1427		0.001	0.003	0.998	540
914	0	0	3	478	1427		0.001	-0.001	1.000	503
915	0	0	3	493	1425		0.013	0.007	1.002	543
916	0	0	3	495			0.012	0.008	1.000	529
917	0	0	3	488	1427		0.013	0.000	1.004	496
918	0	0	3	366	1426		0.006	0.005	0.999	516
919	0	0	3	494			0.005	0.004	1.002	480
920	0	0	3	492	1429		0.004	0.006	0.997	488
921	0	0	3		1427		0.008	0.009	1.003	475
922	0	0	3	493			0.008	0.002	1.001	488
923	0	0	3	494	1428		0.003	-0.002	1.004	459
924	0	0	3		1427		0.001	0.002	1.003	481
925	0	0	3	496	1428		0.007	0.002	1.002	463
926	0	0	3	493			0.003	0.000	1.004	429
927	0	0	3	501	1427		0.008	0.007	1.000	488
928	0	0	3	499	1427		0.004	0.007	0.998	475
929	0	0	3	495	1127		0.004	0.006	1.005	469
930	0	0	3	497	1427		0.002	0.005	0.998	523
931	0	0	3	473	1427		0.005	0.014	0.998	518
932	0	0	3	497	1417		0.007	0.007	1.009	511
933	0	0	3	496	1427		0.009	0.008	0.999	540
934	0	0	3	477	1429		0.010	0.006	0.998	506
935	0	0	3	495	1425		0.000	0.004	1.001	547
936	0	0	3	495	1426		0.001	-0.008	1.002	509
937	0	0	3	497	1428		0.007	0.005	1.001	528
938	0	0	3	495	1425		0.006	0.005	1.000	528

TIME	DIST	VEL	STAT	FURNACE TEMPS PHZ	RMZ	BZ	ACCELEROMETERS Z AXIS	Y AXIS	X AXIS	SAMPLE TEMP	
939	0	0	3	495	1427		0.012	0.010	1.002	528	
940	0	0	3	494	1427		0.005	0.003	1.006	529	
941	0	0	3	495	1425		-0.005	0.009	1.006	528	
942	0	0	3	495	1425		0.008	0.003	1.000	527	
943	0	0	3	495	1425		0.007	-0.001	0.997	527	
944	0	0	3	495	1424		0.005	-0.004	0.997	527	
945	0	0	3	497	1426		0.001	0.006	1.002	527	
946	0	0	3	495	1425		0.008	0.007	0.999	527	
947	0	0	3	495	1424		0.004	0.006	1.002	527	
948	0	0	3	496	1424		0.001	0.009	0.997	528	
949	0	0	3	496	1424		0.011	0.009	0.992	527	
950	7.408	100	4	499	1423		0.002	0.005	1.003	528	**Start Rapid**
951	14.815	100	4	497	1423		0.178	0.074	0.900	527	**Melt phase.**
952	15	100	4	496	1422		-0.044	0.010	0.952	549	
953	15	0	4	495	1422		0.002	0.003	0.999	598	
954	15	0	4	497	1421		0.004	-0.006	1.001	633	
955	15	0	4	497	1421		0.003	0.006	1.003	662	
956	15	0	4	495	1422		0.009	0.008	1.004	676	
957	15	0	4	497	1421		0.005	0.006	0.999	634	
958	15	0	4	496	1418		0.000	0.005	0.999	653	
959	15	0	4	496	1417		0.002	-0.003	0.996	703	
960	15	0	4	495	1419		0.003	0.009	0.998	736	
961	15	0	4	496	1416		0.001	0.001	1.000	765	
962	15	0	4	496	1415		0.005	0.001	0.999	794	
963	22.408	100	4	497	1414		-0.133	-0.134	1.087	823	**Start Rapid**
964	29.996	0	7	496	1414		0.087	0.064	1.031	840	**Quench phase.**
965	29.996	0	7	494	1412		-0.004	-0.003	0.992	769	
966	29.996	0	7	495	1411		0.003	0.005	0.999	638	
967	29.996	0	7	496	1408		-0.003	0.009	1.001	471	
968	29.996	0	7	495	1408		0.003	-0.007	1.002	420	
969	29.996	0	7	495	1407		0.008	0.006	1.006	421	
970	29.996	0	7	495	1407		0.009	0.002	1.000	452	
971	29.996	0	7	495	1405		-0.003	0.004	0.992	420	
972	29.996	0	7	496	1404		0.006	0.005	0.998	321	
973	29.996	0	7	494	1402		0.000	0.006	0.993	206	
974	29.996	0	7	495	1401		0.004	0.006	1.001	117	
975	29.996	0	7	493	1399		0.003	-0.001	1.000	25	
976	29.996	0	7	494	1398		0.004	0.006	0.998	-15	
977	29.996	0	7	495	1399		0.001	-0.004	1.005	-17	
978	29.996	0	7	494	1396		-0.007	-0.002	1.003	-12	
979	29.996	0	7	493	1396		0.003	0.006	0.993	-6	
980	29.996	0	7	494	1394		0.005	0.002	0.999	5	
981	29.996	0	7	493	1392		0.011	0.000	0.994	26	
982	29.996	0	7	492	1392		0.010	0.008	0.995	59	
983	29.996	0	7	492	1390		0.011	0.005	1.004	75	
984	29.996	0	7	493	1388		0.012	0.014	0.994	92	
985	29.996	0	7	492	1387		0.007	0.003	0.998	103	
986	29.996	0	7	494	1386		0.000	0.010	0.998	113	
987	29.996	0	7	494	1383		0.006	0.007	0.996	116	
988	29.996	0	7	492	1382		0.007	0.000	0.999	122	

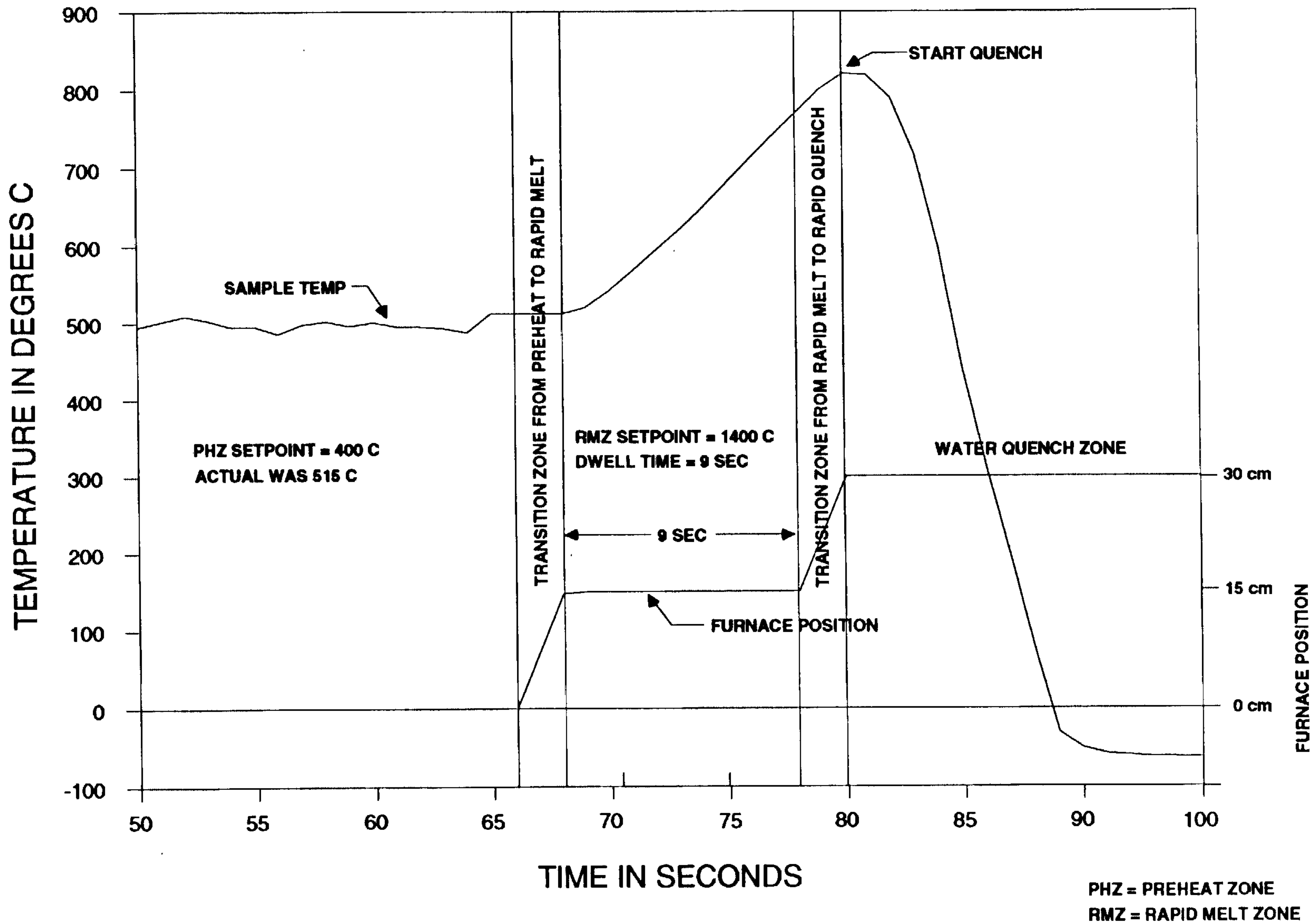
				FURNACE TEMPS			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
989	29.996	0	7	492	1383		0.003	0.000	0.999	125	
990	29.996	0	7	492	1381		0.002	0.002	0.999	130	
991	29.996	0	7	492	1379		0.004	0.001	1.002	132	
992	29.996	0	7	493	1378		0.002	-0.001	0.999	134	
993	29.996	0	7	491	1377		0.002	0.005	1.002	140	
994	29.996	0	7	492	1375		0.005	0.000	1.003	140	
995	29.996	0	7	492	1375		0.002	0.003	1.001	143	
996	46.36	0	7	492	1343		0.012	-0.004	1.005	183	**Raise furnace**
997	46.36	0	7	489	1343		0.011	0.000	1.006	182	**to top.**
998	46.36	0	7	490	1340		0.005	-0.001	1.003	182	
999	46.36	0	7	488	1339		0.006	0.012	1.002	184	
1000	46.36	0	7	490	1338		0.003	-0.007	1.005	182	
1001	46.36	0	7	491	1336		0.010	0.012	1.001	185	
1002	46.36	0	7	490	1336		0.007	0.006	1.002	184	
1003	46.36	0	7	489	1333		0.007	-0.001	1.001	182	
1004	46.36	0	7	490	1331		0.001	0.003	0.997	182	
1005	46.36	0	7	490	1328		0.005	-0.001	1.002	183	
1006	46.36	0	7	490	1331		0.007	0.004	0.999	183	
1007	46.36	0	7	491	1329		0.006	0.008	1.003	184	
1008	46.36	0	7	490	1327		0.006	-0.008	1.001	183	
1009	46.36	0	7	489	1325		0.007	0.012	0.997	184	
1010	46.36	0	7	488	1326		0.003	0.002	0.996	182	
1011	46.36	0	7	489	1323		0.009	0.011	1.002	183	
1012	46.36	0	7	484	1323		0.003	0.003	0.998	183	
1013	46.36	0	7	488	1321		-0.001	-0.001	0.996	182	
1014	46.36	0	7	488	1320		0.004	-0.003	0.994	182	
1015	46.36	0	7	488	1319		0.003	0.002	1.000	183	
1016	46.36	0	7	488	1319		0.009	0.002	0.998	181	
1017	46.36	0	7	486	1316		0.005	0.001	1.005	180	
1018	46.36	0	7	488	1316		0.005	0.002	1.001	182	
1019	46.36	0	7	487	1315		0.003	0.002	1.001	180	
1020	46.36	0	7	490	1314		0.003	0.005	0.999	181	
1021	46.36	0	7	487	1311		0.003	0.005	0.997	180	
1022	46.36	0	7	487	1311		0.011	-0.001	1.005	181	
1023	46.36	0	7	486	1311		0.003	0.002	1.000	178	
1024	46.36	0	7	487	1309		0.007	0.008	1.003	182	
1025	46.36	0	7	488	1307		0.007	0.011	0.992	179	
1026	46.36	0	7	487	1307		0.002	-0.004	0.998	180	
1027	46.36	0	7	486	1305		0.007	0.004	1.002	179	
1028	46.36	0	7	488	1305		0.005	0.002	1.004	179	
1029	46.36	0	7	485	1302		0.004	0.008	1.001	178	
1030	46.36	0	7	486	1301		0.004	0.003	1.004	177	
1031	46.36	0	7	487	1300		0.002	0.002	0.994	178	
1032	46.36	0	7	485	1299		0.004	0.002	1.007	176	
1033	46.36	0	7	486	1298		0.007	0.001	0.998	177	
1034	46.36	0	7	484	1297		0.004	0.010	1.001	176	
1035	46.36	0	7	486	1297		0.001	0.007	1.003	175	
1036	46.36	0	7	486	1296		-0.001	0.002	0.997	176	
1037	46.36	0	7	485	1294		0.010	0.004	1.000	177	
1038	46.36	0	7	485	1293		0.008	0.003	1.003	175	

APPENDIX F

Data file of ground sample RMRQG10 processed on
April 3rd, 1992
Repeat run number 2 of RMRQG8

RMRQ PROCESSING OF AL ALLOY + SiC

DATE OF RUN 04/03/1992 FILE ID: RMRQG10



RAPID MELT/RAPID QUENCH FURNACE EXPERIMENT - GROUND BASED RUN

File Name: RMRQG10.WR1
Data of Sample Processing: April 3, 1992
Rapid Melt Zone Setpoint = 1400 C
Preheat Zone Setpoint = 400 C (NOTE: PHZ power was turned off due to heat flux from RMZ)
Booster Zone Setpoint = 800 C

Type of Sample: ARL Aluminum alloy with Silicon Carbide for Don Morel of ARL.
Sample was 1/2 of the only remaining orginal flight material left.

NOTES: Third ground based sample processed since October 1991 KC flight.
DIST is furnace travel, VEL is furnace velocity, STAT is experiment status, PHZ is preheat temp
RMZ is Rapid Melt Zone temperature.
Translation distances were 15 cm for each stage with 9 second dwell time at RM phase.
Bad temperature data indicated by blank spaces in FURNACE TEMPS columns.
Repeat run number 2 of RMRQG8 run.

				FURNACE TEMP:			ACCELEROMETERS			SAMPLE
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP
6	0	0	3	513			0.003	0.000	1.000	510
7	0	0	3	505	1429		0.006	0.002	1.005	487
8	0	0	3	510	1428		0.013	0.011	1.000	507
9	0	0	3	509			-0.003	-0.003	0.994	512
10	0	0	3	504	1429		0.010	0.007	0.994	501
11	0	0	3		1425		0.001	0.007	0.998	507
12	0	0	3	510			0.002	0.001	1.001	500
13	0	0	3	506	1429		-0.004	0.001	1.000	482
14	0	0	3	491	1428		0.006	0.001	1.000	508
15	0	0	3	511			0.007	0.007	1.005	503
16	0	0	3	508	1428		0.005	0.002	0.999	492
17	0	0	3	524	1428		0.010	-0.006	1.004	498
18	0	0	3	512			-0.001	0.001	1.000	486
19	0	0	3	509	1429		-0.005	0.009	1.003	497
20	0	0	3	515	1427		0.003	0.001	1.002	501
21	0	0	3	509	1372		-0.003	-0.002	1.005	493
22	0	0	3	511	1428		0.008	0.005	1.004	490
23	0	0	3	515	1427		-0.001	0.008	1.000	493
24	0	0	3	510	1428		0.004	-0.003	1.006	499
25	0	0	3	511			0.011	0.009	0.997	
26	0	0	3	518	1431		0.013	0.016	0.994	505
27	0	0	3	511	1430		-0.001	-0.001	0.998	499
28	0	0	3	512			-0.004	-0.002	1.002	482
29	0	0	3	514	1427		-0.006	-0.001	1.004	500
30	0	0	3		1427		0.007	0.003	1.000	491
31	0	0	3	512	1375		0.008	0.011	0.998	497
32	0	0	3	513	1428		0.008	0.004	1.001	505
33	0	0	3	504	1429		0.003	0.005	0.999	500
34	0	0	3	510	1419		0.002	0.000	1.000	497
35	0	0	3	512	1426		0.005	0.006	1.001	509
36	0	0	3	515	1428		0.008	0.007	1.002	499
37	0	0	3	511	1426		0.003	0.006	0.996	509
38	0	0	3	510	1428		0.007	0.002	0.996	512
39	0	0	3	512	1428		0.003	0.003	1.004	512
40	0	0	3	511	1425		-0.001	-0.002	1.001	512
41	0	0	3	511			0.005	0.003	1.006	513
42	0	0	3	496	1430		0.000	0.012	0.997	509
43	0	0	3	513	1425		0.007	0.001	1.004	505
44	0	0	3	511			0.005	0.001	1.001	511

				FURNACE TEMP:			ACCELEROMETERS			SAMPLE	
TIME	DIST	VEL	STAT	PHZ	RMZ	BZ	Z AXIS	Y AXIS	X AXIS	TEMP	
45	0	0	3	508	1429		0.005	0.006	0.996	500	
46	0	0	3	513	1425		0.002	0.003	1.000	510	
47	0	0	3	512			0.006	0.011	0.993	513	
48	0	0	3	508	1428		0.008	0.006	0.996	495	
49	0	0	3		1426		0.002	0.006	1.001	508	
50	0	0	3	511			0.005	0.006	1.000	497	
51	0	0	3	509	1430		0.004	0.003	1.001	494	
52	0	0	3	512	1428		0.002	0.007	0.996	510	
53	0	0	3	513			0.012	0.005	1.001	503	
54	0	0	3	511	1428		0.007	0.005	1.007	495	
55	0	0	3	523	1429		0.003	0.006	0.997	496	
56	0	0	3	513			0.005	0.005	0.996	487	
57	0	0	3	511	1428		0.009	0.005	1.004	499	
58	0	0	3	538	1427		-0.004	0.002	0.996	503	
59	0	0	3	510			0.009	0.007	0.997	497	
60	0	0	3	511	1427		0.001	0.000	1.002	502	
61	0	0	3	517	1426		0.003	0.001	0.997	496	
62	0	0	3	512	1335		0.005	0.000	1.003	495	
63	0	0	3	512	1428		0.005	0.002	0.999	493	
64	0	0	3	510	1428		0.005	0.009	1.000	488	
65	0	0	3	512	1426		0.002	-0.001	1.005	512	
66	0	0	3	513	1425		0.009	0.006	0.998	512	
67	7.408	100	4	511	1426		-0.011	0.008	1.014	512	**Start Rapid**
68	14.815	100	4	512	1425		-0.098	-0.028	0.967	512	**Melt phase.**
69	15	100	4	512	1428		-0.121	0.003	1.049	520	
70	15	0	4	511	1425		0.004	0.000	1.005	541	
71	15	0	4	511	1425		0.004	-0.001	1.004	567	
72	15	0	4	510	1425		0.006	0.002	1.003	594	
73	15	0	4	511	1424		0.005	-0.008	1.004	621	
74	15	0	4	513	1424		0.004	0.006	0.997	650	
75	15	0	4	510	1423		0.001	0.004	0.997	680	
76	15	0	4	512	1420		-0.005	0.000	0.999	712	
77	15	0	4	511	1422		0.005	-0.002	1.001	742	
78	15	0	4	514	1422		0.002	0.007	0.994	772	
79	22.408	100	4	512	1421		-0.074	-0.092	0.988	801	
80	29.996	0	7	512	1420		0.251	0.082	1.058	821	**Start Quench**
81	29.996	0	7	511	1418		0.007	-0.001	1.003	819	
82	29.996	0	7	511	1417		0.006	0.001	1.001	790	
83	29.996	0	7	511	1417		0.003	-0.001	1.001	720	
84	29.996	0	7	511	1416		0.000	0.001	0.998	596	
85	29.996	0	7	510	1414		-0.004	0.001	1.004	440	
86	29.996	0	7	511	1413		0.011	0.002	0.999	309	
87	29.996	0	7	510	1412		-0.003	0.004	0.997	192	
88	29.996	0	7	510	1411		0.008	0.006	1.008	75	
89	29.996	0	7	510	1410		0.000	0.011	1.003	-31	
90	29.996	0	7	509	1409		-0.007	0.003	0.999	-51	
91	29.996	0	7	510	1407		0.002	0.001	0.993	-58	
92	29.996	0	7	510	1407		0.004	-0.002	1.001	-63	
93	29.996	0	7	511	1405		0.001	-0.001	1.003	-64	**Furnace raised**
94	46.36	0	7	509	1375		0.013	0.003	1.004	-54	**to top.**