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Fall 2010 AHSE 2110, SCI 1410: The Stuff of History: Materials and Culture in Ancient, Revolutionary and Contemporary Times: Course Materials: Weekly Assignment Document 7

Robert Martello  
*Franklin W. Olin College of Engineering*, robert.martello@olin.edu

Jonathan Stolk  
*Franklin W. Olin College of Engineering*, jonathan.stolk@olin.edu

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Greetings! Springtime is nearly upon us, my phantasmagoric friends. The day grows slightly longer with each passing moment, and soon we shall arrive at the vernal equinox (March 21), at which point we can joyously say “We are now at the vernal equinox.” New England may still be chilly, but it is a special chilliness that almost seems to say “Yes, you’re cold… but tomorrow you might be slightly less cold.” And best of all, of course, spring break lies just around the corner! It’s time to pour a steaming mug of cherry coke, grab a Red Sox cap, fire up a Dirty Dancing DVD, and snuggle up to this week’s WAD. As you get to know WAD7, you’ll soon recognize that it’s rather tender and sensitive – nothing like the social WAD6, the trendy and fashionable WAD4, or the psychotic WAD3. WAD7 desperately needs your continual attention and support, as it has a mild case of asthma and sunburns quite easily. Worse, it tends to get intimidated by all the Part Two project activities (especially all that noisy forging) and it finds 80s music “a bit over the top.” Please be conscious of the vulnerable nature of WAD7. Treat it kindly, show it a little bit of Olin love, and it will return the favor.

PROJECT WORK

DUE DATE: Ongoing

This is an exciting week for us because we are focusing intently upon the projects. We want you to do some focused history reading this week, and all reading is entirely group-specific. Please find some Rob chapters and other sources (oh yes, above all, do not forget the other sources) that provide usable evidence and intriguing ideas to inform your project. On the materials side, you should be making excellent progress in the fabrication goals by this point and materials testing should be well underway. And best of all… we have our first exam of part two!

The big goals for the second week of this project are to finalize the plan for your project. All of you have answered a number of questions by this point: what metal and fabrication process are you studying? How do they relate to Paul Revere? How cool is the song “Down Under?” What will you make? What (in vague terms at least) will you do with the stuff that you make? What are your expected results? Which Rob chapter(s) and other sources will you read? What do you hope to find in those sources?

Let’s kick it up a notch. Shift the big-picture questions into more specific questions, such as the following:

- What is the primary goal of this project? Which fundamental questions (which should bridge history and materials science) will you ask and answer? What makes these questions significant?
- What historical evidence will appear in your final poster? What questions will the evidence address? Where and how will you get this evidence? How much interpretation will you perform? (Answer: a lot!)
- What materials science evidence will appear in your final poster? How will you obtain this evidence? How will you communicate this evidence – tables, graphs, sketches, micrographs, photos?
- How will you connect materials theory (e.g., phase diagrams, phase transformations, strengthening mechanisms, nucleation and growth, diffusion) to your processing variables, your experimental property data, and the broader performance context of your artifacts?
- What is the relationship between specific materials science evidence and specific historical evidence in this paper?

Your materials science project work this week should be goal driven: if you run a test, do it because it will give you relevant data. As Sara Schwalbenberg likes to say, “Move with a purpose.” Similarly, you must work on
your history project by doing more than preparation for your presentation: keep a set of notes during your readings, and start organizing your notes into categories that will at some point become sections of your poster. Try analyzing your data and synthesizing your evidence as you go. This will highlight missing pieces of your analysis, bring important questions to the forefront early in the process, and lower the anxiety as the poster deadline approaches.

**HISTORY READINGS**

**DUE DATE: This week (no specific date, but no later than Friday)**

This week you should finish reading the historical materials of highest relevance to your project – book chapters, articles, and other materials that you may locate. Please read exam question one before you start the readings, because it too relates to your readings.

By the end of this week you should be envisioning a more specific poster that has a thesis, evidence, and a conclusion. You are allowed to cite book chapters as a source, but you must find other evidence sources as well. What might you use?

Revere’s words are an excellent source of evidence. You can look at my chapters for Revere quotations, and then use footnotes to point you to the *Revere Family Papers*. Also use the finding aid that you started reading last week to find additional info.

Revere’s numbers are as good or better than his words. Again, you can start with numerical data from my chapters (I have tables that you might find useful) and if needed, let the citations point you to the *Revere Family Papers*. In addition, the finding aid and some of the other sources listed below might help you.

You can look at some Revere-era or older metallurgical texts to see other perspectives related to state-of-the-art technology and techniques (including some images). See the sources listed below.

You can also look for other sources of information, including the black binder or even the Library of Congress. It all depends on what you seek. Dee Magnoni can help you find new sources if needed!

The following sections describe four places that you might look for historical evidence. Feel free to ask Rob and Jon if you are not sure of the relevance of any of these.

**READING ONE: Rob’s Chapters (Required)**

Each team has a primary chapter from Rob’s book that closely pertains to your topic, as well as secondary chapters that might apply as well. You should have read at least the first chapter of relevance last week. This week you are required to read more of the book. A few hints (see starred recommendation ratings preceding each entry below):

*** Chapters one and three deal with Revere’s silverworking before and after the Revolutionary War, respectively. If you focused on one of these chapters previously, read the other now.

** Chapter two is a study of Revere’s actions during the Revolutionary War, which might be of interest to groups looking at how the war changed his operations.

* Chapter four looks at iron casting, probably not terribly useful or interesting to anyone not named Sarah.

*** Chapter five has a LOT of material in it: bells, cannon, and forging. This chapter touches on many important issues.

* Chapter six narrates his exciting transition to copper rolling -- again, probably not too useful.

**** Chapters seven and eight describe Revere’s operations at the end of his career when he adopted many proto-industrial techniques. Sections of these chapters describe his labor, capital, environmental,
and technological practices, and the technology sections has subsections describing all of his operations (bell casting, forging, etc.) at the end of his career. Do not skip these chapters, but definitely skim them!

**READING TWO: The Black Binder (Optional but recommended)**

AC413 is proud to host the black binder, which moves about the room with a whimsy worthy of Mark Somerville.

The black binder contains the following photocopied articles:

1. “An Outline of the Life and Works of Paul Revere” (old fashioned overview of his career, has some silver drawings that might be of use, but probably won’t)
2. “The Pride Which Pervades thro every Class”: The Customers of Paul Revere (very useful for the **silver groups** if they care about his customers)
3. *The Revere Furnace* (helpful for the **bell** group, and maybe for **bolts and spikes/forging** folks too)
4. *The Bells of Paul Revere* (helpful... you guessed it ... for the **bell group**)
5. “The Plant of the Revere Copper Co.” (helpful for anyone who cares about his property in Canton, the environment in which he worked)

If you are interested, please refer to the end of this document to read “The Legend of the Black Binder” (optional).

**READING THREE: Paul Revere: Artisan, Businessman, and Patriot (Optional. Most useful for silver and forging groups)**

Olin has a copy of *Paul Revere: Artisan, Businessman, and Patriot* in the library’s reserve section, under our class name, and two copies in the tiny bookshelf in AC413. This book has two chapters on silver, one chapter on copper rolling, a chapter on his lineage, and a chapter on freemasonry. The silver groups will possibly find this helpful, the bolt and spike groups might find the copper rolling chapter mildly useful, anyone interested in Revere’s family will appreciate that chapter, and others need not apply. This book is notorious for having the weakest binding of any book ever produced in the history of the human race. We challenge you to read it, or even to speak or breathe in its general vicinity, without cracking the spine.

**READING FOUR: Older texts (Optional; though Diderot encyclopedia is highly recommended)**

The library (reserve section for our course) contains the following four books:

1. *On Divers Arts*, by Theophilus (published in 1122 AD)
2. *The Pirotechnica*, by Vannoccio Biringuccio (around 1540 AD)
3. *De Re Metallica*, by Georgius Agricola (1556 AD)
4. *A Diderot Pictoral Encyclopedia of Trades and Industry*, by Denis Diderot (1751 AD)

These primary sources offer snapshots of metalworking knowledge at different times and in different places. Anyone looking for images can do no better than the Diderot encyclopedia, which is also very close to Revere’s time period. Diderot includes materials on silver, iron, bells, and cannon. Although the other works are far earlier that Revere, there are many ways you might make use of the image or the technical and scientific explanations.
MATERIALS SCIENCE READINGS

DUE DATE: Friday, March 12, class time

TEXTBOOK READING
- Askeland 4th edition: Chapter 9 (Phase Diagrams) and Chapter 10, especially 10-3 – 10-5 (Eutectic Phase Diagrams)
- Askeland 5th edition: Chapter 10 (Phase Diagrams) and Chapter 11, especially 11-3 – 11-5 (Eutectic Phase Diagrams)
- Callister 6th or 7th edition: Chapter 9 (Phase Diagrams)

OPTIONAL SUPPLEMENTAL READING
Ashby’s “Teaching yourself phase diagrams” from his Engineering Materials 2 textbook is sometimes helpful if you are having difficulty understanding phase diagrams as described in your textbook. This supplemental reading is posted on the course web site. Use it as you see fit!

STOLK’S TAKE ON THE MATSCI READINGS:

I love phase diagrams, almost as much as I love coffee. Actually, the two things are similar in many ways. “Coffee” can describe solid or liquid forms of the same substance. Phase diagrams often depict solid and liquid forms of the same substance. Coffee comes in a variety of flavors, some very simple and some quite complex. Phase diagrams can be very simple (e.g., Cu-Ni) or quite complex (e.g., Cu-Sn). Coffee smells delightful. Phase diagrams smell like oxidized metal mixed with pureed turnips (i.e., delightful). Coffee serves in a range of social, cultural, motivational, and cognitive roles. Phase diagrams bring people together, shape our beliefs and attitudes, spark our imagination and creative efforts, and further our understanding of the world. Coffee is delicious. Phase diagrams taste like Ground Ball Grape flavored Big League Chew (i.e., delicious). Need I go on?

There are many types of phase diagrams. Chances are you’ve seen a few unary (one chemical component) temperature-pressure diagrams in your chemistry or physics classes. You know what I’m talking about – the water phase diagram, with the liquid, solid, and vapor phases, and the triple point. Yeah, I bet you’ve seen that. Unary diagrams are nice and all, but they’ve served their purpose for now, so we’re going to leave them in the dust right now. Yes, indeed, it’s time to double our pleasure, double our fun, with binary diagrams. For our materials phase diagrams, we’ll hang onto that temperature axis from the unary diagrams, as we frequently heat and cool materials during processing operations. But since we usually deal with materials at ambient pressures, we can treat pressure as constant, and get rid of that pesky pressure variable. This frees up the pressure axis to be used for something else. What variable would you like to put on the x-axis? I’m thinking that composition would make a great choice, as it will enable us to see what happens when we mix two materials together. Guess what, you just arrived in binary land (or “B-land”, as the big wave surfers and antique stamp collectors like to call it). Welcome. Take off your shoes, hang your hat, and stay a while.

Will a binary phase diagram serve you well during your Part Two project? Maybe. The silver teams are set, since Revere usually dealt with sterling silver (Ag-Cu). And the iron teams will be okay, since pig iron is basically Fe and C, with minor amounts of impurities. The copper teams don’t really need a phase diagram, since they’re dealing with a single chemical component. But what about those bronze teams? Were Revere’s bronze alloys limited to two chemical components? Not really, but perhaps we should make our lives a little easier by assuming that the bronzes were primarily composed of two elements. Sound okay to you? If not, take a few minutes to explore ternary phase diagrams, which are pretty cool but a bit more difficult to interpret.

I encourage you to think about binary phase diagrams as a tool that can help you understand how two different components interact with each other as a function of temperature and/or composition. Believe it or not, this understanding can help you predict the microstructure and properties of the material. But let’s not get ahead of
ourselves. Take a moment to consider what, exactly, the phase diagram can tell you. What information is available from a binary temperature-composition diagram? Your textbook and the Ashby supplemental reading do a nice job of introducing phase diagrams concepts, so I’m not going to waste document real estate for that, but I will provide a few questions for you to think about as you read:

1. Can you label the phases present in all the unlabeled regions of a phase diagram? This is often a necessary first step before you begin to gather more detailed information on phase compositions and relative amounts (weight percentages) of the phases.

2. Can you say anything in general about how well your two chemical components like each other? For example, binary isomorphous phase diagrams have a single solid phase (isomorph = “one form”), which means that at no point do the two different components (e.g., Cu and Ni) reach a point where they have this sort of discussion:
   - Cu: Nickel, you really cramp my style.
   - Ni: Me?! I’m so sick of your freakin’ face centered cubic structure that I’m ready to pack up my valence atoms and walk out the door.
   - Cu: My fcc structure is beautiful, and you know it. Your atomic radius and electronegativity, on the other hand, leave much to be desired. You think you can go around pushing and pulling me and my electrons without any consequences?
   - Ni: Okay, that’s it. I’m leaving, and I’m taking all my nickel friends with me. We’re going to start a new community, based entirely on our preferred social structure and ways of interacting.
   - Cu: Fine, go! But I suspect you’ll be back when the temperature starts to rise in your utopian nickel dream-world!

   Nope, nickel and copper would never have that conversation. Silver and copper, on the other hand, is a different story. You’ll notice on the silver-copper phase diagram that this system has two terminal solid solutions, meaning that there is a point at which silver is no longer miscible in copper, and vice versa. Other binary systems, like the Cu-Sn bronze system, show a number of intermediate phases or intermetallic phases in the middle of the diagram, which appear when the two elements join forces to create an entirely new phase, with a different structure and properties.

3. What type(s) of three-phase equilibria appear on your phase diagram? These are the horizontal lines within the diagram, and they indicate that some sort of reaction (e.g., eutectic, eutectoid, peritectic) is taking place. Can you interpret what this reaction means in terms of microstructural and property changes?

4. Given a particular binary phase diagram and composition, could you sketch the appearance of the microstructure as a function of temperature (moving vertically through the diagram)? Given an isotherm, could you sketch the structural changes that occur as a function of composition (moving horizontally through the phase diagram)?

5. The binary phase diagrams you’re studying now usually show conditions of thermodynamic equilibrium. What isn’t shown on the phase diagrams is how much time it may take for the binary system to get to a state of thermodynamic equilibrium. Does it take a millisecond for a reaction to proceed? An hour? A year? Which reactions would you expect to occur more quickly? What effect(s) would fast cooling of an alloy have on its microstructure and properties?

Finally, there’s a lot of new terminology in the phase diagrams reading, e.g., eutectic, solvus and liquidus and solidus lines, three phase equilibria, solubility limits, etc. Don’t try to memorize all of these at once; rather, do your best to integrate these terms into your language as you discuss your Part Two materials and processes.

Enjoy your phase diagrams. Sip them like a fine cup of espresso. Ride them like a North Shore wave. Appreciate their ins and outs, their ups and downs, their noble strengths, their innermost weaknesses, their sunshine-filled pros, their gloomy and dismal cons, their thrilling highs, and their chilling lows, as you enjoy all the nuances of this glorious journey called life.
EXAM 2.1

DUE DATE: Friday, March 11, 12:30 PM

**********NOTE 12:30 SUBMISSION TIME**********

NOTE: Work on this exam as a team and submit one exam per group

Instructions: Examination questions are graded and count towards your course grade as shown in the “Grade Breakdown” table in your syllabus. You may work on this as much as you like as a team, and each team should submit a single exam via email to both instructors no later than 12:30 PM on Friday, March 11. Please use Word format for Question One, and either Word or pdf format for Question Two. You may write your solutions to Question Two by hand, but please scan and submit these in pdf format.

Question One: Poster Planning and Evidence Gathering

1. What is your up-to-date thesis? If you do not completely understand your thesis, tell us the primary historical and materials science questions that you will ask, as well as the expected answers to these questions (take your best guess). But do your best to cast your entire project in the form of a three story thesis that lays out some relevant context; states a hypothesis (which you can think of as the answer to an important question) that is controversial and non-obvious; and explains the significance of this entire topic.

2. What will be the main sections of your poster? Explain the goal of each section in one or two sentences. For the purposes of this question, anything that appears as a discrete bundle of content on the poster counts as a section. We don’t care about the exact order/placement of these sections at this time, though hopefully you laid those out in your draft poster due earlier this week.

3. For each of the sections listed in the prior question, what will you use for evidence? Include one of the following for each section:
   - Specific pieces of evidence if you have them. Briefly recap the data that you have located – a quote, statistics, a paraphrasing, an image, etc., for historical information. For materials science information you can either include the data if you can, or describe it to us. Also cite each piece of evidence, tell us where you found it (not needed for the results of experiments – we know that they came from the lab). This is by far the preferred way to address this question and if you do not have any specific evidence by this point we will be concerned.
   - If you do not have specific evidence yet for some sections, tell us the evidence you hope to locate and your plan to find it.

4. Complete a plan of work for the last two weeks of part two, beginning with your triumphant return from Spring Break and ending on Friday April 1 (the due date for the poster). Create mini-milestones along the way – when will you finish each test? When will you locate sources? Write and proofread text? Print the poster? You know the drill.
   - For a miniscule amount of extra credit, answer this question by crafting a timeline that we can print and post in AC 413. Give yourself explicit deadlines for tasks so we can check them off as you proceed from here to victory.

5. Tell us your major concerns at this point. Relate this to the plan of work: which steps could be problematic? Can Rob and Jon help at this point?
Question Two: Phase Diagrams

For this question, you are going to try to predict material microstructures based on a binary phase diagram for one of the alloys you’re using in your project. You’re all doing casting as one of your processes, right? Let’s consider your casting process, and forget about forging or rolling for now.

1. First things first: we need a phase diagram. Go forth and find a binary phase diagram for the two primary constituents of one of your Part Two project alloys. Your textbook has a few phase diagrams, but you’ll likely need to search beyond the textbook. I find that ASM Handbooks Online (available through our library website) has some good phase diagram information. Or, if you want tons of information on phases in binary alloy systems, check out T. B. Massalski’s *Binary Alloy Phase Diagrams*, a three-volume set of books in the library stacks.

2. Consider the terminal solid solutions in your alloy system (the phases at the extreme right and left ends of the diagram). What are the solubility limits for each of these terminal solid solutions?

3. Select an alloy composition that is relevant for your project work. For example, if you’re working with sterling silver, you may want to select Ag with 7.5 wt.% Cu as your alloy composition. Starting at a temperature high enough that your alloy is entirely liquid, select at least five different temperatures at which you’d like to take a closer look at your alloy. Be sure to choose temperatures that you think may help you explain the microstructural changes that occur in your actual project artifacts.

4. Let’s get some information off the phase diagram for your binary alloy at the various temperatures. Assume very slow (equilibrium) cooling of your alloy.
   a. What phases exist at each temperature?
   b. What are the compositions of the phases at each temperature?
   c. What are the relative amounts of the phases at each temperature?
   d. What does the microstructure look like at each temperature?

5. Now that we have a bunch of quantitative details on your alloy at different temperatures, let’s think about the appearance of the microstructure as your alloy slowly cools. Sketch the microstructure of your alloy at each of your five temperatures.
   a. On each sketch, label the phases present.
   b. On each sketch, label the microconstituents. A microconstituent is defined as a portion of the microstructure that has an identifiable or characteristic appearance. For example, the product of a eutectic reaction is called “eutectic solid”, a two-phase microconstituent that may be in the form of layered regions (lamellar eutectic), speckled regions, etc. For a more concrete example, take a look at the figure to the right. This is a micrograph of an aluminum-silicon alloy, with about 5% silicon. The large, light colored, blobby-looking regions are the aluminum solid solution that forms above the eutectic temperature, in the triangular-shaped α+L region of the phase diagram. The speckled regions are the eutectic solid, which is a two-phase structure of the α and β phases that forms during the eutectic reaction.

6. Here’s a preview question for next week’s mat sci readings: What mechanical properties would you expect for the various (a) phases and (b) microconstituents that appear in your binary alloy?
MATERIALS SCIENCE PROBLEMS

When you work through the practice problems, consider how the concepts apply to your Part Two project topic. Will your materials have one phase, two phases, or multiple phases in the solid state? If you are dealing with a two-component or multi-component alloy, what are the solubility limits of each component in the other components? How do the solubility limits change as a function of temperature? How will your microstructure appear? Does your alloy system form two distinct microstructural regions, or “microconstituents”? How might the presence of different phases affect the properties? Wow, I’m starting to sound like a broken record.

Use the binary, isomorphous, molybdenum-vanadium phase diagram for Problems 1-3. Note: the dashed curve in the phase diagram indicates that there is some error or uncertainty in the location of the liquidus line; the uncertainty in the liquidus line should not affect your calculations.

1. Sketch the expected trend in hardness as a function of composition for Mo-V alloys.

2. For a 50 wt% vanadium alloy at 2200 °C, determine the following:
   a. Phases present
   b. Compositions of the phases
   c. Percent or fractions of the phases

3. What is the solubility limit of molybdenum in vanadium at 1900 °C?

Use the silver-copper phase diagram shown on the next page for Problems 4-8.

4. What are the solubility limits of Ag in (Cu) and Cu in (Ag)? The (Cu) and (Ag) phases are the same as α and β, respectively (just different naming methods).

5. For equilibrium solidification of a Cu-Ag alloy containing 40 weight percent Ag,
   a. State the temperature at which solidification begins.
   b. State the temperature at which solidification is complete.

6. For a Cu-Ag alloy of 50 wt.% Ag,
   a. Determine the phases present, compositions of the phases, and relative amounts (weight fractions) of the phases at a temperature just above the eutectic temperature.
   b. Determine the phases present, compositions of the phases, and relative amounts of the phases when solidification is just complete (at a temperature just below the eutectic temperature).
7. For a 50 wt.% Ag alloy, determine the fractional amounts of *microconstituents* when solidification is just complete.

8. Sketch the 50 wt.% silver alloy at a temperature just below the eutectic temperature. Label both the phases and the microconstituents.

9. The molybdenum-rhenium phase diagram is provided on the next page. Note that all the single-phase regions labeled.
   a. Label all two-phase regions.
   b. Specify the temperatures and compositions for all 3-phase equilibria in this system. For each 3-phase equilibrium, write the reaction upon cooling.
   c. Assuming no phase transformations occur at lower temperatures, specify the strengthening mechanisms that are possible for an alloy of Mo with 18 wt. % Re.
   d. BONUS: How would you form an alloy of Mo with 10 wt. % Re? Could you make it in one of our furnaces?
THE LEGEND OF THE BLACK BINDER (PART ONE)

Ages ago, when the Mesopotamians dominated the world,¹ the dread king Martolk cast his shadow over proud Uruk. The blood of Gilgamesh flowed through his veins, but while he inherited his ancestor’s divine strength he lacked the nobility and public spirit of his mighty forbear. Indeed, Martolk’s cruelty was only exceeded by his ambition. He was, indeed, bad to the bone.

Martolk’s legions knew no defeat, and it was said that divine providence turned their enemies’ spears to clay, while making their own weapons unstoppable. As further test of his prowess, he singlehandedly caused elaborate health care reforms to become law, bailed out a number of troubled financial institutions, and ate over nine pounds of brie, all in the same day. All agreed that neither stress nor strain had the slightest impact upon him. With each victory his reputation grew and his avarice remained unsated, and soon even his most trusted advisors questioned their future. What would happen to them, and indeed, to the world, when Martolk reigned supreme?

On one cloudless day, at a time when Martolk was leading his legions to yet another victory, the grand vizier Stello gambled his life on a risky venture. Summoning his magical arts and his courage, he stealthily entered Martolk’s tent in search of any charm or portent that might help him bring an end to the rising darkness. Moments passed, time seemed to freeze, and Stello dared not breathe. When all hope seemed lost, he pushed aside a pile of brie rinds and at last his eyes settled upon the object of his search. The black binder.

(To be continued, but only if enough people express sufficient interest.)

¹ Except for Japan of course.